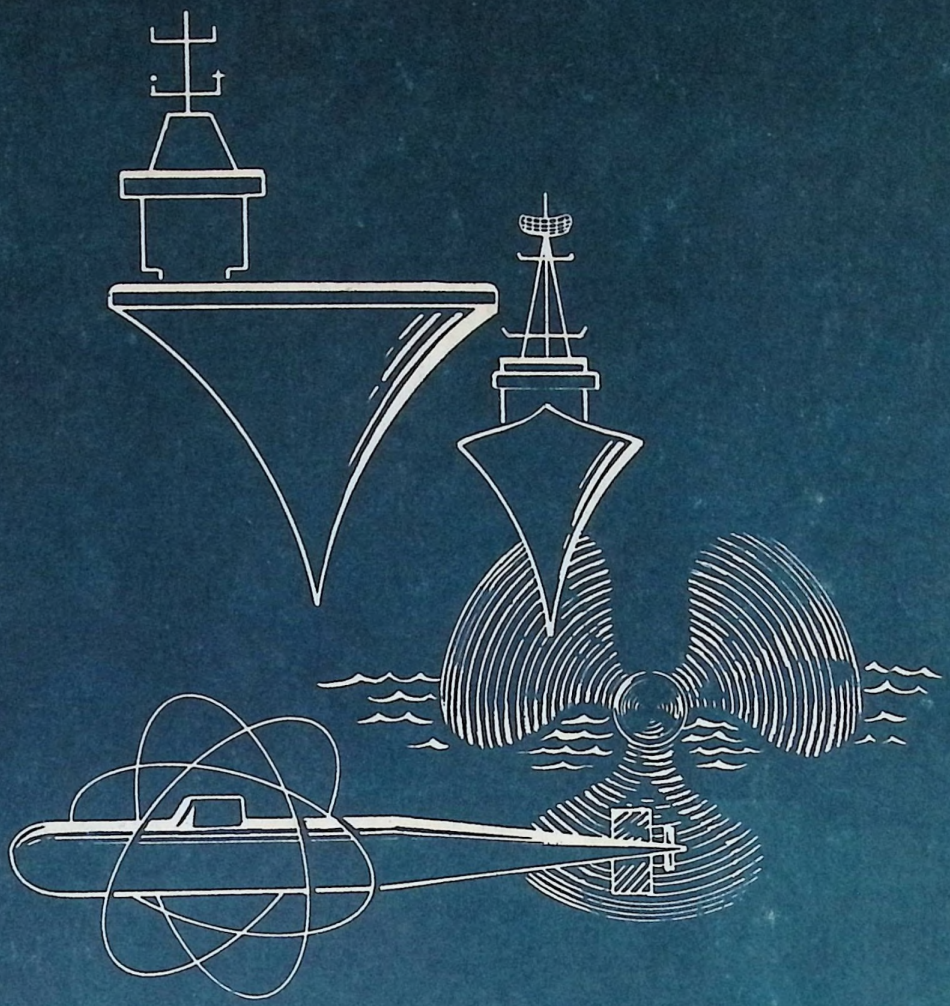


MACHINIST'S MATE 3&2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10524-E

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PREFACE

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable Machinist's Mates to acquire the theoretical knowledge and operational skills required to advance to Machinist's Mate Third Class and Machinist's Mate Second Class. Combined with the necessary practical experience and a review of other applicable training manuals, a knowledge of the information in this self-study package will help the student meet advancement requirements.

Designed for individual study and to support on-the-job training, the RTM provides subject matter that relates directly to the occupational qualifications of the Machinist's Mate rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This self-study package was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Schools Command, Great Lakes; Naval Safety Center, Norfolk, Virginia; Naval Development and Training Center, San Diego; and Naval Sea Systems Command.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

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

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

WE SERVE WITH HONOR

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

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

Our responsibilities sober us; our adversities strengthen us.

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

THE FUTURE OF THE NAVY

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

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

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

Never have our opportunities and our responsibilities been greater.

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Nonresident Career Course follows Index

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CHAPTER 1

ADVANCEMENT

This training manual is designed to help you to increase your knowledge in the various aspects of the Machinist's Mate rating and to help you advance in rating to MM3 and MM2. Your contribution to the Navy depends on your willingness and ability to accept increasing responsibilities as you advance in rate. When you assume the duties of a Machinist's Mate, you begin to accept certain responsibilities for the work of others. As you advance in your career, you accept responsibilities in military matters as well as in the occupational requirements of the Machinist's Mate rating.

MACHINIST'S MATE RATING

The Machinist's Mate rating is a general rating; that is, it covers a broad occupational field of related duties and functions.

Machinist's Mates are assigned to all types of ships. Most Machinist's Mates are assigned to "M" Division where they operate and maintain ship propulsion machinery and associated equipment such as: pumps, distilling plants, compressors, valves, oil purifiers, heat exchangers, governors, reduction gears, shafts, and shaft bearings.

Machinist's Mates who are assigned duties other than in enginerooms maintain and repair machinery such as: steering engines, anchor windlasses, cranes, winches, elevators, laundry equipment, galley equipment, and air conditioning and refrigeration equipment.

The nature of the Machinist's Mates duties depends largely on the type of ship or station to which he is assigned. Repair ships and tenders furnish other ships with spare parts, repairs, and other services that are beyond the facilities of the ship's crew. The duties of a Machinist's Mate assigned to a repair ship or tender may consist mainly of repairs and other services to ships assigned to the tender or repair ship. As a Machinist's Mate, you may choose an area of specialization.

This manual is organized to give you a systematic understanding of your job. The occupational standards used in preparing the text are contained in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068-D. We recommend that you study the Machinist's Mate section of NAVPERS 18068-D to gain an understanding of the skills required of a Machinist's Mate. Then, study the subject matter carefully. The knowledge you gain will enable you to become a more proficient operator and the Navy will profit from your skills.

As you advance to MM3 and then to MM2, your responsibilities for military leadership will be about the same as those of petty officers in other ratings since every petty officer has military as well as technical duties. Your responsibilities for technical leadership will be special to your rating and directly related to your work as a Machinist's Mate. Operating and maintaining a ship's engineering plant and associated equipment requires teamwork along with a special kind of leadership ability that can be developed only by personnel who have a high degree of technical competence and a deep sense of personal responsibility. Strive to improve your leadership ability and technical knowledge through study, observation, and practical application.

Technical leadership involves more than just giving orders. In fact, you can demonstrate some

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of the most important aspects of technical leadership even if you are not required to tell anyone else what to do. As an MM3 and MM2 you demonstrate technical leadership when you follow orders exactly, when you observe safety precautions, when you accept responsibility, when you continue to increase your knowledge of the Machinist's Mate's job, and when you perform every detail of your work with complete integrity and reliability.

Integrity of work is really a key factor in technical leadership, and all other factors relate to it in some way. Integrity of work is demonstrated in big ways and little ways—the way you stand a messenger watch, the way you perform PMS, the way you deal with machinery failures and casualties, and the way you wipe up deckplates. When you perform every job just as well as you can, and when you constantly work to increase your knowledge, you demonstrate integrity of work in a concrete, practical, everyday sort of way. When your work has integrity, you are demonstrating technical leadership.

NAVY ENLISTED CLASSIFICATION CODES

The Machinist's Mate rating is a source of a number of Navy Enlisted Classification codes (NEC's). NEC's reflect special knowledge and skill in certain ratings. The NEC coding system is a form of management control over enlisted skills. It identifies skills and training required for specific types of operations or equipment. The Chief of Naval Personnel details personnel who have acquired those skills to those ships that require the skills. There are a number of NEC's that Machinist's Mates may earn at certain grade levels by satisfactorily completing an applicable course of instruction at a Navy school. Your personnel office will have complete information on NEC's and qualification procedures.

THE NAVY ENLISTED ADVANCEMENT SYSTEM

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

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

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

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

1. Those requirements that must be met before you may be considered for advancement.
2. Those factors that actually determine whether you will be advanced.

QUALIFYING FOR ADVANCEMENT

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

1. Have a certain amount of time in paygrade.
2. Demonstrate knowledge of material in your mandatory Rate Training Manuals by achieving a suitable score on your command's test, by successfully completing the appropriate NRCC's or, in some cases, by successfully completing an appropriate Navy school.
3. Demonstrate ability to perform the *Personnel Advancement Requirement (PAR) Program,* NAVPERS 1414/4.
4. Be recommended by your commanding officer.
5. For petty officer third class and second class candidates ONLY, demonstrate knowledge of military subjects by passing a locally

administered military/leadership examination based on the naval standards for advancement (from NAVPERS 18068 series).

6. Demonstrate knowledge of the technical aspects of your rate by passing a Navywide advancement examination based on the occupational standards applicable to your rate (from NAVPERS 18068 series, those standards listed at and below your rate level).

Figure 1-1 is a detailed view of the requirements for advancement of active duty personnel and figure 1-2 is similar information for inactive duty personnel. Remember that the advancement standards can change. Check with your division officer or training officer to be sure that you know the most recent standards.

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

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all of the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which persons of all of those qualified will actually be advanced in rate are:

1. The score made on the advancement examination.
2. The length of time in service.
3. The performance marks earned.
4. The number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceeds the number of qualified personnel, then all of those qualified will be advanced. More often, there are more qualified people than there are vacancies. When this happens, the Navy advances those who are BEST qualified by combining three personnel evaluation systems:

1. Merit rating system (annual evaluation and commanding officer recommendation)
2. Personnel testing system (advancement examination score—with some credit for passing previous advancement exams)
3. Longevity (seniority) system (time in rate and time in service)

Simply stated, each individual is given credit for what has been achieved in the three series of performance, knowledge, and seniority. A composite, known as the final multiple score, is derived from these three factors. All of the candidates who have passed the examination from a given advancement population are then placed on one list. Based on the final multiple score the person with the highest multiple score is ranked first, and so on, down to the person with the lowest multiple score. Advancement authorizations are then issued for candidates for E4, E5, and E6, beginning at the top of the list, for the number of persons needed to fill the existing vacancies. Candidates for E7 whose final multiple scores are high enough will be designated PASS SELBD ELIG (Pass Selection Board Eligible). Their names will be placed before the Chief Petty Officer Selection Board, a BUPERS board charged with considering all so-designated eligible candidates for advancement to CPO. Advancement authorizations for those being advanced to CPO are issued by this board.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the most in preparing for advancement. They were not content to just qualify; they went the extra mile in their training. Through that training and their work experience they developed greater skills, learned more, and accepted more responsibility. While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement?

1. Learn the naval standards for your paygrade level.
2. Learn how to perform the work defined by the occupational standards for your rating.
3. Work on the Personnel Advancement Requirement (PAR) Program for your rating.

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REQUIREMENTS*	E1 to E2	E2 to E3	#E3 to E4	#E4 to E5	E5 to E6	##†E6 to E7	##†E7 to E8	##†E8 to E9
SERVICE	6 mos. service.	6 mos. as E-2.	6 mos. as E-3. 2 years time in service.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 7 years time in service.	36 mos. as E-6. 10 years time in service.	36 mos. as E-7. 8 of 13 years time in service must be enlisted.	36 mos. as E-8. 10 of 16 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)		Class A for PR3, DT3, IS3, AME3, HM3, FTB3, MT3, MU3, EW3	Naval Justice School LN2		Navy School for AGC, MUC.††		
PERSONNEL ADVANCEMENT REQUIREMENT (PAR) NAVPERS 1414/4			Personnel Advancement Requirement (PAR) must be completed for advancement to E-4 through E-7.					
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navywide examinations required for all PO advancements.			Navywide selection board.		
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NAVEDTRA 10052 (current edition).				Nonresident career courses and recommended reading. See NAVEDTRA 10052 (current edition).		
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

*All advancements require commanding officer's recommendation.
†2 years obligated service required for E-7, E-8, and E-9.
#Military leadership exam required for E-4 and E-5.
**For E-2 to E-3, NAVEDTRAPRODEVCEN exams or locally prepared tests may be used.
††Waived for qualified EOD personnel.
##Advancement to E-7 will be 10 years TIS effective 1 January 1979; to E-8, 13 years TIS effective 1 November 1978; to E-9, 16 years TIS effective 1 November 1978.

Figure 1-1.--Active duty advancement requirements.

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	6 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 9 yrs service.	36 mos. with total 12 yrs service.	24 mos. with total 15 yrs service.
TOTAL TRAINING DUTY IN GRADE†	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS		Specified ratings must complete applicable performance tests before taking examination.						
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PERSONNEL ADVANCEMENT REQUIREMENT (PAR) NAVPERS 1414/4		Personnel Advancement Requirements (PAR) NAVPERS 1414/4 must be completed for advancement to E4 through E7.						
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam	Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E4 and E5.					Standard Exam Selection Board.	
AUTHORIZATION	Commanding Officer	NAVEDTRAPRODEVCEN						

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

Figure 1-2.—Inactive duty advancement requirements.

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4. Study the required rate training manuals for your rating.

5. Study other material applicable for advancement in your rating such as shown in the *Bibliography for Advancement Study*, NAVEDTRA 10052. (Note: If you are working for advancement to second class, remember that you may be examined on third class standards as well as on second class standards).

The following sections describe these five factors and give you some practical suggestions on how to use them in preparing for advancement.

Naval Standards

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

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

Occupational Standards

Occupational Standards are requirements that are directly related to the work of each rating.

Both the naval standards or requirements and the occupational standards are divided into subject matter groups.

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068-D has replaced the "quals manual" and the NEC manual. Section I contains the occupational and naval standards for advancement to each paygrade in each enlisted rating. Section II contains the Navy Enlisted Classification Codes.

Advancement Examinations

The Navywide advancement examinations for paygrades E-4 and E-5 contain 150 questions related to the occupational areas of your rating.

On the day you take your advancement examination, your examination proctor will announce that you are to remove the last sheet of your test booklet and give it to him. This last page of your booklet is the Exam Information Sheet, shown in figure 1-3, and on the reverse side is the Profile Form Information Sheet, shown in figure 1-4. When you turn in your examination, the sheet will be returned for you to keep.

Several weeks following your examination, you should receive a profile card similar to the one shown inside the black frame in figure 1-4. Suppose your profile card (fig. 1-4) shows a "P" on section 5 (see the arrow) of the examination, you should then refer back to the Exam Information Sheet, figure 1-3. If you then compared section 5 on the profile card to the section of figure 1-3 marked by the marginal arrow, you would find the subject, Piping and Valves. Since you had received a "P" for poor on this section, study would appear necessary on that subject and standards before your next examination.

Your Education Services Officer should be able to furnish you with a standards and bibliography sheet for each examination you are to take. This bibliography will cite the publications used in examination development. These sheets along with your profile card and Exam Information Sheet will help you plan your study for examinations.

PERSONNEL ADVANCEMENT REQUIREMENT (PAR) PROGRAM, NAVPERS 1414/4

The Personnel Advancement Requirement (PAR) is a new system of evaluation that

GIVE THIS SHEET TO YOUR PROCTOR

MM2 EXAM

EXAM INFORMATION

SUBJECT-MATTER SECTION IDENTIFICATION

THESE STANDARDS ARE FROM SECTION I, NAVY ENLISTED OCCUPATIONAL STANDARDS, OF THE MANUAL OF NAVY ENLISTED MANPOWER AND PERSONNEL CLASSIFICATIONS AND OCCUPATIONAL STANDARDS

NAVPERS 18068-D INCLUDING CHANGE 2

THE BASIC BIBLIOGRAPHY FOR THIS EXAMINATION IS CONTAINED IN BIBLIOGRAPHY FOR ADVANCEMENT STUDY (NAVEDTRA 10052-Y)

FOR ALL EXAMINATIONS WITH SERIAL NUMBERS FROM 790001 TO 799999

1. This examination was divided into SUBJECT-MATTER SECTIONS. The titles of these sections are general in nature and represent the occupational requirements of this rate. The chart below shows both the sectional breakdown for THIS examination and the standards from The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards (NavPers 18068-D) used to support the questions.

2. The basic bibliography for THIS examination is contained in Bibliography for Advancement Study (NAVEDTRA 10052-Y). It should be remembered that the publications listed for a given rating and paygrade may have suggested reading lists or may make specific references to other publications. These reading lists and other specific referrals must be considered as part of the TOTAL bibliography.

3. This SUBJECT-MATTER SECTION IDENTIFICATION SHEET is to be used with the PROFILE ANALYSIS FORM (explained on the back of this sheet) to identify a candidate's strengths and weaknesses in terms of subject-matter for this particular examination.

4. USNR-R usage of the PROFILE ANALYSIS FORM is covered by separate correspondence.

EXAMINATION SECTION	SUBJECT-MATTER SECTION TITLE	STANDARDS SUPPORTING THE QUESTIONS (FROM NAVPERS 18068)
1	PROPULSION	30424, 30434, 31237, 31238, 31244, 31246A, 31246B, 31246E, 31247, 31401, 42362, 48031F, 94205, 94207, 94210
2	AUXILIARY MACHINERY	30430, 30433E, 30433F, 30437, 48033A, 94179, 94182, 94183, 94184, 94188, 94193, 94194
3	DISTILLING	18469, 30424, 30428, 42261, 42362, 94196
4	REFRIGERATION AND A/C	30433G, 94165, 94171, 94172, 94548
5	PIPING AND VALVE	30433A, 42362, 94168, 94175, 94181, 94182, 94194, 94545
6	SHOP	94183, 94208, 94209, 94210, 94211
7	CASUALTY CONTROL	18467, 31248, 42362, 48031A, 48031C, 48031D, 48031E, 48031H, 48032D, 48033A, 94183

NAME _____ RATE _____

DIV _____ SHIP/STA _____

THIS SHEET MUST BE USED WITH THE MANUAL OF NAVY ENLISTED MANPOWER AND PERSONNEL CLASSIFICATIONS AND OCCUPATIONAL STANDARDS (NAVPERS 18068)

Figure 1-3.—Exam Information Sheet.

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UNCLASSIFIED UPON REMOVAL FROM EXAMINATION BOOKLET

GIVE THIS SHEET TO YOUR PROCTOR

PROFILE FORM INFORMATION

DEPARTMENT OF THE NAVY
NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER
PENSACOLA, FLORIDA 32509

FROM: COMMANDING OFFICER

TO: (YOUR NAME WILL APPEAR HERE)

SERIAL/DATE

ACTIVITY CODE 12345 AB

(YOUR EXAM SERIAL NUMBER AND THE DATE WILL APPEAR HERE)

SUBJ: EXAMINATION PROFILE INFORMATION

(5)

THE INFORMATION PROVIDED BELOW IS A PROFILE OF YOUR RELATIVE STANDING WITH ALL OTHERS IN YOUR RATE IN EACH SUBJECT-MATTER SECTION. THE INFORMATION IS TO BE USED WITH THE SUBJECT-MATTER IDENTIFICATION SHEET FOR THE EXAMINATION SERIAL INDICATED. STANDINGS ARE BASED ON OVER 90% RETURNS; NO SIGNIFICANT CHANGE WITH ALL RETURNS IN.

EXAMINATION STATUS (1)	YOUR FINAL MULTIPLE (2)	MINIMUM MULTIPLE REQUIRED (3)	(4) SECTION	1	2	3	4	5	6	7	8	9	10	11	12
			STANDING	A	A	HA	L	P	LA	P	A	E			

COPY TO SERVICE RECORD

CODE INTERPRETATION

S (Superior)= upper 10%
E (Excellent)= upper 20%
H (High) 30%

HA (High Average)= upper 40%
A (Average)= middle
LA (Low Average)= lower 40%

L (Low)= lower 30%
P (Poor)= lower 20%
VP (Very Poor)= lower 10%

YOU MAY CONTACT YOUR ESO FOR DATA USED FOR YOUR MULTIPLE COMPUTATION

Fold and TEAR OFF along this line only.

INSTRUCTIONS

A. The EXAMINATION PROFILE INFORMATION FORM is prepared at the Naval Education and Training Program Development Center to help each candidate analyze his strengths and weaknesses.

B. The information on the EXAMINATION PROFILE INFORMATION FORM is generally self-explanatory. The circled numbers above will have entries as follows:

1. Your PASS/FAIL status and Navy Standard Score attained.

2. Your final multiple unless you are designated as a discrepancy or fail the examination.

3. The final multiple required for advancement or selection board eligibility unless you are designated as a discrepancy or fail the examination. For ratings which are all advance ratings, the word "PASS" will appear in this block.

4. SECTION/STANDING entries. The numbered boxes refer to those subject-matter sections shown on the reverse side of this sheet for the examination which you took. The STANDING line will show letter codes indicating how you, individually, performed in each subject-matter section compared with all other candidates taking this same examination.

*5. Previous cycle PNA point information. Current cycle points earned if eligible are included.

*APPLICABLE TO PAYGRADES E4-6 ONLY.

NOTE: Since subject-matter sections vary in the number of questions, this profile cannot be used to compare overall examination performance between candidates and is valid only for section-by-section comparison.

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Figure 1-4.—Profile Form Information Sheet.

replaces the *Record of Practical Factors*, NAVEDTRA 1414/4. The PAR is based on the new occupational standards and is presented in task statements, whereas the old Record of Practical Factors was stated in terms of practical factors and knowledge factors which required lengthy and detailed checkoff lists. The PAR allows a command to evaluate the overall abilities of an individual in a day-to-day work situation.

The E-8 and E-9 paygrades are exempted from the program because there are other means of selection for advancement to these paygrades. Also, the E-3 apprenticeships are so broad that it is impractical to develop a single PAR for this paygrade.

The PAR for each rating lists the requirements for advancement to paygrades E-4 through E-7 in one pamphlet. The PAR is comprised of three sections which contain descriptive information, instructions for administration, special rating requirements, and advancement requirements.

Section I—Administration Requirements—contains the individual's length of service, time in paygrade, and a checkoff for the individual's having passed the E-4/E-5 military/leadership examination.

Section II—Formal School and Training Requirements, contains a checkoff entry to show the individual has completed the applicable Navy military requirements and rate training courses.

Section III—Occupational and Military Ability Requirements—is a checkoff list of task statements. Items in this section are to be interpreted broadly and do not demand actual demonstration of the item nor completion of alternate local examination, although demonstration is a command prerogative. Individuals are evaluated by observation of their ability to perform tasks in related areas by training received or, if desired, by demonstration.

PAR forms are stocked in the Navy Supply System.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

The purpose of EOSS is to detail the sequential operational functions for the complete cycle of plant evolutions. Each plant evolution becomes a plant procedure which is supplied to the Engineering Officer of the Watch. The use of correct operating and casualty control techniques should reduce casualties resulting from personnel error and increase equipment use and life.

If EOSS is followed, all watchstanding will be improved and standardized, and watchstanders will develop and maintain maximum proficiency in engineering operation and casualty control procedures. These improvements will contribute to the operational readiness of the engineering propulsion plant.

EOSS has a secondary feature in that it is an excellent aid for indoctrinating and training newly assigned engineering personnel, providing training for advancement in rating, and preparing for refresher training. This training, in turn, will also help to assure the overall operational readiness of the engineering propulsion plant.

EOSS is broken down into two subdivisions: Engineering Operational Procedures (EOP) and Engineering Operational Casualty Control (EOCC).

Since EOSS is tailored for each particular ship, complete details are not given in this training manual. For complete information, study the EOSS provided for your ship. It is a ready reference.

PERSONNEL QUALIFICATION STANDARDS

The Personnel Qualification Standard is a document which describes the knowledge and skills a trainee must have to perform certain duties. It will speed up learning progress since each person will know exactly what information to obtain to prepare for qualifying in increasingly complex duties. It individualizes learning so that each person may take advantage of opportunities to learn on the job. It places the responsibilities for learning on

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the learner and encourages self-achievement. By providing a convenient record of accomplishment, it offers a means whereby supervisors can check individual speed and performance.

Since the Personnel Qualification Standards have been assembled by groups of experienced officers and petty officers, they attempt to represent the guidance which would be furnished if each person had an individual instructor throughout each step.

Personnel Qualification Standards are designed to support advancement in rating requirements as stated in the *Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, (NAVPERS 18068 series.)

Every Personnel Qualification Standard contains the following sections:

1. Introduction
2. Glossary of Qualification Standard Terms
3. Table of Contents
4. 100 series--Theory
5. 200 series--System
6. 300 series--Watchstanding
7. 400 series--Qualification Cards
8. Bibliography
9. Feedback Forms

PURPOSES, BENEFITS, AND LIMITATIONS OF THE PLANNED MAINTENANCE SYSTEM

PURPOSES

The Planned Maintenance System (PMS) was established for several purposes:

1. To reduce complex maintenance to simplified procedures that are easily identified and managed at all levels.
2. To define the minimum planned maintenance required to schedule and control PMS performances.
3. To describe the methods and tools to be used.
4. To provide for the detection and prevention of impending casualties.
5. To forecast and plan manpower and material requirements.
6. To plan and schedule maintenance tasks.
7. To estimate and evaluate material readiness.
8. To detect areas requiring additional or improved personnel training and/or improved maintenance techniques or attention.
9. To provide increased readiness of the ship.

BENEFITS

PMS is a tool of command. By using PMS, the Commanding Officer can readily determine whether his ship is being properly maintained. Reliability is intensified. Preventive maintenance reduces the need for major corrective maintenance, increases economy, and saves the cost of repairs.

PMS assures better records, containing more data that can be useful to the shipboard maintenance manager. The flexibility of the system allows for programming of inevitable changes in employment schedules, thereby helping to better plan preventive maintenance.

Better leadership and management can be realized by reducing frustrating breakdowns and irregular hours of work. PMS offers a means of improving morale and thus enhances the effectiveness of all hands.

LIMITATIONS OF PMS

The Planned Maintenance System is not self-starting; it will not automatically produce good results; considerable professional guidance is required. Continuous direction at each echelon must be maintained, and one individual must be assigned both the authority and the responsibility at each level of the system's operation.

Training in the maintenance steps as well as in the system will be necessary. No system is a substitute for the actual technical ability required of the petty officers who direct and perform the upkeep of the equipment.

SOURCES OF INFORMATION

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

In this section we shall discuss most of the publications you will use. The detailed information you need for advancement and for everyday work is contained in them. Some are subject to change or revision from time to time--some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rate. At best, it is a waste of time; at worst, it is likely to be dangerously misleading.

NAVEDTRA PUBLICATIONS

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

The naval training publications described herein include some that are absolutely essential for anyone seeking advancement and some that, although not essential, are extremely helpful.

NAVEDTRA 10052

Bibliography for Advancement Study, NAVEDTRA 10052 is a very important publication for any enlisted person preparing for advancement. It lists required and recommended rate training manuals and other reference materials to be used by personnel working for advancement.

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

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

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

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

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

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

Besides training manuals, NAVEDTRA 10052 lists official publications on which you may be examined. You should not only study the sections required, but should become as familiar as possible with all publications you use.

Rate Training Manuals

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

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

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based. However, during the life of any edition of a rate training manual, changes will be made to the official sources and discrepancies will arise. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVEDTRA 10052, the Naval Education and Training Program Development Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVEDTRA 10052 for a given rate, the examination writers will use the most recent material.

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

1. Study the naval standards and the occupational standards for your rating before you study the training manual and refer to the standards frequently as you study. Remember, you are studying the manual primarily to meet these standards.

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

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan. Look at the illustrations and read bits here and there as you see things that interest you. Review the Glossary, which provides definitions that apply to words or terms as they are used within the engineering field and within the text. There are many words with more than one meaning. Do not assume that you know the meaning of a word! As you study, if you can not recall the use of a word, look it up in the Glossary. A table on conversion to the metric system appears in Appendix II for your convenience.

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

What do I need to learn about this?
What do I already know about this?
How is this information related to information given in other chapters?
How is this information related to the occupational standards?

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

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

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

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

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

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

Other NAVEDTRA Publications

Some additional NAVEDTRA publications that you may find useful are listed and described in the following paragraphs. In addition, you may find it useful to consult the training manuals prepared for other ratings in Occupational Fields 3 and 4 (Engineering and Hull). Reference to these training manuals will add to your knowledge of the duties of others in the engineering department.

Another publication you will find of value is *The Metric System*, (NAVEDTRA 475-01-00-75-1) which is packaged with a self-study course. Over the next few years, the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted. See your Education Services Officer for information on how to obtain this study package.

NAVSEA PUBLICATIONS

The publications issued by the Naval Sea Systems Command are of particular importance to engineering department personnel. Although you do not need to know everything in these publications, you should have a general idea of where to find the information contained therein.

Naval Ships' Technical Manual

The *Naval Ships' Technical Manual* is the basic engineering doctrine publication of the Naval Sea Systems Command. The manual is kept up-to-date by means of quarterly changes. As new chapters are issued they are being designated by a new chapter numbering system.

The following chapters of the *Naval Ships' Technical Manual* are of particular importance

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to Machinist's Mates; both the new and old number for each chapter are listed.

NEW	OLD	CHAPTER
078	(9950)	Gaskets and Packing
079(3)	(9880.III)	Engineering Casualty Control
231	(9411)	Propulsion Turbines (Steam)
241	(9420)	Reduction Gears
254	(9460)	Condensers and Air Ejectors
262	(9450)	Lubricating Oils, Greases, and Hydraulic Fluids and Lubricating Systems
502	(9500)	Auxiliary Steam Turbine
503	(9470)	Pumps
505	(9480)	Piping Systems
516	(9590)	Refrigeration Systems
531	(9580)	Distilling Plants
550	(9230)	Industrial Gases
551	(9490)	Compressed Air Plants
556	(9210)	Hydraulic Equipment
589	(9830)	Elevators

NAVSEA Journal

The *NAVSEA Journal* is a monthly publication that contains interesting and useful articles on all aspects of shipboard engineering. This magazine is particularly useful because it presents information that supplements and clarifies information contained in the *Naval Ships' Technical Manual.* It is also of considerable interest because it presents information on new developments in naval engineering. The *NAVSEA Journal* was formerly known as the *Naval Ship Systems Command Technical News.*

The manufacturers' technical manuals furnished with most machinery units and many items of equipment are valuable sources of information on construction, operation, maintenance, and repair. The manufacturers' technical manuals that are furnished with most shipboard engineering equipment are given NAVSHIPS numbers.

Drawings

Some of your work as a Machinist's Mate requires an ability to read and work from mechanical drawings. You will find information on how to read and interpret drawings in *Blueprint Reading and Sketching,* NAVEDTRA 10077 (with changes).

In addition to knowing how to read drawings, you must know how to locate applicable drawings. For some purposes, the drawings included in the manufacturers' technical manuals for the machinery or equipment may give you the information you need. In many cases, however, you will find it necessary to consult the onboard drawings. The onboard drawings, which are sometimes referred to as ship's plans or ship's blueprints, are listed in an index called the ship drawing index (SDI). The SDI lists all working drawings that have a NAVSHIPS drawing number, all manufacturers' drawings designated as certification data sheets, equipment drawing lists, and assembly drawings that list detail drawings. The onboard drawings are identified in the SDI by an asterisk (*).

Drawings are listed in numerical order in the SDI. Onboard drawings are filed according to numerical sequence. There are two types of numbering systems in use for drawings that have NAVSHIPS numbers. The older system is an S-group numbering system. The newer system, used on all NAVSHIPS drawings since 1 January 1967, is a consolidated index numbering system. A cross-reference list of S-group numbers and consolidated index numbers is given in *NAVSHIPS' Consolidated Index of Materials and Services Related to Construction and Conversion.*

ENGINEERING HANDBOOKS

For certain types of information, you may need to consult various kinds of engineering handbooks—mechanical engineering handbooks, marine engineering handbooks, piping handbooks, machinery handbooks, and other handbooks that provide detailed, specialized technical data. Most engineering handbooks contain a great deal of technical information, much of it arranged in charts or tables. To make the best use of engineering handbooks, use the table of contents and the index to locate the information you need.

CHAPTER 2

GENERAL ENGINEERING SAFETY

The first portion of this chapter concerning accident prevention has been provided by the Naval Safety Center, Norfolk, Virginia, to define the role of Petty Officers and other service personnel in the important tasks of shipboard safety.

ACCIDENT PREVENTION

Why is accident prevention necessary? The "product" of the Navy is national defense. Therefore, the quality of our performance must be far superior to that of any competitor. The Navy's business is deadly serious, conducted by professionals, restricted by limited resources, and allows no room for waste. Accidents produce waste. Therefore, when accidents are reduced, waste is reduced and readiness is improved.

Accidents can and must be prevented. The job of everyone in the Navy includes accident prevention. By preventing accidents, personal injury and damage to material and equipment is prevented. The ultimate goal is the prevention of all accidents. Everyone in the Navy must continually strive to attain this goal. The first step can be taken by recognizing the need for accident prevention and by understanding that the objective of everyone in the Navy should be the elimination of accidents.

An ACCIDENT is any unplanned or unintended event that results in personal injury and/or property damage; it is caused by an individual's not doing something that should have been done or by doing something that should not have been done. The causes of the action, or inaction, may be due to the lack of technical skills, the lack of self-discipline, or both. Performing a job correctly is also performing the job in the safest manner known. Correct operational procedures are also the safest known procedures.

A NEAR-ACCIDENT is an accident that almost happened. It's an occurrence which, except for location or timely action, would have resulted in property damage to equipment or material or personal injury; it does serve notice that a hazardous condition exists which could result in a future accident. The near-accident is significant because it serves as a warning. Ignoring the conditions that cause near-accidents is a sure invitation to a future accident.

ACCIDENT PREVENTION (Safety) is the process of eliminating accident-producing causes before an accident occurs. Accident prevention is brought about by personnel performing tasks in the correct, and therefore most desirable, manner. This is the result of successful technical and disciplinary training.

Accidents can be prevented with the full cooperation of all personnel in eliminating unsafe acts and conditions. Each person must become an accident prevention specialist, trained in recognizing and correcting dangerous conditions and in avoiding unsafe acts. These actions must become habitual, for personal habits in any environment will determine the chances for accident involvement. It is for these reasons that high standards of cleanliness and orderliness must be maintained. Insistence on good housekeeping and frequent inspections, both formal and informal, to ensure adherence to these standards will serve both to reveal unsafe conditions and to ensure corrective action. The formation of safe and intelligent work habits is of equal importance to development of knowledge and skill in the

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performance of any task. Of particular importance in the elimination of unsafe acts, is the proper use of tools. All tools and equipment used should conform to Navy standards for quality and type and should be used only in the manner intended. All tools should be maintained in good repair. All damaged, worn, or nonworking tools should be replaced. When a job is completed or when work is interrupted, all tools should be accounted for and returned to toolboxes or to the tool issue room. This should be done as carefully as a surgeon accounts for all his instruments following an operation. Detailed information on the use, care and selection of general tools is contained in the Rate Training Manual, *Tools and Their Uses,* NAVEDTRA 10085 (Series). Study and frequent review of information regarding tools is recommended for all personnel using or supervising the use of tools.

A Navy ship's environment holds a great potential for accidents. Fuel, ammunition, high temperatures, electrical circuits, steel decks, saltwater, ladders, voids, and machinery, all create conditions which could entrap the unwary. Navy personnel must learn to live safely within this hazardous environment by being aware of its elements. An effective method of living safely with these hazards must become part of every individual in the Navy.

PEOPLE CAUSE ACCIDENTS. Since people cause accidents, accident prevention actions must be directed toward people. Individuals can prevent accidents if they recognize and understand accident cause factors and are motivated sufficiently to carry out corrective action.

Research has shown that Unsafe Acts are a direct cause of 88% of all accidents while Unsafe Conditions are a direct cause in only 10%. Basically then, most accidents are caused by people and are not the result of uncontrolled events or "Acts of God." If the principal cause is the human being, then people can prevent accidents through proper knowledge, hazard awareness, and corrective action.

Almost everything known about accident prevention has been learned from accidents. Past experience indicates what went wrong, how often, and what has to be done to correct a problem. Safety rules, operation, and maintenance procedures reflect lessons learned from past accidents. However, accidents can be prevented when people look for hazards and avoid or correct them before a mishap occurs.

SUPERVISOR'S ROLE

The safety-minded supervisor is the key to a successful accident prevention program. As first line supervisors, Navy Petty Officers know the most about their areas of responsibility. They have daily contact and familiarity with the personnel, machines and materials involved. They know the standard practices and circumstances in their work areas as well as the hazards involved. They have a personal and professional interest in identifying accident cause factors. They are in a position to take the most immediate action to prevent an accident from occurring or recurring. They can communicate most effectively with their people because they speak the language of the individual worker and understand their people best. Petty officers make accident prevention a part of the job. Petty Officers must motivate their people to develop and use correct (safe) work habits and to believe in accident prevention. They maintain the Navy's standards of performance for their people. Lack of interest on the part of supervisors can only result in a lack of interest in those working under their direction. If the supervisor is a poor leader, feelings of distrust and anger are generated. When subordinates understand the principles of accident prevention, they insist on safe practices at all times, recognize hazardous methods and procedures, and take corrective (accident preventive) measures immediately. When supervisors have strong personal commitments to safety, this serves to properly motivate all hands. Experience has shown that a lack of knowledge or skill is the single biggest cause of accidents--people doing something they don't know how to do. When personnel are taught the RIGHT way to do a job, it is impossible not to teach them the SAFE way, because the right way is the safest way. This is why on-the-job training and supervision are so important.

HAZARD IDENTIFICATION

As children, our parents attempted to prepare us to live safely in our environment. We were cautioned over and over about the hazards we would encounter, whether in the bathtub, swimming pool, on the street, in the workshop or the medicine cabinet. In school, our teachers supplemented safety instructions. These warnings were made even more vivid by our own experience. We slipped in the bathtub, broke our toys, cut ourselves with knives, damaged our bicycles, etc. Not only were hazards made known to us, but we experienced the consequences of failing to heed the warnings. Today we are still learning about hazards.

Obviously, we can't expect to experience everything in life ourselves. We must learn from the experiences of others and hope that these experiences are documented so that the lessons are clear. Safety precautions, operating instructions, NATOPS Manuals and the NAVSEA technical manuals are examples of such documentation. By reading and understanding all of the various written material that highlight hazards for any given environment, we can prepare ourselves to live successfully in that environment. Although knowledge of hazards alone is not enough to ensure the prevention of accidents, the first and basic rule of accident prevention is to recognize hazards and determine accident-cause factors. Experience has shown that in the majority of cases, accidents were caused by human failings. The most prevalent causes of accidents are lack of knowledge or skill and behavioral problems. All applicable instructions must be understood before attempting any job in order to recognize the hazards and allow for accident-free performance.

Individuals must learn to cope with the hazards within their environments that cannot be changed. Personnel are less likely to be involved in accidents if they live in such a manner that, by their habits, they avoid existing hazards. This is true whether or not the persons have knowledge of these hazards. It is immaterial whether their actions are conscious, deliberate, or not. People can be trained to deal habitually with most known hazards. The intelligent person will try to avoid hazards rather than ignoring them and accepting the risks posed by the environment.

People have a natural tendency to reject or repress threats. For accident prevention to be successful, an individual's willingness to accept unnecessary risk must be overcome. Training alone will not suffice to prevent accidents. A positive attitude toward the goals of accident prevention must be developed. These attitudes should be based on awareness of hazards and knowledge of their nature and threat. Only then can accident prevention traits be developed.

ACCIDENT PREVENTION TRAINING

Accident prevention training in the Navy begins during indoctrination and continues with orientation and on-the-job training. It is not a matter of merely telling people to "be careful." Doing the job PROPERLY requires passing on knowledge to those less knowledgeable and experienced in a way which leaves the trainee properly motivated. Written operating procedures, in all of their various forms, are provided to assist in this training process.

Training in the proper use and checking of protective devices and equipment must be part of any indoctrination. This accident prevention element should be an integral step in any procedure related to a piece of equipment or system.

Sufficient time must be allotted to follow correct procedures in order to minimize lost time, money and readiness as a result of mishap. Only the individual actually responsible for the consequences should make the decision to vary from the correct procedures. This will not normally be the operator or the immediate supervisor. They should understand that, in other than emergency situations, this decision is not theirs. In the absence of a direct order to do otherwise, the proper procedure must be carried out. Whenever good work practices are sacrificed to meet time requirements, injury and damage become more probable. Personnel who feel rushed to accomplish a task are more likely to commit an error. Even if a mishap does not occur, the necessity to correct errors caused by hurrying results in delay and inefficiency. Established procedures should never be violated where life or limb might be endangered.

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The shipboard environment by its very nature alters the effectiveness of both personnel and equipment. Space limitations may require that a machine be installed in less than the optimum position or location. This can result in more difficult operations or reduced life expectancy. The ideal location for a pump may be in a cool, dry place pumping clean freshwater. However, its required use may be in a hot, moist bilge pumping saltwater. This may result in the equipment being placed low in the ship with a minimum amount of space available for maintenance. In such an environment, less effective operation and more frequent overhauls may be expected. People work best in a cool, medium-dry, clean, and spacious area. However, a ship must maximize space utilization and heat producing machinery must be used. Therefore, when individuals are forced to work in a hot, humid, noisy, and cramped environment, their effectiveness and capacity for work will be reduced.

Hazard awareness takes on even greater importance when the environment is considered. Supervisors must learn from personal experiences and improve their hazard awareness in order to promote accident prevention. They must also correct any hazardous situation. Further, they are challenged with developing this ability in subordinates.

SUMMARY

The accident prevention program is the sum of all actions taken to get all jobs done correctly and will result in the reduction of accidental damage to equipment and/or injury to personnel. It includes the establishment, maintenance, and enforcement of accident prevention standards and practices. Accident prevention training and education, supervision of operations, maintenance and repair, and accident investigation and reporting are also included. Accident prevention cannot be isolated or separated from other activities.

Supervisors, as the individuals most technically qualified and closest to the equipment and people concerned, must actively participate in any accident prevention program. Their participation is fundamental to the success of the program. The Commanding Officer establishes the program and gives it direction, but it is the supervisor who makes it work. Supervision and personnel management by the supervisor, requires assessing individual qualifications, providing guidance, and developing proper attitudes (pride in a job well done). They are responsible for identifying and correcting discrepancies. They are the individuals most qualified to train others to recognize unsafe work practices.

SAFETY

In establishing a Department of the Navy Safety Program, the Secretary of the Navy stressed: "Safety is an inherent responsibility of command. . .assignment of safety responsibility at all echelons of command is a basic requirement." This means responsibility right down through second and third class petty officers. Most accidents that occur in noncombat operations can be prevented if all personnel cooperate in eliminating unsafe conditions and acts.

To assist shipboard personnel in carrying out their responsibilities concerning safety, the Chief of Naval Operations has issued instructions on the subject. In addition, safety information is issued periodically in various publications, pamphlets, and directives by commands, bureaus, and offices of the Navy Department. Also, the Naval Safety Center, Norfolk, Virginia, monitors safety in the fleet and obtains accident data from completed Accident/Near Accident Reports (3040 forms) and Accidental Injury/Death Reports (5100 forms) and from Safetygrams, which are submitted informally by ships. Publications issued by the Center of particular interest to forces afloat include *FATHOM* and *Ship's Safety Bulletin.*

The 3-M (Maintenance Material Management) system is potentially the most valuable contribution to shipboard safety yet devised. It is easily capable of supporting a major portion of an overall shipboard safety program. The 3-M is a primary management information system that progressively exercises management control, policy direction, and technical supervision from one echelon to another. A flow of accomplishments and things to be accomplished can be developed between

interested managers at all levels. The 3-M System is divided into two subsystems: PMS (Planned Maintenance System) and MDCS (Maintenance Data Collection System). Both are tools in various stages of growth and transition. Both are solid bases for a highly efficient shipboard accident prevention plan.

We shall discuss some of the areas in which you should exercise above average caution; some points to help you teach safety accurately and effectively; and some of the approved methods of action so that you will be able to rehearse your actions and be ready in the event of a casualty.

You will find detailed instructions and procedures pertaining to safety in manuals such as *Naval Ships' Technical Manual* (NSTM); Chapter 001 (9000), gives an index of NSTM chapters which will be important to you. The safety precautions discussed in this chapter are NOT intended to replace those in various manuals. Safety precautions related to specific machinery are included at appropriate points throughout this training manual.

SAFETY RULES

Each individual is responsible for understanding and observing safety standards and regulations which are established to prevent personnel injury and damage to property and equipment. As a supervisor, you are responsible for setting a good example; you cannot ignore safety regulations and expect others to follow them.

To help your people perform their work as safely as possible, you must OBEY THE TEN COMMANDMENTS OF SAFETY:

1. LEARN the safe way to do your job before you start.
2. THINK safety and ACT safety at all times.
3. OBEY safety rules and regulations–they are for your protection.
4. WEAR proper clothing and protective equipment.
5. CONDUCT yourself properly at all times–horseplay is prohibited.
6. OPERATE only the equipment you are authorized to use.
7. INSPECT tools and equipment for safe condition before starting work.
8. ADVISE your superior promptly of any unsafe condition or practice.
9. REPORT any injury immediately to your superior.
10. SUPPORT your safety program and take an active part in safety meetings.

ACCIDENTS

Accidents don't just happen; they are preventable. As a petty officer aboard ship and on shore, it is your job to prevent them. All accidents have a "cause." Deviation from one or more safety precautions has been established as the cause of the majority of accidents.

It is also your job as a petty officer to know, and be able to perform, the proper action when an accident does occur.

Accidents are always unexpected by the persons to whom they occur. If this were not so, accidents would not happen. A person who expects an accident to occur will do something to avoid it. For example, if a sailor expects a hatch to come unlatched and fall on someone, the sailor will see to it that the toggle pin secures the latch before anyone uses the ladder.

There are two practical implications from the idea that accidents occur because they are unexpected. First, it pays to train people to know about the unexpected. The more sailors know about what can and might happen, the more likely they will act so that such things do not happen. For example, if sailors understand that someone may open an air valve while they are working on an air compressor line, they will be more likely to protect themselves by making sure that all valves that can admit air to that section of piping are wired and tagged shut prior to commencing work.

The second implication is that it pays to convince people that the unexpected will occur sooner or later unless they take appropriate precautions. The more you convince sailors that the unexpected will occur unless they take definite steps to guard against it, the more likely they will apply those precautions. For example, sailors, when convinced that, sooner or later, they will get a foreign object in their eyes unless

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they wear goggles, are very unlikely to use a power grindstone without wearing goggles. Being convinced about what will occur prompts them to protect themselves.

Accidents usually involve some type of unexpected contact of a person or ship with some object or substance or exposure in the environment. There are exceptions. One exception is the overexertion accident in which persons injure themselves by putting excessive strain on some part of their body; for example, a back injury caused by lifting a heavy object while in an awkward position.

To focus attention more specifically on what we are trying to prevent, we must stress that accidents are contacts. We are trying to prevent certain types of unexpected contacts. Once you get into the habit of thinking of accidents as contacts, you will recognize more potential accidents in the work you supervise. Being contact-minded will enable you to do a better job of observing for unsafe practices, inspecting for unsafe conditions, and analyzing jobs for safer methods. Think of accidents as unexpected contacts.

Basic Types of Unsafe Acts

There are many variations of the basic types of unsafe acts. Once you know the basic unsafe acts and understand why they are unsafe acts, you should have no trouble recognizing the many variations. Some of the basic unsafe acts that you should be alert for and should emphasize in your safety training are:

1. OPERATING OR USING EQUIPMENT WITHOUT AUTHORITY: Sometimes sailors will use equipment or operate machines, valves, and switches without authorization. Unauthorized persons usually lack the knowledge or skill to operate equipment safely.

2. FAILURE TO SECURE AGAINST UNEXPECTED MOVEMENT: Any equipment or materials capable of unexpected startup or unexpected movement such as slipping, sliding, rolling, falling, or drifting must be made secure against such possibilities. Specific examples are failure to tag out or disconnect the controller of an electric pump before making repairs or adjustments and failure to install battens to prevent stores from shifting in a storeroom.

3. OPERATING OR WORKING AT AN UNSAFE SPEED: Some personnel try to get things done too quickly. They will operate a machine or vehicle at an excessive speed. Or, they will take short cuts on a job to hurry it along. Rushing a job by running, throwing, improvising, or taking short cuts invariably increases the risk of an accident.

4. REMOVING OR MAKING SAFETY DEVICES INOPERATIVE: Equipment guards and other safety devices are never installed unless a serious hazard requires their installation. It is a serious unsafe practice to render such devices inoperative by removing or tampering with them. Examples include disconnecting speed-limiting governors to gain speed, gagging pressure relief valves to stop leaks, making limit switches inoperative to gain more room for movement, and permanently removing machinery guards to make adjustments or to make lubrication easier.

5. USING DEFECTIVE TOOLS OR EQUIPMENT: Most tools and equipment develop defective, unsafe conditions in time through normal wear and sometimes because of misuse or abuse. When they do, they should be repaired or replaced. Continued use of equipment in a defective condition invites accidents. Examples of this unsafe practice include using tools with loose handles, chisels with mushroomed heads, and portable electric tools with frayed cable or an unsuitable ground.

6. USING TOOLS OR EQUIPMENT UNSAFELY: Sailors will often use sound tools and equipment in an unsafe way. Frequently, they may use a tool or equipment for a purpose other than that for which it was designed, such as using a screwdriver as a chisel or punch. Just as frequently, they may use a tool or equipment for the right purpose but in a wrong way, such as hammering with the side of a hammer or exerting abrupt force on a wrench.

7. TAKING AN UNSAFE POSITION OR POSTURE: Many accidents occur because people put themselves in hazardous positions relative to the things around them. Examples include working directly below where overhaul work is being done, walking under crane lifts, and standing too close to a tool-swinging shipmate.

An unsafe posture concerns how people position their bodies, not where they position it. A typical example of unsafe posture is lifting a heavy object with your legs straight and your back arched down to the load.

8. SERVICING OF MOVING, ENERGIZED OR OTHERWISE HAZARDOUS EQUIPMENT: Repair or service work should NEVER be undertaken when the equipment is either moving, energized, or pressurized. Failure to shut down, deenergize, or depressurize equipment before repairing, cleaning, lubricating, adjusting, or inspecting can be fatal. Whenever such equipment is worked on, appropriate securing and tag out procedures should be followed.

9. ENGAGING IN HORSEPLAY: Many accidents with serious injury consequences are caused by horseplay of one kind or another; such actions must be recognized as a basic type of unsafe act. Roughhousing, throwing objects, splashing water, and similar hazardous antics should NOT be tolerated by any petty officer.

10. FAILING TO WEAR PERSONAL PROTECTIVE EQUIPMENT: When personal protective equipment is prescribed and issued, it is because past accident experience has made the decision. Failure to wear hardhats, safety goggles, face shields, and protective clothing is an open invitation to serious injury.

The way to prevent unsafe practices is to eliminate their causes. We must eliminate, as much as possible, inadequate job skills, lack of incentive to work safely, motivations that conflict with working safely, physical and mental conditions of unfitness to work safely, and other personal factor causes of unsafe practices. The way to eliminate unsafe conditions is to correct BOTH the conditions AND the causes of the conditions.

General Housekeeping Standards

Good housekeeping goes hand in hand with safety and efficiency. It is a combination of orderliness and cleanliness. To promote orderliness, see to it that all items (1) have an assigned place for storage, (2) are kept in their assigned places when not in use, and (3) are stowed in their assigned places in a ready-for-sea condition.

To promote cleanliness, see to it that the sources of avoidable uncleanliness are corrected and the unavoidable conditions are regularly cleaned up. Establish housekeeping standards for your own area of supervision and assign individual responsibility for complying with those standards.

PRECAUTIONS AND PROCEDURES

In all cases of accident, every endeavor must be made to localize the damage. The compartment involved must be isolated to prevent damage from spreading to other compartments and interfering with proper attendance to other machinery in use. All personnel on duty must remain at their proper stations and give strict attention to the machinery in operation. When considerable leaks of steam occur in a space, the upper part of the compartment generally becomes filled with steam; people must not be allowed to go up the ladders at such times because of great danger of their being seriously injured or overcome when they inhale the steam. If it becomes necessary to abandon the compartment, the best avenue of escape is to another compartment on a lower level. To assist in escaping, a knowledge of the location of equipment such as the engine, turbines, pumps, blowers, and their emergency stop controls and switches is also essential.

In case of oil fires in bilges, close the master valve and stop the oil pump. Shut down or keep blowers running when oil fires occur, depending on circumstances whether it is better to risk fanning the flames or to aid personnel in escaping. Under some circumstances, it may be necessary to energize the CO_2 flooding system. In such a case, make absolutely sure the compartment is free of personnel. The fire should be fought as soon as possible to gain control and to keep it from spreading. ALL engineering department watchstanders should know how to operate the Twin Agent Fire Extinguishing System (TAFES). This information is available in the damage control booklets *Extinguishing Agents* NAVEDTRA 465-05-00-77 and *Nozzles and Application* NAVEDTRA 465-04-00-77.

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Casualties resulting in personal injury, no matter how minor, must be reported to the Engineering Officer of the Watch when underway and to the Duty Engineering Officer when in port. This action is required so that the appropriate entry may be entered in the Engineering Log.

HANDLING MATERIAL

When working on shipboard machinery, there are several things you can do to prevent accidents. Chain hoists are usually provided to lift heavy objects. However, if you must remove a heavy object by hand, there is a proper way to do it. Stand close to the load, with your feet solidly placed and slightly apart. With knees bent, grasp the object firmly, and then lift by straightening your legs, keeping your back as vertical as possible. NEVER stand on a slippery deck to lift a heavy object or to reach for it.

Materials should NEVER be thrown from elevated places to the deck. Suitable lowering equipment should always be used.

Lifting or lowering operations being performed by several persons should be done on signal from one person, and then only when all personnel are in the clear.

NEVER overload a chain hoist, block and tackle, crane, or any other lifting device. Defective or broken straps should NEVER be used.

Before any material is handled, it should be examined and personnel should be protected against sharp edges, protruding points, or other factors likely to cause accidents.

Before opening a fitting or piece of equipment, be sure that ALL valves which permit entrance of steam, water, air, oil, etc. into the fittings of equipment are closed, tagged, and secured by locking or wiring to prevent accidental opening. Tag out requirements are specified in OPNAVINST 3120.32. Your ship will have local instructions concerning tagouts. Basically, two types of tags are used: the "DANGER–DO NOT OPERATE" tag which is commonly referred to as the "red tag" and the "CAUTION" tag which is commonly referred to as the "yellow tag." Danger tags are used when operation of the valve, switch, etc. will cause dangerous hazards to personnel or equipment. The caution tag is used to specify instructions for operating a valve, switch, etc. These specific instructions must be followed to prevent a hazard when operating the tagged component.

Keep work areas clear of stray gear such as tools, fire hazards, and oil.

Warn others away from any known unsafe condition.

WORKING WITH HANDTOOLS

You and your people should take certain precautions when working with handtools. Normally, there should be no problems when working with these tools, but there are certain conditions under which they may constitute a danger to you. One source of danger, often neglected or ignored, is the use of handtools that are no longer considered serviceable. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises, particles striking the eye, and the like. Such tools should be condemned, replaced, or, if at all possible, repaired, before they cause accidents.

USING POWER TOOLS

To protect yourself and others working adjacent to you, take special precautions when using a power drill and a power grinder. In the first place, do not attempt to use these tools until you have had adequate instruction in their usage and you have been authorized to use them. Experimentation with power tools can be dangerous to you and result in damage to the tools. If a power drill slips, you can easily injure a finger or a hand. Always use goggles or a face shield when buffing or grinding, or when there is danger of flying particles. THERE IS NO EXCEPTION TO THIS RULE.

Do NOT use electrical equipment or machines with frayed or otherwise deteriorated insulation. Electrically driven portable machinery and fixed electrical equipment must have the frame grounded.

Aboard ship, electrically driven portable handtools MUST NOT be operated unless they are equipped with ground wire connections between their metal housings and the steel structure of the ship. THERE IS NO

EXCEPTION TO THIS RULE. These tools must be equipped with an approved type of grounding plug. You must inspect the attached cable and plug of a tool, before you use it, to make certain that the insulation and contacts are in good condition. Tears, chafing, exposed insulated conductors, and damaged plugs are sufficient reasons for replacement. The tools must be inspected and tested periodically (usually weekly) by a qualified Electrician's Mate to ensure that they are properly grounded and in safe operating condition electrically. Any electrically powered handtools that have not been inspected by an Electrician's Mate must be considered unsafe for use.

Get a copy of *Tools and Their Uses,* NAVPERS 10085 and study it carefully to learn how to use power tools safely.

USING PERSONAL EQUIPMENT

Personal radios, television sets, record players, or tape recorders having metal cases or metal backs or bottoms are safety hazards in many cases. In much of such equipment the chassis forms a part of the circuit and the exposed metal parts are energized, thereby creating the danger of shock to personnel touching them. Moreover, grounding these metal parts to the ship's structure would place a ground on the 115-volt lighting system which is contrary to the safety instructions.

In general, the molded housing on an electric shaver is a nonconducting plastic material, and the cutting blades are isolated from any contact with the electrical components within the shaver. For this reason, 3-prong grounding plugs are not required on electric shavers. For safe use aboard ship, your electric shaver should have a completely insulated housing and isolated cutting blades, and the housing and cord must be free of cracks. If in doubt whether your electric shaver complies, have it checked by the electric shop. If your electric shaver falls in a washbowl of water, let it go. Do NOT touch it until you unplug the cord from its receptacle connector. Do NOT try to energize it. Take it to the electric shop for a safety check first.

Personally owned or non-Navy standard electric lights, fans, and tools are NOT authorized. They are generally a shock hazard because of inferior insulation, leakage currents, and flimsy structure. Periodic inspections should be made to eliminate them from the ship. Adequate numbers and types of Navy lights, fans, and tools are available to meet all needs.

Personally owned hobby equipment such as handheld, motor-driven carving tools are frequently found to be of flimsy construction and unsafe for use aboard ship. Such equipment may be retained aboard ship subject to the following precautions:

Before any portable, electrically operated hobby devices are used aboard ship, they must be inspected and tested by the Electrician's Mate. Equipment that passes this inspection will be tagged as safe, giving the date of inspection. This equipment should be frequently reinspected, at least once each 6 months.

At any time that a hobby tool is damaged or is obviously defective, that is, if molded housing, cords, or plugs contain cracks or breaks or if the cord insulation breaks when sharply bent, it must be repaired and reinspected by the Electrician's Mate before it is used. No personal electrical equipment, such as radios, television sets, record players, tape recorders, or other personal appliances as listed above, shall be used aboard ship without the Engineering Officer's Tag of Approval. Periodic inspection should be made to enforce this vital safety regulation.

PREVENTING OIL FIRES

An oil fire can be caused by the ignition of oil or oil vapor in any place where oil is allowed to spray when under pressure or is allowed to collect by leakage or spillage from the system. While specification requirements for Navy Special fuels (flashpoint 150° F), JP-5 (flashpoint 140° F), and diesel fuel (flashpoint 140° F) are designed to make shipboard storage and handling as safe as possible, if the flashpoint is exceeded, an explosive mixture with air may result. Fuel oils of lower viscosity characteristics than those prescribed for Navy Special Fuel Oil are used in the naval service but flashpoint must be 140° F minimum. Such fuels are either distillates or blends of residual and cutting stocks. The distillate fuels contain no residual

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component. The blended fuels, depending on their viscosities, may require little or no preheating for either pumping or burning. Distillate fuels should be pumped and burned without preheating.

All fuels and lubricating oils are extremely dangerous if atomized (sprayed) through a leak in a flange or gasket. If the spray strikes a hot surface, fire and possibly an explosion will result. Be sure you know the fuel and oil piping systems in your space and ensure that all flange safety shields are installed.

The following precautions must be taken to prevent oil fires:

1. DO NOT ALLOW OIL TO ACCUMULATE ANY PLACE. Particular care must be taken to guard against accumulation of oil in drip pans, under pumps, in bilges, or on the deck plates.
2. If leakage from lubricating oil systems occurs at any time, immediate action must be taken to repair the leak or, in case of a large leak, to stop the oil pumps, in accordance with low lube oil pressure casualty procedures as described in the ship's Casualty Control Book.
3. Any oil spilled must be wiped up at once.
4. Electrical apparatus shall be inspected frequently and any condition likely to cause sparking shall be corrected before the apparatus is used again.
5. Have the Oil Pollution Act posted by fire and bilge pump.
6. Do NOT pump bilges at night.
7. In port, pump bilges only to a donut, and have a sailor stationed topside to observe discharge. The topside observer must be in communication with the person controlling the pumping. Sound-powered phones are the most reliable form of communication.
8. Have hull valves locked and precautions posted by the valves.
9. Have permission from Duty Engineering Officer prior to pumping bilges.

WORKING ALOFT

When radio or radar antennas are energized by transmitters, no one may go aloft unless advance tests show positively that no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the "surprise" may cause the person to let go involuntarily. There is also shock hazard if nearby antennas are energized, such as those on stations ashore or aboard a ship moored alongside or across a pier.

Danger also exists when radar or other rotating antennas might knock people working aloft from their perch, causing them to fall.

When you work on a stack, draw and wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous. In any case, working on a hot stack is NOT authorized.

Observe these safety precautions when you are going aloft:

1. You must have permission of the Communications Watch Officer (CWO), the OOD, and the Engineering Officer.
2. You must have the assistance of another person along with a ship's Boatswain's Mate qualified in rigging.
3. Wear a parachute type safety harness and dyna-brake device attached to a line no less than 1 ½-inch nylon. A shipmate must be assigned to tend the line. To be of any benefit, the harness must be fastened securely as soon as you reach the place where you will work. Some people complain on occasion that a harness is clumsy and interferes with movement. It is true the job may take a few minutes longer, but it is also true that a fall from the vicinity of a stack is usually fatal.
4. Do NOT attempt to climb while loaded with tools. Keep both hands free for climbing. Tools can be raised to you by your assistant below. Tools should be secured with preventer lines to avoid dropping them on your shipmate.
5. Ensure yourself of good footing and good grasp at all times.
6. Remember the nautical expression of old seafarers: HOLD FAST.

WORKING IN CLOSED SPACES

Since you normally think of breathing as an automatic body function, you seldom worry about whether the air is safe (or unsafe) to breathe. But aboard naval ships this is a very real problem which has cost many lives. This is especially true in spaces that are not well ventilated or that have been closed for appreciable lengths of time. Unventilated storerooms, blisters, double bottoms, tanks, cofferdams, pontoons, voids, and cold boilers are typical "iron coffins."

The air you breathe is composed of several gases. Under normal conditions, approximately 20% of the air content is oxygen. If for any reason this percentage is reduced much below 16%, you cannot survive. Fire, rusting, the drying of paint, and the decomposition of organic material can all contribute to oxygen deficiency. If you step into a closed compartment and there is insufficient oxygen in the air to support life, the results will be painfully swift. You will be immediately weakened. Your body may not respond even to your most desperate efforts to escape. If the oxygen content is particularly low, you may have time for only a few futile gasps before losing consciousness. Death may be only a breath away in an oxygen-deficient atmosphere. But BEWARE even if the air does contain enough oxygen, it may also contain concentrations of other gases which are flammable, toxic, or both. Flammable or toxic gases and vapors may be just as deadly as the lack of oxygen.

The first question that comes to mind is, "What precautions should I take before entering a closed or poorly ventilated compartment?" Aboard a naval ship, no person may enter any closed compartment or poorly ventilated space until the gas free engineer or an authorized representative has declared that the applicable safety and entry precautions have been complied with and that the danger of poisoning or suffocation or ignition of flammable materials or gases has been eliminated or reduced to the lowest practicable minimum.

ELECTRICAL SAFETY

Even though the care and maintenance of electrical equipment is the responsibility of an Electrician's Mate, as an MM you should be familiar with the precautions to be observed when working around electrical equipment. Any person working around electrical circuits and equipment must always observe safety precautions to avoid injury caused by contact with electrically charged objects.

Electrical shock due to contact with an energized circuit can cause serious injury. Even low voltage circuits (115 volts and below) can cause death upon contact, especially if current passes through the chest.

Shipboard conditions are particularly conducive to severe shocks because (1) the body is likely to be in contact with the ship's metal structure and (2) the body's resistance to electricity may be low because of perspiration or damp clothing. You must always be alert and extremely careful when you work in the vicinity of electrical circuits aboard ship.

You should exercise extreme care to prevent short circuits. Short circuits may be caused by accidentally placing or dropping a metal tool, flashlight case, or some other conducting object on an energized line. The arc or the fire that may result can cause extensive damage to equipment and personnel. Safety precautions are posted in the vicinity of electrical equipment. If these simple rules are observed, injury or accident will seldom occur. When working around electrical equipment, keep in mind that electricity strikes without warning, that hurrying reduces caution and invites accidents, and that every electrical circuit is a potential source of danger.

Rescue of Victims

Even when safety precautions are observed, accidents may occur. You should be familiar, therefore, with the procedures to follow when rescue from electrical contact is necessary and injury from electricity has been received. Rescuing a person who is in contact with an electrically charged object is likely to be a difficult and dangerous job.

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You MUST NOT TOUCH the victim's body, the charged object, or any other object that may be conducting electricity. You may be electrocuted yourself!

> WARNING
>
> DO NOT ATTEMPT TO ADMINISTER FIRST AID OR COME IN PHYSICAL CONTACT WITH AN ELECTRIC SHOCK VICTIM BEFORE THE VICTIM HAS BEEN REMOVED FROM THE LIVE CONDUCTOR.

When attempting to administer first aid to an electric shock victim, proceed as follows:

1. Shut off the high voltage.
2. If you cannot shut off the high voltage, remove the victim immediately, observing the following precautions:

a. Protect yourself with dry insulating material.

b. Use a dry board, belt, dry clothing, or other available nonconductive material to free the victim from the live wire. DO NOT TOUCH the victim.

c. After you have removed the victim from the live conductor, proceed to administer artificial respiration as described below.

Resuscitation and Artificial Respiration

The following instructions on resuscitation for electric shock were furnished by the Bureau of Medicine and Surgery.

Artificial resuscitation after electric shock includes artificial respiration to reestablish breathing and external heart massage to reestablish heart beat and blood circulation (fig. 2-1).

To aid a victim of electric shock after removal from contact with the electricity, immediately apply mouth-to-mouth artificial respiration.

If there is no pulse, immediately apply heart massage. Do NOT waste precious seconds by carrying the victim from a cramped, wet, or isolated location to a roomier, drier, more frequented location. If desired, breathe into the victim's mouth through a cloth or a handkerchief. If assistance is available, take turns breathing into the victim and in massaging the heart (fig. 2-1).

CARDIAC ARREST (LOSS OF HEARTBEAT).–If the subject has suffered an

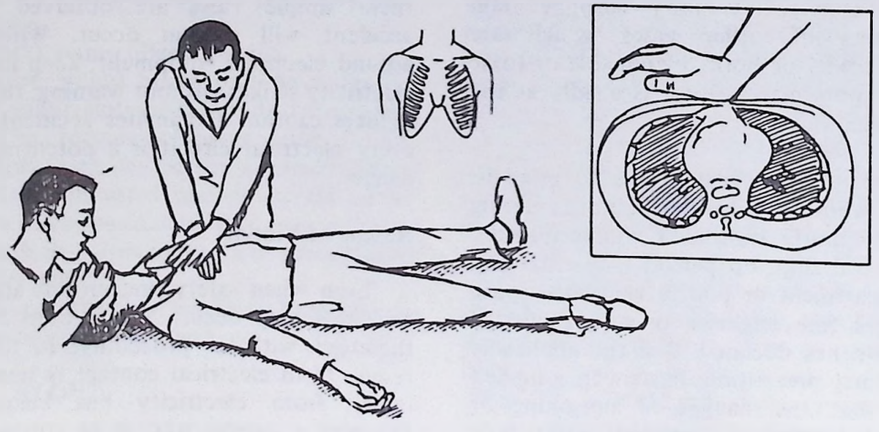


Figure 2-1.–Resuscitation procedure. 4.224

electric shock and has no heartbeat, cardiac arrest has occurred. Absence of any pulse at the wrist or in the neck will verify cardiac arrest. Associated with this, the pupils of the eyes will be dilated, and respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances, severe brain damage will occur in 4 minutes unless circulation is reestablished by cardiac massage.

CLOSED CHEST CARDIAC MASSAGE.–This method has been adopted as practical and can be administered by anyone who is properly instructed. The object in closed chest cardiac massage is to squeeze the heart through the chest wall, thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

Lay the subject face up; a firm surface, such as the deck, is preferred. Expose subject's chest.

Kneel beside victim; feel for lower end of his sternum (breastbone); place one of your hands across breastbone so the heel of your hand covers the lower part; place your other hand on top of the first so that the fingers point toward the victim's neck, as in figure 2-1.

With your arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the victim's breastbone. The amount of pressure to apply will vary with the subject. Apply pressure as smoothly as possible. With an adult victim, depress the chest wall 2 to 3 inches with each pressure application.

Repeat each application of pressure about 60 to 80 times per minute.

An assistant should be ventilating the subject's lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone, you must concentrate on the massage until help can arrive.

Direct other assistants, when available, to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed.

Pause occasionally to determine whether a spontaneous heartbeat has returned.

PRECAUTIONS: Make every effort to keep your hands positioned as described to prevent injuries to the liver, ribs or other vital organs.

No matter how carefully the treatment has been applied, possible chest bone damage may occur. If the patient is to be moved, it should be done very carefully to prevent possible injury to internal organs by unrecognized bone fractures.

Since the heart cannot recover unless it is supplied with oxygenated blood, cardiac massage must be accompanied by mouth-to-mouth artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half-minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

The mouth-to-mouth or mouth-to-nose technique of artificial respiration is the most effective of all the resuscitation techniques.

It is the most practical method for emergency ventilation of an individual of any age who has stopped breathing, in the absence of equipment or of help from a second person, regardless of the cause of cessation of breathing.

Persons who are trained in first aid do not usually have the experience, training, and essential equipment to determine whether lack of breathing is a result of disease or accident. Therefore, some form of artificial respiration should be started at the earliest possible moment.

Any procedure that will obtain and maintain an open air passageway from the lungs to the mouth and provide for an alternate increase and decrease in the size of the chest, internally or externally, will move air in and out of a nonbreathing person.

The mouth-to-mouth or mouth-to-nose technique has the advantage of providing pressure to inflate the victim's lungs immediately. It also enables the rescuer to obtain more accurate information on the volume, pressure, and timing of efforts needed to inflate the victim's lungs than are afforded by other methods.

When a person is unconscious and not breathing, the base of the tongue tends to press

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against and block the upper air passageway. The procedures described below should provide an open air passageway when a lone rescuer must perform artificial respiration.

First, if there is foreign matter visible in the mouth, wipe it out quickly with your finger or a cloth wrapped around your finger. Tilt the head back so the chin is pointed upward (view A, fig. 2-2). Pull or push the jaw into a jutting out position (views B and C, fig. 2-2). These maneuvers should relieve obstruction of the airway by moving the base of the tongue away from the back of the throat.

Open your mouth wide and place it tightly over the victim's mouth. At the same time pinch the victim's nostrils shut (view D, fig. 2-2) or close the nostrils with your cheek (view E, fig. 2-2). You may close the victim's mouth and place your mouth over the nose (view F, fig. 2-2).

Blow into the victim's mouth (view D) or nose (view F). Air may be blown through the victim's teeth, even though they may be clenched. The first blowing efforts should determine whether there is an obstruction.

Remove your mouth, turn your head to the side, and listen for the return rush of air that indicates air exchange. Repeat the blowing effort. Blow vigorously at the rate of about 12 breaths per minute.

If you are not getting air exchange, recheck the victim's head and jaw positions. If you still

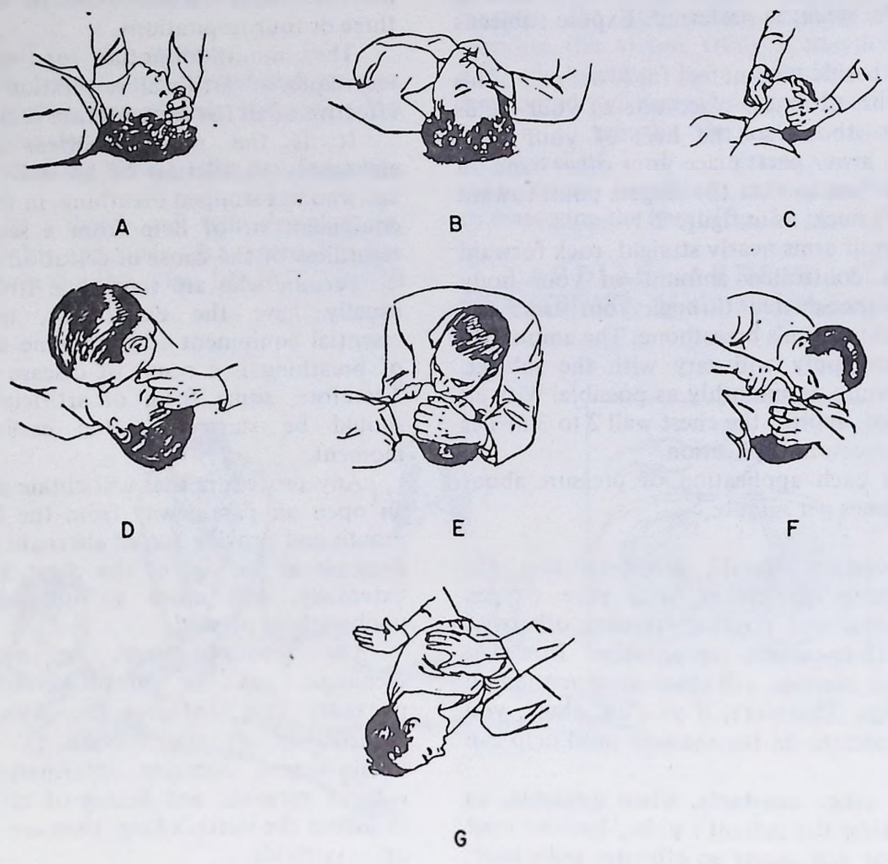


Figure 2-2.–Mouth to mouth respiration.

do not get air exchange, quickly turn the victim on one side and administer several sharp blows between the shoulder blades in the hope of dislodging foreign matter (view G, fig. 2-2).

Again sweep your finger through the victim's mouth to remove foreign matter. Those who do not wish to come into contact with the person may hold a cloth over the victim's mouth or nose and breathe through it. The cloth does not greatly affect the exchange of air.

TAKING ON FUEL

When fueling at sea, an MM will be mostly concerned with properly manning the engineroom. However, an MM may be assigned to a fueling station topside. You may be detailed to bring special equipment to a fueling station to dispose of spilled oil. You may be responsible for having available spanner wrenches or other tools used in making up fuel hose connections, or in opening or closing valves. The fueling detail shall take every precaution to prevent tanks from overflowing. No leak should be neglected, and any oil that may be spilled should be disposed of as soon as possible. During fueling, smoking and open flames are forbidden. Line handlers shall wear life jackets and take every precaution to prevent falling or being washed overboard.

WHO IS RESPONSIBLE?

Safety is everyone's responsibility. It cannot be left to an individual or an office. Everyone must always be on the alert to avoid causing an accident to anyone.

One of the basic rules of safety requires the proper behavior of every individual. Practical jokes and horseplay cannot be tolerated. The possible consequences are too high a price to pay for the small amount of humor derived.

Another basic rule requires cleanliness, or just plain good housekeeping practices. Decks must be kept clean and free from oil. Oil spots are very slippery and frequently result in accidents.

The assignment of safety personnel is a good practice because they will spot many unsafe acts or tools that would normally go unnoticed because other personnel are usually engrossed in work with which they are familiar. It is also a good idea to change the safety observers periodically and rotate their duties.

Safety is a never-ending job that must be emphasized so strongly that doing all jobs in a safe manner becomes the accepted and routine procedure at all times.

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CHAPTER 3

STEAM TURBINES

Aboard ships, steam turbines are the mechanisms that convert the thermal energy of steam into mechanical energy to perform useful work. Steam turbines produce power for ship propulsion and are prime movers of some auxiliary machinery associated with the propulsion plant, such as forced draft blowers, ship's service generators, and certain large pumps.

As a Machinist's Mate you will need a thorough understanding of the engineering plant. This chapter will provide general background information to give you a foundation upon which to build as you learn more about the specific propulsion machinery aboard your ship and work toward your PQS qualification.

In this chapter, we will discuss turbine theory, types and classifications of turbines, turbine construction, support systems and controls, and general turbine operation, maintenance and care. You will find some basic information on propulsion units and the principles of operation in *Fireman,* NAVEDTRA 10520.

Before we begin our discussion on the operating principles of the steam turbine, let us briefly describe energy and its relationship to work, power, and horsepower.

ENERGY

Energy may be described as the ability to do work. In the physical sense, work is done when a force acts on matter and moves it. We use heat energy to turn a steam turbine and electric energy to drive motors. The mechanical energy of the pistons in an automobile engine is transmitted to the wheels by the crankshaft, transmission, drive shaft, differential gears, and rear axles. Nuclear energy is used to generate electric power and to drive naval ships.

The most important characteristic of energy is that it cannot be created or destroyed; it can only change its form.

For example, look at figure 3-1. Chemical energy (stored in the fuel oil) is converted to thermal energy in the boiler. This thermal energy is then transferred to the feedwater and steam within the boiler. The steam is used to carry this thermal energy to the ship's turbines where the thermal energy is then converted to mechanical energy. (You will learn how this is accomplished later in the turbine theory section of this chapter.) The mechanical energy of the turbines is used to turn the propeller which pushes the ship through the water.

STORED ENERGY

Stored energy is energy that is actually contained in, or stored in, an object. There are two kinds of stored energy: potential and kinetic.

Potential Energy

Potential energy is energy within an object waiting to be released, while kinetic energy is energy that has been released. For example, potential energy exists in a rock resting on the edge of a cliff, in water behind a dam, and in steam behind a closed turbine throttle valve. Stored energy in steam is called ENTHALPY and is usually expressed in units of the British thermal unit (Btu). Specific enthalpy is the

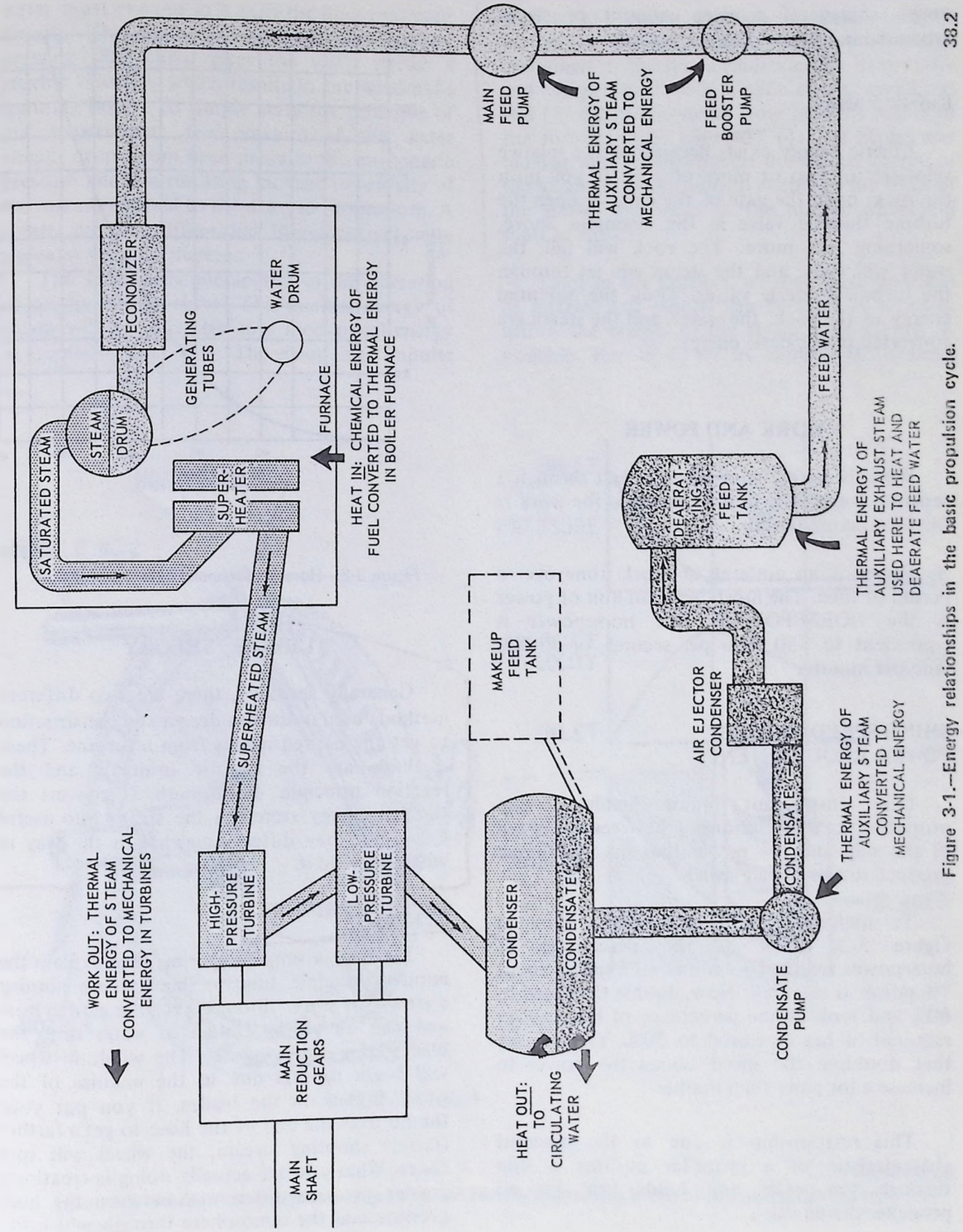


Figure 3-1.—Energy relationships in the basic propulsion cycle.

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stored energy of a given amount of steam expressed in units of Btu per pound.

Kinetic Energy

Kinetic energy exists because of the relative velocities of two or more objects. If you push the rock, open the gate of the dam, or open the turbine throttle valve in the examples above, something will move. The rock will fall, the water will flow, and the steam will jet through the turbine's nozzle valves. Thus, the potential energy of the rock, the water, and the steam are converted into kinetic energy.

WORK AND POWER

Work is simply moving an object through a resisting force. The unit of measure for work is the foot-pound (ft-lb).

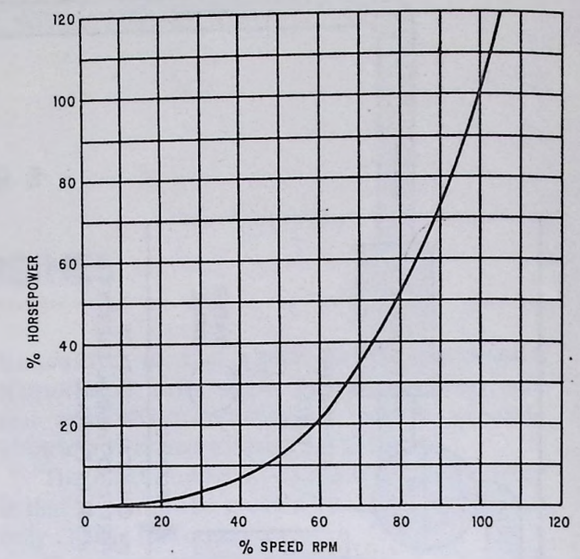
Power is an amount of work done over a period of time. The most common unit of power is the HORSEPOWER. One horsepower is equivalent to 550 ft-lb per second, or 33,000 ft-lb per minute.

SHIP'S SPEED VERSUS POWER REQUIREMENTS

One important factor involving ship propulsion is the relationship between the speed of the ship and the power that the plant must produce to attain that speed.

To understand this relationship, look at figure 3-2. Look at the percentage of horsepower required to run at 40% speed; about 7% power is required. Now, double the speed to 80% and look at the percentage of horsepower required; it has increased to 50%. You can see that doubling the speed causes the power to increase a lot more than double.

This relationship is due to the inherent characteristic of a propeller pushing a ship through the water and holds true for all propeller-driven ships.



47.179

Figure 3-2.—Horsepower-speed cube relationship.

TURBINE THEORY

Generally speaking, there are two different methods used in turbine design and construction to get the desired results from a turbine. These methods are the impulse principle and the reaction principle. Both methods convert the thermal energy stored in the steam into useful work, but they differ somewhat in the way in which they do it.

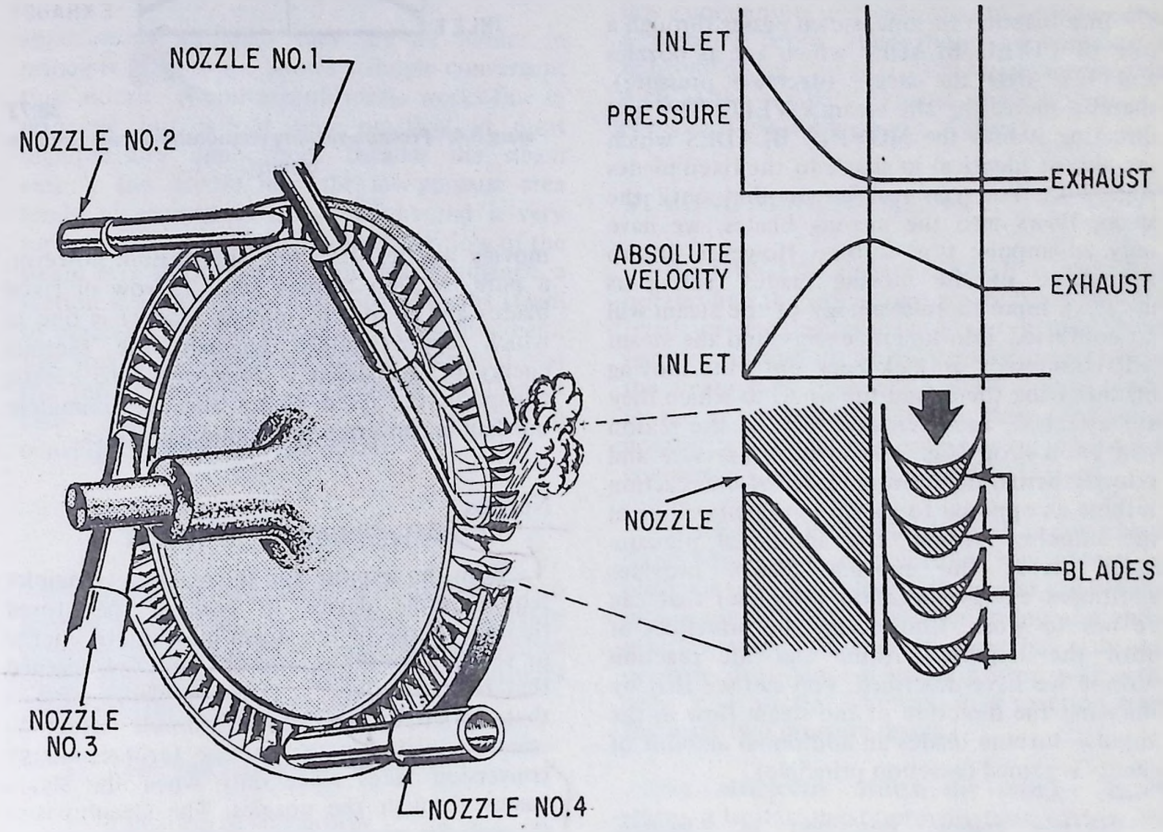
IMPULSE PRINCIPLE

Let's use a simple experiment to explain the impulse principle. Imagine that you are running a stream of water through a regular garden hose and you direct the stream of water onto the blades of a toy windmill. The windmill wheel will begin to spin due to the impulse of the water stream on the blades. If you put your thumb over the end of the hose to get a farther (faster) shooting stream, the wheel will spin faster. What you are actually doing is creating a greater pressure differential between the hose pressure and the atmosphere through which the

water must expand as it exits the hose past your thumb. The expansion through the greater pressure differential gives the water stream a greater velocity, which results in the windmill's spinning faster. To simply state the principle of our experiment: the pressure of the water stream drops from hose pressure to atmospheric pressure and the resulting increase in velocity of the stream is equal to the decrease in pressure. A greater pressure differential, therefore, will cause a greater velocity increase.

The same principle applies to the operation of an impulse turbine. The thermal energy of steam will be converted into mechanical energy in essentially four steps. The steam in an impulse turbine (1) passes through stationary nozzles which (2) convert some of the thermal energy contained in the steam (indicated by its pressure and temperature) into kinetic energy (velocity) and (3) direct the steam flow into the blades of the turbine wheel (fig. 3-3). (4) The blades and moving wheel then convert the kinetic energy of the steam into mechanical energy in the form of the actual movement of the turbine wheel and shaft or rotor.

Later in the chapter, we shall show how sets of nozzles and wheels can be used in series to utilize the energy of the steam as efficiently as possible. For now, let us explore the reasons



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Figure 3-3.—Pressure-velocity relationship across the nozzles and moving blades of an impulse type turbine.

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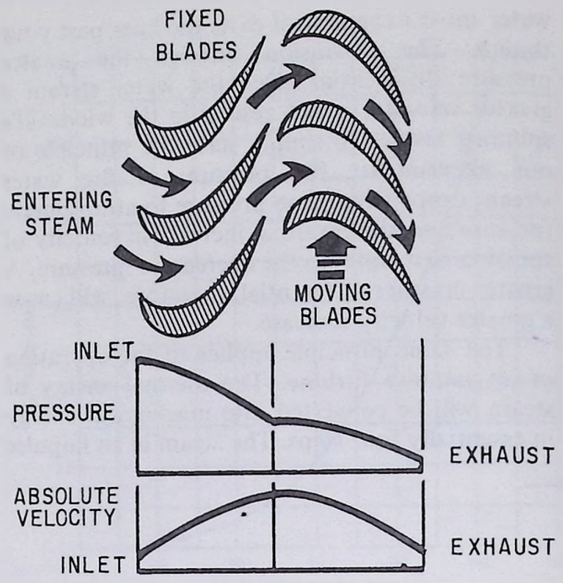
that an impulse turbine uses a certain amount of reactive force as opposed to operating purely on the principle of impulse.

REACTION PRINCIPLE

Newton's third law of motion states that for every action there is an equal but opposite reaction. The recoil of a fired gun is a simple example of this law. If you were to let a pressurized firehose loose with the nozzle wide open, the velocity of the water exiting from the end of the nozzle would cause the nozzle and hose to kick back and fly all over the place, causing possible injuries to equipment and personnel.

In a reaction turbine, steam passes through a row of FIXED BLADES which act as nozzles and EXPAND the steam (decrease pressure), thereby increasing the steam's VELOCITY and directing it into the MOVING BLADES which are almost identical in shape to the fixed blades (fig. 3-4). You can readily see that until the steam flows into the moving blades, we have only an impulse type turbine. However, due to the shape of the moving blades (acting as nozzles), more thermal energy of the steam will be converted into kinetic energy and the steam will counteract or kick back onto the moving blades giving them, and the wheel to which they are attached, more energy. This is the reason you see a drop (fig. 3-4) in both pressure and velocity across the moving blades of the reaction turbine as opposed to a drop in velocity alone in the impulse turbine. The additional pressure drop across the moving blades provides additional energy (reaction principle) that can be put to work. Considering the principles of both the impulse turbine and the reaction turbine we have described, you can see that by changing the direction of the steam flow in the impulse turbine blades an additional amount of energy is gained (reaction principle).

Hero's engine, described in *Fireman*, NAVEDTRA 10520, is an absolute reaction turbine in that all the thermal energy of the steam that is used is converted into kinetic energy and then into mechanical energy in the



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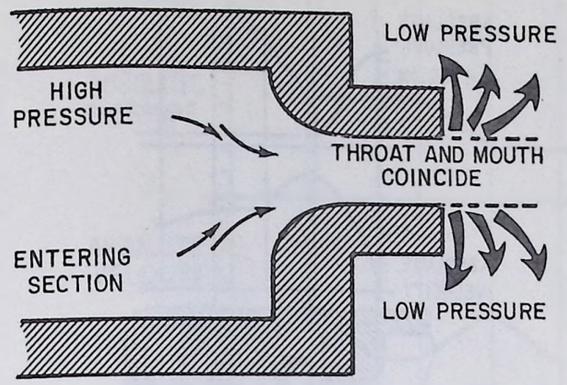
Figure 3-4.—Pressure-velocity relationship across reaction blading.

moving nozzles. In actual application, however, a pure reaction turbine stage (a row of fixed blades and a row of moving blades) is one in which approximately one-half the thermal energy of the steam is converted into kinetic energy in the fixed blades and approximately one-half is converted in the moving blades.

Nozzles

Both the impulse and the reaction principles require some device to convert the stored thermal energy of the steam into kinetic energy or velocity. In the reaction turbine you learned that both the fixed and moving blades serve as that device by producing a nozzle effect to create velocity. In the impulse turbine, energy conversion takes place only when the steam passes through the nozzles. The steam passes through the nozzles from a high pressure area to a lower pressure area, thereby giving high velocity to the steam.

Nozzles come in many different shapes and are engineered and designed for various



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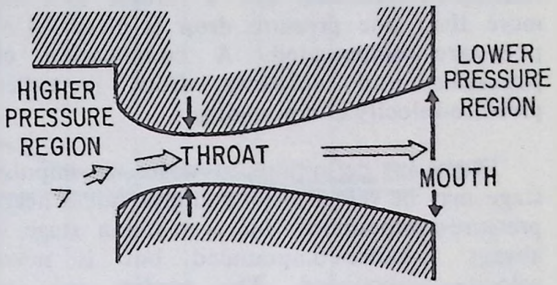
Figure 3-5.—Convergent nozzle.

applications although they are all similar in principle. Figure 3-5 shows a simple convergent type nozzle. A convergent nozzle works fine in principle but is not very practical in most high-pressure applications because the steam exiting the nozzle into the low-pressure area tends to expand in all directions and is very turbulent. It is difficult to direct the flow of the steam efficiently. To control this turbulence, a section is added to the nozzle to allow the steam to emerge from the nozzle in a smooth stream. The area of the nozzle is gradually increased past the throat to form a DIVERGENT section of the nozzle. Figure 3-6 shows a convergent-divergent type nozzle.

TURBINE CLASSIFICATION

Thus far we have classified turbines into two general groups—impulse turbines and reaction turbines—depending on the method employed to cause the steam to do useful work. Turbines may be further classified according to:

1. Type and arrangement of staging
2. Direction of steam flow
3. Repetition of steam flow
4. Division of steam flow



47.181

Figure 3-6.—Convergent-divergent nozzle.

A turbine may also be classified as to whether it is a condensing unit (exhausts to a condenser at a pressure below atmospheric pressure) or a noncondensing unit (exhausts to another system such as the auxiliary exhaust steam system at a pressure above atmospheric pressure).

STAGING ARRANGEMENTS

An IMPULSE turbine STAGE is one set of nozzles and the succeeding row or rows of either fixed or moving blades. Fixed blades in an impulse turbine do nothing more then redirect the steam flow from one row of moving blades to the next. A simple impulse stage (one set of nozzles and one row of moving blades) is commonly referred to as a RATEAU stage.

A REACTION turbine STAGE is one row of fixed blades and a succeeding row of moving blades. From these descriptions you can see one important difference between an impulse and a reaction stage: an impulse stage has only one pressure drop since a pressure drop will occur only in a nozzle; whereas, in a reaction stage there are two pressure drops.

To efficiently utilize the energy of the steam, a turbine must normally have blading and nozzles which will cause more than one pressure drop and/or more than one velocity drop as the steam passes through it. This is called COMPOUNDING. A turbine that has more than

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one velocity drop is classified as velocity-compounded and a turbine that has more than one pressure drop is classified as pressure-compounded. A combination of pressure and velocity drops is called pressure-velocity compounding.

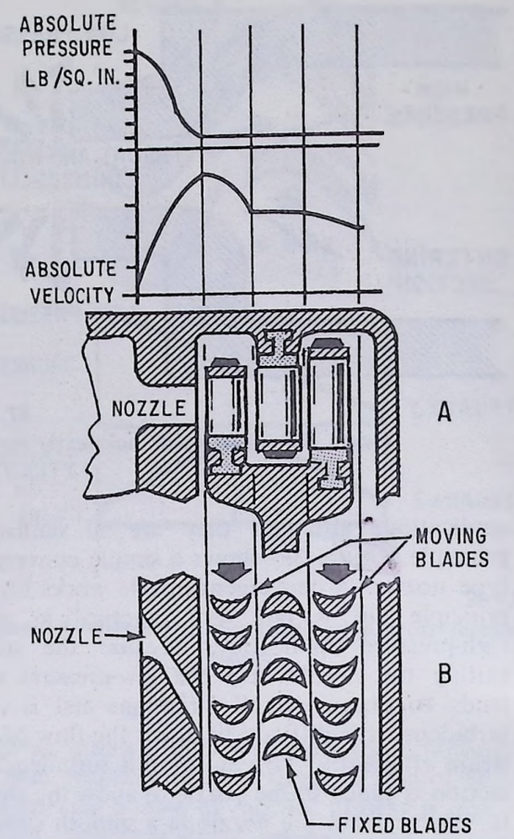
From our definitions of stages, an impulse stage may be velocity-compounded but is never pressure-compounded and a reaction stage is always pressure-compounded but is never velocity-compounded. This applies only to stages and NOT to the turbines. Turbines may be designed and constructed to incorporate practically any combination of stages and, therefore, may be compounded in any manner desired. Let's look at some of the combinations.

Velocity-Compounded Impulse Turbine

A velocity drop in an impulse turbine occurs only in the moving blades; therefore, to obtain more than one velocity drop across an impulse turbine, there must be more than one row of moving blades. (Velocity-compounding can also be achieved when only one row of moving blades is used if the steam is directed in such a way that it passes through the blades more than once. This point will be taken up in greater detail in the discussion on the direction of steam flow.) Figure 3-7 shows a velocity-compounded impulse turbine with two rows of moving blades. (NOTE: Two sectional views of the same blading are shown.) This type arrangement is called a Curtis stage, and, of course, it has two velocity drops occurring across it.

Pressure-Compounded Impulse Turbine

Another method of increasing the efficiency of an impulse turbine is to put two or more Rateau (simple impulse) stages in a row. This combination produces a pressure-compounded impulse turbine which has as many pressure drops as it has stages. Figure 3-8 shows a pressure-compounded impulse turbine.



47.182

Figure 3-7.—Pressure-velocity relationships in a velocity-compounded impulse turbine.

Pressure-Velocity-Compounded Impulse Turbine

A turbine which has one velocity-compounded (Curtis) stage followed by a series of simple-impulse (Rateau) stages is a pressure-velocity-compounded turbine. This type turbine (fig. 3-9) is commonly used for ship propulsion. NOTE: Only the upper half of the rotor and blading are shown.

Pressure-Compounded Reaction Turbine

All reaction turbines are pressure-compounded—that is, they are arranged

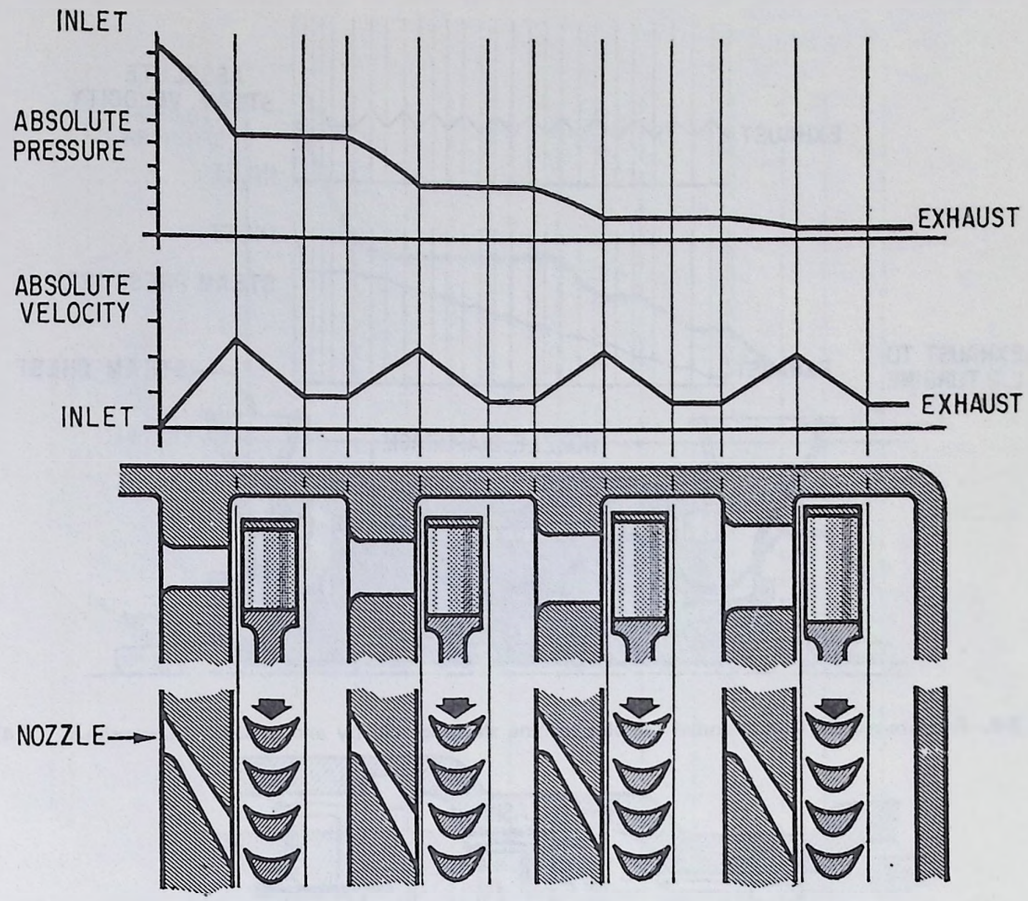


Figure 3-8.—Pressure-velocity relationships in a pressure-compounded impulse turbine. 47.183

so the pressure drop across the turbine from inlet to exhaust is divided into many steps by means of alternate rows of fixed and moving blades (Fig. 3-10). Note the small curved arrows between the blades and casing and the stator blades and rotor. The arrows indicate that a small amount of steam leaks around these areas and does no work.

Impulse and Reaction Combination Turbine

Another type of turbine is a combination impulse and reaction (fig. 3-11). This type of turbine design uses a velocity-compounded impulse (Curtis) stage at the high-pressure end of the turbine followed by reaction blading. The impulse blading causes a large pressure and temperature drop at the beginning, using a large amount of thermal energy. The reaction part of the turbine is more efficient at the lower steam pressure existing at the low-pressure end of the turbine. Therefore, you can see that for certain applications this would be a highly efficient machine with the advantages of both impulse and reaction blading. Figure 3-12 illustrates a type of the combination turbine commonly referred to as a modified Parson's turbine.

DIRECTION OF STEAM FLOW

There are three different ways in which steam can flow through a turbine: axial flow, helical flow, and radial flow.

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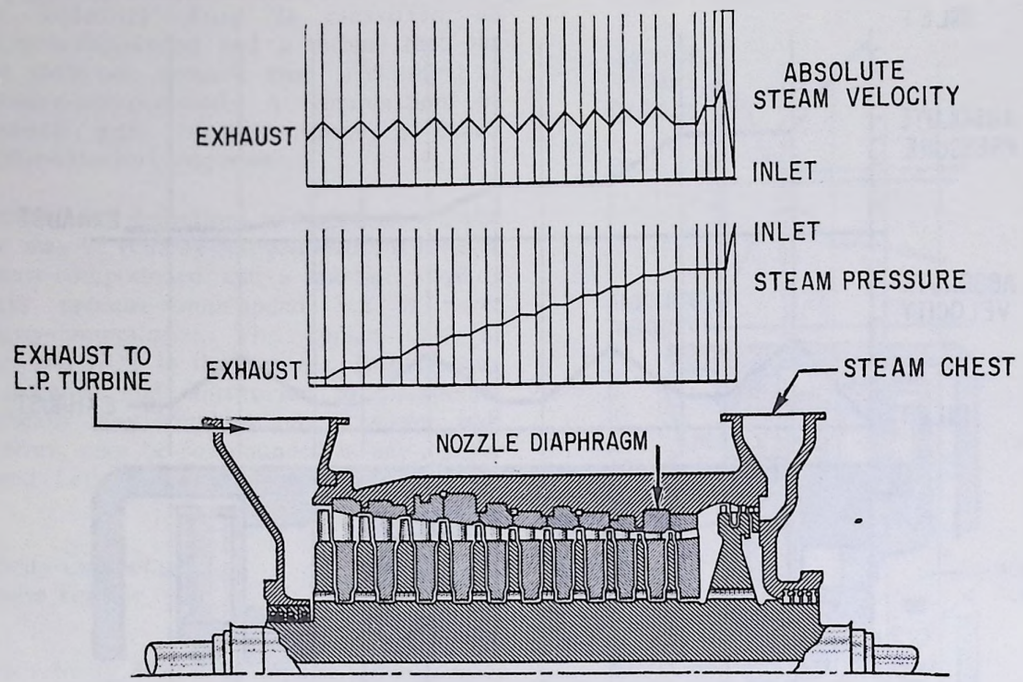


Figure 3-9.—Pressure-velocity-compounded impulse turbine showing velocity and pressure relationships. 47.184

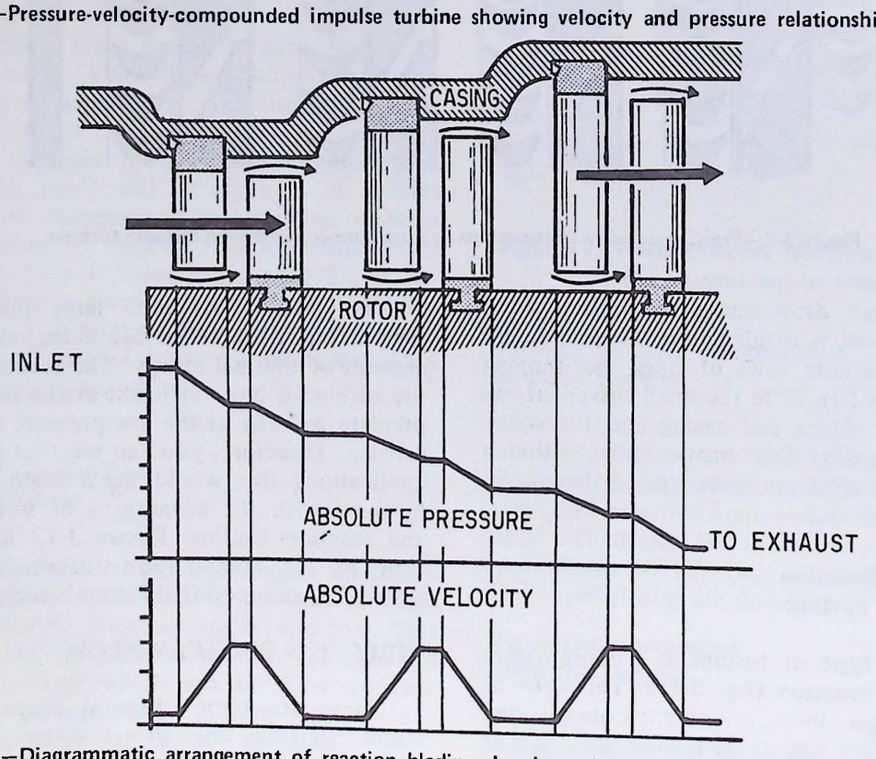
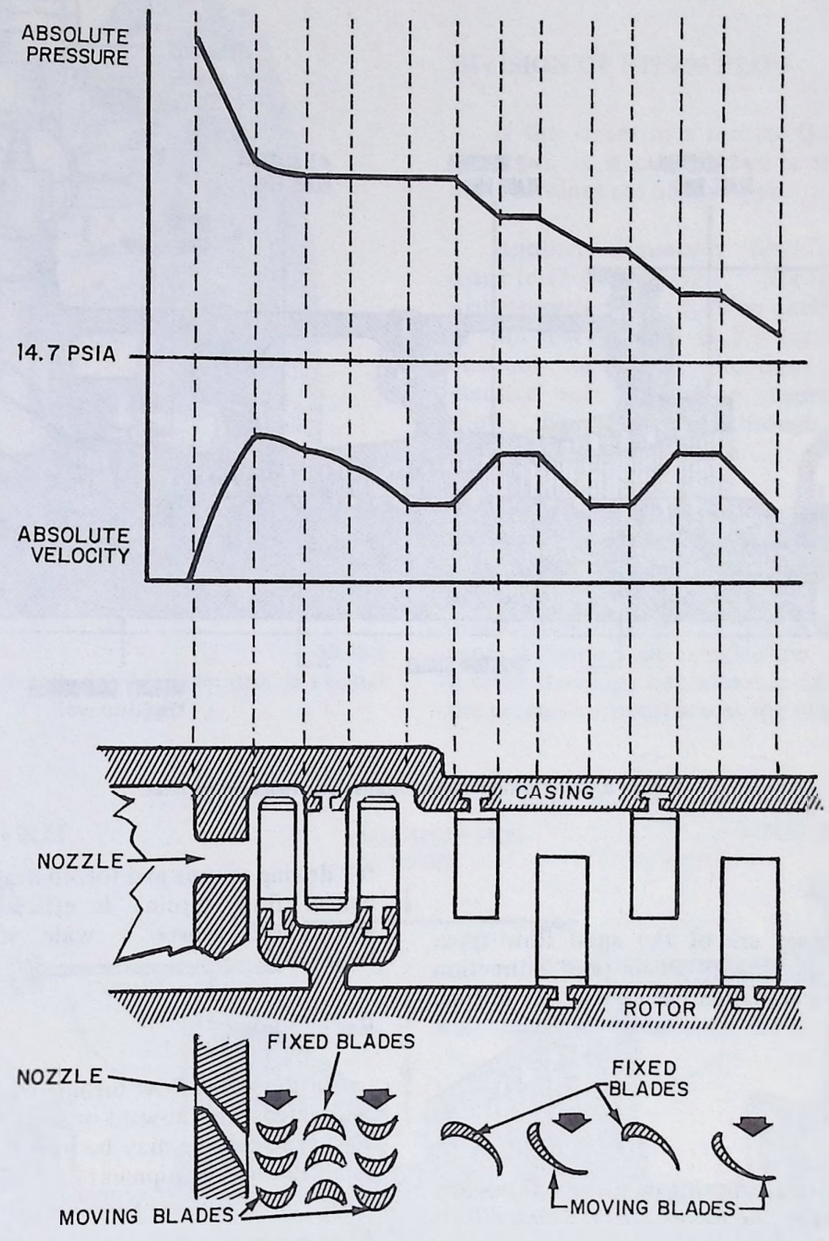


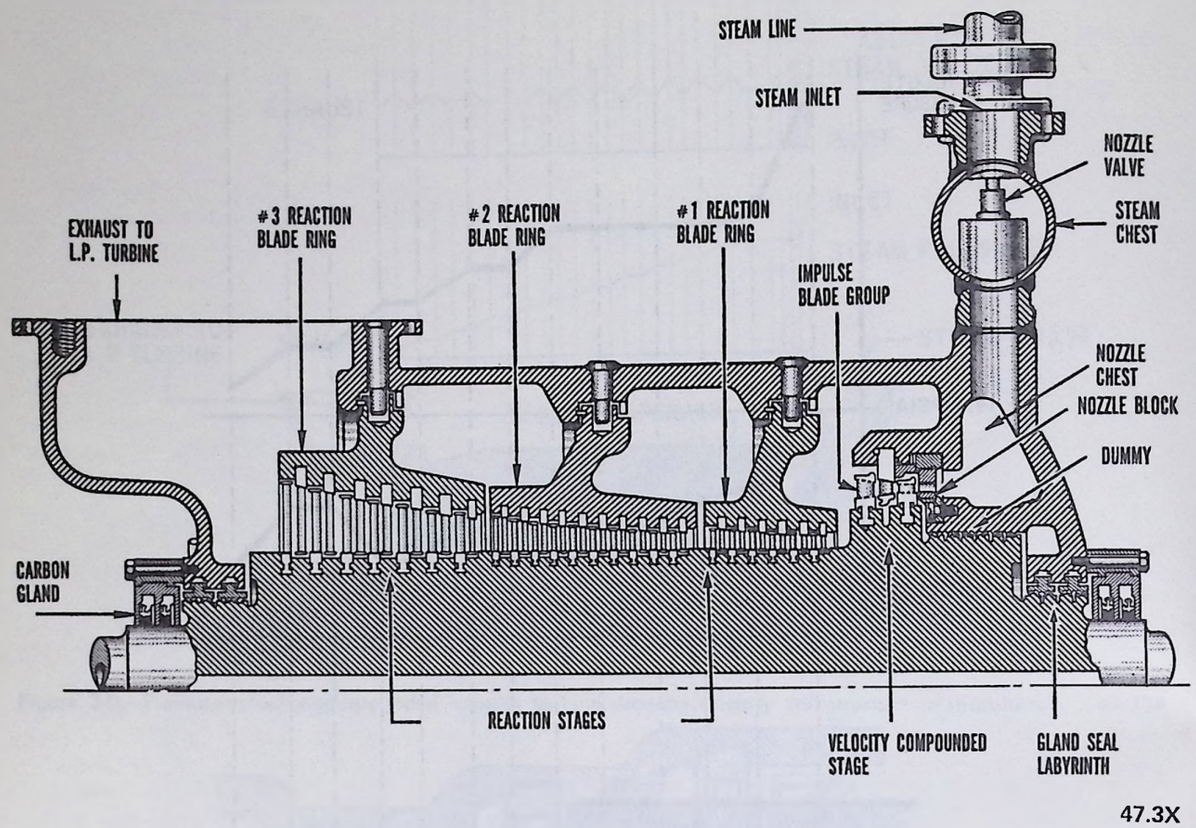
Figure 3-10.—Diagrammatic arrangement of reaction blading showing velocity and pressure relationships. 47.185



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Figure 3-11.—Diagrammatic arrangement of combination impulse and reaction turbine showing pressure velocity relationships.

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47.3X

Figure 3-12.—Combination impulse and reaction turbine.

Axial Flow

Most turbines are of the axial flow type, which means the flow of steam is in a direction that is almost parallel to the axis of the turbine shaft. Figure 3-12 illustrates an axial flow turbine.

Helical Flow

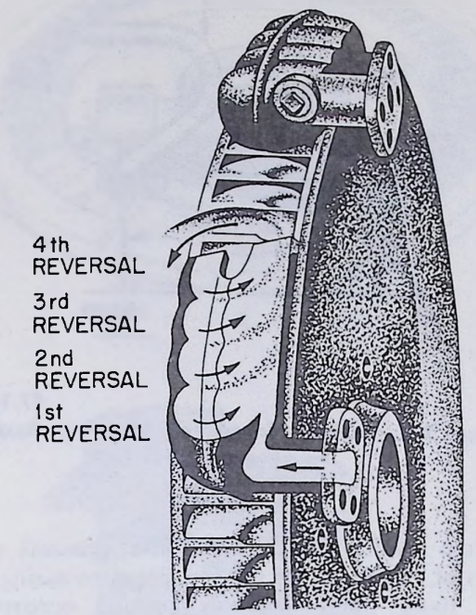
The steam in a helical-flow turbine flows at a tangent (angle) to the rotor. This tangential flow is directed into buckets fixed onto the turbine wheel and then back out of the buckets into stationary reversing chambers to be directed back into the buckets. The process is repeated several times. Figure 3-13 illustrates a helical flow turbine. This type of turbine may be used for driving pumps and forced draft blowers. The helical flow turbine is efficient for use in applications where a wide speed range is required.

Radial Flow

In the radial-flow turbine the flow of steam is directed either toward or away from the rotor. This type turbine may be used for driving some small auxiliary equipment.

REPETITION OF STEAM FLOW

Most turbines are of the single-entry type since the steam only passes once through the blades. All multistage turbines are of the single-entry type. However, some turbines, such



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Figure 3-13.—Cutaway view of steam path in a helical flow turbine.

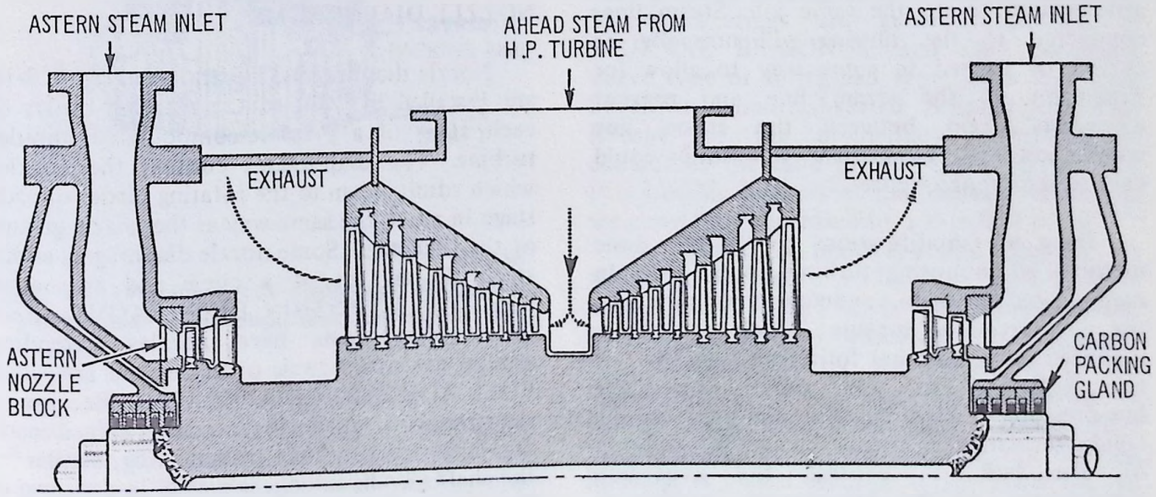
as the helical-flow, are of the reentry type. In a reentry turbine the steam is passed more than once through the blades.

DIVISION OF STEAM FLOW

If the steam in a turbine flows in only one direction, it is classified as a single-flow unit. Most turbines are of this type.

Another commonly used method is the double-flow design. Steam from the high-pressure (H.P.) turbine enters at the center of the low-pressure (L.P.) turbine and flows outward in both directions through two identical sets of turbine staging. Figure 3-14 shows the steam flow through a double-axial flow, low-pressure turbine.

The double-flow turbine has very little, if any, axial thrust and is quite a bit smaller than a single-flow turbine designed for the same capacity and low-exhaust pressure. The double-flow turbine is generally of the reaction type because the single-flow reaction type turbine develops considerable axial thrust from the pressure drop(s) across the moving blades.



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Figure 3-14.—Low-pressure double-axial flow reaction turbine.

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TURBINE COMPONENTS AND CONSTRUCTION

Now that you are familiar with basic turbine theory we will briefly discuss turbine components, parts and construction. This information is supplementary to information in *Fireman,* NAVEDTRA 10520.

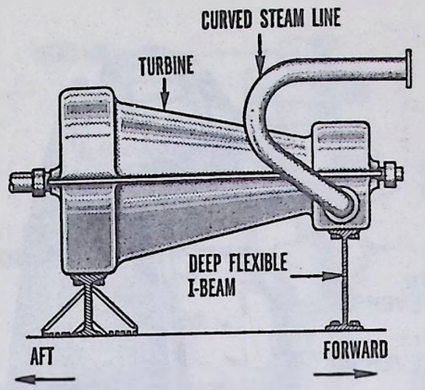
TURBINE SUPPORT

A turbine must be securely attached to the ship; however, it must also be free to expand and contract as necessary to prevent severe damage due to distortion caused by the large temperature and torsional changes that occur in the turbine. Usually, it is undesirable to allow a turbine to expand in the aft direction, because of turbine-reduction gear alignments, so the aft end of a turbine is secured rigidly to the structure.

There are two basic methods and designs that meet both the rigidity and expansion requirements of turbine foundations.

1. The forward end of the turbine may be mounted with a flexible I-beam as shown in figure 3-15. The I-beam will flex either fore or aft as the turbine expands or contracts.
2. Elongated bolt holes or grooved sliding seats may be used instead of the I-beam arrangement to do the same job. Steam lines connected to the turbine will normally be curved or looped in some way to allow for expansion of the steam line and prevent excessive strain between the steam line connection and the turbine. The strain could have serious consequences.

There are modifications to the two basic methods of mounting turbines to the ship. In many ships, the main condenser is supported by the low-pressure turbine which is rigidly mounted on beams that form an integral part of the hull structure. In other ships, the low-pressure turbine may be mounted on the condenser which, in turn, forms an integral part of the hull. In general, the expansion arrangement of the low-pressure turbine is similar to that of the high-pressure turbine except that the flexible forward support is



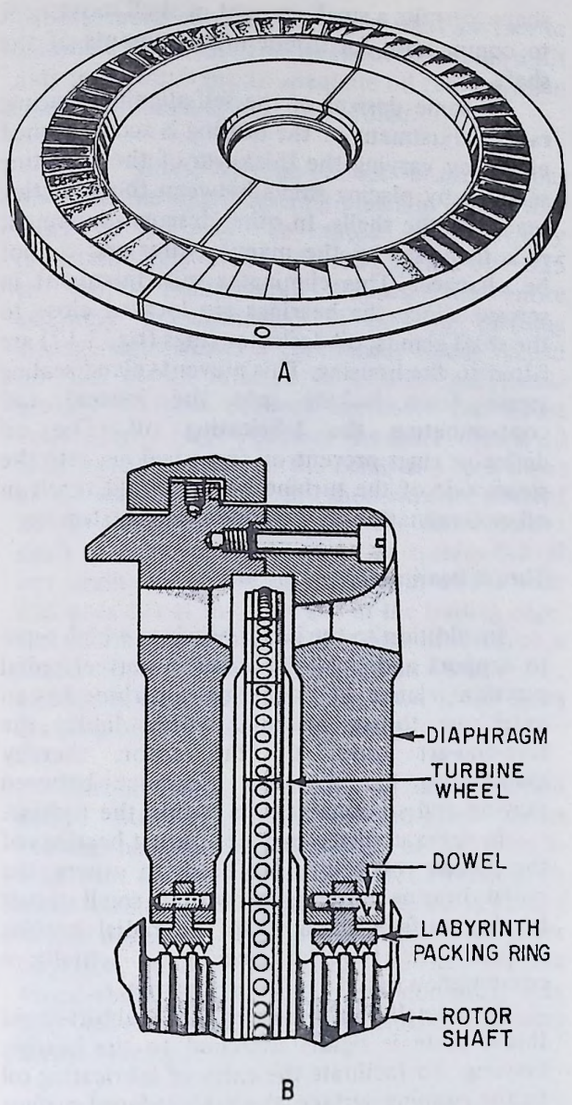
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Figure 3-15.—Turbine foundation, showing flexible I-beam.

seldom used. Instead, some arrangements use keys at the center of the low-pressure casing as the fixed point with expansions occurring equally in the forward and aft directions from the keys. Some arrangements fix the after end of the casing by fitted bolts while the forward end uses clearance bolts to allow for the expansion motion. Another arrangement uses fitted bolts at each end; these bolts fix the ends to flexible twin inlet necks on the condenser.

NOZZLE DIAPHRAGMS

Nozzle diaphragms, illustrated in figure 3-16 are installed in front of the rotating blades of each stage of a pressure-compounded impulse turbine. The diaphragms contain the nozzles which admit steam to the rotating blades of each stage in much the same way as the nozzle groups of the first stage. Some nozzle diaphragms admit steam in an arc of a circle and are called PARTIAL ADMISSION DIAPHRAGMS; other nozzle diaphragms have nozzles extending around the entire circle of blades and are called FULL ADMISSION DIAPHRAGMS. Because of the pressure drop that exists across each diaphragm, a labyrinth packing ring, similar to the shaft gland packing, is placed in a groove in the inner periphery of the diaphragm to minimize the leakage of steam across the diaphragm and along the rotor. Any leakage



47.14X

Figure 3-16.—Turbine nozzle diaphragms. A. Impulse nozzles and nozzle diaphragms. B. Internal construction.

through the inner periphery of the diaphragm will reduce the amount of the steam thermal energy being converted to mechanical energy and therefore reduces the work developed by the stage. Figure 3-16B illustrates the placement of these rings which are installed in sections and are spring-backed to hold them together and in place.

BEARINGS

The rotor of every turbine must be positioned radially and axially by bearings. Radial bearings carry the weight of the rotor and maintain the correct radial clearance between the rotor and the casing. Thrust bearings limit the axial movement of the rotor.

Some small auxiliary turbines use ANTIFRICTION BEARINGS, including ball and roller bearings. Our discussion, however, will be limited to FRICTION type BEARINGS, whose dissimilar metallic surfaces are separated by, and depend upon, an intervening fluid oil film for lubrication and cooling.

The effectiveness of fluid oil-film lubrication, as illustrated and explained in chapter 8 of this manual, depends on a number of factors: the lubricant's properties of cohesion, adhesion, and viscosity; its temperature; its cleanliness; the clearance, alignment and surface condition of the bearing and journal; load; and speed.

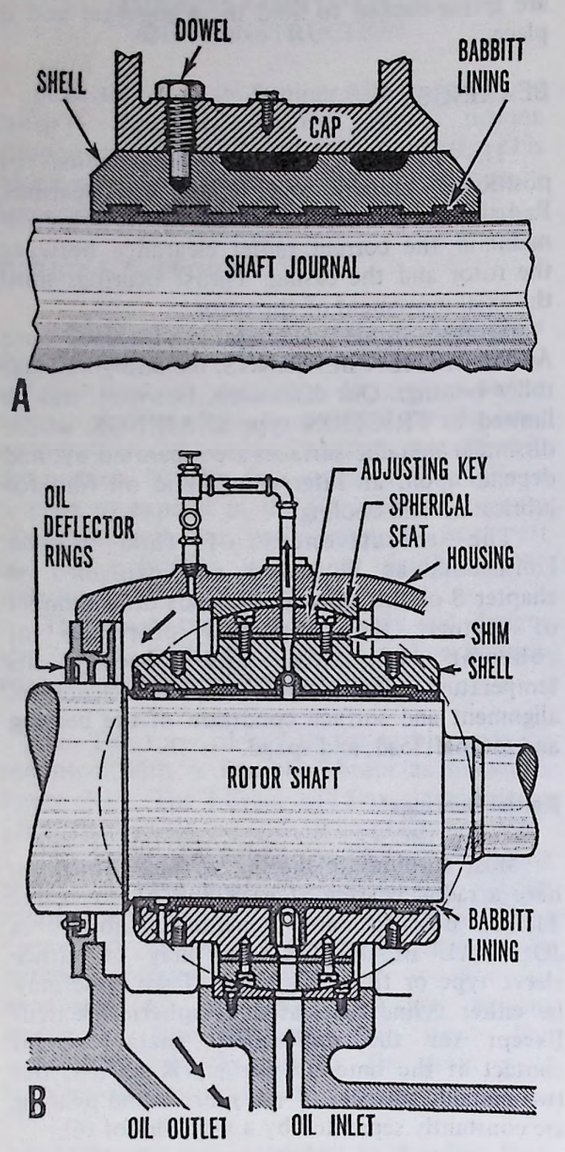
Radial Bearings

Most turbines, including all main turbines, have a radial bearing at each end of the rotor. These bearings are generally known as JOURNAL BEARINGS, and may be either sleeve type or tilting-pad type. Each type may be either cylindrical-seated or spherical-seated. Except for the momentary metal-to-metal contact at the time the turbine is started, the two metallic surfaces of the journal and bearing are constantly separated by a thin film of oil.

A typical cylindrical-seated bearing is illustrated in figure 3-17A. The shell is lined with BABBITT METAL (a composition of tin, lead, and antimony), which quickly disposes of the friction heat by transferring it to the lubricating oil passing through the bearing. A dowel keeps the sleeve from turning. The bearing cap, or upper half of the bearing housing, is bolted securely to the lower half of the bearing housing. The bolts are not shown.

The adjustable, spherical-seated, self-aligning bearing (fig. 3-17B) is used in most main

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Figure 3-17.—Turbine rotor bearings. A. Cylindrical-seated bearing. B. Adjustable spherical-seated bearing.

turbines. The shell assembly consists of upper and lower cylindrical shells around which are fitted adjusting keys, or bushings, with spherical-shaped outer surfaces or seats. The male spherical seat fits into a similarly shaped female seat in the bearing housing—the spherical shape permits a small amount of shell movement to compensate for minor misalignments of the shaft.

In some designs of the self-aligning bearing, radial adjustment of the bearing is accomplished either by varying the thickness of the adjusting seats or by placing shims between the adjusting seats and the shells. In other designs adjustment is initially set by the manufacturer and cannot be changed. This eliminates misadjustment in service. Since the bearings are located close to the shaft glands, oil deflector rings (fig. 3-17) are fitted to the housing. This prevents gland sealing steam from leaking into the journal and contaminating the lubricating oil. The oil deflector rings prevent oil from leaking into the steam side of the turbine which would result in oil contamination of the condensate system.

Thrust Bearings

In addition to the radial bearings which serve to support and hold the rotor in correct radial position relative to the casing, a turbine has an axial, or thrust bearing, which limits the fore-and-aft travel of the rotor, thereby maintaining the necessary clearance between moving and stationary parts within the turbine.

In some auxiliary turbines, thrust bearings of the ball or roller type are used. In others, the radial bearing is designed with a small thrust bearing surface, along with the radial bearing surface; this type of bearing is actually a combination radial and thrust bearing.

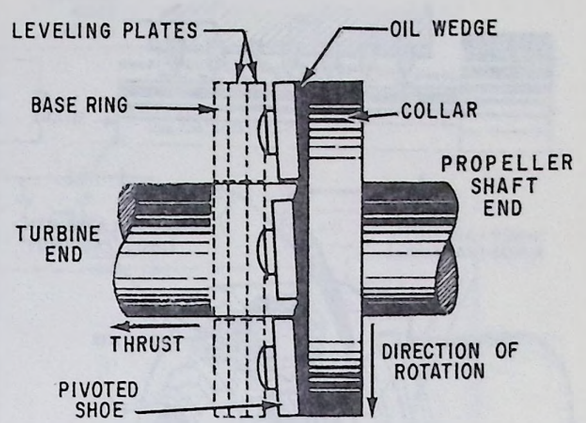
In a small thrust bearing, the babbitt-faced thrust plate is rigidly attached to the bearing housing. To facilitate the entry of lubricating oil to the running surface, the babbitt-faced surface is usually provided with radial grooves. This type bearing works satisfactorily for light loads and slow shaft speeds. However, in a thrust bearing of a large, high-speed turbine or propeller shaft, a rigidly mounted thrust plate, even though grooved, will not maintain an adequate oil film between the thrust face of the bearing and the thrust face of the collar. To overcome this difficulty, main turbine and propeller shafts are equipped with a pivoted shoe-type (Kingsbury) thrust bearing. In this type of bearing the thrust plate, instead of being a single rigidly mounted, babbitt-faced piece, consists of a number of

babbitt-faced segments, or shoes, that are free to assume a slight tilt. This freedom to assume a tilt aids in maintaining an adequate oil film between the shoe faces and the thrust collar.

The Kingsbury-type thrust bearing shoes pivot on the upper leveling plates in such a way that they may be tilted very slightly (approximately 0.001 to 0.002 inches or 0.025 to 0.050 millimeters). Because the entire assembly is submerged in oil, the pivoting arrangement allows a continuous wedge-shaped oil film (often referred to as a hydrodynamic wedge) to form between the shoes and thrust collar (fig. 3-18). Whenever the shaft rotates, oil is dragged in (between the collar and each shoe) at the leading edge of the shoe which is beveled 30° to allow the oil to enter. The thrust on the shaft or collar has a tendency to squeeze the oil out again. Since the oil streams in at the edge and goes out at the sides and at the trailing edge, the oil film under the leading edge of the shoe is thicker than at the trailing edge. In other words, as long as the shaft is rotating, each of the shoes is riding on a hydrodynamic wedge of oil.

Turbine thrust is usually in one direction only; however, most pivoted-shoe thrust bearings have shoes on both sides of the collar to take care of axial thrust in either direction. In some turbines, where the rotor thrust is always in one direction, or only very slight in the other direction, pivoted shoes may be used on the thrust-absorbing side only; the nonthrust side may have three shoes, or a smaller diameter thrust bearing.

A thrust bearing may be installed in a separate housing, or it may be enclosed within the radial bearing housing. For details on construction and principles of operation of a pivoted-shoe thrust bearing, refer to chapter 4 of this manual.



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Figure 3-18.—Diagrammatic arrangement of a pivoted-shoe thrust bearing, showing oil film.

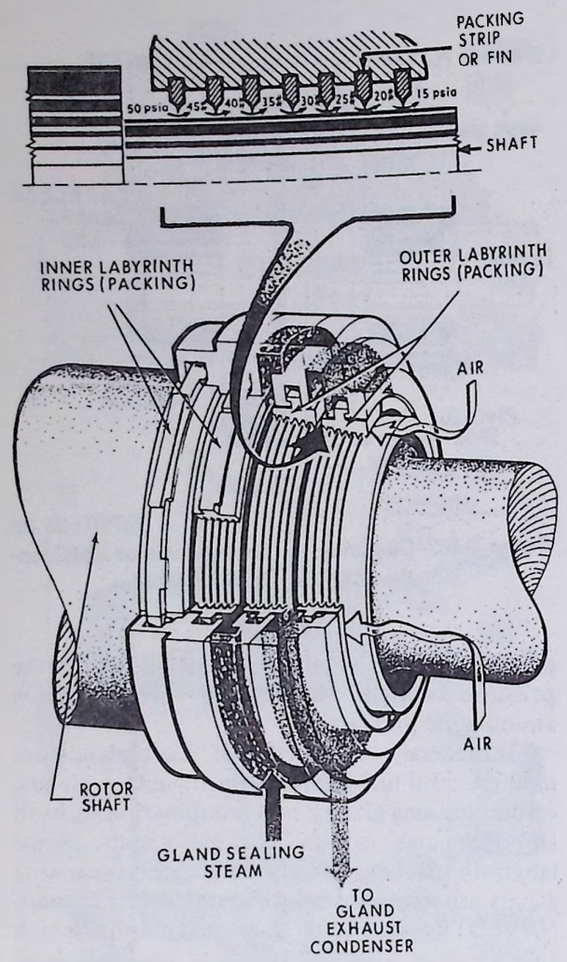
SHAFT PACKING GLANDS

When the pressure inside the turbine casing is greater than atmospheric pressure, shaft packing glands are used to prevent the escape of steam from the casing. The packing glands also prevent air from entering the turbine when the pressure within the casing drops below atmospheric pressure.

In general, three types of shaft glands are used on naval turbines; labyrinth packing glands, carbon packing glands, or a combination of both labyrinth and carbon packing glands. Since labyrinth packing glands and carbon packing glands are discussed and illustrated in *Fireman*, NAVEDTRA 10520, the paragraph which follows deals with the labyrinth packing gland because it is the most widely used method of sealing a turbine shaft in naval turbines.

LABYRINTH PACKING is used in the glands and interstages of modern steam turbines. Labyrinth packing consists of machined packing strips or fins mounted on the casing surrounding the shaft so as to make a very small clearance between the shaft and the strip. Figure 3-19 shows a labyrinth packing gland. The principle of labyrinth packing seals is that as steam leaks through the very narrow spaces between the packing strips and the shaft, the steam pressure drops. As the steam passes from one packing strip to the next, its pressure is gradually reduced and any velocity that it might gain through nozzling effect is lost by the action of the steam as it ricochets back and forth in the gland.

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Figure 3-19.—Turbine gland.

Gland Seal

Packing alone will neither stop the flow of steam from the turbine nor prevent the flow of air into the turbine. Gland sealing steam is used to prevent the entrance of outside air into the turbine, which would reduce or destroy the vacuum in the main condenser. Figure 3-19 shows how gland sealing steam of approximately 2 psig (17 psi absolute) is led into a space between two sets of gland packing. In older ships, steam is supplied from the auxiliary exhaust steam line through a stop valve. Two weight-loaded valves operate automatically to maintain a pressure of ½ to 2 psig on the glands.

During periods of warming-up, low-speed operation, backdown, and securing, these weight-loaded valves are open. When the turbine is speeded up and the steam flowing from the labyrinth gland of the high-pressure turbine reaches 2 psig, the valve supplying the high-pressure turbine closes automatically, admitting no more gland steam from the auxiliary exhaust line. The high-pressure turbine gland is then supplying enough steam leakage to seal the low-pressure glands. As the turbine speed is increased still further and the pressure in the sealing system rises to approximately 2 ½ psig, the excess steam is led, by a manually operated or an automatically operated valve, either to the main condenser or to the low-pressure turbine (depending on the ship).

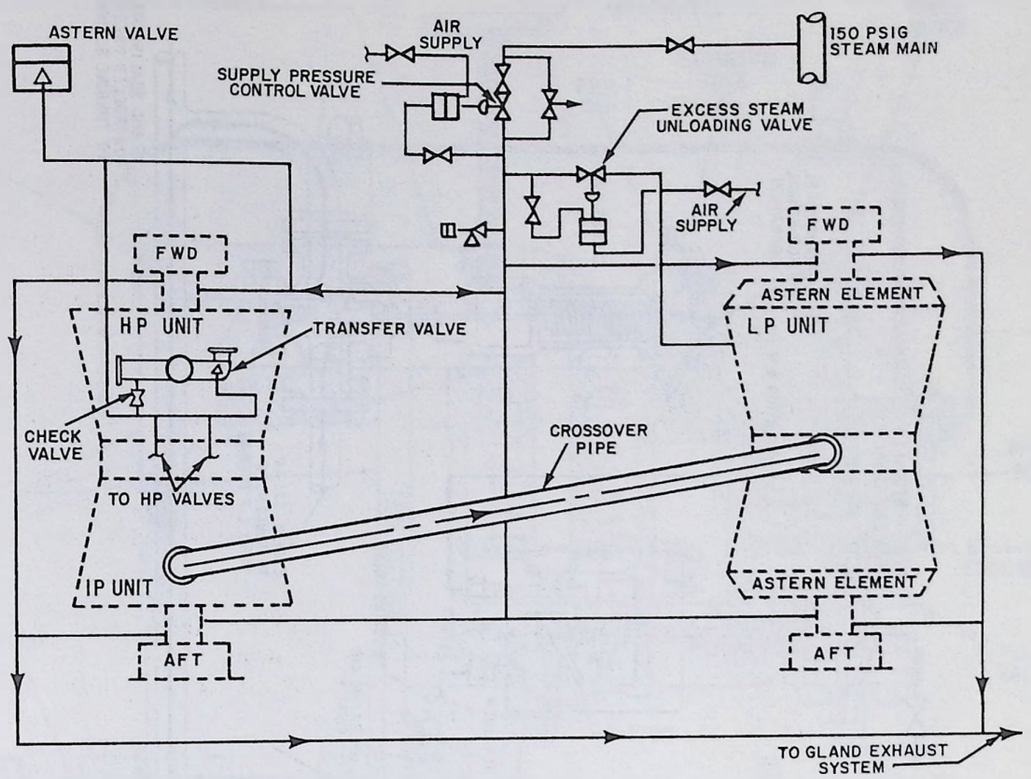
The leak-off connections are linked to the GLAND LEAK-OFF PIPING, which collects and condenses the steam that leaks from the gland, thus preventing the escape and loss of steam to the atmosphere.

A fan-type GLAND SEAL EXHAUSTER puts a slight vacuum on the leak-off piping. The vacuum draws the leak-off steam through a GLAND EXHAUST CONDENSER where the steam is condensed and returned to the feed system.

Most ships utilize two different methods to supply gland seal to the propulsion and generator turbines. Both methods are basically the same as previously described in that steam is supplied to the glands when the pressure drops to a point that it is needed, and excess steam is relieved from the system when the pressure increases too high.

Figure 3-20 illustrates a modern propulsion unit with its gland seal steam supply system.

Steam from the 150 psig steam system is admitted to the gland sealing system through an air-operated supply valve. If the pressure in the system becomes excesssive, as in high power operation, excess steam is "dumped" to the



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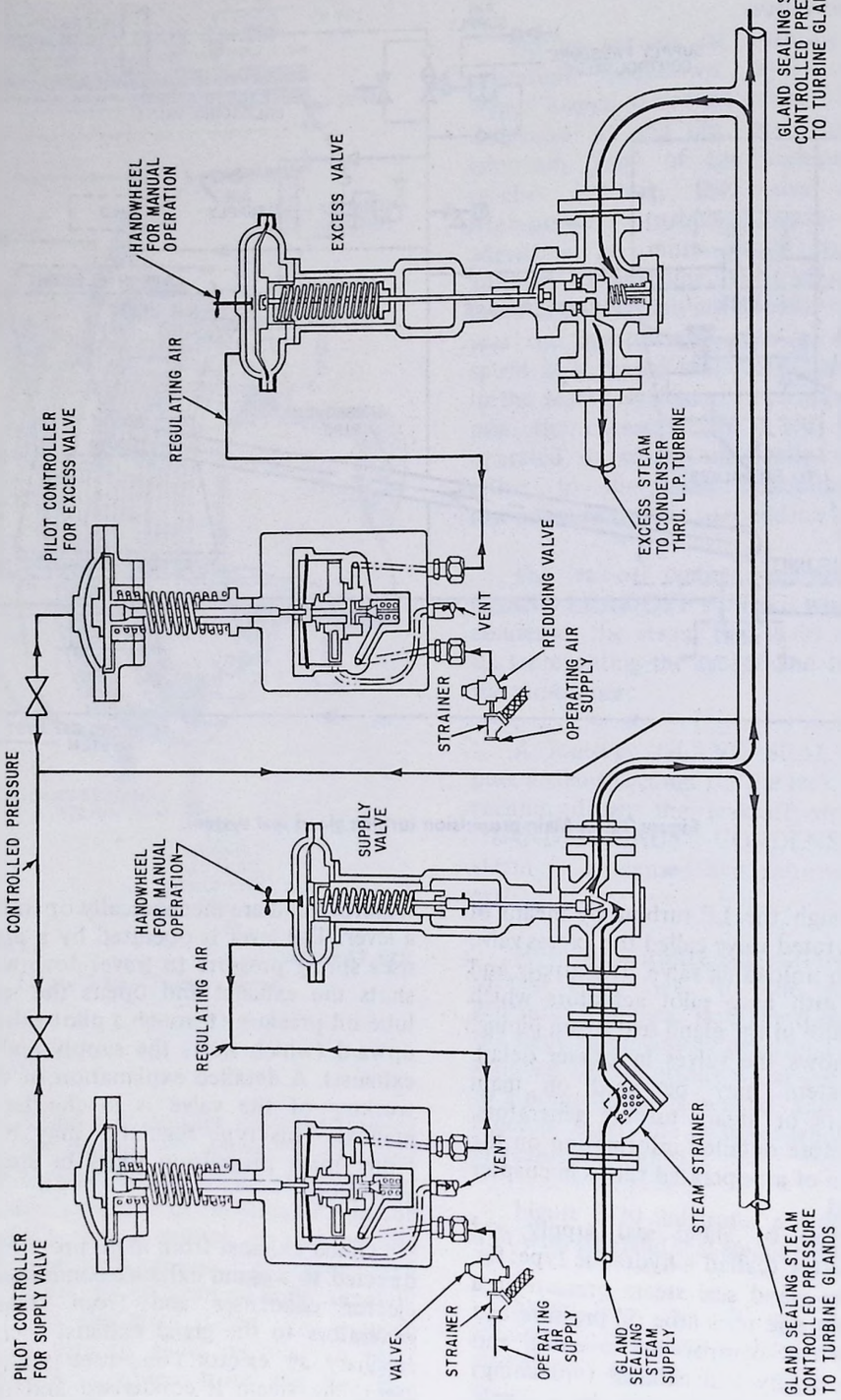
Figure 3-20.—Main propulsion turbine gland seal system.

condenser through the LP turbine by means of another air-operated valve called the excess valve or excess steam unloading valve. The supply and excess valves both have pilot actuators which sense the pressure in the gland seal steam piping. Figure 3-21 shows the valves in greater detail. This type system may be used on main propulsion units or steam turbine generators. You will find more detailed information on the actual operation of air-operated valves in chapter 6 of this manual.

Another type of gland seal supply and unloading regulator (called a hydraulic type; fig. 3-22) senses the gland seal steam pressure in a bellows assembly and uses lube oil pressure and spring pressure to control the opening and closing of the supply and exhaust (unloading) valves. Both valves are located in a single manifold and are mechanically operated through a lever. The lever is operated by a piston which uses spring pressure to travel downward (which shuts the exhaust and opens the supply) and lube oil pressure (through a pilot valve) to travel upward (which shuts the supply and opens the exhaust). A detailed explanation of the internal working of the valve is in chapter 6 of this manual. This type regulator may be found in either main propulsion units or steam turbine generators.

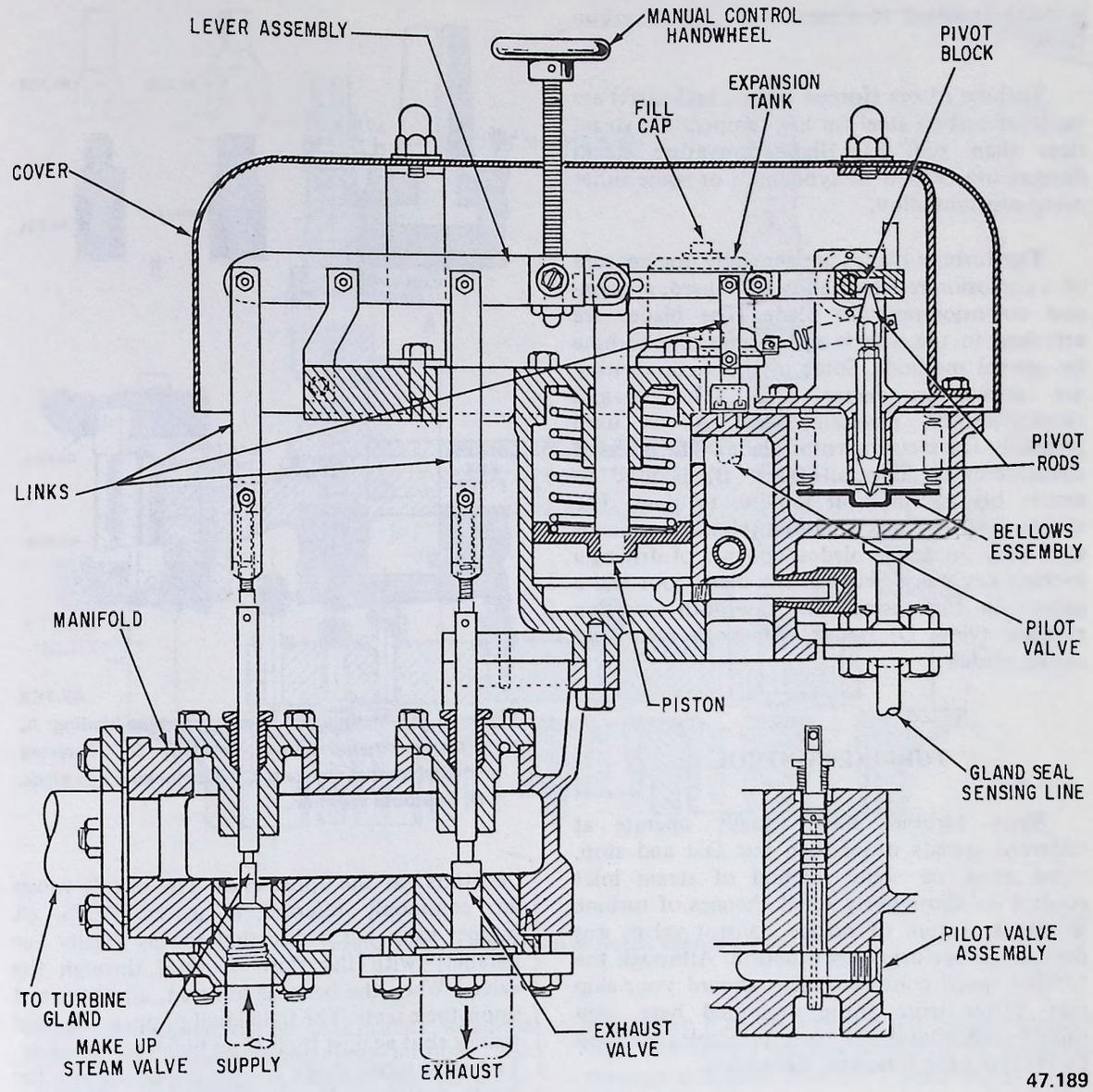
Gland exhaust from main propulsion units is directed to a gland exhaust condenser or the air ejector condenser and from steam turbine generators to the gland exhaust section of the auxiliary air ejector condenser where in both cases, the steam is condensed and returned to

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Figure 3-21.—Gland seal regulator mechanism.



47.189

Figure 3-22.—Hydraulic type turbine gland seal regulator.

the feed system. Air and other noncondensable gases are discharged to the atmosphere.

TURBINE MATERIALS

The materials used in constructing turbines will vary somewhat depending on the steam and power conditions for which the turbine is designed.

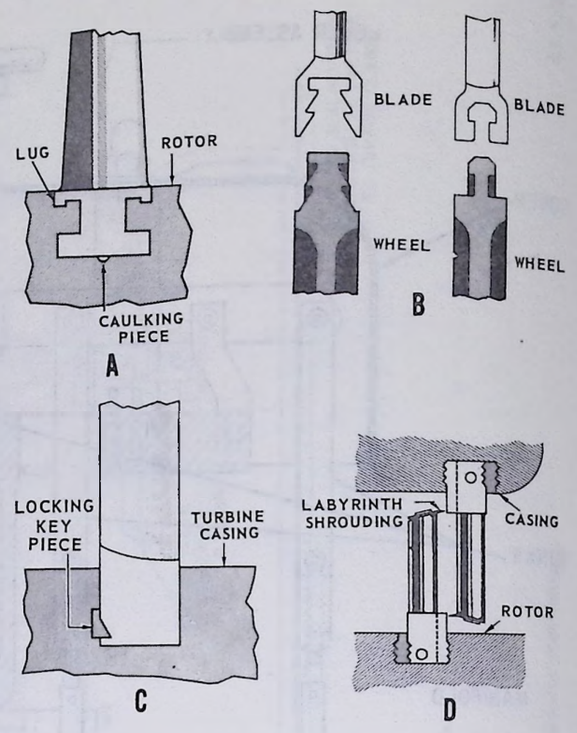
Turbine casings are generally constructed of cast carbon steel for nonsuperheated steam applications. Superheated applications use casings made of carbon molybdenum steel. For some newer submarines, the turbine casings are constructed of 12% chrome stainless steel which

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is more resistant to steam erosion than carbon steel.

Turbine rotors (forged wheels and shaft) are made of carbon steel for low-temperature steam (less than 650° F). High-temperature steam designs use carbon molybdenum or some other creep-resistant alloy.

The turbine blades are generally constructed of a corrosion-resistant alloy for a hard, erosion- and corrosion-resistant blade. The blades are attached to the wheels and casings of a turbine by several methods. Some of the methods used are shown in figure 3-23. The straight circumferential dovetail (view A) is used primarily for securing rotor blades. The inverted circumferential dovetail (view B) is used to secure blading in most impulse turbines. The side-locking key piece method (view C), which is used only on casing blades, consists of driving a locking key piece between the blade root and a groove in the casing. The sawtooth serration method (view D) is used for both rotor and casing blades.



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Figure 3-23.—Methods of securing turbine blading: A. Straight circumferential dovetail. B. Inverted circumferential dovetail. C. Side-locking key piece. D. Sawtooth serration.

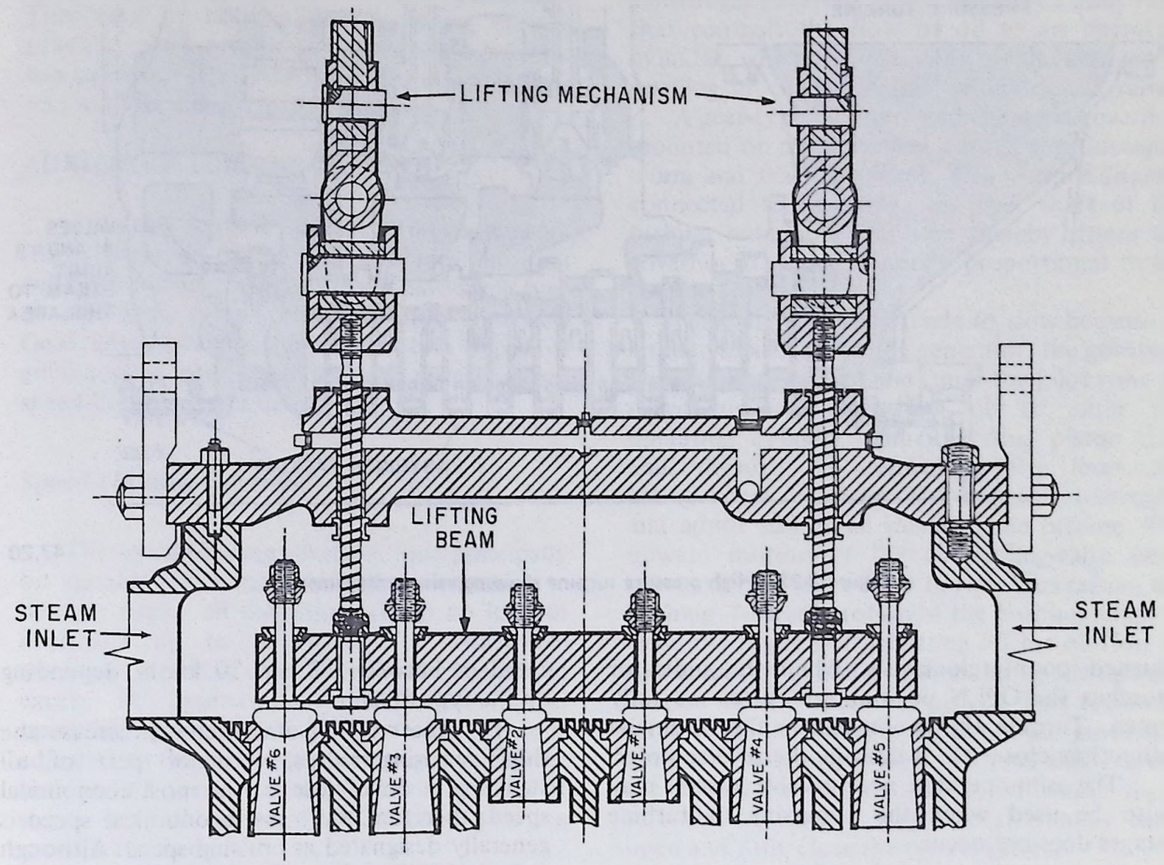
TURBINE CONTROL

Since turbines must usually operate at different speeds other than just fast and stop, there must be some method of steam inlet control to allow fairly small changes of turbine speed. A system of nozzle control valves was devised to perform this function. Although the turbine speed control system aboard your ship may differ from those described here, you should understand the basic principles involved by studying the following discussion.

NOZZLE CONTROL VALVES

One typical type of nozzle control valve system is shown in figure 3-24. This method controls speed by varying the number of nozzle valves that are opened. A lifting beam mechanism, drilled with holes, fits over the nozzle valve stems. The nozzle valve stems are of varying lengths and are fitted with shoulders or "buttons" at the upper ends. The nozzle valves are commonly referred to as POPPETS. (A poppet valve has a disc that moves axially [or parallel] with the flow of fluid through the valve.) When the beam is lowered, all valves rest upon their seats. The individual poppets are held tightly shut against their seats by steam pressure. The mushroom shape of the poppets gives the steam pressure adequate surface area to "hold down" the valves. When the beam is raised, the valves open in succession; the shorter ones open first, then the longer ones. Several types of valve linkage arrangements are used to change throttle valve handwheel rotary motion into lifting motion to raise and lower the beam.

Another nozzle control valve arrangement is shown in figure 3-25. Five valves are used to admit steam to the high-pressure turbine. The



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Figure 3-24.—Arrangement of nozzle control valves.

valves are controlled by a camshaft which is rotated by throttle handwheel motion. The camshaft is arranged to open the valves in succession. Valves #1 and #2 admit steam to the first-stage chest of the turbine. With valves #1 and #2 fully open, the pressure in the steam chest is approximately equal to line pressure. The first-stage nozzles are passing steam to the first stage at the limit of their capacity. To further increase the power and speed of the turbine, it is necessary to increase the amount of steam flowing through the turbine. Valve #3 is then opened admitting steam from the chest through a bypass to the second-stage nozzles. With valve #3 fully open, it is necessary to open valve #4 which admits steam from the chest through a bypass into the fourth-stage nozzles. With valve #4 wide open, the turbine should operate at almost its full power rpm. To get maximum speed and power, valve #5 must be opened to admit steam to the sixth-stage nozzles.

In some ships, as the handwheel is rotated, an indicator on the throttle control valve mounting shows which valves are open. Valve #1 begins to open as soon as the indicator moves away from the SHUT position. The other valves open at the points indicated as the handwheel is

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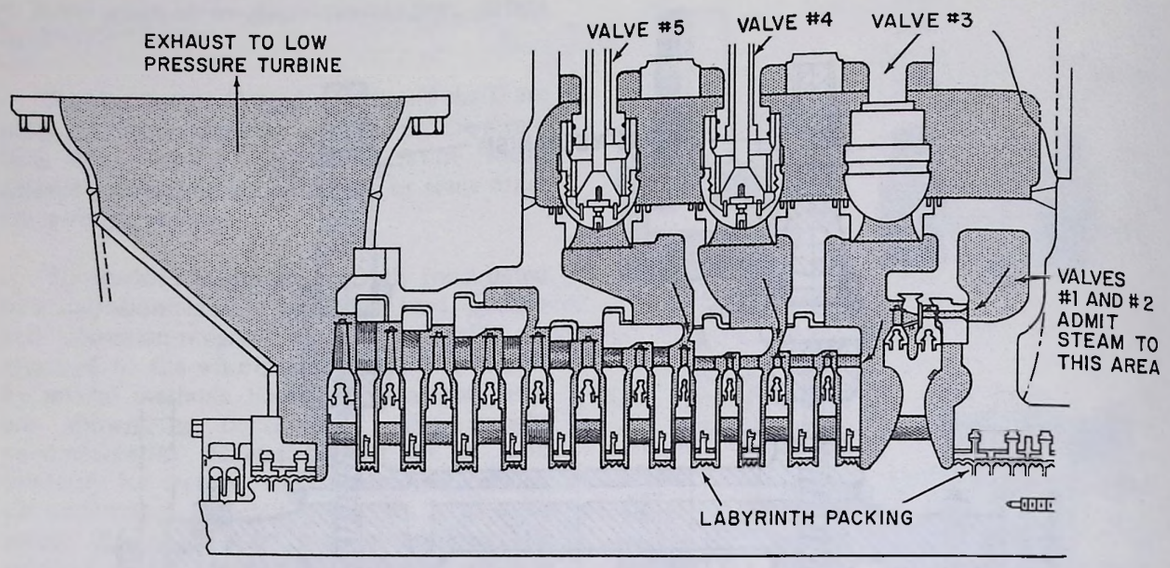


Figure 3-25.—High-pressure turbine showing valve arrangement.

turned counterclockwise. When the indicator reaches the OPEN position, all valves are fully open. Turning the handwheel in the clockwise direction closes the valves in the reverse order.

The cam-operated nozzle valve system may also be used when the bypassing of turbine stages does not occur.

CRUISING ARRANGEMENTS

Every ship has a speed at which the fuel consumption per mile is at a minimum. The most economical speed is based upon the combined fuel consumption per shaft horsepower (shp) per hour of the propulsion engines and the auxiliary machinery. However, a considerable quantity of fuel is required to generate steam used by the auxiliary machinery, even when the ship is stopped; as the speed is increased, there is only a very gradual increase in the amount of fuel consumed (per hour) by the auxiliary machinery. Therefore, as the ship's speed is increased, the percentage of the total fuel consumed by the auxiliary machinery actually decreases. For turbine-driven ships, these varying rates of fuel consumption for the auxiliary machinery result in a most economical speed of between 12 and 20 knots, depending on the type of ship.

To conserve fuel and thereby increase the ship's cruising radius, a major part of all steaming is done close to the most economical speed; therefore, the most economical speed is generally designated as cruising speed. Although it is desirable to have the economical speed as high as possible, there is a practical limit above which this speed cannot be raised because of the progressively increasing resistance of water to the ship's hull as the speed of the ship is increased. Increasing the efficiency of the main engines will tend to raise the most economical speed. The propulsion turbines are designed to have their best steam rate at the cruising speed.

It is also desirable for combatant ships to be able to steam at or near full power for long periods of time. This requirement makes it necessary that propulsion plants be designed with a relatively high turbine efficiency at high speeds.

Maximum efficiency in a turbine is obtained when the optimum ratio of blade speed to steam speed exists. Therefore, to obtain the lowest possible fuel consumption per shaft horsepower (shp) per hour at cruising speed AND at full power, it

is necessary that propulsion turbines be designed so the optimum ratio of blade speed to steam speed will be approached at both these speeds. This may be accomplished by using cruising stages; high-pressure, intermediate-pressure, low-pressure (HP-IP-LP) turbine combinations; and in older ships, cruising turbines.

AUXILIARY TURBINE CONTROL

Auxiliary turbine control differs somewhat from that of propulsion turbines in that auxiliary turbines must normally have some type of automatic speed-control governor or device. Generally speaking, there are two types of governors in use: constant-speed governors and speed-limiting governors.

Speed-Limiting Governor

The speed-limiting governor, used principally on variable-speed machines, allows a turbine to operate under all conditions (from no load to overload) up to the speed for which the governor is set; it does not allow operation in excess of approximately 105% of normal operating speed. Since this type of governor is adjusted to the maximum operating speed of the turbine, it has no control over the admission of steam until the upper limit of safe operating speed is reached.

Constant-Speed Governor

The constant-speed governor is used on constant-speed machines to maintain a constant speed up to design limits regardless of the load on the turbine. Constant speed governors are usually set so that the turbine cannot even momentarily exceed 100% of normal operating speed. They are used primarily on turbine-generator units.

Ship's service generators supply electricity for lighting and power throughout a ship. Since a constant voltage and frequency must be maintained in the ship's electrical system, the generator turbine operates at a constant speed even under greatly varying loads. This speed is maintained by a constant-speed governor.

One type of ship's service generator turbine control mechanism (fig. 3-26) consists of a centrifugal governor which operates a pilot valve that controls the flow of oil to an operating cylinder, which in turn, controls the amount of opening or closing of the turbine nozzle valves.

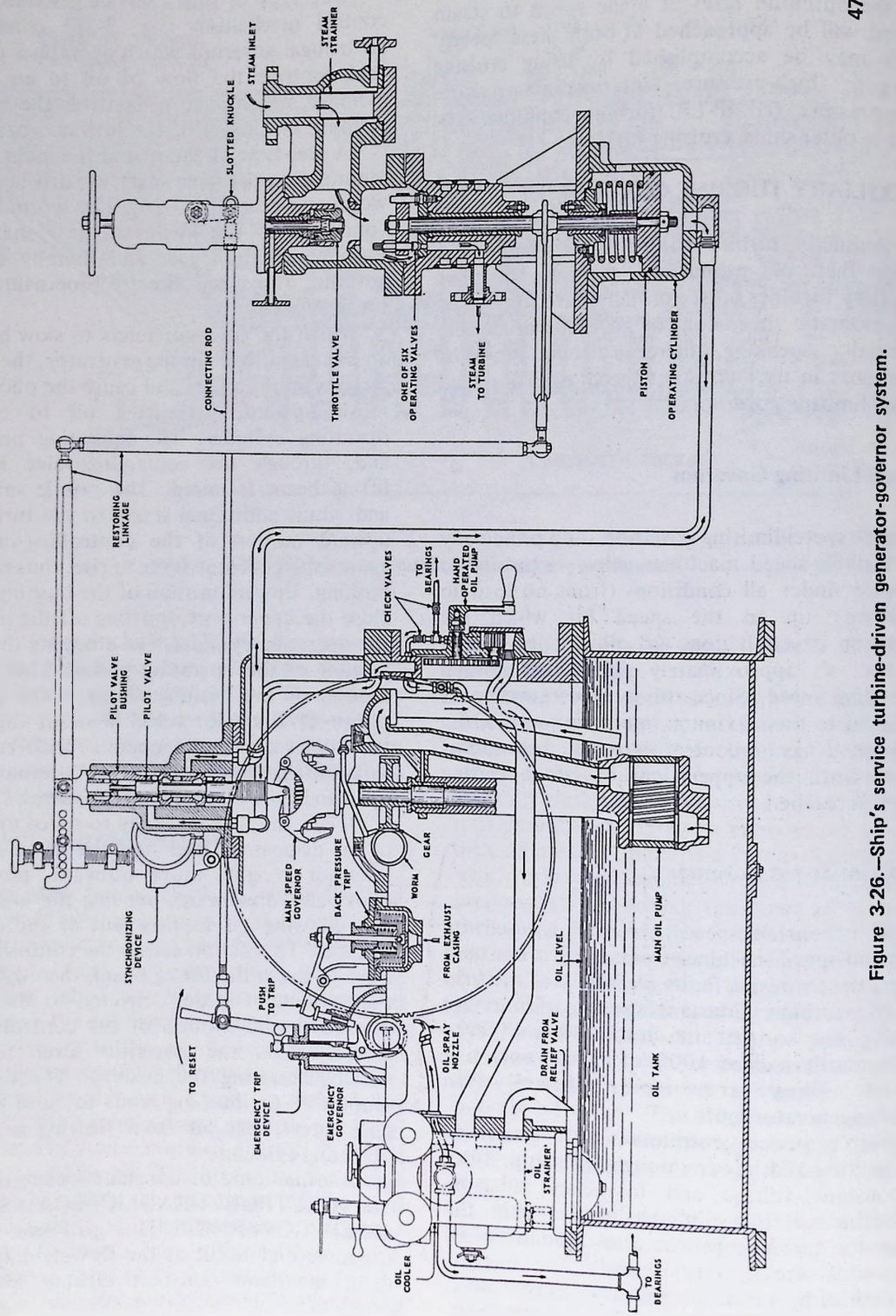
A gear-type oil pump and the main governor, mounted on the same shaft, are driven through a worm and gear (fig. 3-26). The worm is directly connected to the low-speed gear shaft of the turbine reduction gear and thereby drives the governor at a speed directly proportional to the turbine speed.

When the governor tends to slow because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward, permitting oil to enter the operating cylinder. The operating piston rises and, through the controlling-valve lever, the lifting beam is raised. The nozzle valves open and admit additional steam to the turbine. The upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port, shutting off the oil flow to the operating cylinder, and stopping the upward motion of the operating piston. This followup motion of the bushing regulates the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

When the turbine tends to speed up because of a decreased load on the generator, the governor weights move outward, moving the pilot valve downward, opening the lower ports, and allowing oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, thereby reducing the amount of steam delivered to the turbine. The downward motion of the controlling-valve lever causes the governor lever to lower, thereby lowering the bushing. The downward motion of the bushing tends to close the lower port, preventing oil from flowing out of the operating cylinder.

Another type of constant-speed governor is the ELECTROHYDRAULIC LOAD-SENSING SPEED GOVERNOR. This governor produces the same end result as the flyweight type; that is, it maintains constant turbine speed with

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Figure 3-26.—Ship's service turbine-driven generator-governor system.

varying load on the generator. Basically, the governor uses an attached gear-type oil pump to provide actuating oil pressure to a hydraulic actuator. The hydraulic actuator is controlled by an electrical signal from the system control box. When the control box sends a signal (increased electrical load on the generator) to the actuator to admit more steam to the turbine, the actuator allows control oil to pass to a remote servo piston in the hydraulic valve actuator (fig. 3-27). The remote servo piston moves a pilot valve plunger which allows operating oil to move an operating piston which mechanically opens the steam valve. The whole system is designed so that in case of failure the end result will be the closing of the steam valve to the turbine. A cutout valve is provided to minimize the manual pumping of oil required when starting the turbine. It shuts off the path for the running oil pressure to the bottom of the operating piston which will tend to counteract the starting oil pressure on the top of the piston. More detailed information about electrohydraulic load-sensing speed governors is contained in *Electrician's Mate 1 & C*, NAVPERS 10547.

SAFETY DEVICES

Safety devices differ from control devices in that they have no control over the turbine under normal operating conditions. It is only during some abnormal condition that safety devices come into use—to either stop the unit or control its speed.

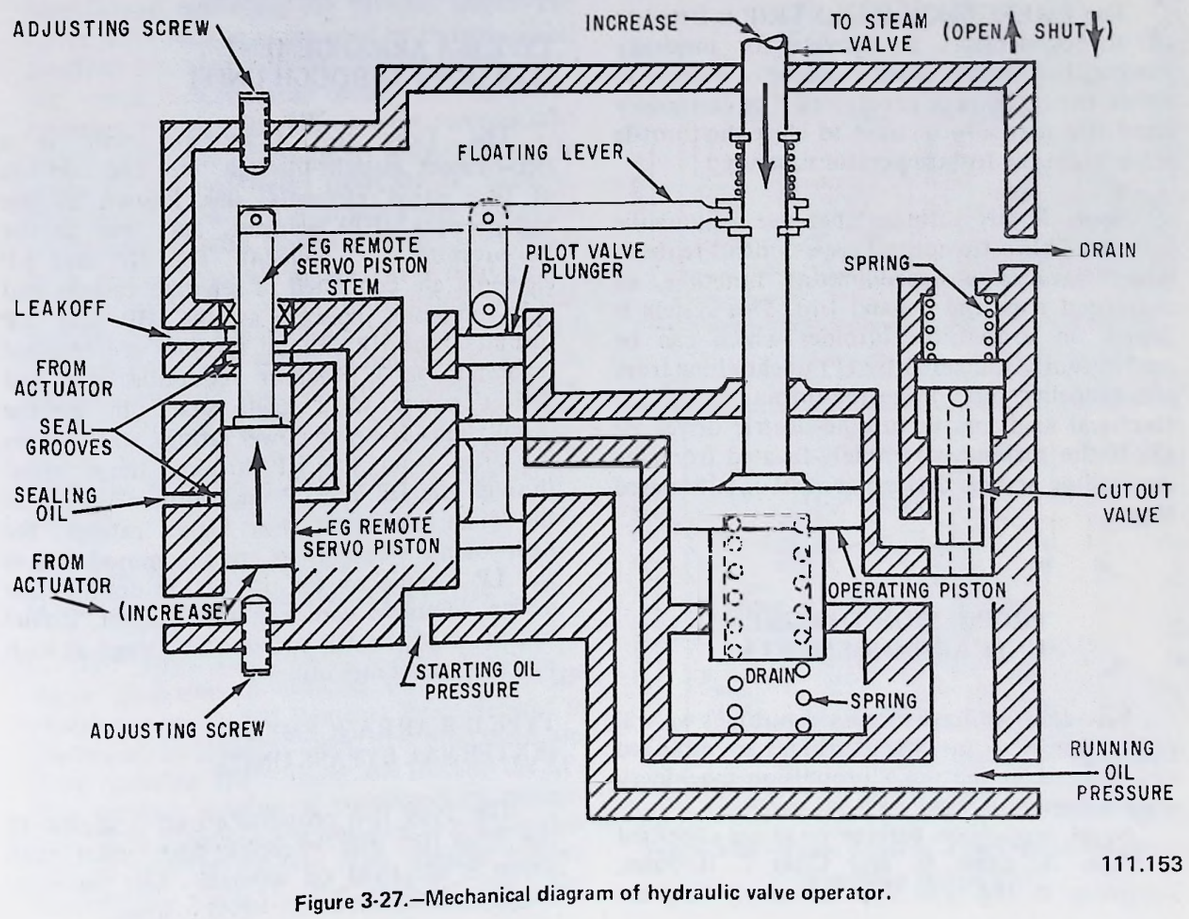


Figure 3-27.—Mechanical diagram of hydraulic valve operator.

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All turbogenerators have four safety devices: an overspeed trip, a back-pressure trip, a low-oil pressure trip or alarm, and an emergency hand trip.

The OVERSPEED TRIP shuts off the steam supply to the turbine after a predetermined speed has been reached, thus stopping the unit. Overspeed trips are set to trip out at approximately 110% of normal operating speed.

The BACK-PRESSURE TRIP is used to close the throttle automatically whenever the back or exhaust pressure reaches a set pressure.

The LOW-OIL PRESSURE TRIP is used on turbogenerators to close the throttle if the lubricating oil pressure drops below a specified pressure. Some only have low-oil pressure alarms.

The EMERGENCY HAND TRIP is fitted to all turbogenerators to provide for manually closing the throttle quickly in case of damage to either the turbines or generators. The emergency hand trip may also be used to close the throttle valve when the turbogenerator is secured.

Some MAIN turbines that use a hydraulic system of throttle control have control features which include a speed-limiting function, an overspeed trip, and a hand trip. This system is found on propulsion turbines which can be inadvertently unloaded by (1) unclutching from the propeller shaft in geared-turbine drives, (2) electrical load loss in turbine-electric drives, or (3) if the turbine is remotely located from the controlling station (bridge control of automated ships).

PROPULSION TURBINE UNIT ARRANGEMENTS

Now that we have discussed turbines we will discuss the ways in which turbines are arranged and utilized in the main propulsion machinery aboard ship.

Naval propulsion turbine units are classified as Class A, Class B, and Class C turbines, according to the type ship for which they are designed. Class A turbines are designed for use in submarines. Class B turbines are designed for use in amphibious warfare ships, surface combat ships, mine warfare ships, and patrol ships. Class C turbines are designed for use in auxiliary ships.

Propulsion units in naval ships are also classified according to design features. There are six major types.

TYPE I ARRANGEMENT (SINGLE-CASING UNITS)

The Type I propulsion unit consists of one or more ahead elements, each contained in a separate casing and identified as a single-casing turbine. Each turbine is single-flow and of equal rating within the propulsion unit. The turbines may drive the propeller shaft directly through a reduction gear or indirectly via an electric generator and propulsion motor.

TYPE II-A ARRANGEMENT (STRAIGHT-THROUGH UNIT)

The Type II-A propulsion unit is a two-element straight-through unit and consists of two ahead elements, one known as the high-pressure (HP) element, and one as the low-pressure (LP) element. The HP and LP elements are contained in separate casings and are commonly known as the HP and LP turbines. The HP and LP turbines are coupled separately to a common reduction gear and deliver power to a single shaft. In turbine installations of lower power ratings, steam flows in series from the HP turbine steam chest through the HP and LP single-flow elements to the main condenser. For higher ratings, the high-volume steam flows are accommodated in the LP turbine by the use of the double-flow design described earlier in this chapter. Partial bypassing of the HP turbine first stage at high power is sometimes utilized.

TYPE II-B ARRANGEMENT (EXTERNAL BYPASS UNIT)

The Type II-B propulsion unit is similar to the Type II-A unit, except at high power main steam is admitted via separate chest valves to stages downstream of the HP first stage.

TYPE II-C ARRANGEMENT (INTERNAL BYPASS)

The Type II-C unit is similar to the Type II-A unit except at speeds above specified cruising power, steam is bypassed (valved) from the HP first-stage shell to downstream stages.

TYPE III ARRANGEMENT (SERIES-PARALLEL)

The Type III propulsion unit consists of one HP element, one intermediate pressure (IP) element, and one LP element. The HP and IP elements are combined in a single casing, and the combination is referred to as an HP-IP turbine. The HP-IP and LP turbines are placed in a cross-compound arrangement (fig. 3-28). The transfer valve, bypass check valve, and turbine throttle valves are all controlled by the throttleman operating the throttle wheel. The valves will function as required by throttle wheel position (speed requirements). For power up to the most economical point of operation (cruising power), the HP element receives inlet steam, with the IP element being supplied in series by exhaust steam from the HP element. (See figure 3-28A). For power above this point of operation, both elements receive inlet steam in a manner similar to that in a double-flow turbine with the IP element being supplied directly by some inlet steam. (See figure 3-28B.) At high power the HP-IP turbine is completely a double-flow unit with the HP element exhaust passing directly to the LP turbine inlet. (See figure 3-28C.) In all modes, steam exhausted from the IP element flows directly into the LP turbine.

TYPE IV ARRANGEMENT (CRUISING GEARED-AND-VENTED)

The Type IV propulsion unit consists of three elements: a cruising element, an HP element, and an LP element. Each element is contained in separate casings so that there are three turbines–the cruising, the HP, and the LP. The cruising turbine is connected in tandem through a cruising reduction gear to the forward end of the HP turbine. The cruising turbine contributes power to the propeller shaft for

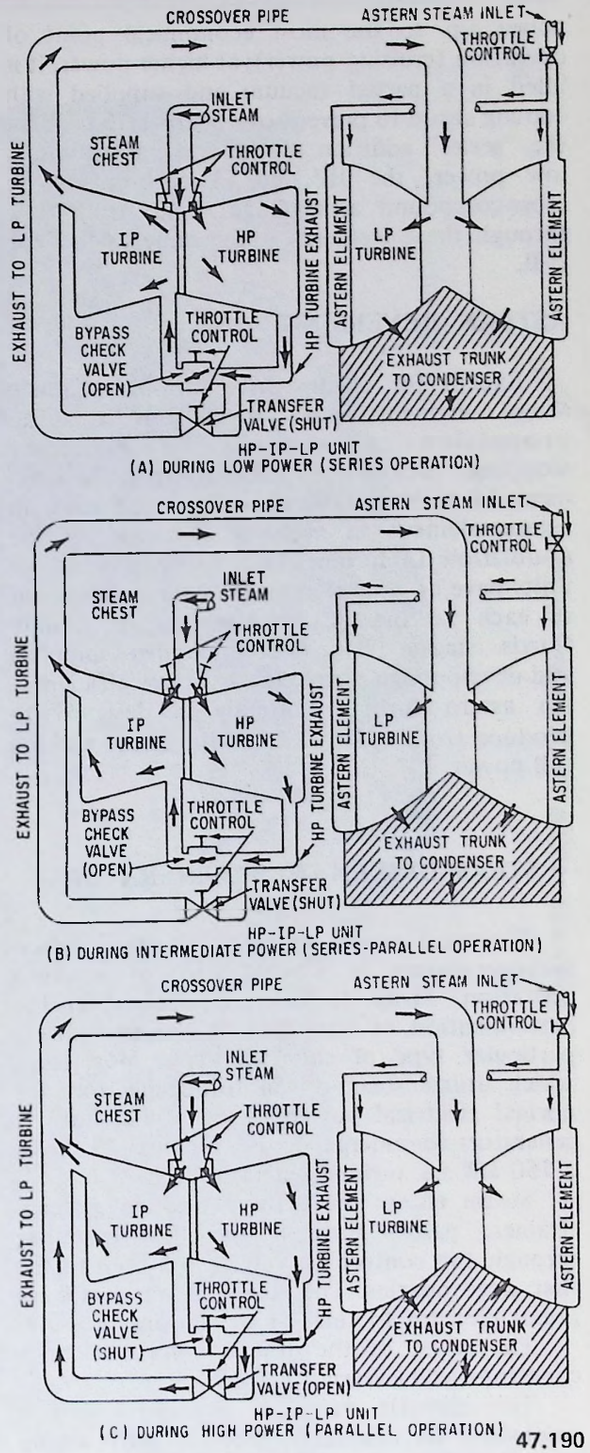


Figure 3-28.–Steam flows in a type III (series-parallel) propulsion turbine unit.

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power up to the most economical point of operation (cruising power); at higher power, it is idled in a partial vacuum and supplied with cooling steam to prevent overheating. Except for the "series" addition of the cruising turbine at low power, the HP and LP turbines are in cross-compound arrangement, and steam flow through these elements is the same as in Type II-B.

ASTERN (REVERSING)

Except for electric-drive propulsion units, astern elements are provided with steam propulsion turbine units for emergency stopping, backing, and maneuvering. In units using LP turbines (all except Type I), there is an astern element in each exhaust end of the doubleflow LP turbine. The single-casing turbine units have an astern element in the exhaust end of each turbine. Astern elements are usually Curtis stages (velocity-compounded impulse) and develop high torque but have low efficiency. An astern turbine normally is designed to produce from 1/5 to 1/2 of the ahead turbine full power.

STEAM-DRIVEN TURBOGENERATORS

Electrical power provided by steam-driven turbogenerators is a vital part of a ship's operation. Many factors are involved in the determination of how many turbogenerators a particular type of ship will have. Most ships which utilize steam-driven turbogenerators for normal electrical power also have diesel-driven generators for emergency use. Figure 3-29 shows a 750 kW a.c. turbine generator unit.

Steam enters the turbine through a steam strainer, passes through the throttle valve, through the controlling valves, and then to the first stage nozzles. The steam then passes from initial pressure to final or condensing pressure.

The speed of the unit is controlled by a constant-speed governor.

The throttle valve is provided with a handwheel for manual control and for resetting the valve after it has been tripped. The throttle valve closes when the overspeed trip or back-pressure trip functions, or when the manual trip lever is pushed.

Most submarines use a direct drive turbogenerator which usually has a flexible coupling installed between the turbine and the generator. Direct drive turbogenerators are used on submarines for ship's service because the inlet steam conditions are relatively low and, therefore, the available energy of the steam to the turbine is low compared with surface ships. This permits the turbine to operate at low speeds and still maintain a satisfactory efficiency. The elimination of the reduction gears reduces the noise level of the turbogenerator.

Operation of turbogenerators should be in accordance with the Engineering Operational Sequencing System.

GENERAL PRECAUTIONS ON OPERATION

1. The maximum temperature of oil leaving any bearing should NOT exceed 180° F (82° C).
2. The temperature rise of oil passing through any bearing should NOT exceed 50° F (10° C).
3. Be sure that all control and safety devices are in proper operating condition. If they are not, the unit should be stopped and the trouble should be located and corrected before the unit is started again.

OTHER AUXILIARY TURBINES

Except for steam turbine-driven electric generators, the auxiliary turbines are usually impulse turbines of either the helical-flow or axial-flow type. Depending on the type of ship, they operate against a back pressure of approximately 15-17 psi.

Auxiliary equipment using turbines for power will vary with ship type. Electric motors for most equipment are replacing small turbines on the newer ships. However, forced draft blowers and main feed pumps are still turbine-driven on most ships.

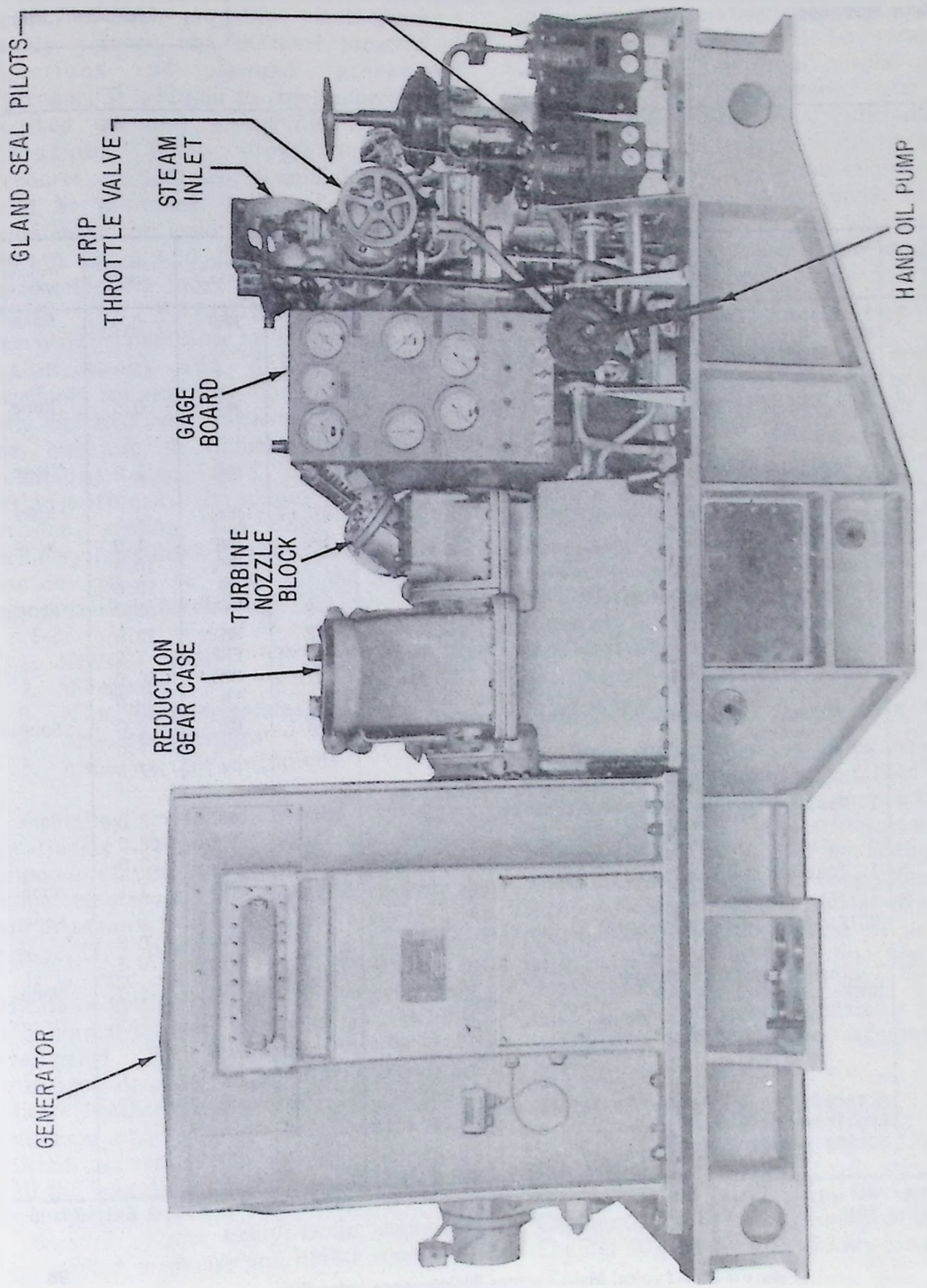


Figure 3-29.—750kW a.c. turbine generator set.

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SYSTEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
Main Turbines		September 197-

CONFIGURATION

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN-HOURS	RELATED MAINTENANCE
C3 D62B N	1. Inspect throttle valve operating linkage. NOTE: Accomplish weekly, or before lighting off, whichever occurs first.	W-1R	MM3	0.4	None
C3 D62D N	1. Clean and inspect gland seal control air strainer.	M-2	MM3	0.5	None
94 E81G N	1. Measure turbine bearing wear.	Q-1	MM1	1.0	None
C3 D62F N	1. Lift turbine sentinel valves by hand.	Q-2	MM3	0.1	None
45 D62G N	1. Measure turbine thrust.	S-1	MMC MM1 FN	1.0 10.0 10.0	None
95 H78U N	1. Inspect foundation bolts.	A-9	MM3	1.0	None
94 E81H N	1. Inspect high-pressure turbine bearings. 2. Inspect low-pressure turbine bearings.	C-2	MM1 EM2 MM3 FN	30.0 1.0 30.0 30.0	S-1
C3 D62J N	1. Measure high-pressure turbine nozzle clearance. 2. Measure low-pressure turbine nozzle clearance.	C-3	MMC MM1 FN	2.0 7.0 7.0	None
45 G58T N	1. Inspect turbine labyrinth packing.	C-4	MMC MM1 FN	2.0 12.0 12.0	None
T C3 D62L N	1. Test sentinel valves.	C-7	MM3	3.1	None
95 H76W N	1. Turn over turbines and reduction gear. NOTE: When in port, accomplish weekly.	R-5W	EngOff MM1 MM3	0.5 0.5	None
C4 F52G N	1. Inspect main steam strainer. NOTE: Accomplish after steam system has been opened for inspection or repair and during each scheduled shipyard overhaul. A scheduling aid: Schedule Maintenance Requirements C-2 and C-4 for accomplishment during shipyard overhaul.	R-8C	MM1 FN	4.0 4.0	None

MAINTENANCE INDEX PAGE (MIP)
OPNAV 4700-3 (A) (REV. 3/69)

SYSCOM MIP CONTROL NUMBER E-1/174-95

Figure 3-30.—Typical Main Turbine Maintenance Index Page. 98.171

PLANT MAINTENANCE

Maximum operational reliability and efficiency of steam propulsion plants require a carefully planned and executed program of inspections and planned (preventive) maintenance in addition to strict adherence to prescribed operating instructions and safety precautions. When proper maintenance procedures are followed, abnormal conditions should be prevented. A list of maintenance requirements for main propulsion turbines is shown in figure 3-30. Part of the 3-M system, this Maintenance Index Page (MIP) shows the SCOPE and FREQUENCY of planned (preventive) maintenance for the turbines.

Continuous and detailed inspection procedures are necessary not only to discover partly damaged parts which may fail at a critical time, but also to eliminate the underlying conditions which lead to early failure (maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability). Particular and continuous attention must be paid to the following symptoms of malfunctioning:

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

Operating personnel should thoroughly familiarize themselves with the specific temperatures, pressures, and operating speeds of equipment required for normal operation, so that departures from normal operation will be more readily apparent.

If a gage or other instrument used to indicate operating conditions of machinery gives an abnormal reading, the cause must be fully investigated. The installation of a spare instrument or a calibration test will quickly indicate whether the abnormal reading is due to instrument error. However, indications must be believed and actions must be taken accordingly until the indication is proven wrong. 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. In case of pressure-governor-controlled equipment, changes in the operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal pressures, lubricating oil temperatures, and system pressures are indicative of either inefficient operation or poor condition of machinery.

In cases where 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. Prompt inspection may eliminate a wave of repeated casualties.

Abnormal wear, fatigue, erosion, or corrosion of a particular part may be indicative of a failure to operate the equipment within its designed limits or loading, velocity and lubrication, or it may indicate a design or material deficiency. Unless corrective action can be taken which will ensure that such failures will not occur, special inspections to detect damage should be undertaken as a routine matter.

Strict attention must be paid to the proper lubrication of all equipment, and this includes frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in the unit.

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 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 is an equal quantity of freshwater. Saltwater is particularly harmful to units containing oil-lubricated ball bearings.

You will find more information on routine turbine checks and operations in Chapter 9 of this manual and more in-depth information on turbines in the *Naval Ship's Technical Manual* Chapter 231 (9411) for propulsion turbines and Chapter 502 (9500) for auxiliary turbines.

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CHAPTER 4

REDUCTION GEARS AND RELATED EQUIPMENT

This chapter deals primarily with reduction gears used in geared-turbine drive ship's propulsion systems, and related equipment such as bearings and shafting. We shall discuss the construction, operation, and precautionary care of main reduction (propulsion) gears (used with propulsion turbines) and reduction gears used on auxiliary turbines. Unless otherwise specified, the information deals with steam turbine drives, with which Machinist's Mates are associated. The information which follows is supplementary to that in *Fireman,* NAVEDTRA 10520.

REDUCTION GEARS

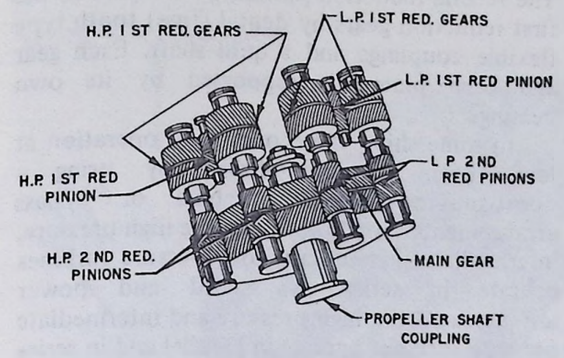
Reduction gears are coupled to the turbine rotor shafts. Through various arrangements of gearing wheels, the reduction gears combine, convert, and reduce the high and possibly different speeds of the turbine rotor shafts to a single low speed required for the main propulsion shaft and propeller. Reduction gears may have input from one or more turbines. The gear arrangement used depends on the number of input turbines and their horsepower.

High-speed propellers are relatively inefficient, compared to the low-speed propellers. They waste much of their horsepower just churning up water, instead of using it to move the ship. Therefore, turbine speeds are geared down to the appropriate speed for the size propeller the ship can carry—hence, the term geared-turbine drive.

Reduction gears are classified according to the number of steps used to bring about the reduction of speed and according to the arrangement of the gearing. When two gears are run together (in mesh) and the driving gear is larger than the mating gear, the gear is referred to as a speed increaser. When the driving gear (called a pinion) is smaller than the mating gear, it is referred to as a speed decreaser. The ratio of the speeds is proportional to the diameters of the pinion and gear. When there are just two gears, the train is known as a single-reduction gear (single speed increaser or decreaser). Double-reduction gears are used to keep the size of the bull (large) gear, attached to the propeller shaft, from becoming too large.

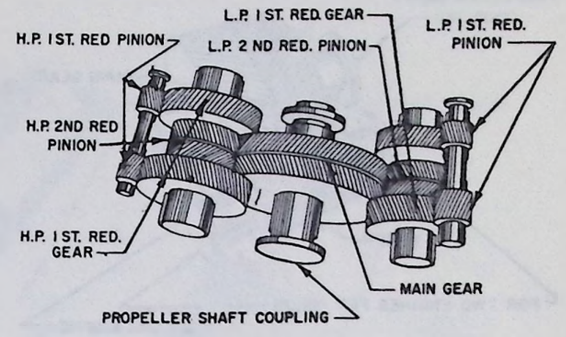
PROPULSION REDUCTION GEARS

Turbine drives normally use double-reduction gears. The locked-train, or divided-power path train gear (fig. 4-1) is used principally for combatant type ships. The articulated gear (fig. 4-2) is commonly found on auxiliary and amphibious warfare ships. The nested gear (fig. 4-3) was used on early auxiliary ships. The single-reduction type (fig. 4-4 and fig. 4-5) is installed on older ships where low turbine speeds permit the use of this gear arrangement and on many diesel propulsion units. Propulsion gears that are driven by electric motors are generally in accordance with either figure 4-4 or 4-5. In such installations, either 1, 2, or 4 motors are used. For diesel engines, where the gear arrangements are also in accordance with either figure 4-4 or 4-5, the diesels used (1, 2, 3, or 4) are generally connected to the propulsion gears by hydraulic clutches, electric clutches, or air-actuated clutches. Engines which are unidirectional generally have either a reversing gear for astern operation or a controllable reversible pitch (CRP) propeller for astern operation. The newer gas turbine ships use



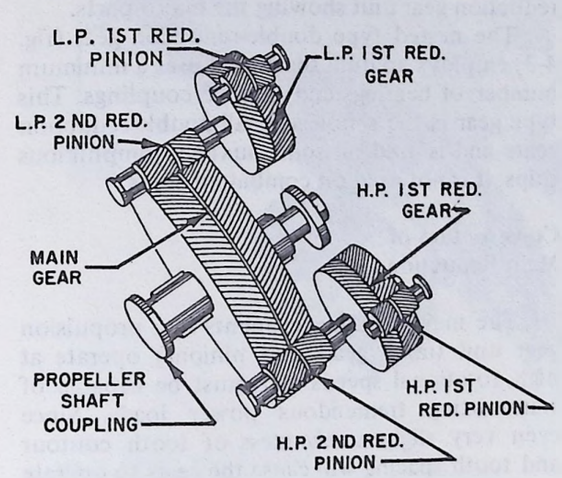
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Figure 4-1.—Locked train, double-reduction gear.



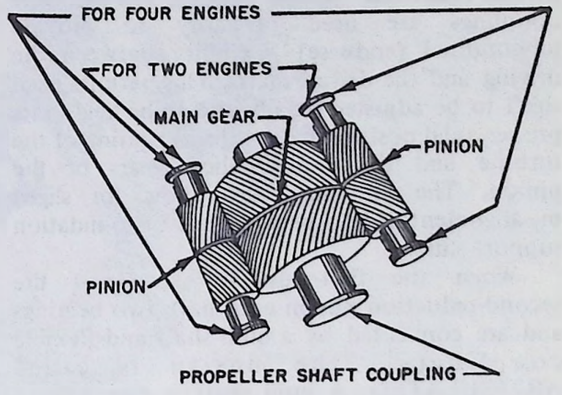
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Figure 4-3.—Nested type, double-reduction gear.



47.28

Figure 4-2.—Articulated, double-reduction gear.



47.169

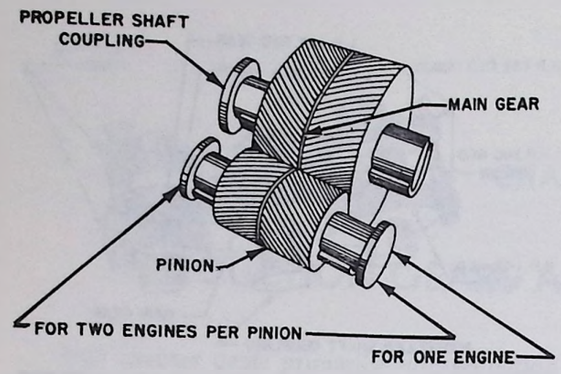
Figure 4-4.—Two pinion, single-reduction gear.

propulsion gear arrangements, as shown in figure 4-1.

All propulsion reduction gearing in combatant ships has double helical gears. Double helical gears produce smoother action of the reduction gearing and avoid tooth shock. Since a double helical gear has two sets of teeth at complementary angles to each other, axial thrust, such as is developed in single helical gears, is eliminated. Each member of a double helical gear set should be capable of axial float to prevent excessive tooth loads due to mismatch of the meshing gear elements. (Axial float means capable of free motion, neither supporting nor supported by other gears axially.) Also, there is usually a groove around the center of the gear where the teeth sets come together. This groove allows a path for the flow of oil which might otherwise create large hydraulic pressures between the gears when they mesh.

In a double-reduction gear, a high-speed pinion, connected to the turbine shaft by a flexible coupling, drives a first-reduction gear which is connected to, or is mounted on, the

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47.170

Figure 4-5.—One pinion, single-reduction gear.

second-reduction pinion shaft. The flexible couplings are used primarily to provide longitudinal (endwise) flexibility between the driving and the driven shafts. This permits each shaft to be adjusted axially and to be held in its proper axial position by the thrust bearing of the turbine and the double-helical gears of the pinion. The couplings also allow for slight misalignment due to bearing wear or foundation support shift.

When the first-reduction gear and the second-reduction pinion each have two bearings and are connected by a quill shaft and flexible coupling(s), the design is called ARTICULATED. A quill shaft is essentially a gear coupling, having two shaft rings with internal teeth and a shaft having external teeth around each end. The shaft rings are bolted on the far ends of each of the two gears to be connected, and the floating member, now called a quill shaft, passes through the hollow centers of both gears and is supported only at the ends where its teeth mesh with the shaft ends. The quill shaft can be seen in figures 4-8 and 4-12, later in this chapter.

An articulated LOCKED TRAIN GEAR has single high-speed pinions each driving two first-reduction gears connected by quill shafts to two separate second-reduction pinions (each gear and pinion mounted in its own two bearings).

The reduction gear shown in figure 4-2 is a parallel shaft, articulated reduction gear. Each high-speed pinion drives one first-reduction gear. The second-reduction pinions are coupled to the first reduction gears by dental (fine) tooth type flexible couplings and a quill shaft. Each gear and each pinion is supported by its own bearings.

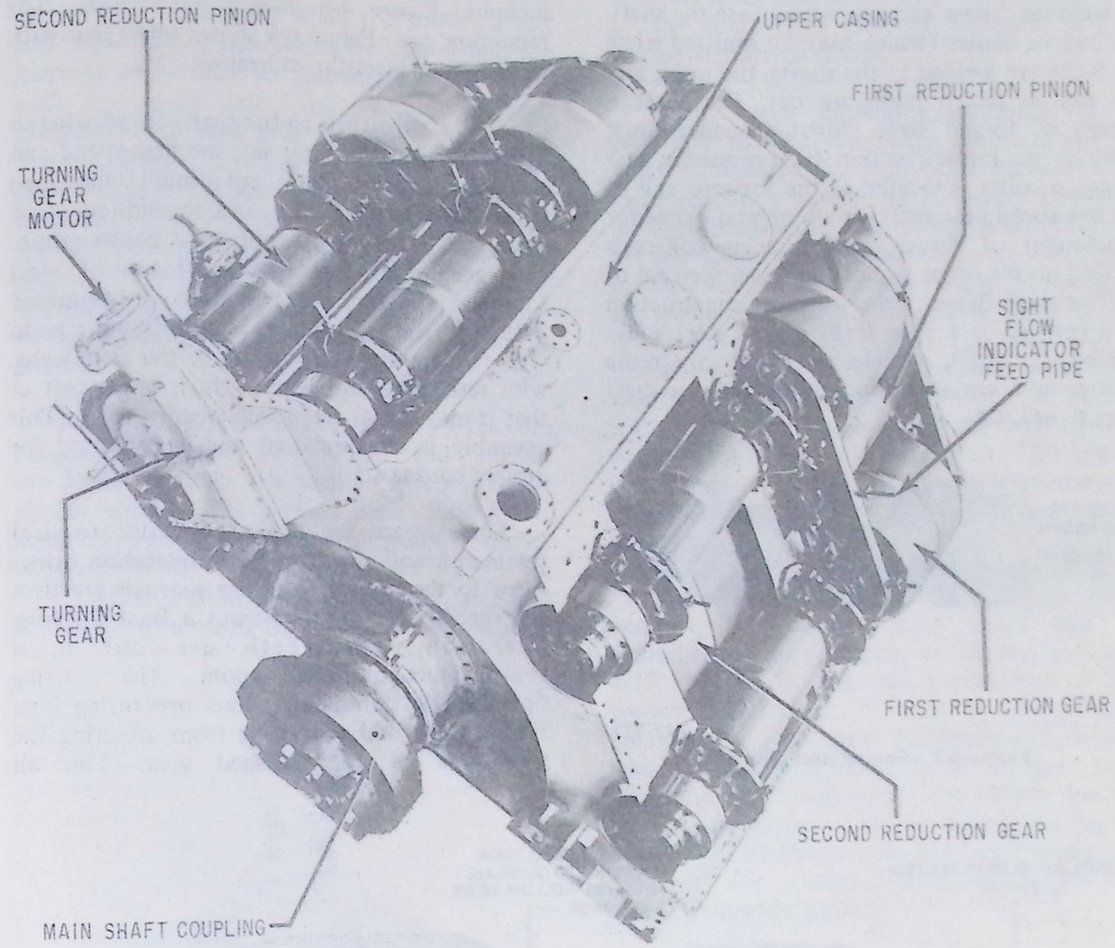
In some ships, the economy of operation at low power is accomplished by using a combination HP-IP turbine or bypass arrangements. For low power, the high pressure, intermediate pressure and low pressure turbines operate in series. As speed and power are increased the high pressure and intermediate pressure turbines operate in parallel and in series with the low pressure turbine. The reduction gear arrangement driven by the HP-IP turbine unit is similar to the reduction gear shown in figure 4-1. Figure 4-6 illustrates a main reduction gear unit showing the major parts.

The nested type double-reduction gear (fig. 4-3) employs no quill shafts and uses a minimum number of bearings and flexible couplings. This type gear is the simplest of all double-reduction gears and is used on some auxiliary/amphibious ships; it is not used on combatant ships.

Construction of Main Reduction Gears

The main rotating elements in a propulsion gear unit (main gears and pinions) operate at high rotational speeds and must be capable of transmitting tremendous power loads. Since even very slight unevenness of tooth contour and tooth spacing will cause the gears to operate noisily or even to fail, special precautions are taken to manufacture the gears to very close tolerences. The gears are cut in rooms in which the temperatures and humidity are closely controlled. Expansion and contraction of the gear-blank, during machining, are negligible; oxidation, due to moisture in the air, is virtually eliminated. In addition, all gears are carefully checked for errors.

CASINGS.—Except for some small units, gear casings are of welded construction. Most gears have an upper and a lower casing and gear case covers. These casings are of box-girder construction with integral-bearing blocks. The low speed (bull) gear-bearing housing is an



47.30

Figure 4-6.—Typical destroyer-type propulsion gear.

integral part of the lower casing. Gear case covers, bolted and securely locked to the upper casing, are arranged so that their removal provides access to gearing and bearing caps. Inspection plates are usually provided in covers and gear cases so that the rotating parts may be sighted.

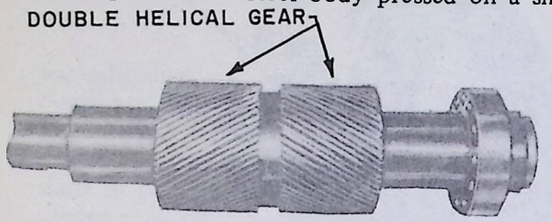
Casings are arranged for access to oil spray fittings so that the fittings may be cleaned. Turning gears, tachometer drives, lube oil pump drives, sight flow and thermometer fittings, thermocouples or resistance temperature-element (RTE) junction boxes, and electrostatic precipitator vent connections are attached to gear casings.

GEARS.—In general, pinions are forged steel, one-piece construction as shown in figure 4-7.

The gear wheel construction and materials depend on the size of the gear. For small gears, the entire gear wheel may be made from a single

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steel forging. Large gears are generally built up by welding. These sections usually are the shaft, the hub or center (which may be omitted when the webs are welded to the shaft), the webs, and the rim in which teeth are cut. The shaft is always of forged steel. When propeller-thrust bearings are located within the propulsion gear casing, a collar is located at the forward end of the low speed gear shaft, or an integral flange for attachment of thrust bearing facing collars is located on the other end of the shaft, forward of the line shaft flange. Other types of construction used consist of a close-grained cast steel body, welded to a shaft, with teeth cut directly in the casting or a cast-steel body pressed on a shaft



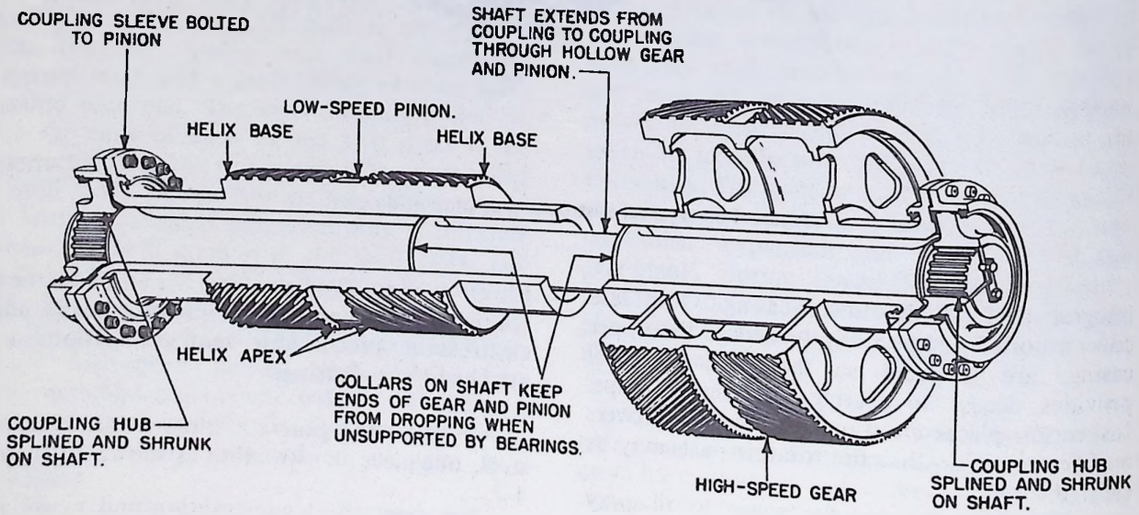
47.171

Figure 4-7.—Forged steel pinion.

and secured by fore and aft shrink rings and a locknut. Figure 4-8 illustrates a typical first reduction gear. Figure 4-9 shows a bull gear with flange for an after-thrust bearing.

In a double-reduction articulated divided-power path gear set, the high-speed and second-reduction pinion are usually machined from forgings. The first- and second-reduction gears are usually of a fabricated construction. The gear shaft and rim are made of steel forgings. The rim and the shaft are assembled with steel webs, welded to the shaft and rim. In wide-faced gears, the position of the steel webs, with respect to the gear teeth, is important in that it may affect gear tooth wear patterns. This assembly is stress-relieved and heat-treated for desired hardness.

Some gears are rough cut prior to heat treatment, and the final finish operation brings them to the proper size. The journals are then cut slightly oversize to permit a final finishing operation. The teeth are cut in a temperature-controlled room. The cutting operation is continuous, thus preventing heat that is generated in cutting from affecting the roundness of the finished gear. The air



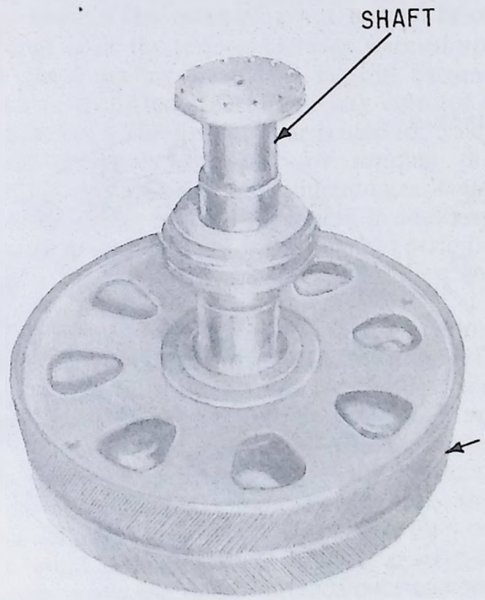
47.172

Figure 4-8.—Cutaway view of intermediate rotor assembly articulated gear.

temperature control prevents changes in the ambient temperature from affecting the roundness of the gear. When the tooth cutting and the finishing operations are completed, the journals are finished so that they are concentric with the shaft axis. The assembly is then balanced. The bull gear is made in a similar fashion. Some first-reduction gears and bull gears in naval use are keyed and locked to the shaft with a locking device. This is done before the teeth are cut and before balancing. When the gears are all completed, the contact between pinion and gear is usually checked in a gear rolling machine before they are assembled in the gear case.

FLEXIBLE COUPLINGS.—Flexible couplings provide longitudinal and angular flexibility between the turbine shafts and the pinion shafts. This permits each shaft to be adjusted axially to its proper position to obtain total axial float.

In most installations the flexible couplings are of the gear-tooth type. Power is transmitted



47.173

Figure 4-9.—Bull gear assembly with shaft.

through a floating intermediate member with external teeth that mesh with the internal teeth of the shaft rings (sleeves) mounted on the driving and driven shafts.

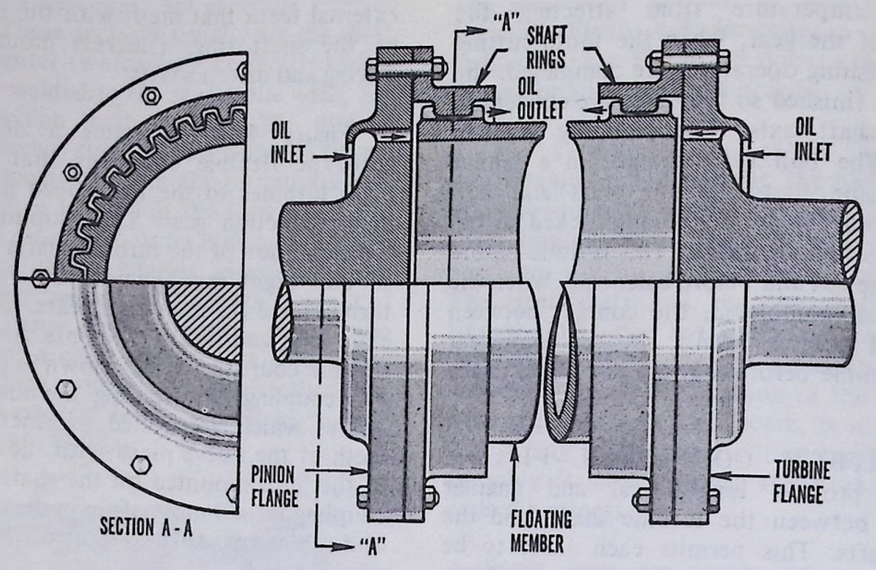
Figure 4-10 illustrates a design of the gear-type flexible couplings that connect the main turbines to the high-speed pinions of the main reduction gear. The couplings also allow for expansion of the turbine shafts and take care of any slight misalignment between the main turbines and the reduction gears, such as thermal expansion and hull movements. Another type of flexible coupling used is shown in figure 4-11. In this coupling the floating member is the two sleeves which are bolted together; the internal teeth of the sleeve mesh with the external teeth of the hubs mounted on the shaft. This type of coupling is used most often in diesel engine gears and where self-contained lubrication is advantageous.

The design of the flexible couplings, which connect the first-reduction gears and the second-reduction pinions, is shown in figure 4-12 and 4-8. In this case, a quill shaft of high torsional flexibility is used as the floating member to obtain equal distribution of the load among the several elements of the gear train. The quill shaft runs inside the hollow bore of the high-speed gear and the slow-speed pinion. Figure 4-12 illustrates how flexibility is obtained between the first-reduction gear and the second-reduction pinion.

A steady flow of oil from the supply passages of adjacent bearings is directed into the flexible couplings when the reduction gears are turning. The oil is caught by projecting lips of the turbine and pinion flanges (fig. 4-10) or sleeves. Centrifugal action forces oil through the horizontal holes in the flanges to the coupling teeth. Oil is discharged from the teeth into coupling guards and then flows into the oil drain system.

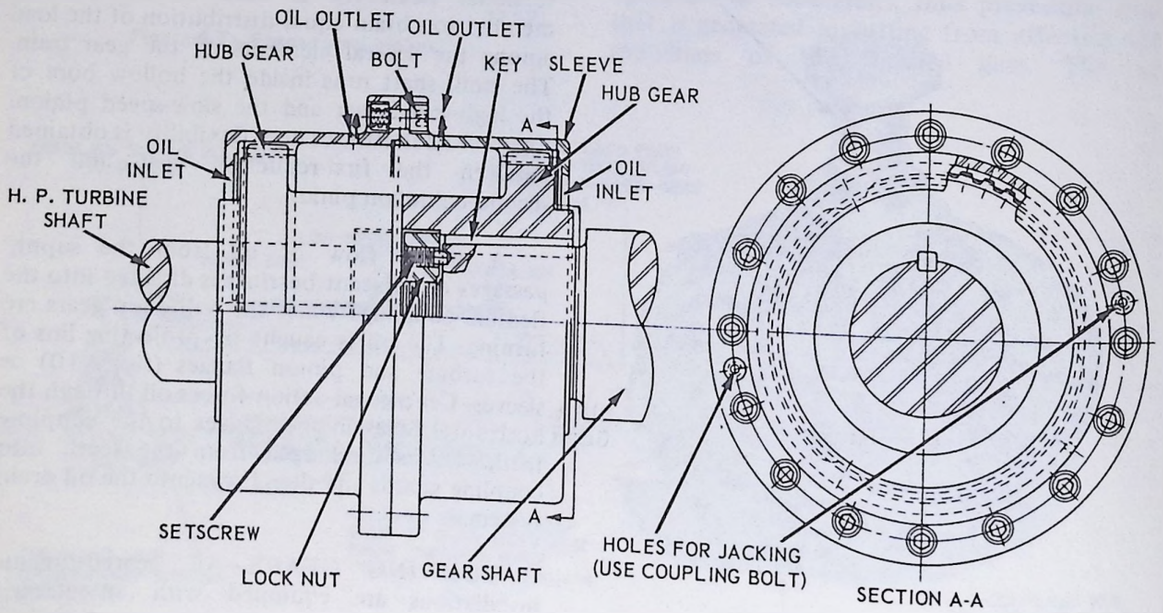
TURNING GEARS.—All geared-turbine installations are equipped with an electric motor-driven jacking or turning gear. A typical turning (jacking) mechanism is illustrated in figure 4-13. The unit is used for rotating the

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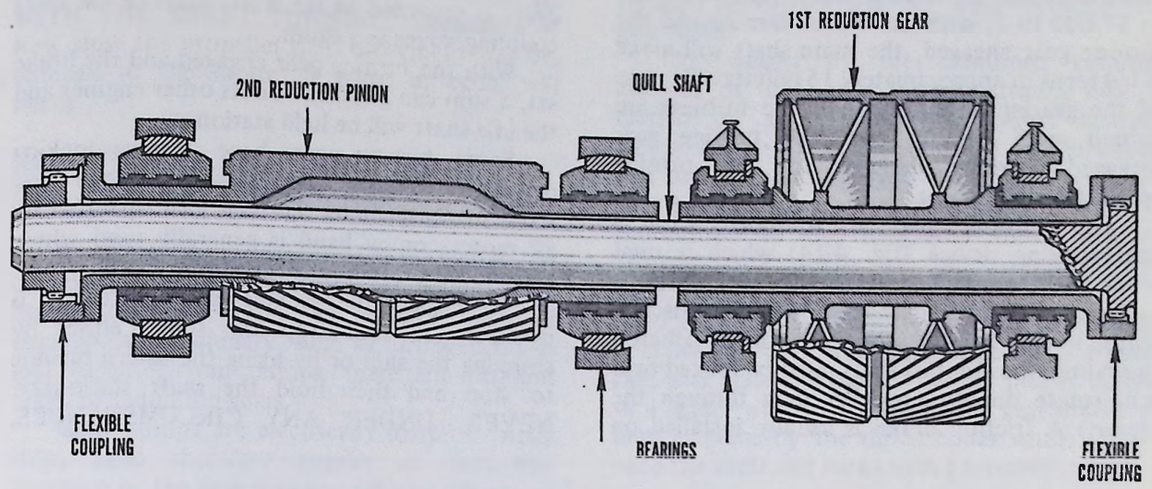
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Figure 4-10.—Gear-type flexible coupling.



47.33

Figure 4-11.—Another gear-type flexible coupling.

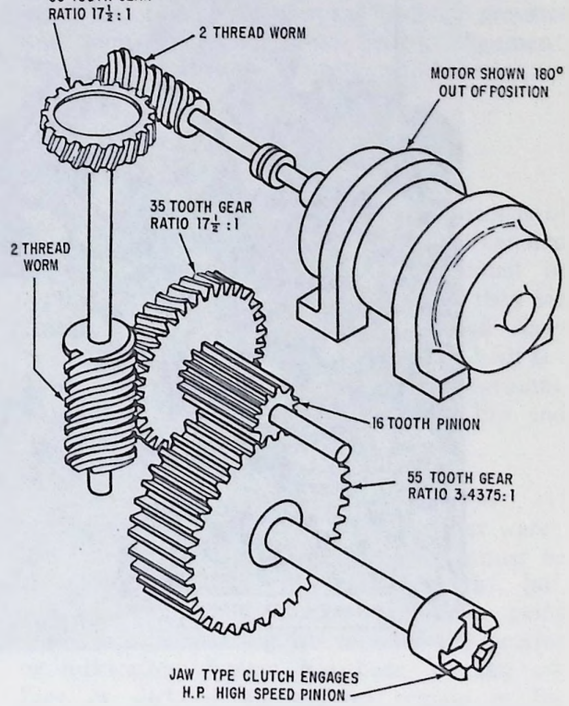


47.32X

Figure 4-12.—Quill shaft assembly.

main engine during warming up and securing periods so that the turbine rotor can heat or cool evenly. (The rotor of a hot turbine or of one that is in the process of being warmed up, with gland sealing steam cut in, will become bowed or distorted if left stationary even for a few minutes.) The turning gear is used for other routine purposes such as for rotating the reduction gear to bring the reduction gear teeth into view during routine inspection. In addition, the turning gear is used for the required periodic rotation of the main engines when they are secured.

The turning gear (fig. 4-13) is mounted on top and at the after end of the reduction gear casing. A shaft, extending from the end of the high-pressure first-reduction pinion to the after end of the reduction gear casing, connects to the turning gear by means of a manually operated jaw clutch. Engaging this clutch connects the pinion to an electric motor, through a train of gears, which usually consists of one or more sets of worm gears and one or more sets of spur or helical gears. Engaging the clutch and operating the motor will turn one first-reduction pinion, causing the reduction gears, the main engines, and the main (propeller) shaft to turn. On some installations, the reduction ratio between the



47.34

Figure 4-13.—Turning gear mechanism.

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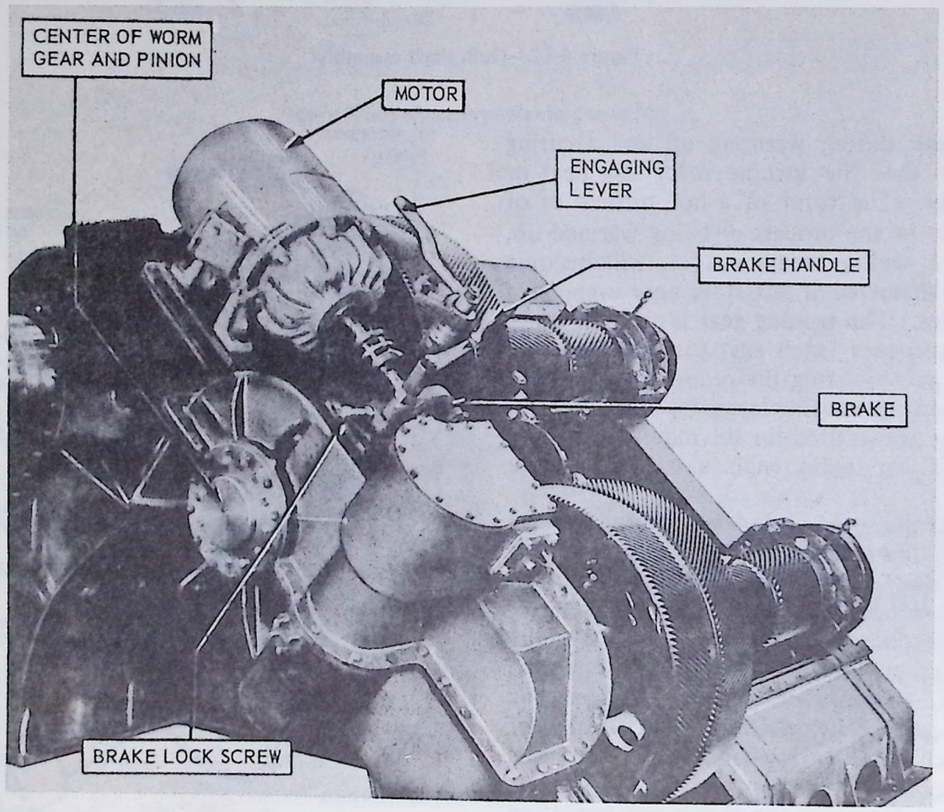
main shaft and the electric motor may be as high as 17,000 to 1; with the motor turning and the turning gear engaged, the main shaft will make 1 1/4 turns in approximately 15 minutes. Because of the gearing arrangement, if the turbines are turned with steam, with the turning gear engaged, serious damage to the turning mechanism will occur.

The turning gear is equipped with a shaft-locking device (fig. 4-14) which is used when it becomes necessary to lock a shaft against rotation while underway. (On multiscrew ships, if one shaft is stopped with the other(s) operating, the stopped shaft must be locked or it will rotate due to propeller drag through the water.) A friction brake is usually installed on the first-reduction worm shaft. Either a brake drum is mounted on the worm shaft or the shaft coupling serves as a drum.

With the turning gear engaged and the brake set, a ship can go ahead on its other engines and the idle shaft will be held stationary.

Some turning gears have positive locking devices which use internal and external gear teeth in engagement. Turning gear operated by air motors or by hand is generally used where continuous turning is not required.

To engage the jacking gear clutch it is necessary to first stop the shaft, either by stopping the ship or by using the astern turbine to stop and then hold the shaft stationary. NEVER, UNDER ANY CIRCUMSTANCES,



47.35

Figure 4-14.—Propulsion gear after end, high-pressure side, showing turning gear and propeller-locking mechanism.

ATTEMPT TO ENGAGE THE JACKING GEAR WITH THE SHAFT TURNING. Regardless of how slow the propeller shaft movement may be, damage to the motor or gears, or both, will occur.

REDUCTION GEARS FOR AUXILIARY MACHINERY

In the previous section of this chapter, we discussed propulsion gears of the double-helix, double-reduction type. In smaller units of engineroom machinery, such as turbogenerators and turbine-driven pumps, there are different types of reduction gears.

Most pumps are electrically driven in many ships (and therefore require no reduction gearing); or the ship may use a design where one pump of a type is electrically driven and the other is turbine driven; or if four pumps of a type are used, the design may be a two and two arrangement. Due to the many different designs of auxiliary reduction gears, selected examples are used in these explanations.

Turbogenerators

In a typical ship's service turbogenerator, a single-reduction, single-helix type of reduction gear, the pinion is forged integral with the shaft. One end of the pinion shaft is flanged and bolted rigidly to the turbine shaft. On the other end, a high-speed thrust bearing is mounted to maintain the axial position of the pinion and turbine rotor. The gear wheel is a steel forging, pressed and keyed on its shaft. One end of the shaft is coupled solidly to the generator shaft; the turbine end is extended to carry the gear that drives the oil pump and governor.

Main Circulating Pumps

Some turbine-driven main circulating pumps employ single-reduction, double-helical gears with a ratio of approximately 8 to 1. These gears (fig. 4-15) reduce the turbine speed of approximately 5,000 rpm to the pump speed of 600 rpm. A gear-type pump mounted on the lower end of the pinion shaft provides lubrication for the reduction gear. Oil is sprayed through an orifice into the space between the gear teeth.

The weight of the combined rotating element of the pump and the driving unit is carried on a Kingsbury-type thrust bearing which supports a collar mounted at the upper end of the reduction gear shaft. The weight of the turbine rotor and the pinion shaft is transmitted to the Kingsbury thrust bearing through the teeth of the double-helical reduction gear.

The pinion is a solid forging, while the gear is constructed by welding a forged hub, forged rim, and plate sidewalls. The gear hub is bolted to a spider which is keyed to the gear shaft and held in place by the thrust collar which screws onto the shaft and locks with a setscrew.

REDUCTION GEAR CARE AND OPERATION

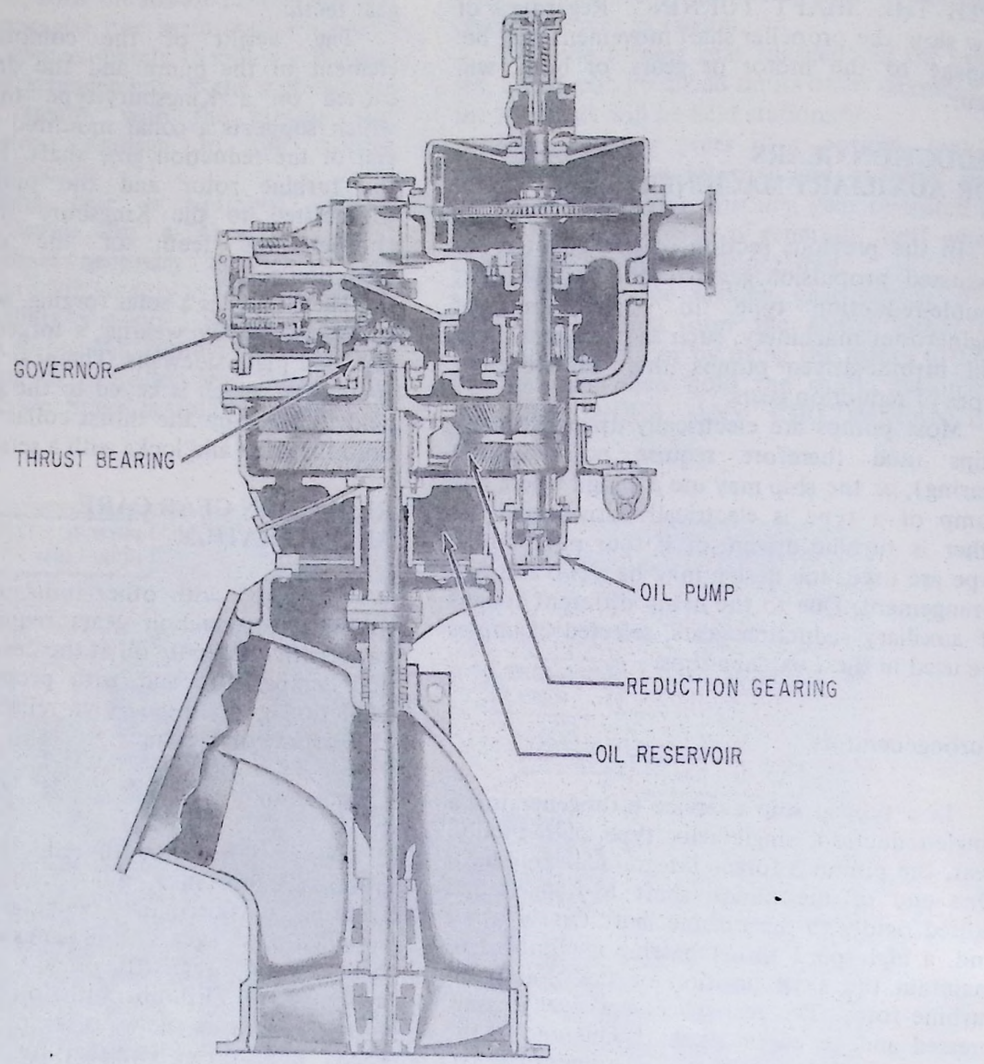
Compared with other units of engineroom machinery, reduction gears require very little care. With clean pure oil at the designed pressure and temperature and with proper alignment, reduction gears should give reliable service for the lifetime of the ship.

Lubrication

Proper lubrication of reduction gears is of utmost importance. Oil at the designated working pressure and temperature must be supplied to the gears at all times while they are being turned over, with or without load. Navy symbol 2190 TEP lubricating oil is used for the propulsion gears as well as for the turbines. Clean pure oil is essential for long life and successful operation of the gear.

Oil must be free from all impurities—especially such impurities as water, dirt, grit, and metallic particles. Care must be taken to remove all metal flakes, dirt, lint, and fine chips when new gears are being worn into a working fit or after the gearing or lubrication system has been worked on. Lint or dirt, if allowed to remain in the system, will clog the oil spray nozzles that lubricate the gears. KEEP OIL SPRAY NOZZLES OPEN AT ALL TIMES. NEVER ALTER

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47.37

Figure 4-15.—Vertical propeller type, main condenser circulating pump.

THE OIL SPRAY APPARATUS WITHOUT PROPER AUTHORITY.

Fine metallic particles that are not picked up by the magnets in the lube oil strainers, or dirt that may get through the strainers, may become embedded in the babbitted bearings and eventually score the journals. In addition, the mixture of dirt and metallic particles may erode metal from the gear tooth surfaces. The solution to this problem calls for clean, purified oil.

For this reason, a lube oil purifier (centrifuge) is installed in the engineroom to remove water and other impurities from the oil used to lubricate the bearings of the main engine turbines and the bearings and teeth of the reduction gears.

Effects of Acid and Water in Oil

Water in the oil is extremely dangerous. Even small amounts soon cause pitting and corrosion of the teeth. Water emulsifies the oil, leading to possible clogging of the oil sprays and orifices. Acid is equally dangerous. The oil must be tested frequently for water as well as for acid content.

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 tank which is integral with the skin of the ship.

Immediate location and sealing of the leak or removal of the source is not enough. Steps must also be taken to remove the contaminated oil from all steel parts and surfaces. Postponement of such treatment may cause badly corroded and pitted gears, journals, couplings, and bearings.

Water also may contaminate the lube oil from condensation within the lube oil system, primarily the reduction gear casings. For this reason, when the main engines are secured, the oil should be circulated until the temperature of the oil and of the reduction gear casings is reduced to the temperature called for by the securing procedure. While the oil is circulated, the cooler should be operated and the gears should be rotated continuously, using the turning gear. The purifier should also be operated while the oil is being circulated and after circulation until water is no longer discharged from the purifier. This procedure will minimize condensation from the interior of the main reduction gear casing, reducing formation of rust. The securing procedures for reduction gears in chapter 9420 (241) of the NSTM should be observed.

Sump Oil Level

Since some reduction gears are located directly above the lubricating oil sump tank or are in a casing which also serves as the sump, positive means should be taken to ensure that the bull gear wheel will not dip into the oil. The proper oil level in the sump is indicated on a liquid level indicator, or may be read with a dipstick in some installations. If the bull gear is permitted to rotate in the oil, the churning action will aerate the oil and cause the oil temperature to rise. Oil churning can also prevent full speed operation of the shaft. This condition can be noted by high bearing temperatures and an excessive amount of air in bubbler sightflow glasses. If this occurs, the engines must be slowed or stopped until the excess oil can be removed and normal conditions restored. Many bull gears have an oil exclusion pan fitted at time of manufacture to ensure against rotation of the gears in the oil. Other reduction gear constructions separate the reduction gears from the main sump completely, having oil return lines from the reduction gear casing to the sump.

Unusual Sounds

A properly operating reduction gear has a certain definite sound. Any unusual noises from the reduction gears should be investigated. The gears should be operated with caution until the cause is discovered and remedied.

REDUCTION GEAR CASING OPENING AND ACCESS

Access into reduction gear casings is strictly controlled, and in most cases the direct presence of the Engineer Officer is required for any inspection or any work on or around the reduction gears where access is possible. Access does not necessarily have to be the opening of the inspection covers; other maintenance such as oil bubbler repair or work on other items such as the flexible couplings or gear vents on some ships allows access to the gears. Section 9420.61 of chapter 9420 of the NSTM provides the requirements and suggested procedures and precautions for access control to main reduction gearing. Also, the Maintenance Requirement Cards for performing maintenance tasks on reduction gearing, in which access is required, provide another reference.

The following procedures are offered as an example of the rules which may be in force when reduction gear access is required. Actual

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approved procedures will differ somewhat, but the basic rules and concepts will apply.

Usually, a controlled area will be set up around the work area. This area may also require the use of some type of tent to surround and cover the access being opened to protect against material dropped from above or thrown into the area. Flashlights, wrenches, inspection mirrors, and other tools used should be securely tied with a lanyard to either a person or a fixed object. Items with potentially loose parts such as a flashlight, should be taped in such a way that the parts will not fall free from the flashlight if it comes apart. Personnel entering the controlled area should not have jewelry such as watches, rings, necklaces, arm-bracelets, unsecured eyeglasses, etc on their person. Pockets should be empty and taped; T-shirts or plain, pocketless undershirts should be worn in the area or all buttons and pockets on the shirts should be securely taped. A watch should be posted at the entrance to the controlled area at all times that the reduction gear access is in progress to ensure these procedures are followed and to limit access to the area to those persons designated by the Engineer Officer. These procedures (and those similar) are necessary because of the seriousness and expense of reduction gear casualties which can be caused by even a small piece of foreign material getting into the wrong place. You learned some of these reasons in the discussion of reduction gear construction.

BEARINGS

Although bearings in main propulsion units vary greatly in size, composition, and lubrication requirements, their purposes are the same. Bearings are used to guide and support rotating elements and to prevent free axial or radial movement of these elements. Radial or journal bearings are designed to carry loads applied in a plane perpendicular to the axis of the shaft. Thrust bearings are designed to carry loads applied in the same direction as the axis of the shaft and are used to restrict axial movement.

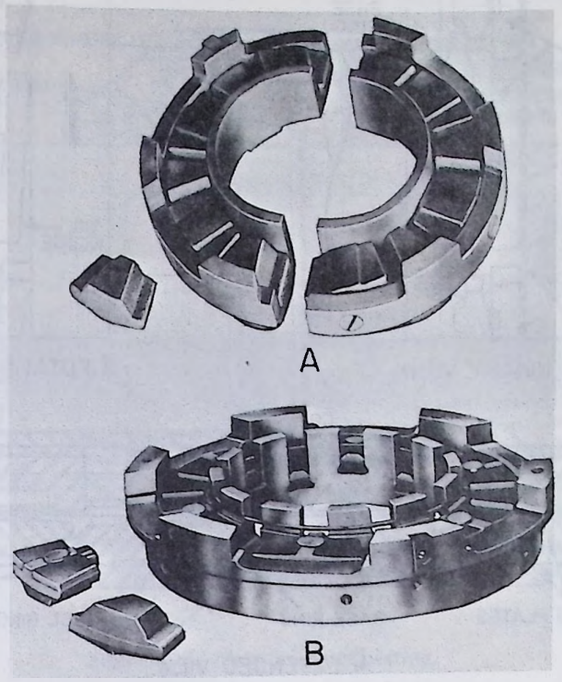
Lubrication of bearings differs according to type. For example, babbitt-lined bearings are lubricated by an approved lubricating oil while stern tube and strut bearings, which are lined with hardwood, phenolic, or a rubber composition, are saltwater lubricated. Bearings are designed to operate with a small lubricant clearance (the difference between the outside diameter of the journal and the inside diameter of the bearing is the clearance) which must always be maintained within specified limits. With proper clearances and proper lubrication, bearings will operate successfully for many years. The information given in this training manual is of a general nature. You can obtain additional information from chapters 241 (9420), 243 (9430), and 244 (9431) of *Naval Ships' Technical Manual.* For details concerning a particular unit consult the manufacturers' technical manual.

MAIN REDUCTION GEAR AND PROPULSION TURBINE BEARINGS

Reduction gear bearings must not only support the weight of the gears and their shafts but must also hold the shafts in place against the tremendous forces exerted by the shafts and gears when they are transmitting power from the turbine shaft to the propeller shaft. Like other radial bearings in main engine installations, these bearings are of the babbitt-lined split type. However, instead of being spherically seated and self-aligning, the reduction gear bearings are rigidly mounted into the bearing housings by dowels or locking screws and washers. The angular direction of the forces acting upon a main reduction gear bearing changes with the amount of propulsion power being transmitted by the gear. In some designs, thermocouples or resistance-temperature elements (RTE) for measuring oil temperature are installed in bearings or may be installed in sight-flow fittings.

To avoid wiping, reduction gear bearings must be positioned so that the heavy shaft load is not brought against the area where the bearing halves meet (the split). For this reason most of the bearings in a reduction gear are placed so that the split between the halves is at an angle to the horizontal plane.

Turbine bearings, unlike reduction gear bearings, are self-aligning by means of a spherical



147.51X

Figure 4-16.—Kingsbury pivoted-shoe thrust bearing.

seat for the bearing shells. Turbine bearings are pressure-lubricated by means of the same forced-feed system that lubricates the reduction gear bearings.

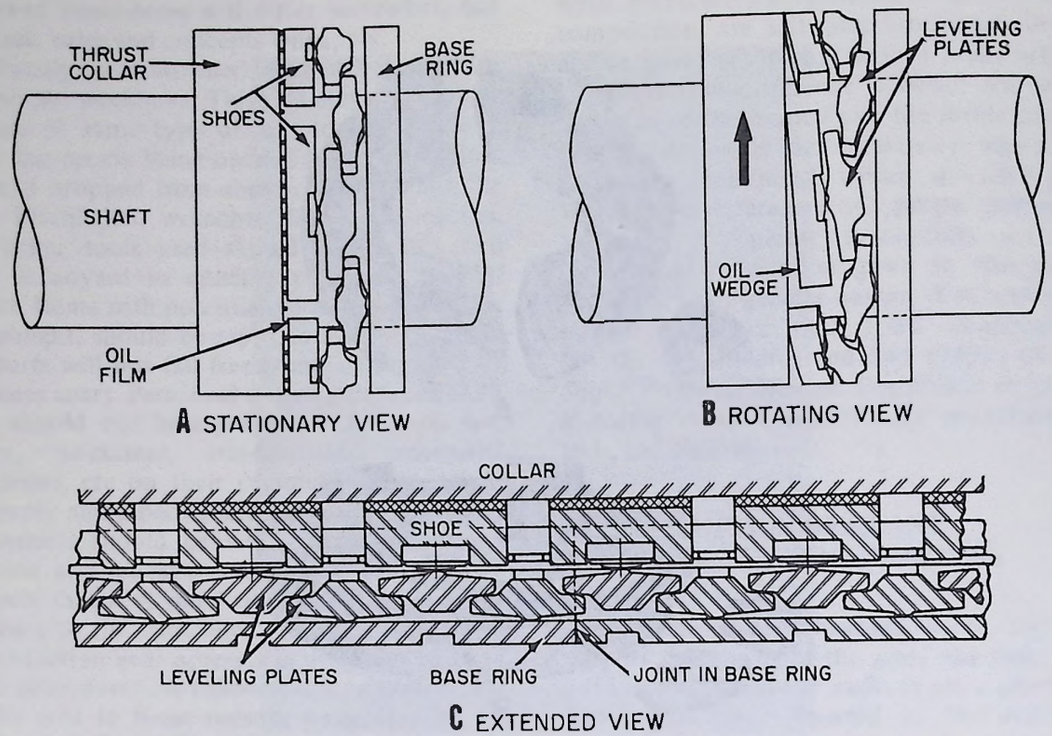
MAIN THRUST BEARINGS

The main thrust bearing, which is usually located in the reduction gear casing, absorbs the axial thrust transmitted through the shaft from the propeller.

Kingsbury or segmental pivoted-shoe thrust bearings of the type shown in figure 4-16 are commonly used for main thrust bearings. This type of bearing consists of pivoted segments or shoes (usually six or eight) against which the thrust collar revolves. Ahead or astern axial motion of the shaft, to which the thrust collar is secured, is thereby restrained by the action of the thrust shoes against the thrust collar. These bearings operate on the principle that a wedge-shaped film of oil is more readily formed and maintained than a flat film and that it can therefore carry a heavier load for any given size.

In a segmental pivoted-shoe thrust bearing, upper leveling plates upon which the shoes rest and lower leveling plates equalize the thrust load among the shoes (fig. 4-17). The base ring, which supports the lower leveling plates, holds the plates in place and transmits the thrust on the plates to the ship's structure via housing members which are bolted to the foundation. Shoe supports (hardened steel buttons or pivots) located in the shoes separate the shoes and the upper leveling plates which enables the shoe segments to assume the angle required to pivot the shoes against the upper leveling plates. Pins and dowels hold the upper and lower leveling plates in position, allowing ample play between the base ring and the plates to ensure freedom of movement (oscillation only) of the leveling plates. The base ring is kept from turning by its keyed construction which secures the ring to its housing.

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Figure 4-17.—Diagrammatic arrangement of Kingsbury thrust bearing.

MAIN PROPULSION SHAFT BEARINGS

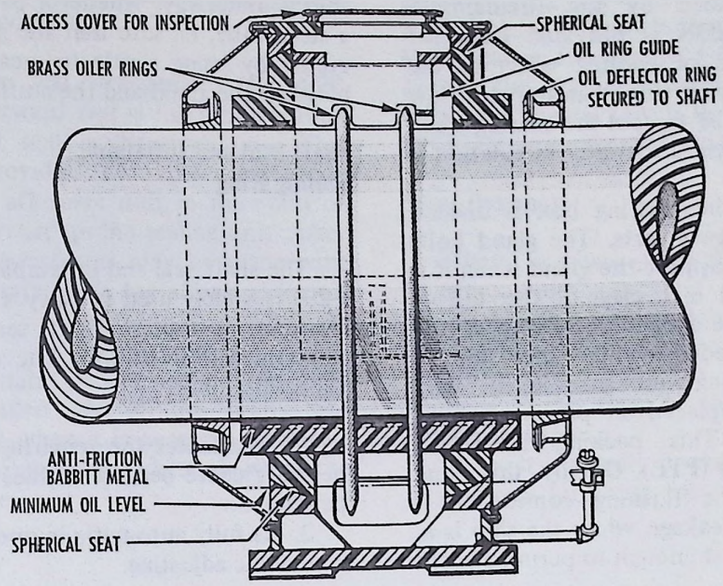
You will be required to watch and maintain the main propeller shaft bearings. The bearings which support and hold the propulsion shafting in alignment are divided into two general groups—the main line shaft bearings or spring bearings and the stern tube bearings and the strut bearings.

Main Line Shaft Bearings or Spring Bearings

Most of these bearings are of the ring or disk-oiled, babbitt-faced, spherical seat, shell type. This bearing (fig. 4-18) is designed primarily to align itself to support the weight of the shafting. The upper half of the assembly consists only of a cap or cover (not in contact with the shaft) 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, shown in figure 4-18, are a loose fit; the inside diameter of the rings is greater than the outside diameter of the shaft plus sleeve. The rings are retained in an axial position by guides or grooves in the outer bearing shell. As the shaft rotates, the friction between the rings and the shaft is enough to cause the rings to rotate with the shaft. As the rings dip into the oil in the sump of the bearings, oil is retained on the inside diameter of the rings and is carried to the upper bearings by the rings. The action of the oil ring guides and contact of the rings on the upper shaft causes the oil to be removed from the rings and lubricate the bearings.

Other ships have main line shaft bearings which are force-lubricated by a pressurized



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Figure 4-18.—Main line shaft bearing.

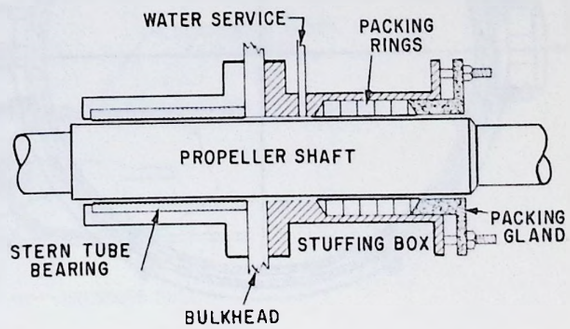
(pump) lube oil system similar to a small main lube oil system.

Temperature of the spring bearings and the oil levels should be checked hourly while underway. Inspection and maintenance will be done in accordance with PMS requirements.

Stern Tube and Stern Tube Bearings

The hole in the hull structure that accommodates the propeller shaft to the outside of the hull is called the stern tube. The propeller shaft is supported in the stern by two stern tube bearings—one at the inner end and one at the outer end of the stern tube. At the inner end of the stern tube is a stuffing box packing gland (fig. 4-19), generally referred to as the stern tube gland. Stern tube stuffing box installations are used only in older ships. Primary sealing for the shafts on most ships is accomplished by automatic shaft seals which are introduced later in this chapter. The stern tube gland seals the area between the shaft and stern tube and yet allows the shaft to rotate. Construction of the stern tube bearings is similar to that of the strut bearings. (See the next section of this chapter.)

The stuffing box is flanged and bolted to the stern tube. Its casting is divided into two annular (ring-shaped) compartments—the forward space being the stuffing box proper, the after space containing a flushing connection to provide a positive flow of water through the stern tube for



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Figure 4-19.—Stern tube stuffing box and gland.

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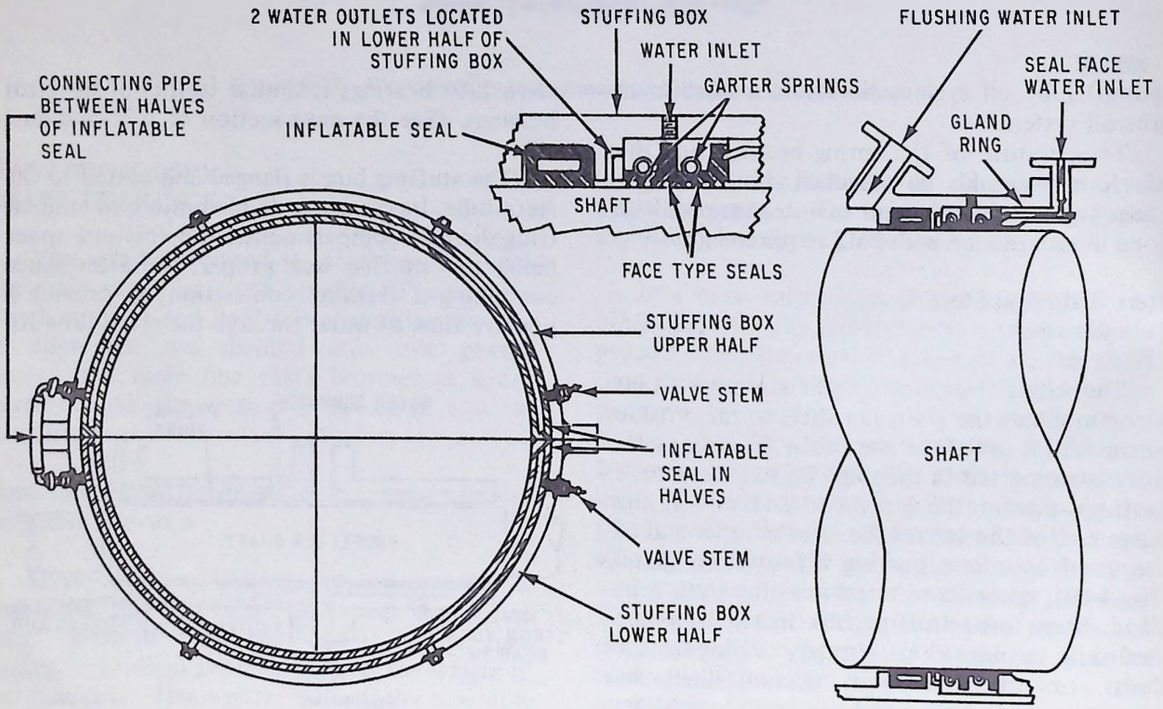
lubricating, cooling, and flushing. This flushing connection is supplied by the firemain. A DRAIN CONNECTION is provided both for testing the presence of cooling water in the bearing and for permitting seawater to flow through the stern tube to cool the bearing when underway, where natural seawater circulation is used.

The gland for the stuffing box is divided longitudinally into two parts. The gland bolts are long enough to support the gland when it is withdrawn at least 1 inch clear of the stuffing box. This permits the addition of a ring of new packing, when needed, while the ship is waterborne. Packing in accordance with MIL-P-24377 has replaced all previously used packing material. This packing is Teflon impregnated asbestos (PTE). Usually, this gland is tightened and the flushing connection is closed to eliminate leakage when the ship is in port, and loosened just enough to permit a slight trickle of water for cooling purposes when the ship is underway. Whenever packing is added to a stern tube, be sure that the gland is drawn up evenly by using a rule to measure the distance between the gland and the stuffing box.

Shaft Seal and Inflatable Sealing Ring

The shaft seal and inflatable sealing ring (fig. 4-20) is widely used in Navy ships. Figure 4-21 illustrates a typical shaft sealing system on submarines (SSN-SSBN). The use of the shaft sealing assembly:

1. Eliminates the repairing or renewing of the shaft sleeve because it does not score or cut the sleeve.
2. Is fully automatic in operation, requiring no periodic adjusting.



47.178

Figure 4-20.—Shaft seal and inflatable sealing ring.

3. Makes possible the removal and reinstallation of all parts without dismantling the shaft or shaft coupling.

In the tandem seal arrangement (fig. 4-20 and 4-21), the forward seal is the prime sealing unit and the aft seal is the spare unit. This arrangement provides for the immediate operation of the aft spare unit in the event of failure of the forward prime sealing unit. Also, repairs to the forward seal may be made with the ship in the water with the after seal in full operation.

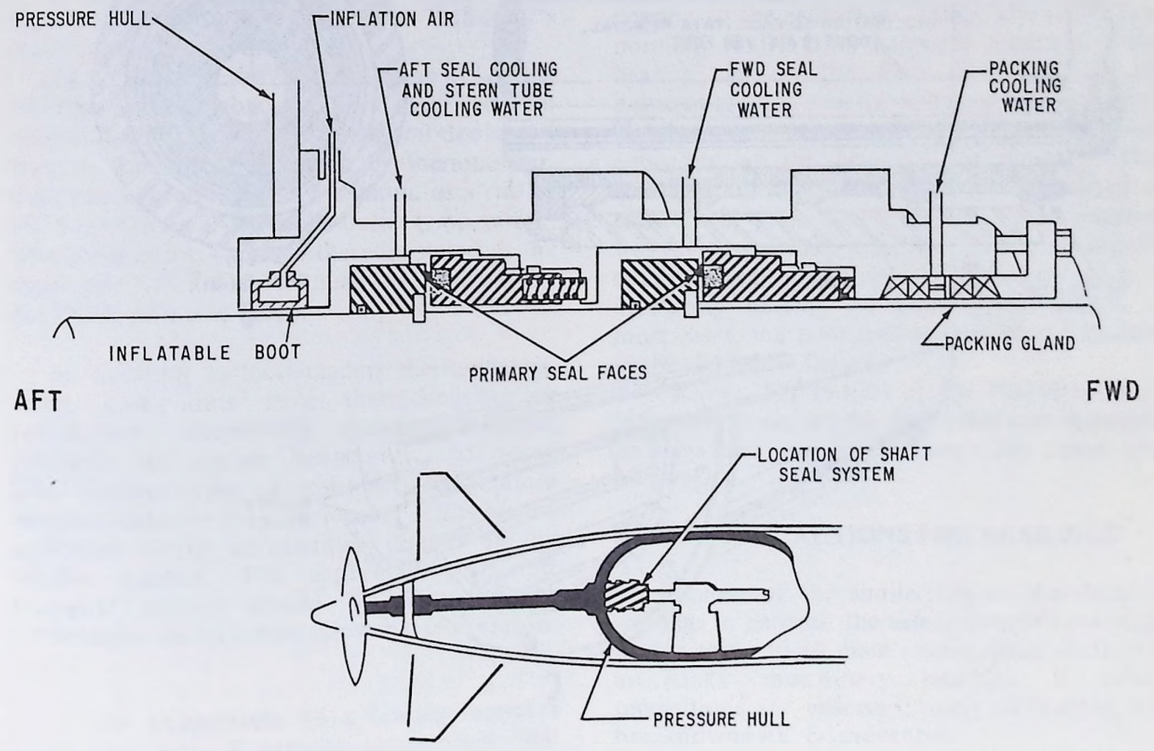
The split inflatable rubber ring seal (fig. 4-20 and 4-21), installed aft of the prime seal assembly, is used when it is necessary to repair or replace the prime sealing elements when the ship is waterborne.

The operation and testing of the split inflatable ring seal are to be done in accordance with ship's instructions and the PMS Maintenance Requirement Card (MRC). Never exceed the maximum pressure designated for inflating the seal (given in NSTM chapter 243 [94301]; overpressurization can rupture the seal.

Strut Bearings

These bearings, as well as 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. One end is bolted to the strut.

Since it is usually impracticable to use oil or grease as a lubricant for underwater bearings,



47.191

Figure 4-21.—Submarine (SSN-SSBN) shaft sealing system.

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some other frictionless material must be used. There are certain materials that become slippery when wet, including synthetic rubber; lignum vitae, a hard tropical wood with excellent wearing qualities; or laminated phenolic material consisting of layers of cotton fabric impregnated and bonded with phenolic resin. Strips of this material, as shown in figure 4-22, are fitted inside the bearing.

A rubber composition is the type used in most Navy installations.

CARE OF BEARINGS AND JOURNALS

Properly operated bearings will give years of satisfactory service but, like all units of engineroom machinery, they require periodic tests, inspections, and maintenance. When bearings are originally installed, the manufacturer takes oil clearance readings which are recorded in accordance with PMS. At regular intervals the ship's force must also take these readings. Any difference between the old and

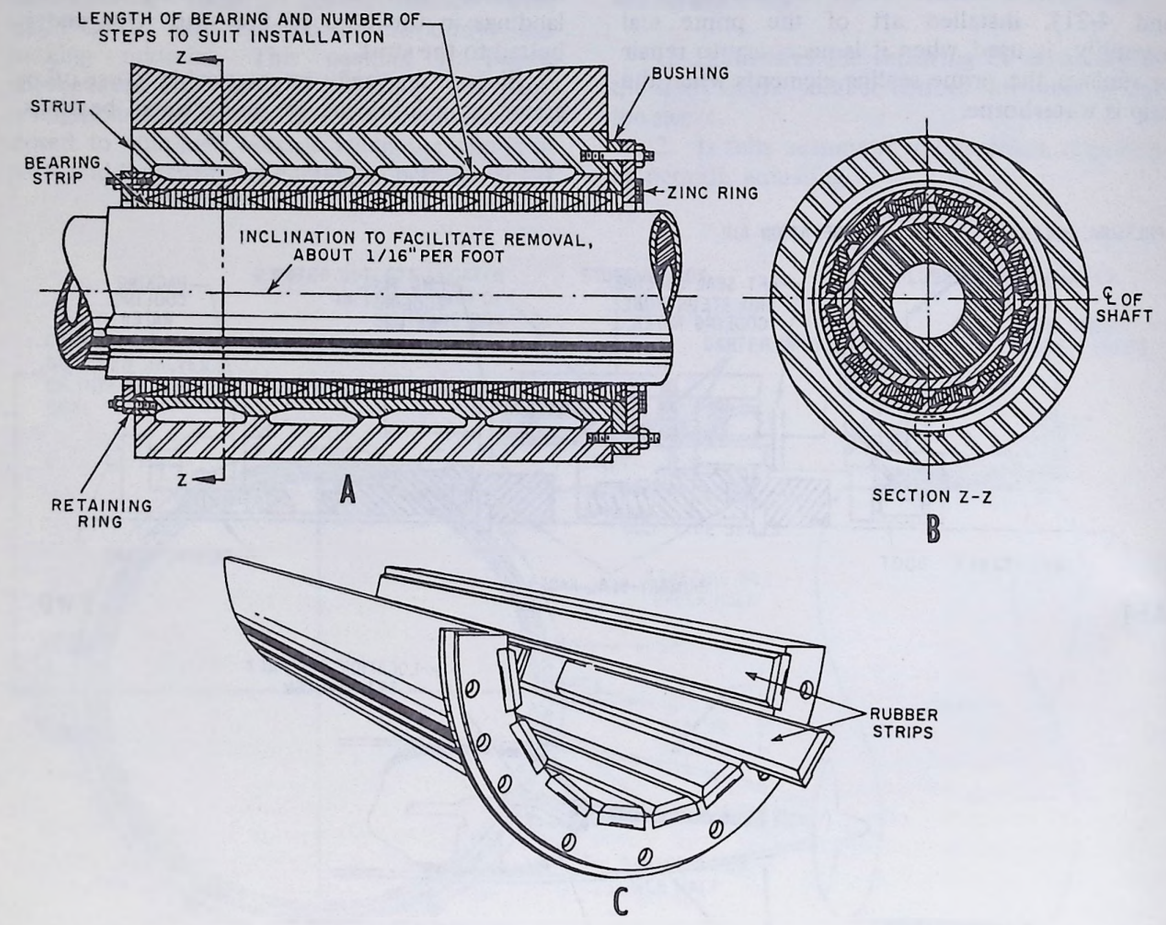


Figure 4-22.—Details of underwater strut bearing. (A) Longitudinal view, (B) Cross-sectional view, (C) Rubber stripping in the bearing. 47.41

the new readings will be the amount of bearing wear.

For main engine bearings the clearances may be taken by depth gage, crown thickness readings or leads. Normally, the depth gage method is used; crown thickness readings are taken only when bearings are removed and marked for these readings, otherwise, leads are taken. For the main gear bearings, crown thickness readings are almost always used. Leads may be used in a few older installations. For bearings installed in auxiliary machinery or on main shaft bearings, leads may be taken. A few line shaft bearings have provisions for depth gage readings as well.

For another example, a dial indicator is frequently used to take thrust bearing clearances.

In all cases, bearings must be inspected at regular intervals in accordance with PMS MRC's maintenance requirements.

In most cases, the first indication of bearing trouble is an abnormal or rapid rise in temperature. The temperature of oil discharged from a bearing, as measured by thermometer, shall not exceed 180° F maximum or a rise of 50° F maximum above cooler outlet temperature, whichever is less (unless otherwise stated in the applicable technical manual or waived by NAVSEA on a case basis).

In addition to local reading thermometers, some gear units have thermocouples or resistance temperature elements installed primarily for remote temperature indication. The thermocouple or resistance temperature element detector may be located either in the sight-flow fitting or mounted directly in the bearing babbitt. The applicable gear unit technical manual should be consulted for information on maximum allowable temperature limits.

If the temperature of a bearing increases above the normal running temperature, the quantity and quality of the lubricant supplied to the bearing should be checked. The supply should be increased by opening the needle valve, if a needle valve is provided, or by increasing the delivery pressure, where practicable. The lubricant should be further cooled by increasing the flow of circulating water to the cooler; however, it should be noted that the temperature of the oil from the cooler should be maintained at a temperature as recommended by the applicable gear technical manual, which in most cases, would range from 120° F to 130° F. If these measures are ineffective, the speed of the unit should be reduced to the point that a satisfactory temperature can be maintained. The bearing should then be examined at the first opportunity for evidence of improper oil flow due to a restriction either in the oil line to the bearing or in the bearing itself.

Erratic flow and/or a complete loss of flow of oil to a single sight-flow indicator at partial to full load condition can occur following reinstallation of a bearing that has been removed for inspection or renewal. This generally is caused by a restriction in the oil line from the bearing to the sight-flow fitting. The restriction normally results from improper assembly of the bearing cap on the shell such that the oil passages are not exactly in line or that improper handling has resulted in a nick or a burr appearing at the edge of the passage. This condition should be checked and corrected at the earliest opportunity as there is no positive way of determining that the bearing is actually receiving its proper supply of cooling oil (such as measuring bearing oil temperature) since, in most cases, the temperature indicator is located in the sight-flow fitting.

Chapter 241 (9420) of the NSTM contains information on wiped and otherwise damaged bearings and the requirements for repair and renewal.

SAFETY PRECAUTIONS FOR BEARINGS

Because of the similarities in operation of bearings in general, the safety precautions listed herein apply to all main engine, main shaft, and auxiliary machinery bearings. If safety precautions are observed, many difficulties and breakdowns will be prevented.

1. NEVER use a piece of machinery if the bearings are known to be in poor condition.

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2. Be sure that bearings have the proper quality and quantity of lube oil before starting the respective machinery.

3. Be sure the operating temperature of each bearing is not above the specified normal for particular load and speed conditions. Investigate and report abnormal temperature immediately. The normal maximum temperature limits for the oil leaving a bearing is 180° F (82° C) or a rise of 50° F (10° C) above cooler outlet temperature, whichever is less.

4. Remember that rapid heating of the bearing is a danger sign. A bearing that feels hot to the hand after an hour's operation may be all right, but the same heat reached in 10 or 15 minutes indicates trouble.

5. Newly installed bearings should, if possible, be given a run-in period with no load applied.

6. Use clean rags (lint free) to clean bearings, shafting, and sumps.

7. In assembling and installing bearings with symmetrical halves, take care NOT to end-to-end one of the halves or to reverse the assembled bearing in its pedestal, as this may cover the lube oil inlet passage.

8. Clean out wells of self-lubricated sliding-surface bearings at frequent intervals and see that the rings run freely and do not drag.

9. Refit or renew a wiped bearing.

10. When taking leads, be sure that the bearing halves are set up metal to metal.

11. Do not file or machine bearing joints.

12. After spotting-in a bearing, be sure that all shavings and dirt are cleaned from the parts.

PROPELLERS AND MAIN PROPULSION SHAFTING

The turbines and reduction gears convert the thermal energy of steam into usable mechanical energy. This mechanical energy is utilized through the propulsion shafting and the propeller.

MAIN PROPULSION SHAFTING

The main propulsion shafting, which may be up to 30 inches in diameter, is divided into two environmental sections—the inboard or line shafting and the outboard or waterborne shafting (fig. 4-23). The main propulsion shafting is made of forged steel and is usually hollow in sizes more than 6 inches in diameter.

The line shafting consists of several sections of shaft, including the thrust shaft when the main thrust bearing is not located in the reduction gear casing. (These sections are usually joined together by bolts through FLANGE TYPE COUPLINGS which are forged integral with the shaft sections.)

The outboard shafting consists of the propeller shaft or tailshaft upon which the propeller is mounted; the stern tube shaft which penetrates the hull of the ship and thus makes the transition between inboard and outboard shafting; and in some cases, an intermediate, or dropout shaft located between the propeller shaft and the stern tube shaft. In some single-shaft surface ships and submarines, the propeller shaft also functions as the stern tube shaft. The outboard shafting is protected from seawater corrosion by a covering of either plastic or rubber except that those areas which turn in bearings have shrunk-on sleeves of bronze or copper-nickel. Outboard shafting sections are usually joined to each other by integral flanges although some older ships may have a removable outboard shaft coupling known as a MUFF-TYPE OUTBOARD COUPLING. The stern tube shaft is connected to the line shafting by a removable coupling known as the INBOARD STERN TUBE COUPLING.

Circular steel or composition shields known as fairwaters are secured to the after end of the stern tube and to the struts and are "faired in" to the shafting to reduce turbulence. This fairing is accomplished by a gradual reduction in diameter from that of the stern tube or strut to that of the shaft. In those cases where a flange is adjacent to a strut or the aft end of the stern tube, the fairwater may either extend beyond the flange (either forward or aft as applicable) and fair into the shaft or fair into a rotating coupling cover which is attached to the flange and shaft. Some ships have watertight rotating coupling covers filled with tallow which seals the flanged coupling from seawater.

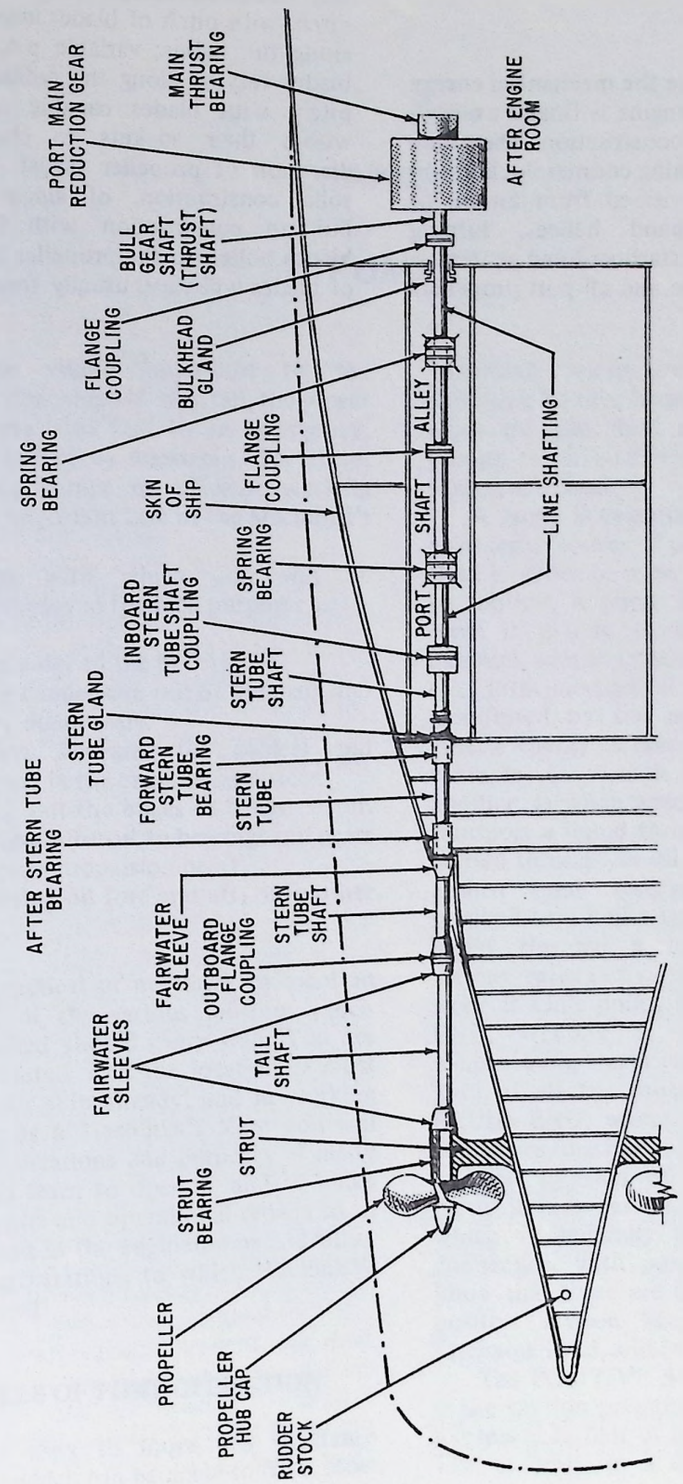


Figure 4-23.—Diagrammatic arrangement of a main propulsion shafting system.

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PROPELLERS

The propellers, where the mechanical energy produced by the main engine is finally utilized, are of various types of construction. They may be left-hand helices, turning counterclockwise in ahead direction when viewed from astern, or they may be right-hand helices, turning clockwise. Normally, all starboard and centerline propellers turn clockwise and all port propellers turn counterclockwise. They may be of constant pitch, with pitch of blades identical at all points along the radius; variable pitch, with pitch of blades varying along the radius; or controllable pitch, with blades capable of being rotated within their sockets to change speed and direction of propeller thrust. They may be of solid construction, of single casting, or of built-up construction with individually cast blades bolted to the propeller hub. The number of blades will vary, usually from three to seven.

CHAPTER 5

PUMPS

Pumps are vitally important to the functioning of your ship. If they fail, the power plants they serve also fail. In an emergency, pump failures can prove disastrous. Therefore, maintaining the pumps in efficient working order is a very important task of the Machinist's Mate.

The pumps with which you will be concerned are employed for such purposes as:

1. Feeding water to the boilers.
2. Drawing condensate out of the main and auxiliary condensers.
3. Supplying seawater for coolers and condensers in the engineering spaces.
4. Pumping out the bilges or ballast water.
5. Circulating lube oil to bearings and gears of the main propulsion plant.
6. Transferring oil fore and aft, or to other ships.

It is not practical or necessary to mention specifically all of the various spots in which pumps are located aboard every ship. You are probably acquainted with the location of most of them on your ship already, and in working and qualifying as a Machinist's Mate you will soon learn the locations and purposes of many more. You will learn to operate, and to make minor adjustments and operational repairs to all the pumps found in the enginerooms and other spaces and watchstations to which Machinist's Mates are assigned.

PRINCIPLES OF PUMP OPERATION

Pumps are used to move any substance which flows or which can be made to flow. Most commonly, pumps are used to move water, oil, and other liquids. However, air, steam, and other gases are also fluid and can be moved with pumps, as can such substances as molten metal, sludge, and mud.

A pump is essentially a device which utilizes an external source of power to apply a force to a fluid in order to move the fluid from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source (steam turbine, electric motor, etc.) into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then utilized to do work—for example, to raise a liquid from one level to another, as when water is raised from a well; to transport a liquid through a pipe, as when oil is carried through an oil pipeline; to move a liquid against some resistance, as when water is pumped to a boiler under pressure; or to force a liquid through a hydraulic system, against various resistances, for the purpose of doing work at some point. Every pump has a POWER END, whether it be a steam turbine, a reciprocating steam engine, a steam jet, or some kind of electric motor. Each pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

The addition of energy to a liquid by a pump usually results in an increase in pressure, which is generally referred to as HEAD. In connection with pump operation, you should know that there are four types of heads: (1) net positive suction head, (2) suction head, (3) discharge head, and (4) total discharge head.

The POSITIVE SUCTION HEAD, or NPSH, is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. For example, in a feed booster pump with a

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deaerating feed tank operating at saturated conditions, the NPSH on the pump equals the pressure resulting from the height of the water above the booster pump suction.

The SUCTION HEAD on a pump means the total pressure of the liquid entering the pump. In a deaerating feed tank operating under saturated conditions, the suction head of the feed booster pump is equal to the NPSH plus the auxiliary exhaust pressure.

The DISCHARGE HEAD means the pressure of liquid leaving the pump and/or the level of liquid with respect to the level of the pump on the discharge side.

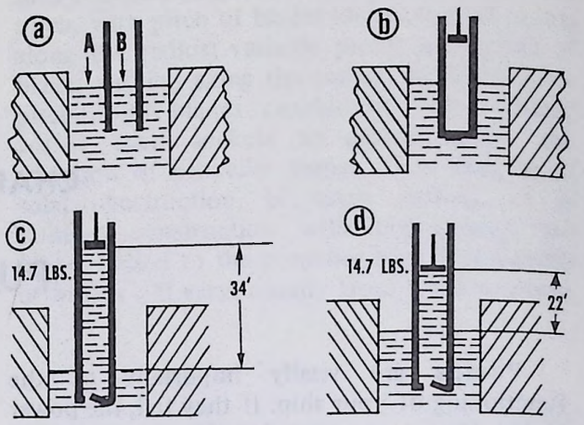
The TOTAL HEAD is the net difference between the suction head and the discharge head.

Suction head is usually expressed in feet of water if positive, and in inches of mercury if negative. When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When the pump is located above the level of the liquid being pumped, the pump must be able to establish a vacuum at the inlet to move the liquid into the pump. Atmospheric pressure, acting on the surface of the liquid will then provide the necessary pressure to move the liquid into the pump.

PRINCIPLE OF SUCTION FORCE

The principle of suction force, or "suction lift", as applied to reciprocating pumps is illustrated in figure 5-1. In diagram (a) the piston cylinder is open at both the top and bottom so the liquid level at A and B is the same. In diagram (b) the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. When the foot valve (check valve) at the bottom of the cylinder opens, diagram (c), as a result of the lower pressure in the cylinder, the liquid will rise up into the cylinder, which causes the liquid level in the well to drop. Assuming the liquid is water and that there is a perfect vacuum below the piston, atmospheric pressure will push water up into the cylinder to a height of 34 feet, even though the piston may be raised higher than 34 feet.

You must understand that the preceding example is for the theoretical condition of a perfect vacuum. In practice, leakage between the piston and the cylinder, friction (fluid) in piping, and gases dissolved in the liquid, limit the suction lift of a pump to a height of approximately 22 feet, as shown in diagram (d) of figure 5-1.



47.43

Figure 5-1.—Diagrams illustrating the principle of suction force.

When a pump is pumping certain liquids such as hot water, oil, or gasoline, some of the liquid will vaporize because of the vacuum on the suction side of the pump. This may cause the pump to become vapor bound, which will reduce the possible suction lift.

The suction force principle applies to other types of pumps, as well as to the reciprocating type, though to a lesser degree and in a somewhat different manner. The centrifugal, propeller, and rotary pumps all use suction force to a certain extent. Here a partial vacuum can be produced by the revolving mechanisms, instead of by the reciprocating plunger. An additional characteristic of centrifugal pumps is that they are not self-priming because they will not pump air. Their casing must be flooded before they will function. In the eductor (jet pump), flow is maintained by the suction force created by a jet of water, compressed air, or steam passing through a nozzle at high velocity. These principles are explained in more detail later in the chapter.

TYPES OF PUMPS

Pumps constitute by far the most numerous units of auxiliary machinery aboard ship. Included among the types are centrifugal pumps, propeller pumps, variable stroke pumps, reciprocating pumps, positive displacement rotary pumps, and eductors. The training manual *Fireman,* NAVEDTRA 10520, gives in clear, simple language and diagrams the basic principles of each of the general classes of pumps and explains the characteristics of each type which make it adaptable to a particular service in the various engineering systems. Be sure to review that material carefully before studying this chapter.

CENTRIFUGAL PUMPS

The centrifugal pump utilizes the throwing force of a rapidly revolving IMPELLER. The liquid is pulled in at the center or EYE of the impeller and is discharged at the outer rim of the impeller.

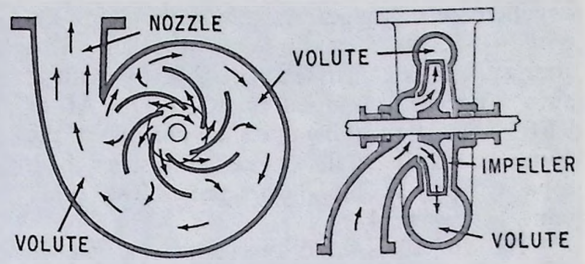
By the time the liquid reaches the outer rim of the impeller, it has acquired a considerable velocity (kinetic energy). The liquid is then slowed down by being led through a volute or through a series of diffusing passages. As the velocity of the liquid decreases, its pressure increases; and thus its kinetic energy is transformed into potential energy.

Types of Centrifugal Pumps

There are many different types of centrifugal pumps, but the two which you are most likely to encounter aboard ship are the volute pump and the volute turbine, or diffuser pump.

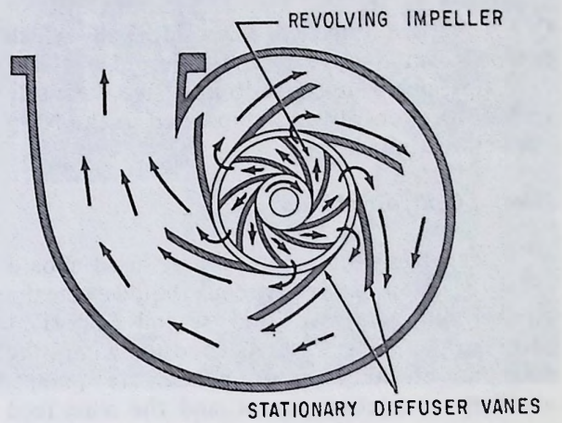
VOLUTE PUMP.—In the volute pump shown in figure 5-2, the impeller discharges into a volute (a gradually widening spiral channel in the pump casing). As the liquid passes through the volute and into the discharge nozzle, a great part of its kinetic energy is converted into potential energy.

DIFFUSER PUMP.—In the diffuser pump shown in figure 5-3, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes which surround the impeller. The liquid is forced through gradually widening passages in the diffuser ring (not shown) and into the volute. Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is an almost complete conversion of kinetic energy to potential energy.



23.18.0

Figure 5-2.—Simple volute pump.



23.19

Figure 5-3.—Diffuser (volute turbine) pump.

Classification of Centrifugal Pumps

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE-STAGE or MULTISTAGE. A single-stage pump has only one impeller. A multistage pump has two or more impellers housed together in one casing; as a rule, each

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impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft. Generally, large, multistage, high capacity pumps are horizontal. Most other pumps are vertical.

The impellers used on centrifugal pumps may be classified as SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions.

Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls which extend from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps used in the Navy have closed impellers.

Uses of Centrifugal Pumps

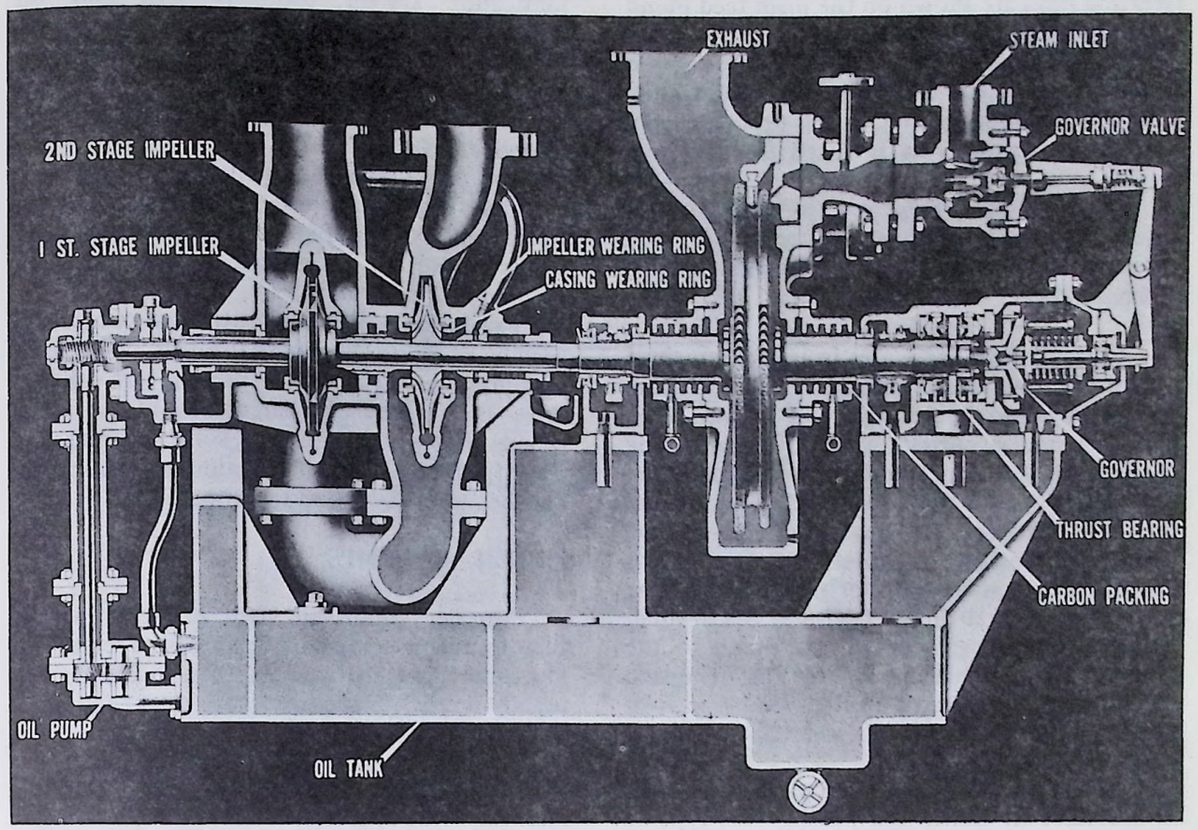
Centrifugal pumps are widely used aboard ship for pumping nonviscous liquids. In the engineroom you will find several important centrifugal pumps: the feed booster pump, the fire and flushing pump, condensate pumps, auxiliary circulating pumps, and the main feed pump.

FEED BOOSTER PUMP.—The feed booster pump takes suction from the deaerating tank and discharges into the main feed pump suction. The booster pump provides a positive suction pressure for the main feed pump, thus enabling the main feed pump to handle feedwater at high temperatures without becoming vapor bound and losing suction. Feed booster pumps operate at or near constant pressure. In a turbine-driven feed booster pump, the pressure is maintained approximately constant by the turbine speed-limiting governor.

CONDENSATE PUMP.—Condensate pumps are vertical, one- or two-stage pumps which are used in both closed and open feed systems. These pumps may be turbine driven or electric motor driven. Because the condensate pump takes suction from a condenser under vacuum, it operates with a fairly low (but positive) suction head; also, the water being pumped is usually warm or hot. Therefore, the large suction chambers and the large impeller eye are distinguishing features of condensate pumps. The area above the impeller area is vented to the main condenser to prevent the pump from becoming vapor bound. The condensate pump is always located below the condenser and, consequently, has a positive suction head into the impeller eye. In a turbine-driven condensate pump, the speed is maintained approximately constant by a speed-limiting governor. Hotwell level is maintained by a level controlled recirculating valve. Some ships use variable speed, electric motor driven condensate pumps which automatically control hotwell level to a desired value by slowing down or speeding up as necessary.

FIRE AND FLUSHING PUMPS.—Fire and flushing pumps are usually single-stage, double-suction, volute-type centrifugal pumps, driven either by an electric motor or by a steam turbine. Turbine-driven units are fitted with a constant-pressure governor and a speed-limiting governor.

MAIN FEED PUMP.—One type of main feed pump is shown in figure 5-4. Main feed pumps are usually of the high-speed, horizontal, turbine-driven type. Main feed pumps usually operate at a discharge pressure of 100 to 150 psig above the maximum operating steam drum pressure of the boiler, except on ships using 1,200 psig steam pressure. On such ships, the discharge pressure of the main feed pumps is approximately 200 to 300 psig above steam drum pressure. It is necessary for main feed pumps on most ships to operate at varying speeds to maintain a constant discharge pressure under all conditions of load. A constant-pressure governor automatically regulates the admission of steam to the turbine to control the discharge pressure; in addition, a speed-limiting governor is installed. However, on some newer ships, feed pumps are provided with a differential-pressure governing system that maintains a constant differential pressure across the feedwater regulating valve, located in the discharge piping of the pump.



38.109

Figure 5-4.—Two-stage main feed pump.

Construction of Centrifugal Pumps

As a rule, the casing for the liquid end of a pump with a single-suction impeller is made with an end plate which can be removed for inspection and repair of the pump. A pump with a double-suction impeller is generally made so that one-half of the casing may be lifted without disturbing the pump.

Since the impellers rotate at very high speed, they must be carefully machined in order to minimize friction, and they must be balanced in order to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates in order to minimize leakage from the discharge side of the pump casing to the suction side.

Because of the high rotational speed of the impeller and the necessarily close clearance, the running surfaces of both the impeller hub and the casing at that point are subject to relatively rapid wear. To eliminate the need for renewing an entire impeller and pump casing solely because of wear in this location, centrifugal pumps are designed with replaceable wearing rings. One ring is attached to the hub of the impeller, and rotates with the impeller; a matching ring is attached to the casing, and is therefore stationary. The replaceable ring on the hub of the impeller is called the IMPELLER WEARING RING, and the ring attached to the casing is called the CASING WEARING RING.

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(Wearing rings are shown on the main feed pump illustrated in fig. 5-4.)

Some small pumps with single-suction impellers are made with a casing wearing ring only, and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate.

In many centrifugal pumps, the shaft is fitted with replaceable sleeves (fig. 5-5). The advantage of using sleeves is that they can be replaced more economically than the entire shaft.

Recirculating lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound when the discharge is entirely shut off. Seal piping (liquid seal) is also installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. A lantern ring (spacer) is inserted between the rings of the packing in the stuffing box. Seal piping (fig. 5-5) leads liquid from the discharge side of the pump to the annular space within the lantern ring. The web of the ring is perforated so that water can flow in either direction along the shaft, between the shaft and the packing.

Mechanical seals instead of packing are used in a variety of centrifugal pumps. One type of mechanical seal is shown in figure 5-6. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for the seal faces. When the seals wear out, they are simply replaced. New seals should not be touched on the sealing face because body acid and grease will cause the seal face to prematurely pit and go bad.

Bearings support the weight of the impeller and shaft, and maintain the position of the impeller, both radially and axially. Some centrifugal pumps have a built-in bearing lubrication system, complete with lube oil pump, sump, cooler, strainer, and temperature and flow indicators. Other bearings are grease-lubricated with grease cups and vent plugs constructed in the housing to allow for periodic relubrication.

The power end of a centrifugal pump may be either a steam turbine or an electric motor. For most constant-speed applications, the turbine drive has no particular advantage over the motor drive.

The turbines used for centrifugal pumps are usually single-stage impulse turbines. As a rule, high-pressure centrifugal pumps are direct drive—that is, the impeller rotates at the same rpm as the turbine. However, some low-pressure centrifugal pumps have reduction gears installed between the turbine and the impeller.

PROPELLER PUMPS

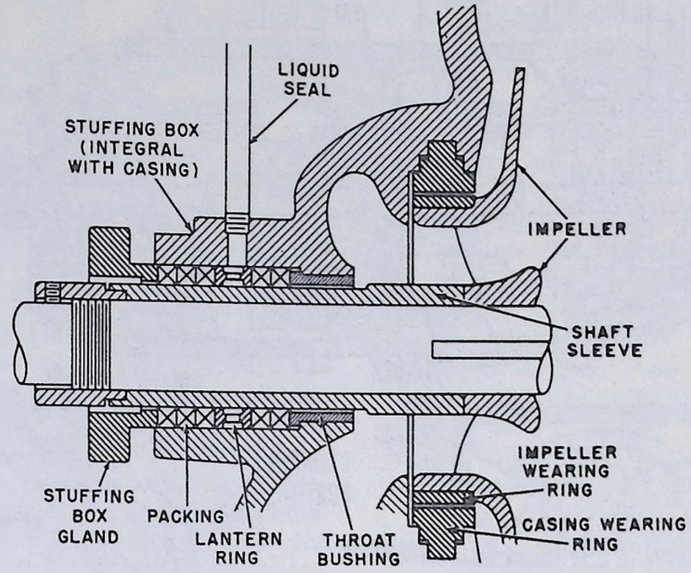
Propeller pumps are used primarily where there is a large volume of liquid with a relatively low total head requirement. These pumps are usually limited to use where the total head does not exceed 40 to 60 feet.

The chief use of the propeller pump is for the main circulating pump (illustrated in *Fireman,* NAVEDTRA 10520). The main condenser circulating pump in most ships has an emergency suction for pumping out the engineroom.

The main condenser circulating pump is of the vertical propeller type. The pump unit consists of three major parts: the propeller, together with its bearings and shaft; the pump casing; and the driving unit, which may be an auxiliary steam turbine or electric motor.

The propeller of this pump is a multibladed screw propeller having a large pitch. The blades are thick at the roots and flare out toward the tips. The blades and hubs are cast or forged in one piece and are then machined and balanced. The lower shaft bearing is a water-lubricated, sleeve-type bearing. The shaft packing gland prevents excessive leakage of water between the casing and the shaft.

Because of the similarity of the centrifugal and propeller type pumps, the information given concerning centrifugal pumps is equally applicable for propeller pumps, except that



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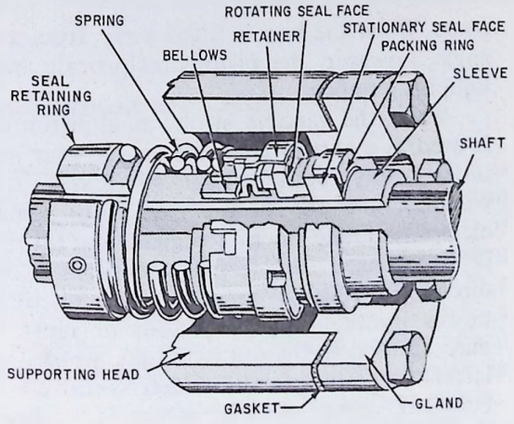
Figure 5-5.—Stuffing box on centrifugal pump.

propeller pumps, since they push the liquid axially along the shaft, do not have volutes like centrifugal pumps.

VARIABLE STROKE PUMPS

Variable stroke (also called variable displacement) pumps are most commonly used on naval ships as part of an electrohydraulic transmission for anchor windlasses, cranes, winches, steering gear, and other equipment. You will be responsible for maintaining and making minor repairs to hydraulic and related equipment outside your ship's engineering spaces. The information which follows is supplementary to that given in *Fireman,* NAVEDTRA 10520.

There are two general types of variable stroke pumps in common use: the axial-piston type and the radial-piston type. In the axial-piston type (fig. 5-7,) the pistons are arranged parallel to each other and to the pump shaft; in the radial-piston type, the pistons are arranged radially from the shaft.



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Figure 5-6.—Type-I Mechanical seal.

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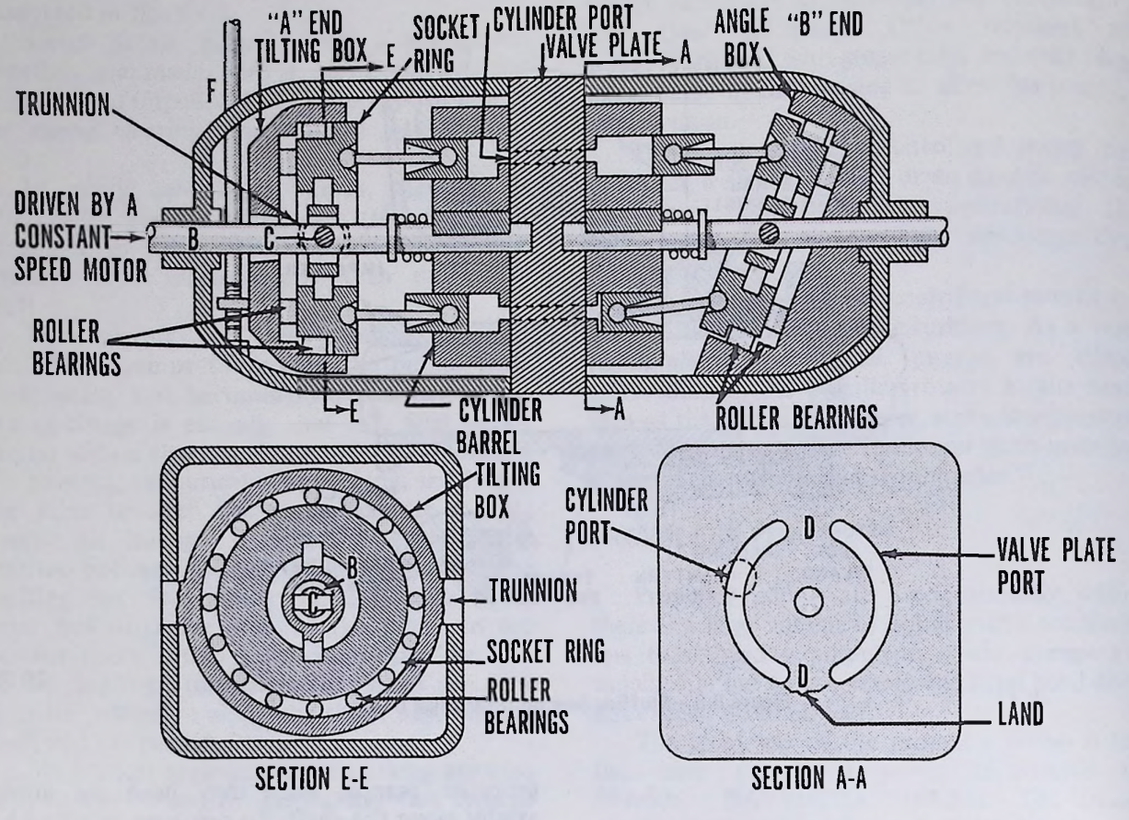


Figure 5-7.—Axial-piston type hydraulic speed gear.

Variable Stroke Axial-Piston Pump

The variable stroke axial-piston pump usually has either seven or nine single-acting pistons which are evenly spaced around a cylinder barrel. An uneven number of pistons is always used in order to avoid pulsations in the discharge flow. (Note that the term "cylinder barrel," as used in this connection, actually refers to a cylinder block which holds all the cylinders.) The piston rods make a ball-and-socket connection with a socket ring. The socket ring rides on a thrust bearing carried by a casting called the TILTING BOX or TILTING BLOCK.

When the tilting box is at a right angle to the shaft, and the pump is rotating, the pistons do not reciprocate; therefore, no pumping takes place. When the box is tilted away from a right angle, however, the pistons reciprocate and the liquid is pumped.

When the variable stroke axial-piston pump is used as a part of a variable speed gear such as in electrohydraulic anchor windlasses, cranes, winches, and the power transmitting unit in electrohydraulic steering engines, the tilting box is so arranged that it may be tilted in either direction. Thus it may be used to transmit power hydraulically to pistons or rams, or it may be used to drive a hydraulic motor. In the latter use, the pump, which is driven by a constant speed electric motor, is called the A-end of the variable speed gear and the hydraulic motor is called the B-end.

The B-end unit of the hydraulic speed gear is exactly the same as the A-end of the variable

stroke pump mentioned previously, except that it generally does not have a variable stroke feature. The tilting box is installed at a permanently fixed angle. Thus, the B-end becomes a fixed stroke axial-piston pump. Figure 5-7 illustrates an axial-piston type hydraulic gear with the A-end and B-end as a single unit; it is used in turrets for train and elevation driving units. For electrohydraulic winches and cranes, the A-end and B-end are in separate housings connected by hydraulic piping.

Hydraulic fluid introduced under pressure to a cylinder causes the piston to be pushed out. In being pushed out, the piston, through its connecting rod, will seek the point of greatest distance between the cylinder barrel and the socket ring. The resultant pressure of the piston against the socket ring will cause the cylinder barrel and the socket ring to rotate. This action occurs during the half revolution while the piston is passing the intake port of the motor, which is connected to the pressure port of the pump. After the piston of the motor has taken all the hydraulic fluid it can from the pump, the piston passes the valve plate land and starts to discharge oil through the outlet ports of the motor to the suction inlet of the pump, and thence to suction pistons of the pump. The pump is constantly putting pressure on one side of the motor while it is constantly receiving hydraulic fluid from the other side. The fluid is merely circulated from pump to motor and back again.

Variable Stroke Radial-Piston Pump

The variable stroke radial-piston pump is similar in general principle to the axial-piston type just described, but the arrangement of component parts is different. In the radial-piston pump, the cylinders are arranged radially in a cylinder body which rotates around a nonrotating central cylindrical valve. Each cylinder communicates with horizontal ports in the central cylindrical valve. Plungers or pistons, which extend outward from each cylinder, are pinned at their outer ends to slippers which slide around the inside of a rotating floating ring or housing.

The floating ring is so constructed that it can be shifted off center from the pump shaft. When it is centered, or in the neutral position, the pistons do not reciprocate and the pump does not function, even though the electric motor is still causing the pump to rotate. If the floating ring is forced off center to one side, the pistons reciprocate and the pump operates. If the floating ring is forced off center to the other side of the pump shaft, the pump also operates but the direction of the flow is reversed. Thus it can be seen that the direction of flow and the amount of flow are both determined by the position of the cylinder body relative to the position of the floating ring.

The shipboard application of reversible type variable stroke pumps is in such hydraulic transmission gear as steering mechanisms, windlasses, etc.

ROTARY PUMPS

Rotary pumps, like reciprocating pumps, operate on the positive displacement principle—that is, each rotation of each stroke delivers a definite quantity of liquid. Positive displacement rotary pumps have largely replaced reciprocating pumps for pumping viscous liquids in naval ships, as they have a greater capacity in relation to their weight and occupy less space.

Rotary pumps are most useful for pumping oil and other heavy, viscous liquids. In the engineroom this type of pump is used for lube oil service. In some ships a rotary fuel oil transfer pump is located in the engineroom. Rotary pumps are suitable for handling liquids over a wide range of viscosities. The power end of a rotary pump is usually an electric motor or an auxiliary steam turbine.

Rotary pumps are designed with very small clearances between rotating parts and stationary parts to minimize leakage (slippage) from the discharge side back to the suction side. Rotary pumps are designed to operate at relatively slow speeds to maintain these clearances; operation at higher speeds causes erosion and excessive wear, which result in increased clearances with a subsequent decrease in pumping capacity.

Classification of rotary pumps is generally based on the type of rotating element. In the

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following paragraphs, the main features of some common types of rotary pumps are discussed.

Simple Gear Pump

The simple gear pump has two spur gears which mesh together and revolve in opposite directions. One is the DRIVING GEAR, and the other is the DRIVEN GEAR. Clearances between the gear teeth (outside diameter of gear) and the casing and between the end face and the casing are only a few thousandths of an inch. As the gears turn, the gears unmesh and liquid flows into the pockets which are vacated by the meshing gear teeth. This creates the suction that draws the liquid into the pump. The liquid is then carried along in the pockets formed by the gear teeth and the casing. On the discharge side, the liquid is displaced by the meshing of the gears, and forced out through the discharge side of the pump.

HERRINGBONE GEAR PUMP.—In the herringbone gear pump, a modification of the simple gear pump, one discharge phase begins before the previous discharge phase is entirely complete; this overlapping tends to give a steadier discharge pressure than is found in the simple gear pump. Power-driven pumps of this type are sometimes used for low-pressure fuel oil service, lubricating oil service, and diesel oil service.

HELICAL GEAR PUMP.—The helical gear pump (fig. 5-8) is still another modification of the simple gear pump. Because of the helical gear design, the overlapping of successive discharges from spaces between the teeth is even greater than it is in the herringbone gear pump, and the discharge flow is, accordingly, even smoother. Since the discharge flow is smooth in the helical gear pump, the gears can be designed with a small number of large teeth, thus allowing increased capacity without sacrificing smoothness of flow.

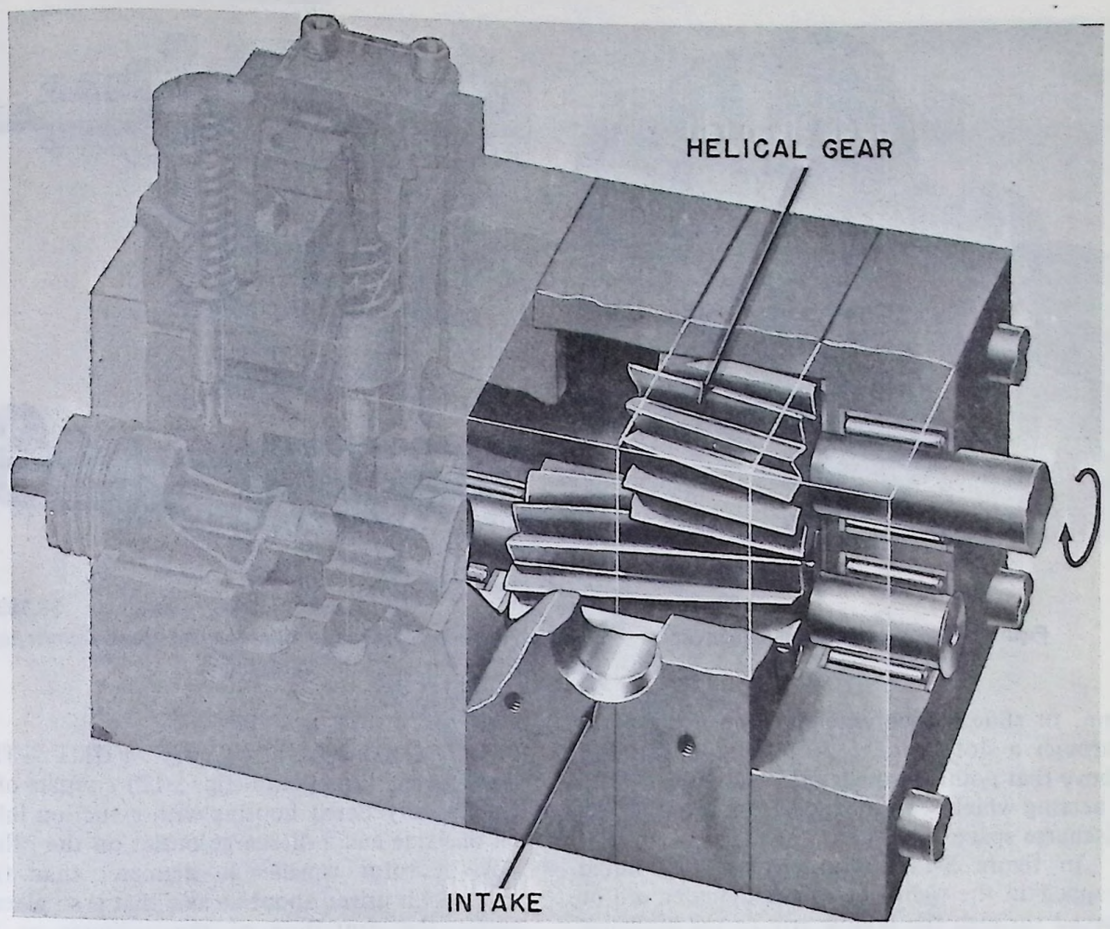
The pumping gears in this type of pump are driven by a set of timing and driving gears, which also function to maintain the required close clearances while preventing actual metallic contact between the pumping gears. Metallic contact between the teeth of the pumping gears would provide a tighter seal against leakage, but it would cause rapid wear of the teeth because foreign matter in the pumped liquid would be present on the contact surfaces.

Roller bearings at both ends of the gear shafts maintain proper alignment, thereby minimizing the friction loss in the transmission of power. Stuffing boxes are used to prevent leakage at the shafts. The helical gear pump is used to pump nonviscous liquids and light oils at high speed. At lower speed, it can be used to pump heavy, viscous materials.

LOBE PUMP.—The lobe pump is still another variation of the simple gear pump. A lobe pump (heliquad type) is illustrated in figure 5-9. The lobes are considerably larger than gear teeth, but there are only two or three lobes on each rotor. The rotors are driven by external spur gears on the rotor shafts. Some lobe pumps are made with replaceable inserts (gibs) at the extremities of the lobes. These inserts take up the wear which would otherwise be sustained by the ends of the lobes; in addition, they maintain a tight seal between the lobe ends and the casing. The inserts are usually seated on a spring and are thus able to automatically compensate for considerable wear of both the gibs and the casing. Replaceable cover plates (liner plates) are fitted at each end of the casing where the lobe faces cause heavy wear.

SCREW PUMPS.—There are several types of screw pumps. The main points of difference between the various types are the number of intermeshing screws and the pitch of the screws. Figure 5-10 shows a positive displacement, double-screw, low-pitch pump. Screw pumps are primarily used for pumping all viscous fluids such as JP-5 and diesel oil. Hydraulic systems on some ships use the screw type pump as the pressure supply for the system. The pump may be either motor-driven or turbine-driven.

In the screw pump, liquid is trapped and forced through the pump by the action of rotating screws. As the rotor turns, the liquid flows in between the threads at the outer end of each pair of screws. The threads carry the liquid along within the housing to the center of the pump where it is discharged.



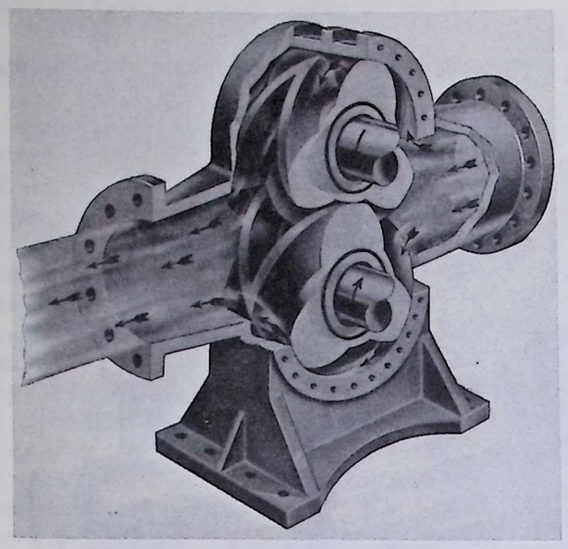
147.114

Figure 5-8.—Helical gear pump.

ROTATING PLUNGER PUMP.—Rotating plunger pumps are used in the naval service for the following applications: fuel oil and diesel oil service, fuel oil booster and transfer service, fuel oil tank drains, and lubricating oil service.

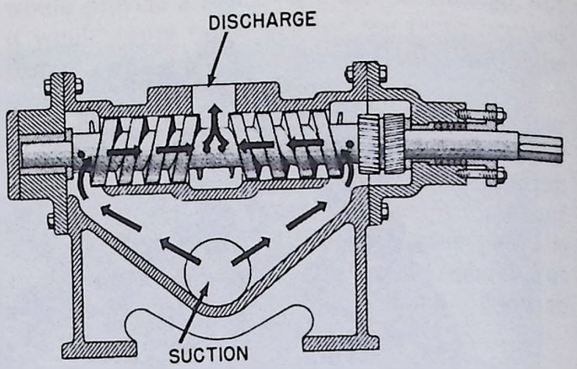
Figure 5-11 illustrates the main operating parts of the rotating plunger pump (sometimes classified as a cam-and-plunger pump). The plunger is shown in three positions, illustrating the pumping process. The main body of the pump is a cylinder with the suction port entering through the side, as shown, in the upper left-hand corner. The drive shaft, concentric with the pump cylinder, carries an eccentric plunger which has a slightly smaller diameter than the pump cylinder. The eccentric plunger operates as a piston. The eccentric arm—that is, the distance from the center of the driveshaft to the outermost point of the eccentric plunger—is equal to the radius of the cylinder (leaving room, of course, for the necessary operating clearances). Therefore, with each revolution of the eccentric, the point of nearest contact of the plunger on the cylinder wall rotates completely around the cylinder. Motion of the plunger about its own center is constrained by a hollow

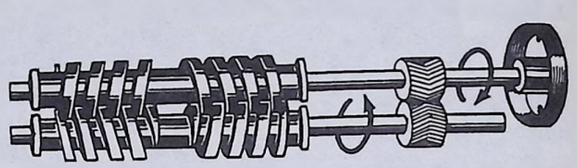
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Figure 5-9.—Lobe pump (heliquad type).





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Figure 5-10.—Positive displacement double-screw low-pitch pump.

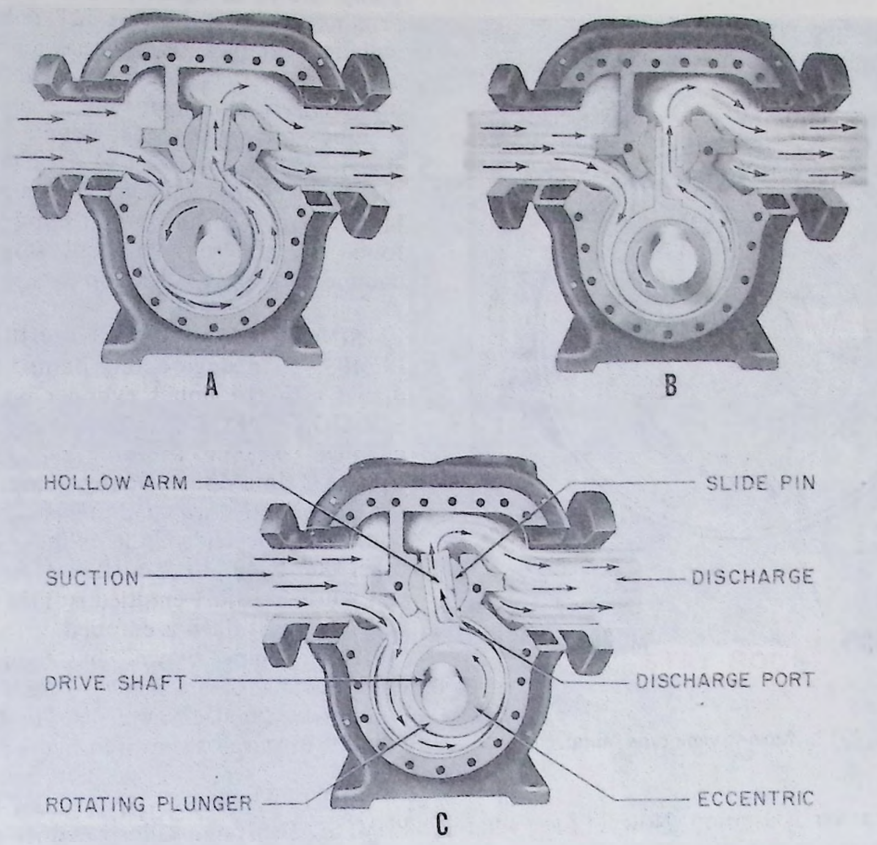
arm, or slide, which extends from the plunger through a slot in the top of the cylinder, and above that point, through a slotted pin carried in a bearing which seals the cylinder space from the discharge space.

In figure 5-11A, you can see that liquid trapped in the right side of the cylinder will be forced through the hollow arm to the discharge line as the eccentric rotates counterclockwise. View B shows the next phase with the space on the left side opening, thereby creating a vacuum which causes liquid to flow in from the suction line. The next stage, shown in view C, illustrates the discharge port at the bottom of the hollow arm beginning to close. The discharge port is closed by the slide pin during the suction portion of the stroke. When the eccentric turns slightly further, the point of contact of the plunger on the cylinder will pass over the suction port and trap the new charge on the discharge side, as shown in view A.

To reduce the tendency to pulsate, rotating plunger pumps usually have two plungers whose driving eccentrics are 180° apart on the shaft. The plungers are separated by a diaphragm through which the shaft extends.

MOVING-VANE TYPE PUMP.—The moving-vane type pump (fig. 5-12) consists of a cylindrically bored housing with a suction inlet on one side and a discharge outlet on the other side. A rotor (smaller in diameter than the cylinder) is driven about an axis that is so placed above the centerline of the cylinder as to provide minimum clearance between the rotor and cylinder at the top and maximum clearance at the bottom. (NOTE: Aboard some naval ships, the Blackmer vane pump has largely supplanted the pivoted vane, particularly for light hydrocarbon transfer such as JP-5. Additional information on such pumps can be obtained from the manufacturer's technical manual for the specific installation.)

The rotor carries vanes, which move in and out as the rotor rotates, to maintain sealed spaces between the rotor and the cylinder wall. The vanes trap liquid on the suction side and carry it to the discharge side where contraction of the space expels liquid through the discharge line. The vanes may swing on pivots, as shown in figure 5-12, or they may slide in slots in the rotor. Vane type pumps are used for lubricating



47.46

Figure 5-11.—Operating parts of the rotating plunger pump.

oil service and transfer, tank stripping, bilge, aircraft fueling and defueling, and in general for handling lighter viscous liquids.

RECIPROCATING PUMPS

A reciprocating pump moves water or other liquid by means of a plunger or piston that reciprocates (travels back and forth) inside a cylinder. Reciprocating pumps are positive-displacement pumps; each stroke displaces a definite quantity of liquid, regardless of the resistance against which the pump is operating.

Classification of Reciprocating Pumps

Reciprocating pumps are usually classified as:

1. Direct acting or indirect acting
2. Simplex (single) or duplex (double)
3. Single acting or double acting
4. High pressure or low pressure
5. Vertical or horizontal

The reciprocating pump shown in figure 5-13 is a direct-acting simplex, double-acting,

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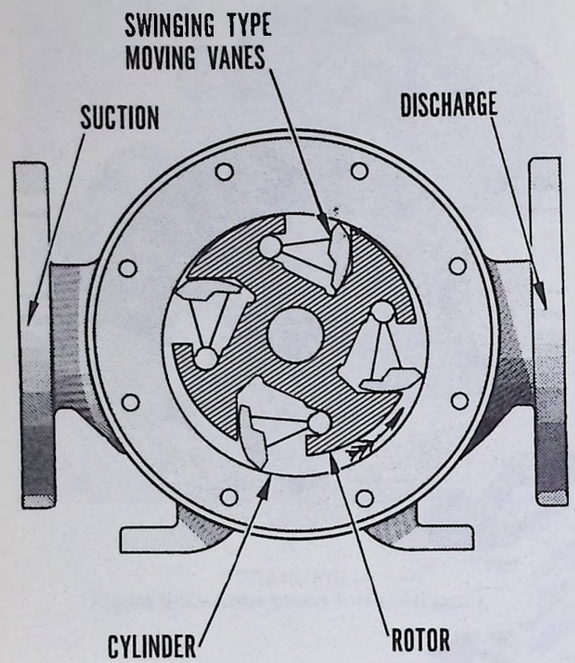


Figure 5-12.—Moving-vane type pump.

high pressure, vertical pump. Now let's see what all these terms mean, with reference to the pump shown in the illustration.

DIRECT AND INDIRECT ACTING PUMPS.—The pump shown is direct acting because the pump rod is a DIRECT extension of the piston rod and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct acting. In an indirect acting pump, there is some intermediate mechanism between the piston and pump plunger. The intermediate mechanism may be a lever or a cam. This arrangement can be used to change relative length of strokes of piston and plunger or to vary the relative speed between piston and plunger. Or the pump may use a rotating crankshaft such as a chemical proportioning pump in a distilling unit.

SIMPLEX AND DUPLEX PUMPS.—The pump shown in figure 5-13 is called a single or simplex pump because it has only one liquid cylinder. Simplex pumps may be either direct acting or indirect acting. A double or duplex pump is an assembly of two single pumps placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block. Duplex reciprocating pumps are seldom found in modern combatant ships, but were commonly used in older ships.

SINGLE-ACTING AND DOUBLE-ACTING PUMPS.—In a single-acting pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a double-acting pump, each stroke serves both to draw in liquid and to discharge liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end which was just emptied is filled and the end which was just filled is emptied.

The pump shown in figure 5-13 is double-acting, as are most of the reciprocating pumps used in the Navy. (NOTE: Only one of two sets of valves is shown in figure 5-13.)

HIGH-PRESSURE AND LOW-PRESSURE PUMPS.—The pump illustrated is designed to operate with a discharge pressure which is higher than the pressure of the steam operating the piston in the steam cylinder; in other words, a high-pressure pump. In a high-pressure pump the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder; therefore, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against a high pressure. A low-pressure pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge. In a low-pressure pump, the steam piston is smaller than the plunger in the liquid cylinder.

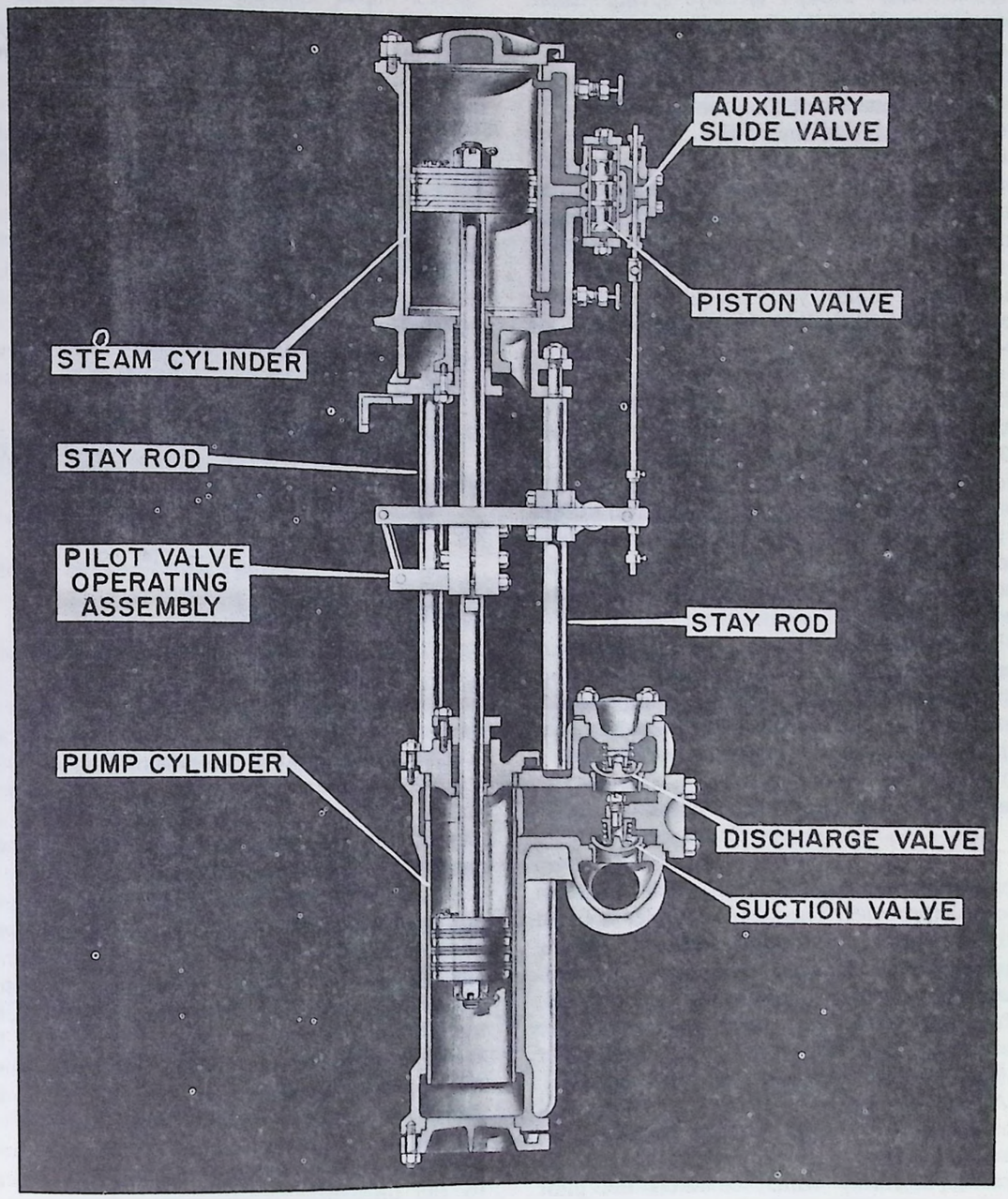


Figure 5-13.—Reciprocating pump.

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The standard way of designating the size of a reciprocating pump is by giving three dimensions, in the following order:

1. The diameter of the steam piston
2. The diameter of the pump plunger
3. The length of the stroke

For example, a 12 X 11 X 18 inch reciprocating pump has a steam piston which is 12 inches in diameter, a pump plunger which is 11 inches in diameter, and a stroke of 18 inches. The designation enables you to tell immediately whether the pump is a high-pressure or low-pressure pump.

VERTICAL AND HORIZONTAL PUMPS.—Finally, the pump shown in figure 5-13 is classified as vertical because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; however, you may occasionally encounter a horizontal pump, in which the piston moves back and forth rather than up and down.

The following discussion of reciprocating pumps is generally concerned with direct-acting, simplex, double-acting, vertical pumps, since most reciprocating pumps used in the Navy are of this type.

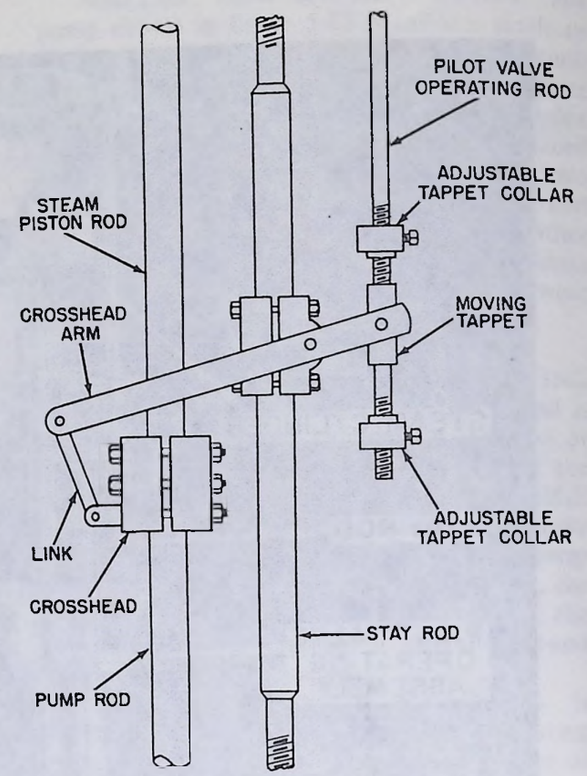


Figure 5-14.—Valve operating assembly.

Construction of Reciprocating Pumps

The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder, so that water resulting from condensation may be drained off.

Automatic timing of the admission and release of steam to and from each end of the steam cylinder is accomplished by a valve operating assembly which connects the pilot valve operating rod and the pump rod (fig. 5-14). As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted so that the pump will make the full designed stroke.

The piston type valve gear, commonly used for automatic timing, consists of a piston type slide valve and a pilot slide valve. The position of the pilot slide valve is controlled by the position of the main piston in the steam cylinder. At the completion of the down stroke of the pump, the crosshead arm moves the moving tappet against the upper adjustable tappet collar to actuate the pilot slide valve which admits steam to reposition the floating piston. The movement of the floating piston opens ports to admit steam to the underside of the piston in the steam cylinder and to exhaust the steam above the piston, thus causing the piston to move upward. Once the pump has completed the up-stroke, the cycle repeats itself in reverse. Piston type valves are used for steam pressures in excess of about

150-200 psi. Floating piston valves also eliminate unbalanced loads and minimize steam leakage and wear.

The liquid end of a reciprocating pump has a piston and cylinder assembly similar to that of the power or steam end. The piston in the liquid end is often called a PLUNGER. A VALVE CHEST, sometimes called a WATER CHEST, is attached to the liquid cylinder. The valve chest contains two sets of suction and discharge valves, one set to serve the upper end of the liquid cylinder and one to serve the lower end. The valves are so arranged that the pump takes suction from the suction chamber and discharges through the discharge chamber on both the up and down strokes.

As in all Navy pumps, a relief valve is installed in the discharge piping between the pump and the discharge valve. The relief valve is to protect the pump and the piping against excessive pressure.

Uses of Reciprocating Pumps

Reciprocating pumps may be used for bilge and fuel oil stripping service, and on older ships, as emergency or auxiliary feed pumps. Reciprocating pumps are good for emergency use because they are relatively simple, reliable, and easy to start and operate under cold conditions. Special precautions must be taken with the bilge pump to see that the suction strainers are kept clean. Clogged suction strainers and foreign matter in the water chest suction and discharge valves are the most frequent causes of trouble in the liquid end of the bilge pump.

EDUCTORS

The pumps discussed so far in this chapter have been electrical or mechanical driven. Eductors, like other types of jet pumps, have no moving parts. They are actuated by water, under a designed or set pressure, and are used to pump large volumes of water (fig. 5-15).

In modern ships eductors have replaced fire and bilge pumps as the primary means of pumping large volumes of water overboard, in applications such as pumping bilges, deballasting, and dewatering compartments. By use of eductors, centrifugal fire pumps can serve, indirectly, as drainage pumps without the risk of becoming fouled with debris from the bilges. The centrifugal pumps pressurize the fire main, and water from the fire main is used to actuate the eductors. In modern combatant ships the eductors have a much larger pumping capacity than fire and bilge pumps. They are installed as part of the piping in the drainage system and are flanged to permit easy removal and disassembly when repairs are necessary.

PUMP CARE AND OPERATION

Pump operation and safety precautions pertaining to pumps should be in accordance with the Engineering Operational Procedures (EOP) subsystem of the Engineering Operational Sequencing System (EOSS) if your ship has EOSS or, *Naval Ships' Technical Manual* and/or the instructions posted on or near each individual pump. The manufacturer's technical manual or Maintenance Requirement Cards (for PMS related maintenance) should be followed for all maintenance work. A Maintenance Index Page (MIP) for one type of condensate pump is shown in figure 5-16. The MIP lists all the maintenance requirements for that pump. The Maintenance Requirement Cards (MRC's), two of which are shown in figure 5-17, list in detail what you have to do for each individual maintenance requirement.

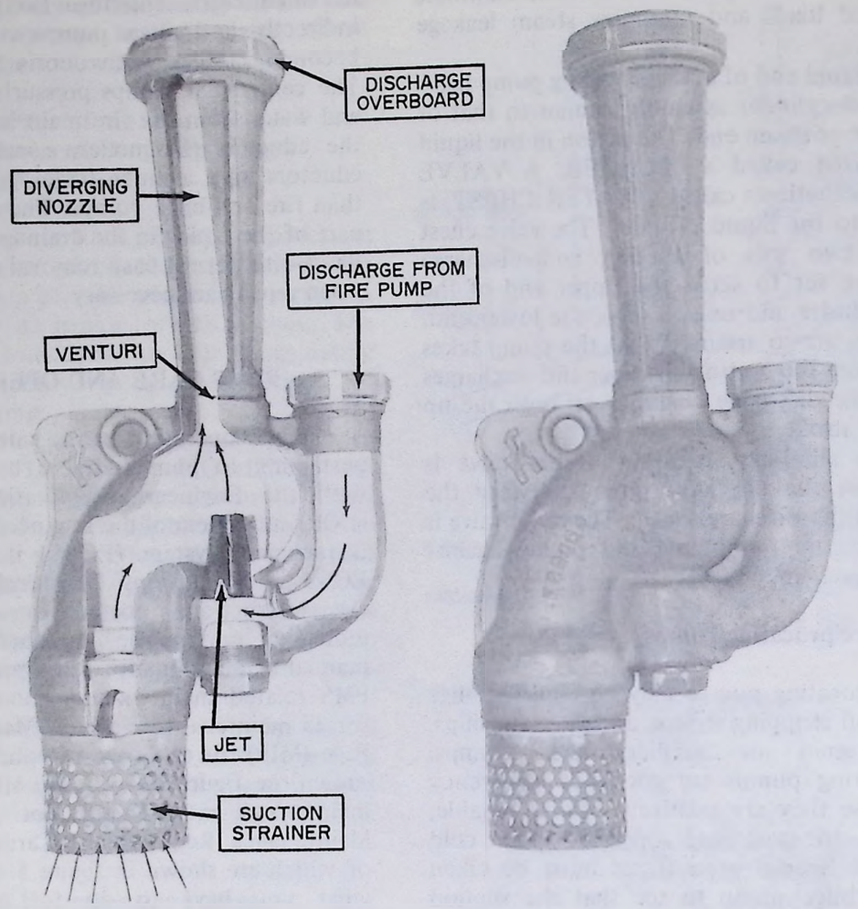
CENTRIFUGAL PUMPS

When properly installed, maintained (using PMS), and operated, centrifugal pumps are usually trouble free. Some of the corrective type maintenance actions that will be required are: repacking, pump alignment, replacing wearing rings, and renewing bearings.

Repacking

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When you are operating a centrifugal

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47.48

Figure 5-15.—Eductor.

pump, be sure that there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several factors. The type of pump, condition of the shaft sleeve, and hours in use, are only a few of the factors that determine the length of service of packing. A freshwater service pump may run for several months with no maintenance required, while a brine overboard pump may have to be repacked about once a month to perform satisfactorily.

To ensure the longest possible service from pump packing, make certain that the shaft or sleeve is smooth when packing is removed from a gland. Rapid wear of the packing may be caused by roughness of the shaft sleeve or shaft. If the shaft is rough, it should be sent to the shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. Navy packing is identified by symbol numbers as explained in chapter 6 of this manual. To find the right packing for a particular pump, check the Maintenance Requirement Card (MRC) for the pump. The MRC lists the symbol numbers and the size and number of rings required.

SYSTEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
Main Condensate Pump		November 197–

CONFIGURATION

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN-HOURS	RELATED MAINTENANCE
B4 F36H N	1. Turn idle pump shaft several revolutions. NOTE: Idle is defined as not having been operated within the past 7 days.	W-1R	MM/EN/BT3	0.1	None
B4 F36J N	1. Inspect packing gland adjustment.	M-8	MM/EN2	0.1	None
A3 D39W N	1. Lubricate and sound test roller/ball bearing(s).	Q-2	MM/BT3	0.5	None
B4 F43N N	1. Lubricate flexible coupling.	Q-10	MM/EN3	0.2	None
B4 F36L N	1. Inspect flexible coupling.	A-1	MM/EN2	1.0	None
B4 F36M N	1. Inspect foundation fasteners.	A-9	MM/EN3	0.1	None
B4 F42J N	1. Inspect pump internal parts.	C-1	MM/EN1 MM/EN2 FN	1.0 8.0 8.0	Q-2 A-1 R-8
A4 E96U N	1. Renew packing NOTE: Accomplish when packing gland has been tightened to within 1/4" of pump housing. Scheduling aid: Schedule MRC C-1 for accomplishment during shipyard overhaul.	R-8	MM/EN3	1.0	None

SYSCOM MIP CONTROL NUMBER E-6/136-B4

MAINTENANCE INDEX PAGE (MIP)
OPNAV 4700-3 (A) (REV. 3/69)

98.171

Figure 5-16.—Pump MIP.

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SYSTEM	COMPONENT	MRC CODE	
	Main Condensate Pump	E-6	Q-2
SUBSYSTEM	RELATED MAINTENANCE	RATES	M'H
	None	MM/BT3	0.5

MAINTENANCE REQUIREMENT DESCRIPTION

1. Lubricate and sound test roller/ball bearing(s).

TOTAL M'H 0.5
ELAPSED TIME 0.5

SAFETY PRECAUTIONS

1. Observe standard safety precautions.
2. Exercise extreme caution when working around operating machinery.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Grease gun
2. Lint-free rags
3. Grease, MIL-G-81322
4. 8" Adjustable wrench
5. Engineer's stethoscope

PROCEDURE

Page 1 of 1

1. Lubricate and Sound Test Roller/Ball Bearing(s).

WARNING: Exercise extreme caution when working around operating machinery.

a. Clean area around drain/vent plug and lubrication fitting.
b. Remove bearing housing drain/vent plug.
c. Screw down grease cup, or inject grease through pressure fitting, as applicable, until new grease appears at drain/vent plug opening.

NOTE: Evidence of water is an indication of bearing seal leakage. Corrective action should be taken.

d. Inspect expelled grease for water and metallic particles.
e. Operate pump for approximately 15 minutes with drain/vent plug(s) removed to expel excess grease.
f. Clean and reinstall drain/vent plug(s).
g. Accomplish bearing sound test; listen for unusual noise indicating possible defective bearing.
h. Stop pump; shut applicable isolation valve(s).
i. Remove excess grease.

A3 D39W N

LOCATION

DATE September 197-

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV FORM 4700-1 (A) (REV. 3-69)

98.176

Figure 5-17.—Pump MRC's.

SYSTEM	COMPONENT	MRC CODE	
	Main Condensate Pump	E-6	M-8
SUBSYSTEM	RELATED MAINTENANCE	RATES	M'H
	None	MM/EN2	0.1

MAINTENANCE REQUIREMENT DESCRIPTION

1. Inspect packing gland adjustment.

TOTAL M'H 0.1
ELAPSED TIME 0.1

SAFETY PRECAUTIONS

1. Comply with Navy Safety Precautions for Forces Afloat, OPNAVINST 5100 series.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Flashlight
2. Safety tags
3. 24 gauge Wire
4. Lint-free rags
5. Flexible rule or steel rule with holder
6. 6" Slip-joint pliers
7. _____ Combination wrench

PROCEDURE

Page 1 of 1

Preliminary

a. Wire applicable isolation valves shut and tag "Do Not Open"/de-energize circuit and tag "Out of Service", as applicable.

1. Inspect Packing Gland Adjustment.

NOTE: Damage to shaft sleeve or shaft occurs when:
(1) Rings are added to stop leakage rather than repacking stuffing box.
(2) Gland nuts are not adjusted evenly.
(3) Gland is improperly adjusted for lubrication.
(4) Packing becomes hard and gland is overtightened to stop leakage.

a. Ensure gland nuts have been adjusted evenly and properly.
b. Measure distance packing gland can be moved before contact is made with housing. Distance should be greater than 1/4"; if not, renew stuffing box packing as described on MRC R-8.
c. Remove wire and safety tags from applicable isolation valves/remove safety tag and energize circuit, as applicable.

B4 F36J N

LOCATION

DATE November 197-

MAINTENANCE REQUIREMENT CARD (MRC)
OPNAV FORM 4700-1 (A) (REV. 3-69)

When replacing packing, be sure that there is a uniform thickness around the shaft sleeves. An excess of packing on one side of the shaft will deflect the shaft and, frequently, cause it to break.

The box should be packed loosely and the packing gland set up lightly, allowing a liberal leaking for stuffing boxes subjected to pressure above atmospheric. Then, with the pump in operation, the gland should be tightened in small (about one flat) increments, with several hours between tightenings, to compress the packing gradually, thereby avoiding excessive heat and scoring of the shaft or shaft sleeve. Remember that a certain amount of leakage is necessary for lubrication and cooling.

After the packing has been compressed, it will usually be necessary to add more packing. The packing leakoff should be examined frequently to ensure that sufficient flow is maintained.

Mechanical Seals

Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on centrifugal pumps. Pumps fitted with mechanical seals eliminate the problem of excessive stuffing box leakage which results in pump and motor bearing failures and motor winding failures. Mechanical seals are ideal for pumps operating in closed systems (such as air conditioning, chilled water systems, and various sonar, radar, and other electronic cooling systems), as this not only conserves the fluid being pumped but also results in improved system operation. Mechanical seals are well suited for pumps operating under varying discharge pressures such as submarine sea-connected pumps.

Mechanical seals are now required for all centrifugal pumps that may operate under vacuum conditions (such as condensate, and ships' potable water pumps).

Seawater pumps for submarine applications are provided with mechanical shaft seals and pressure breakdown sleeves. The pressure breakdown sleeve is designed to limit the leakage to 5 gallons per minute (gpm) in the event of failure of the mechanical shaft seal, under conditions of the maximum suction pressure for which the pump is designed. In addition, these pumps have a backup stuffing box to accommodate a minimum of four rings of packing for use in the event of a mechanical shaft seal failure. The design is such that the packing rings may be inserted without removing the mechanical shaft seal. Backup stuffing boxes are provided for other pumps.

Fire pumps and all seawater pumps installed in surface ships are being provided with mechanical shaft seals with cyclone separators. The glands are designed to incorporate two or more rings of packing for use in the event of a mechanical shaft seal failure. Opposing seal faces are constructed of tungsten carbide against carbon, or tungsten carbide against tungsten carbide. The tungsten carbide seal ring(s) are of solid construction. The cyclone separators are constructed of nickel-copper alloy. Fittings for abrasive separators and pump casing are of the straight thread type with O-ring seal and are constructed of nickel copper alloy. Tubing is copper-nickel (70-30) in accordance with MIL-F-16420.

Mechanical seals shall be replaced whenever the seal is removed for any reason or whenever the leakage rate exceeds 5 drops per minute.

Mechanical shaft seals are positioned on the shaft by means of stub or step sleeves. Mechanical shaft seals shall not be positioned by use of setscrews. Shaft sleeves are chamfered on outboard ends to provide ease of mechanical seal mounting.

Where mechanical shaft seals are used, the design ensures that positive liquid pressure is supplied to the seal faces under all conditions of operation and that there is adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.

Care of Lantern Rings, Sleeves, and Flingers

When a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box, and be sure that the sealing water connection to the lantern ring is not blanked off by the packing. (See fig. 5-5.) Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Be most

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careful to see that water does not leak between the shaft and the shaft sleeves.

Water flingers, fitted on the shaft outboard of the stuffing box glands, to prevent leakage from the stuffing box following along the shaft and entering the bearing housings, must also be kept tight. If the flingers are fitted on the shaft sleeves instead of on the shaft, no water must leak under the sleeves.

Renewing Shaft Sleeves

In some pumps the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press, and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On some small pumps, new sleeves can be installed by removing the water end casing, impeller and old shaft sleeves. New sleeves are carried as repair parts, or they can be made in the machine shop. On large pumps the sleeves are usually pressed on; these pumps must be disassembled and taken to the machine shop, a repair ship, or a navy yard, to have the old sleeve machined off and a new one pressed on.

To prevent water leakage between the shaft and the sleeve, some sleeves are packed, while some have O-rings between the shaft and the abutting shoulder. For detailed information, consult the appropriate manufacturer's technical manual or applicable blueprints.

Alignment of Shafting and Couplings

Shaft alignment must be checked frequently. If the shafts are out of line, the unit must be realigned in order to prevent shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Shaft alignment should be checked with all piping in place.

The driving unit may be connected to the pump by a FLEXIBLE COUPLING. You should remember that flexible couplings (fig. 5-18) are intended to take care of only slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. If the misalignment is excessive, the coupling parts are subjected to severe

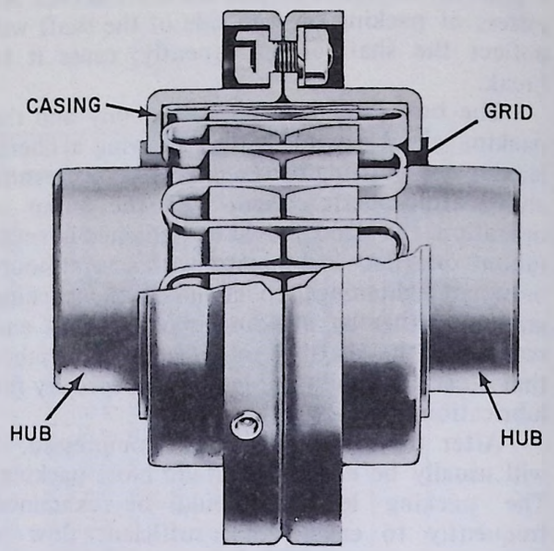


Figure 5-18.—Grid type flexible coupling.

punishment, necessitating frequent renewal of pins, bushings, and bearings.

The driving unit may be connected, or coupled, to the pump by a FLANGE COUPLING. Frequent realignment of the shafting may be necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Misalignments are indicated by such things as abnormal temperatures, abnormal noises, and worn bearings or bushings.

Wedges, or shims, are placed under the bases of both the driven and driving units to facilitate alignment when the machinery is installed. Jacking screws may also be used to level the units. When the pump or driving unit, or both, need to be shifted sidewise to align the couplings, side brackets are welded in convenient spots on the foundations, and large setscrews are used to shift the units sidewise or endwise. When the wedges or other packings have been adjusted so that the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks should be fastened, the units should be securely bolted to the foundation, and the coupling flanges should be bolted together.

These ALIGNMENTS MUST BE CHECKED from time to time, and misalignments must be promptly corrected. There are three methods in general practice for checking the alignments:

1. Use of a 6-inch scale
2. Use of a thickness gage
3. Use of a dial indicator

Shaft alignment should be checked whenever the pump is opened up and whenever a noticeable vibration is observed. If shafts are found out of line or inclined at an angle to each other, alignment of the unit should be undertaken to avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings. The appropriate MRC or technical manual should be consulted in aligning the pump.

Measuring Bearing Clearances

In a centrifugal pump installation fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water must be supplied to the bearing for lubricating and cooling. There are several types of materials used for internal water-lubricated bearings:

1. Laminated phenolic material grade FBM (fabric base bakelite or Micarta)
2. High lead content bronze
3. Graphited bronze
4. Lignum vitae

The condition of all types of internal water-lubricated bearings should be checked frequently to guard against excessive wear which results in misalignment and possible shaft failure.

As far as oil-lubricated sleeve or shell-type bearings are concerned, the bearing clearances should be measured following procedures described on the Maintenance Requirement Card (MRC) for the pump. Clearances should be maintained within the limits shown on the MRC or in the manufacturer's technical manual.

Renewal of Wearing Rings

The clearance between the impeller wearing ring and the casing wearing ring (fig. 5-19) must be maintained as shown in the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. On most ships, this job can be done by the ship's force, but it requires the complete disassembly of the pump. All necessary information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is specified by PMS or can be found in the manufacturer's technical manual.

In deciding whether the wearing rings need renewing, you must consider the capacity of the pump and the discharge pressure of the pump. On low-pressure pumps the wearing ring diametral clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the pump's capacity. For pumps having a discharge pressure up to 75 psi, a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss, with a 0.030 inch wearing ring clearance in excess of standard, may be large with a small pump, but comparatively small with a large pump. For high-pressure boiler feed pumps, the effect of increased wearing ring clearance is readily noticeable in the efficiency and maximum

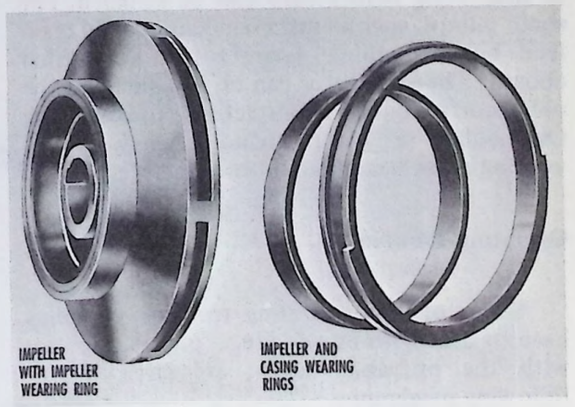


Figure 5-19.—Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

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capacity of the pump. For high-pressure pumps the wearing rings should be renewed when the clearance shown on the manufacturer's plans is exceeded by 100%. It is usually not considered necessary to renew wearing rings unless the wear is at least 0.015 inch. If a pump has to be disassembled because of some internal trouble, the wearing rings should be checked for clearance. Measure the outside diameter of the impeller wearing ring with an outside micrometer and the inside diameter of the casing wearing ring with an inside micrometer; the difference between the two diameters is the actual wearing ring diametral clearance. By checking the actual wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the rings before reassembling the pump. The applicable Maintenance Requirement Cards are a readily available source of information on proper clearances.

The amount of work involved in disassembling the pump, the length of time the pump can be out of commission without affecting the ship, and whether a repair ship or other repair activity will be involved are some of the factors that must be considered in determining whether to renew wearing rings.

Wearing rings for most small pumps are carried aboard as part of the ship's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, such as main condensate, and main feed booster pumps, spare rotors are carried aboard. The new rotor can be installed and the old rotor sent to a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, bearings, and the shaft sleeve.

Operating Troubles

Some of the operating troubles you may have to deal with in centrifugal pumps, together with the probable causes, are given in the following paragraphs.

If a centrifugal pump DOES NOT DELIVER ANY LIQUID, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation; (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at INSUFFICIENT CAPACITY, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes, in pumps operating at less than atmospheric pressure; (3) insufficient speed of the pump; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump DOES NOT DEVELOP ENOUGH DISCHARGE PRESSURE, the trouble may be caused by (1) insufficient speed of the pump; (2) air or gas in the liquid being pumped; or (3) mechanical defects such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump TAKES TOO MUCH POWER, the trouble will probably be indicated by overheating of the motor. The basic cause of the difficulty may be (1) operation of the pump at excess capacity and insufficient discharge pressure; (2) excessively high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids.

If the pump fails to build up pressure when the discharge valve is opened and the pump speed is increased, proceed as follows:

1. Secure the pump.
2. Prime the pump and be sure that all air is expelled through the air cocks on the pump casing.
3. Open all valves on the pump suction line.
4. Start the pump again. If the pump is electric driven be sure the pump is rotating in the correct direction. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

RECIPROCATING PUMPS

Reciprocating pumps are easy to operate and usually are very reliable units.

They do, however, require routine maintenance and, upon occasion, some repair work. It is necessary to consult the manufacturer's technical manual for detail concerning the repair of a specific unit. Routine maintenance, however, is performed in accordance with PMS requirements. For additional information, check *Naval Ships' Technical Manual.*

Before repairing or examining a pump, assemble the Maintenance Requirement Cards and all the pertinent blueprints, drawings, and available data. These drawings and data will give you the required clearances, tools to be used, measurements, information regarding materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired so that you will know what has been done previously, when repairs were made, and what kind of trouble has been encountered with this particular pump.

Whenever reciprocating pumps are opened for repairs, micrometer or caliper measurements should be taken of the main cylinders and the valve chest cylinders. These measurements are made on the fore and aft and athwartships diameters at the top, middle, and bottom. The results should be recorded with accompanying remarks on a diagrammatic sketch showing the measurements obtained and the date on which they were made.

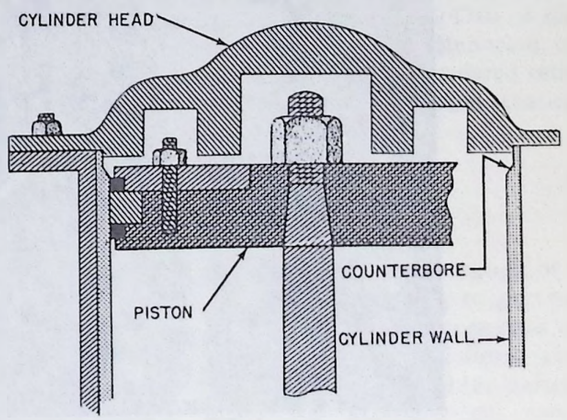
Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles, however, result from fouled water cylinders, worn valves, or from faulty conditions in the pipe connections external to the pump.

Adjustment of Stroke

In order for a steam-driven reciprocating pump to operate properly, the steam piston must travel a little beyond counterbore (fig. 5-20); this means that the pump must operate with a full stroke. A full stroke will result in more even wear throughout the cylinder.

The length of the stroke is adjusted by moving the two adjustable tappet collars on the threaded portion of the valve rod link. The tappet moves between the tappet collars as the lever is moved by the action of the piston rod.

To shorten the stroke of the pump, turn the tappet collar in the direction that moves it toward the tappet. To lengthen the stroke of the pump, turn the tappet collar in the direction that moves it away from the tappet. Once the tappet collars have been set properly, they should be left alone. If it becomes necessary to



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Figure 5-20.—Steam piston at upper end of stroke.

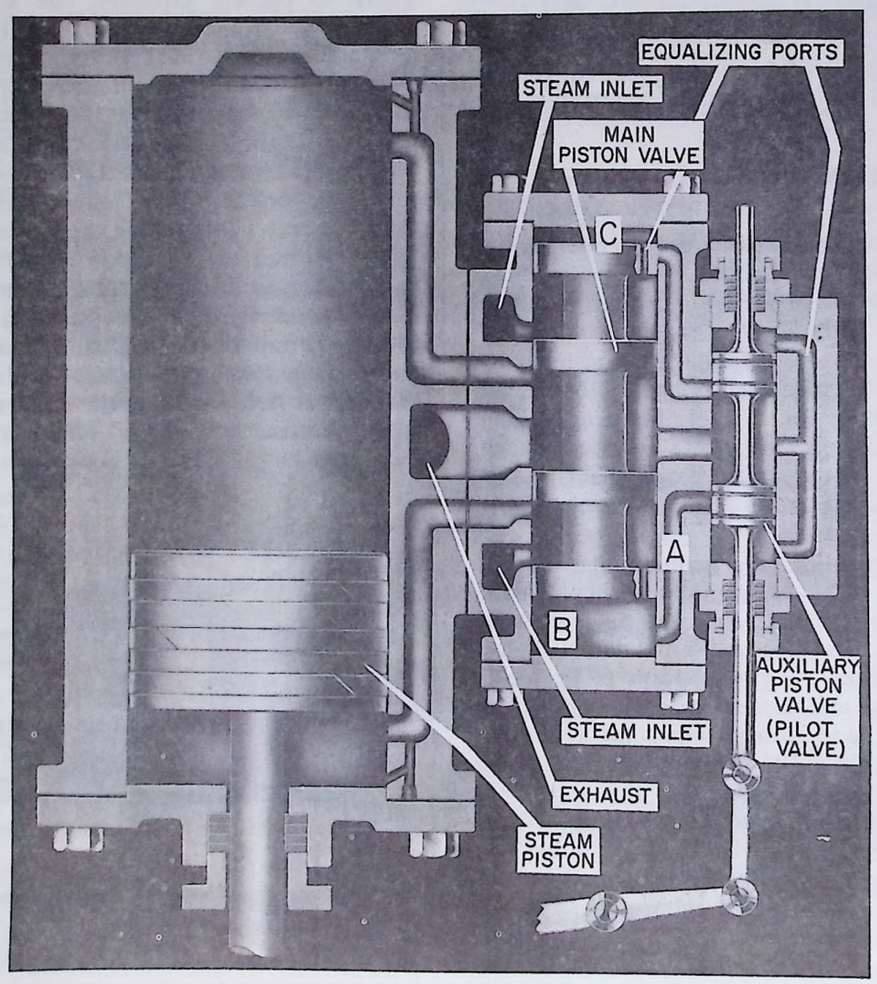
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adjust the tappet collars frequently while the pump is operating, the pump should be stopped and disassembled as soon as possible. The trouble may be in the operating linkage, the auxiliary piston valve, or the main piston valve (fig. 5-21).

Properly adjusted tappet collars will ensure a full stroke for the various pump loads and speeds. Refer to manufacturer's drawings and detailed technical manuals for the method to be followed for specific types of valve gear.

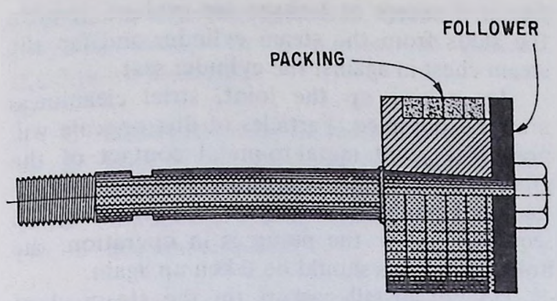
Care of Pistons and Packing

Pistons in the water end of pumps (fig. 5-22) are generally constructed of bronze and are of the body and follower type. The piston itself is not a tight fit and depends on several rings of packing to prevent leakage. These rings of packing are placed between a shoulder at one end of the piston and a follower plate at the other end. To renew this packing, close, wire, and tag the water end suction and discharge



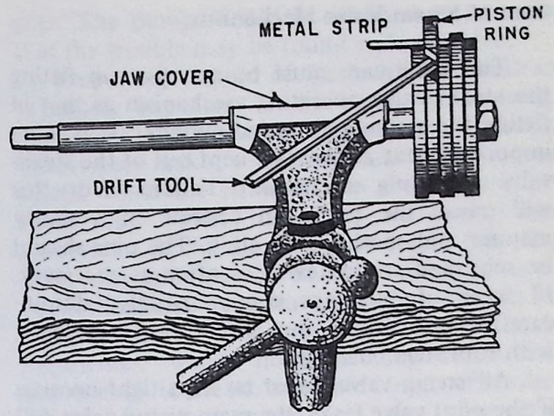
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Figure 5-21.—Steam end assembly for a reciprocating pump.



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Figure 5-22.—Liquid end piston, rod, packing, and follower.



47.52

Figure 5-23.—Steam piston assembly (rings being removed).

valves. Remove the bottom water end cylinder head. Then remove the follower and the old packing. Check the packing chart for the right type and size of packing. If fibrous packing is used, the packing should be soaked in hot water for at least 12 hours before it is cut and installed. The rings should be step-cut, when fitted to the piston. Insert the packing, staggering the ring gaps at 90° intervals.

Replace the follower and, by using a bar, jack the pump over. If the new packing does not bind and there is no groaning in the water end, replace the cylinder head. In emergencies, fibrous packing can be used without soaking, provided it is cut with sufficient clearance to allow for swelling. Failure to provide ample clearance will cause the pump to groan and may result in a scored cylinder.

Worn or Broken Piston Rings

Trouble in the steam cylinder results mainly from faulty piston rings. Wearing of piston rings can cause a pump to lose power or even to stop. If a pump stops in the middle of a stroke while operating slowly, the trouble may be due to worn rings; secure the pump and examine the condition of the rings and the cylinder. If necessary, renew the piston rings.

Figure 5-23 shows a steam piston assembly of a reciprocating pump. The piston rings are cast iron. If the piston rings are broken or worn or have been poorly fitted so that there is excessive leakage by the piston, new rings must be installed.

Scored Water Cylinder

When a water cylinder becomes scored, it is not always necessary to rebore the cylinder or renew the liner. Slight leakage from wear can usually be corrected by stoning the cylinder liner and renewing the packing. If reboring must be done, consult the tolerances allowed in boring cylinders, given in the manufacturer's technical manual or chapter 503 (9470) of the *Naval Ship's Technical Manual*. Reboring or renewal of the liner should be considered only when the scoring is extensive and rapid wearing of the packing takes place.

Scored Steam Cylinder

Scoring a steam cylinder, even though of a minor nature, necessitates reboring to prevent steam leakage past the piston. The presence of such leakage is indicated by a dullness and discoloration of the cylinder walls. Once leakage has started, steam will gradually cut away cylinder walls until piston leakage becomes so excessive that the pump will not operate properly.

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Care of Steam Valve Mechanism

The same care must be exercised in fitting the steam valve operating mechanism as that in fitting the steam piston and cylinder. It is most important that all wear be kept out of the steam valve operating mechanism. Failure to do this will cause the pump to operate in a faulty manner and, perhaps, to stick. The pins should be rebushed and renewed as often as necessary. If wear of bushings occurs rapidly, despite careful lubrication, the holes may be bushed with tool steel bushings.

All steam valves must be kept tight because if the pilot valve leaks, the main piston valve will become steambound; that is, the steam pressures in the various passages and parts of the pilot valve chest and the main piston valve chest cylinders will equalize, and the pump will stop. Flat steam valves should be kept true by scraping, and the piston rings of piston valves should be kept free in the grooves. When scraping flat steam slide valves, the strokes of the scraper should cross so that the scraper will not chatter on the narrow bridges between the ports; any unevenness will result in steam leakage when the valve is in operation.

As a result of frequent spotting-in of the main piston valve and the pilot valve, the relative size and arrangement of port openings may change due to irregular boring. A simple method to check the accuracy of the valve action is to cut paper patterns of the valve and the valve seat faces by laying the paper on the valve and peening with a hammer. Sliding the pattern of the valve over that of the seat will show the exact laps, leads, and port openings, which can be checked with the drawings.

Repairs to Valve Chests, Liners, and Piston Rings

Preventive maintenance of steam valve chests operating under high steam pressures is most important to avoid serious steam cutting and wear. Careful attention to lapping out these early cuts will ensure a tight metal-to-metal fit of the valve chest and steam cylinder.

Prior to making up the metal-to-metal joint, you should blue and test for good overall contact. If the joint is not a good metal-to-metal fit, or if scores or leakage are evident, remove the studs from the steam cylinder and lap the steam chest in against the cylinder seat.

In making up the joint, strict cleanliness must be observed. Particles of dirt or scale will prevent a good metal-to-metal contact of the ground faces. The hold-down bolts should be taken up gradually and alternately in a diagonal sequence. After the pump is in operation, the hold-down bolts should be taken up again.

Do not install gaskets on the steam chest joint. Such a gasket tends to blow out around the steam passage lands, thus aggravating the cutting action of the steam.

Overhauling Water End Valves

All valves in the water end of the pump must be kept tight to ensure satisfactory and economical pump operation. Valves may be faced in a lathe and then ground in on their seats by a simple device which consists of a length of rod slotted to fit a piece of metal which seats across the top of the valve.

It is sometimes desirable to take a cut off the valve seat without removing it. A simple cutter can be made with an extension for a bitstock, similar to the grinding-in device. When flat valves are fitted, the seats may be trued by using a small surface plate and spotting-in the section on the surface plate.

Valve disks and seats should be ground in, or replaced if necessary, in accordance with Maintenance Requirement Cards and manufacturer's instructions.

After the valves have been ground in, test the valves by closing the suction valve, opening the discharge valve, starting the pump, and noting the vacuum that the pump is capable of attaining.

Operating Troubles

From time to time you are likely to have some operating troubles with reciprocating pumps. The most common causes of trouble, together with their symptoms and remedies, are described below.

Lack of proper suction will cause jerky or irregular operation of the pump, or it may cause the pump to race without any appreciable

increase in discharge pressure. Loss of suction may be caused by a number of different conditions, including:

1. Obstructions in the suction line
2. Loss of suction head causing the pump to become vaporbound
3. Air in the system, causing the pump to become airbound

Obstructions in the suction line frequently cause trouble in fire and bilge pumps. Be sure that the suction line is clear and that all stop or check valves in the line are open. Clean the suction line strainer and the bilge strainer.

A pump can lose suction by becoming air-bound—that is, having air trapped in the system. The remedy for this condition is to open the aircocks and vents on the liquid end valve chest; leave them open until water flows out.

Insufficient prime often causes loss of suction in pumps which have a considerable suction lift. A fire and bilge pump can be primed from the sea by opening the sea suction valve for a short time.

Worn packing on the plunger or damaged suction or discharge valves in the liquid end may cause the pump to race without an appreciable increase in discharge pressure. It is not easy to distinguish this kind of trouble from the troubles caused by loss of suction, since the general symptoms are very similar. However, if you suspect that the plunger packing is worn or that the liquid end valves are damaged, you should stop the pump as soon as possible and locate and correct the trouble.

Groaning in the steam end of the pump may indicate that the piston rod packing is too tight, that the piston or a piston ring is broken, that rust has formed in the cylinder, or that the steam cylinder is out of alignment. The pump should be secured so that the difficulty may be found and corrected.

Groaning in the liquid end of the pump is generally due to excessively tight packing or broken or damaged follower plate or other broken parts. Stop the pump and investigate.

Knocking in the steam end of the pump may be caused by too long a stroke, by water in the steam cylinder, by loose pistons or piston rings, or by some difficulty in the piston-type valve gear. The pump should be stopped at once so that the trouble may be found and corrected.

Proper adjustment of the length of stroke is extremely important. If the stroke is too long, the steam piston will hit against the cylinder heads and make a heavy, metallic knocking sound. When the stroke is too short, the pilot valve may block the ports sufficiently to interfere with the admission of steam into the main valve and this may cause the pump to stop. In addition, a short stroke causes shoulders to be worn in the cylinder, and when the stroke is lengthened, these shoulders may cause the piston rings to break. Improper length of stroke, whether too short or too long, may cause great damage to the pump. To adjust the pump stroke, throttle down the pump, and adjust the stroke as necessary.

PUMP CONTROL AND SAFETY DEVICES

Turbines, used to drive pumps, are fitted with devices to control or limit the speed of the turbine, or to regulate the discharge pressure of the unit.

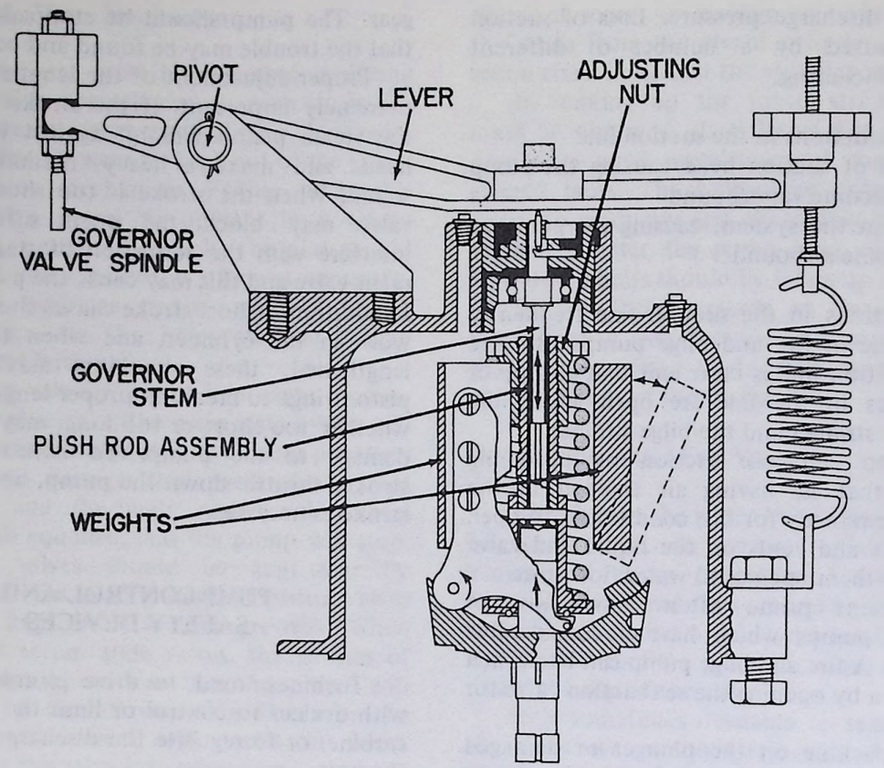
These devices are seldom found on reciprocating pumps. However, all turbine-driven rotary and centrifugal pumps have some type of governor; where discharge pressure has to be controlled, both a constant-pressure governor and a speed-limiting governor are installed.

SPEED-LIMITING GOVERNOR

The speed of turbine-driven condensate and booster pumps is controlled by a speed-limiting governor. This type of governor has no control of the pump speed until it reaches approximately 95% of maximum. Figure 5-24 shows one of the more common types used on main condensate, main feed booster, and lube oil service pumps.

The governor shaft is driven directly by an auxiliary shaft in the reduction gear and rotates at the same speed as the pump shaft. Two flyweights are pivoted to a yoke on the governor shaft and carry arms which bear on a push rod assembly. The push rod assembly is

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47.54

Figure 5-24.—Speed-limiting governor, main condensate pump.

held down by a strong spring. Centrifugal force on the flyweights causes them to be thrown outward. This lifts the arms, which pivot on rollers, against the spring tension on the governor stem whenever the pre-set speed of the governor is reached. If the turbine speed begins to exceed that for which the governor is set, increased centrifugal force acting on the rotating flyweights will cause them to move farther out, thereby causing the governor valve to throttle down on the steam. On the other hand, when the turbine slows down, as from an increase in load, the centrifugal force on the flyweights is reduced, and the governor push rod spring acts to pull the flyweights inward. This rotates the lever about its pivot and opens the governor valve, thus admitting more steam with a resultant speedup of the turbine until normal operating speed is reached.

Therefore, the governor acts as a constant-speed governor (when the turbine is operating above 95% of rated speed) although it is designed only to limit the speed. The speed of the pump may vary somewhat with a change in the load, but the variation will not be great enough to cause unsatisfactory operation of the unit.

Adjustment of the speed to which the turbine will be limited can be made by removing the cover from the governor assembly and changing the tension of the spring that works against the weights. The total travel of the governor valve, from FULLY OPEN to FULLY CLOSED, should be adjusted to ¼ inch. This travel should be checked after each readjustment of the spring. The pump is normally operated with the throttle fully open, passing full steam

pressure to the governor valve, thereby allowing the valve to control the speed of the unit.

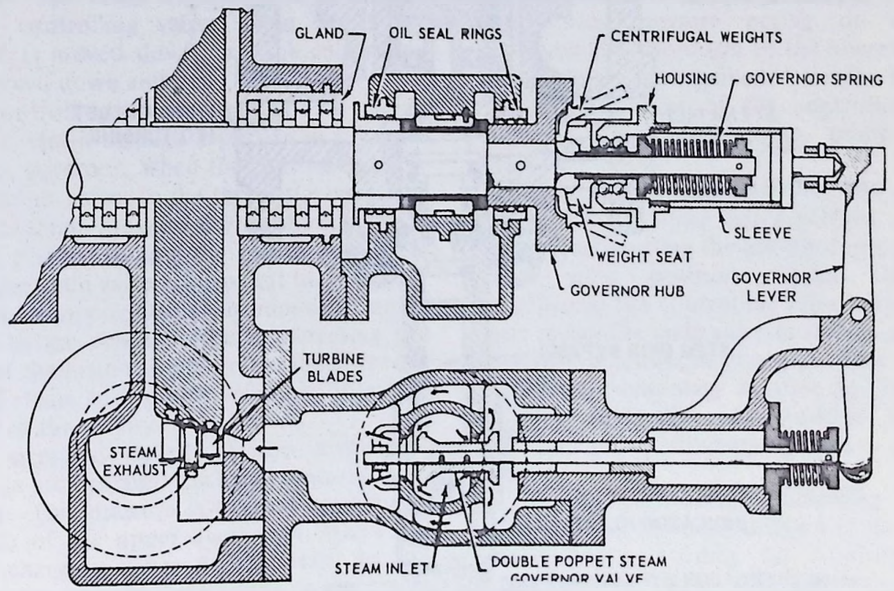
Figure 5-25 shows a CENTRIFUGAL WEIGHT TYPE SPEED-LIMITING GOVERNOR for a main feed pump. Centrifugal weights are mounted on a hub which rotates with the turbine shaft. The weights pivot on knife edges instead of rollers. As the speed of the turbine increases, centrifugal force causes the free ends of the weights to move outward, compressing the governor spring. This action causes the sleeve to move out against one end of the governor lever. The other end of the governor lever is attached to the operating stem of the double-poppet steam governor valve via a pivot point. The outward movement of the sleeve end of the governor lever will cause inward movement at the valve end, thus closing down on the valve and, therefore, reducing turbine speed. Tension on the spring at the outer end of the double-poppet valve stem tends to open the valve again as soon as the turbine shaft has slowed down and allowed the centrifugal weights to move inward.

CONSTANT-PRESSURE GOVERNOR

Many turbine-driven pumps are fitted with constant-pressure pump governors. The function of a constant-pressure pump governor is to maintain a constant pump discharge pressure under varying conditions of load. The governor, which is installed in the steam line to the pump, controls the pump discharge pressure by controlling the amount of steam admitted to the driving turbine.

Two types of constant-pressure pump governors are used in the Navy—the Leslie governor and the Atlas governor. The two types of governors are very similar in operating principles. Our discussion is based on the Leslie governor, but most of the information applies also to the Atlas governor.

A Leslie constant-pressure pump governor for a main feed pump is shown in figure 5-26. The governors used on fuel oil service pumps, lube oil service pumps, fire and flushing pumps, and various other pumps are almost identical. The chief difference between governors used for



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Figure 5-25.—Speed-limiting governor, main feed pump.

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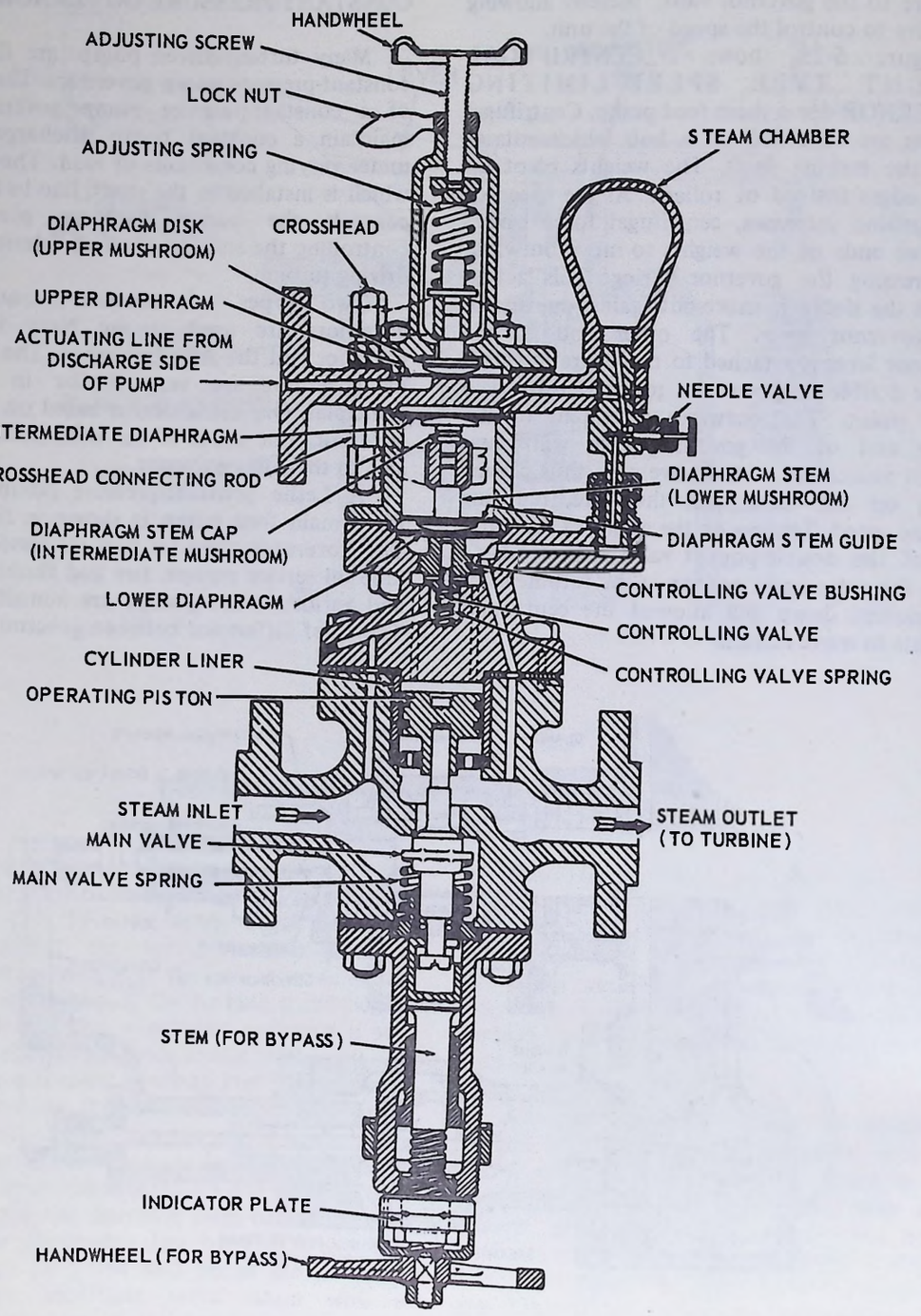


Figure 5-26.—Constant-pressure governor for main feed pump. 38.90

different services is in the size of the upper diaphragm. A governor used for a pump that operates with a high discharge pressure has a smaller upper diaphragm than one used for a pump that operates with a low discharge pressure.

Two opposing forces are involved in the operation of a constant-pressure pump governor. Fluid from the pump discharge, at discharge pressure, is led through an actuating line to the space below the upper diaphragm. The pump discharge pressure thus exerts an UPWARD force on the upper diaphragm. Opposing this, an adjusting spring exerts a DOWNWARD force on the upper diaphragm.

When the downward force of the adjusting spring is greater than the upward force of the pump discharge pressure, the spring forces both the upper diaphragm and the upper crosshead downward. A pair of connecting rods connects the upper crosshead rigidly to the lower crosshead, so the entire assembly of upper and lower crossheads moves together. When the crosshead assembly moves downward, it pushes the lower mushroom and the lower diaphragm downward. The lower diaphragm is in contact with the controlling valve. When the lower diaphragm is moved downward, the controlling valve is forced down and open.

The controlling valve is supplied with a small amount of steam through a port from the inlet side of the governor. When the controlling valve is open, steam passes to the top of the operating piston. The steam pressure acts on the top of the operating piston, forcing the piston down and opening the main valve. The extent to which the main valve is open controls the amount of steam admitted to the driving turbine. Increasing the opening of the main valve therefore increases the supply of steam to the turbine and so increases the speed of the turbine.

The increased speed of the turbine is reflected in an increased discharge pressure from the pump. This pressure is exerted against the under side of the upper diaphragm. When the pump discharge pressure has increased to the point that the upward force acting on the under side of the upper diaphragm is greater than the downward force exerted by the adjusting spring, the upper diaphragm is moved upward. This action allows a spring to start closing the controlling valve which, in turn, allows the main valve spring to start closing the main valve against the now-reduced pressure on the operating piston. When the main valve starts to close, the steam supply to the turbine is reduced, the speed of the turbine is reduced, and the pump discharge pressure is reduced.

At first glance, it might seem that the controlling valve and the main valve would be constantly opening and closing and that the pump discharge pressure would be continually varying over a wide range. This does not happen, however, because the governor is designed to prevent excessive opening or closing of the controlling valve. An intermediate diaphragm bears against an intermediate mushroom which, in turn, bears against the top of the lower crosshead. Steam is led from the governor outlet to the bottom of the lower diaphragm and also, through a needle valve, to the top of the intermediate diaphragm. A steam chamber is provided to ensure a continuous supply of steam at the required pressure to the top of the intermediate diaphragm.

Any up or down movement of the crosshead assembly is therefore opposed by the force of the steam pressure acting on either the intermediate diaphragm or the lower diaphragm. The whole arrangement serves to prevent extreme reactions of the controlling valve in response to variations in pump discharge pressure.

Limiting the movement of the controlling valve in the manner just described reduces the amount of hunting the governor must do to find each new position. Under constant-load conditions, the controlling valve takes a position that causes the main valve to remain open by the required amount. A change in load conditions results in momentary hunting by the governor until it finds the new position required to maintain pump discharge pressure at the new load.

A pull-open device, consisting of a valve stem and a handwheel, is fitted to the bottom of the governor. Turning the handwheel to the open position draws the main valve open and allows full steam flow to the turbine. When the main valve is opened by means of this bypass arrangement, the turbine must be controlled manually. Under all normal operating

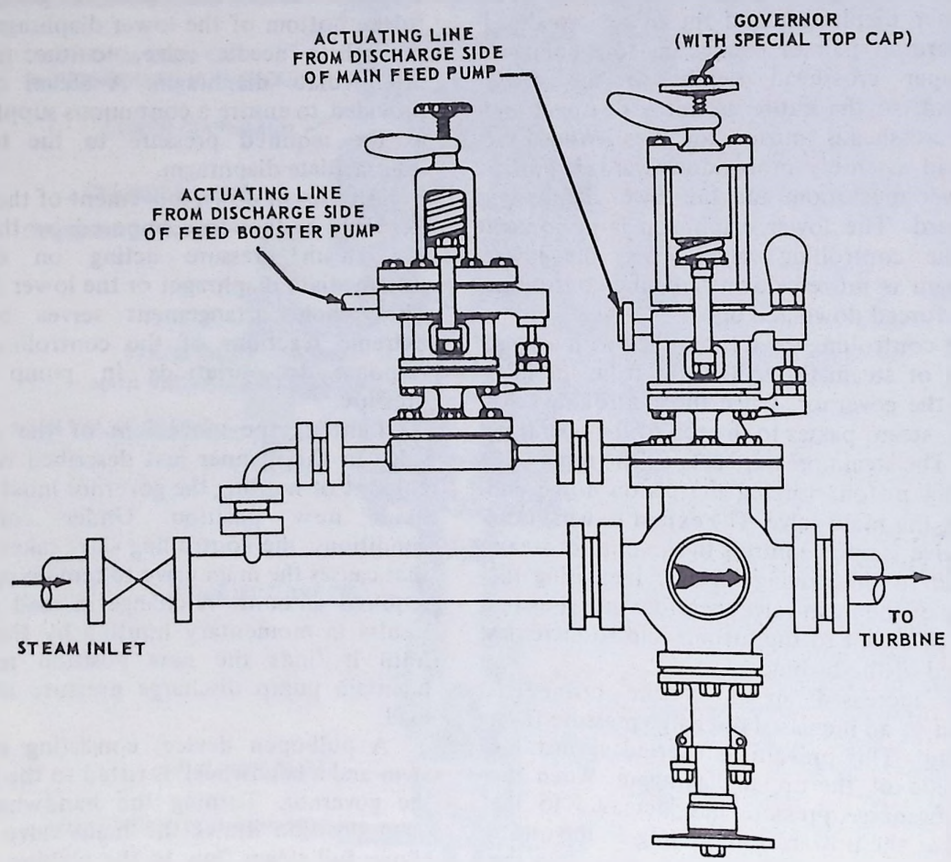
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conditions, the bypass remains closed and the pump discharge pressure is raised or lowered, as necessary, by increasing or decreasing the tension on the adjusting spring.

AUTOMATIC SHUTDOWN DEVICE

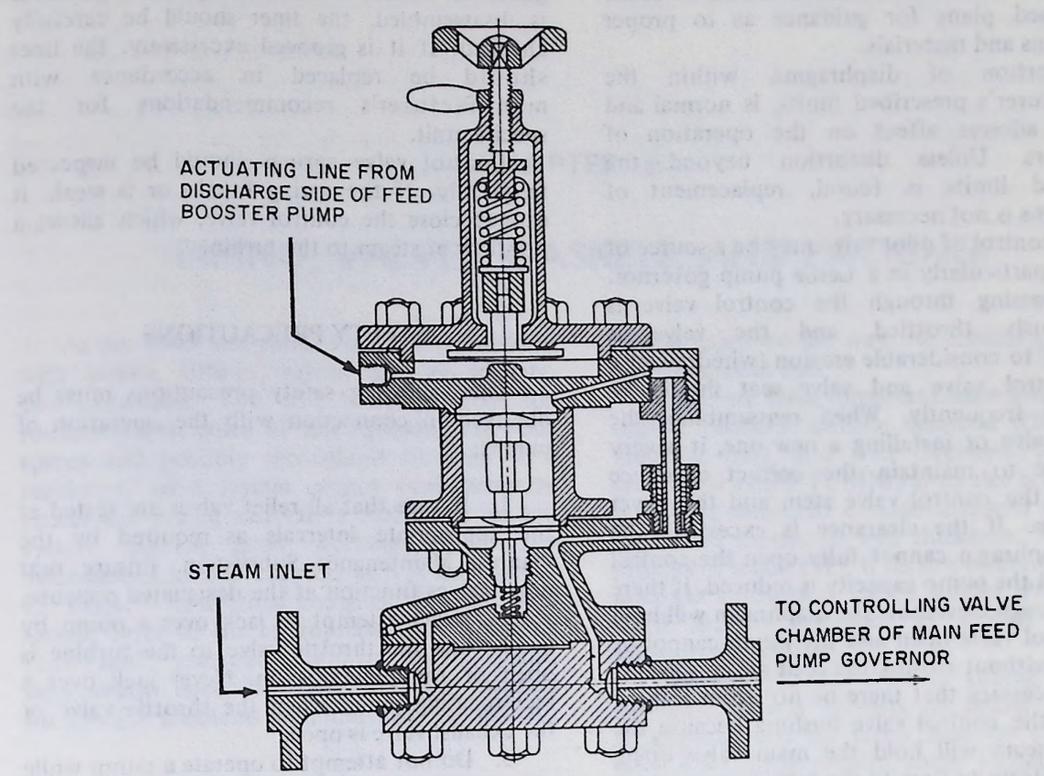
An automatic shutdown device was developed by the Leslie Company to shut down the main feed pump to protect it from damage in the event of loss of feed booster pump pressure (which is the same as main feed pump suction pressure.)

The Leslie automatic shutdown device consists of an auxiliary pilot valve and a constant-pressure pump governor, arranged as shown in figure 5-27. The governor is similar to the Leslie governor just described except that it has a special top cap. In the regular Leslie governor, the steam for the operating piston is supplied to the controlling valve through a port in the governor valve body. In the automatic shutdown device, the steam for the operating piston is supplied to the controlling valve through the auxiliary pilot valve. The auxiliary pilot valve (fig. 5-28) is actuated by the feed booster pump discharge pressure. When the booster pump discharge pressure is inadequate, the auxiliary pilot valve will not deliver steam to the controlling valve of the governor. Thus, inadequate feed booster pump pressure allows



38.91

Figure 5-27.—Automatic shutdown device for main feed pump.



38.92

Figure 5-28.—Auxiliary pilot valve for automatic shutdown device.

the main valve in the governor to close, shutting off the flow of steam to feed pump turbine.

MAINTENANCE AND REPAIR OF GOVERNORS

The maintenance and repair of governors should be accomplished in accordance with the applicable Maintenance Requirement Cards or manufacturer's instructions for the specific equipment. The information which follows is general in nature.

Very little wear is experienced in speed-limiting governors. However, the governor must be kept clean. Dirt or other foreign matter can foul the spring, thus requiring more force to move the weights, thereby allowing the pump to overspeed. Rust on the governor lever fulcrum pin will cause the lever to bind and not function properly. All pins in the linkage and the valve stem must be kept free of paint, rust, and dirt so that the linkage can move freely. Occasionally, a test should be made to determine whether the poppet valve (fig. 5-25) is leaking. The test may be made by pushing the valve onto its seat by hand. If the valve is leaking the turbine will continue to rotate.

When constant-pressure governors are disassembled, all diaphragms should be carefully inspected. If indications of failure are found, the affected part(s) should be renewed. During routine overhaul maintenance of Leslie pump governors, however, it may be necessary to replace serviceable diaphragms because of distortion resulting from normal operating pressure. Unless manufacturer-furnished

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diaphragms are used, reference should be made to finished plans for guidance as to proper dimensions and materials.

Distortion of diaphragms, within the manufacturer's prescribed limits, is normal and has no adverse affect on the operation of governors. Unless distortion beyond the prescribed limits is found, replacement of diaphragms is not necessary.

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

Faulty governor operation may also result from the wearing of grooves in the cylinder liner. The grooves, which limit the travel of the main valve, become worn when the piston is moved through a short travel; this reduces the capacity of the pump and causes failure of the governor. Whenever a constant-pressure governor is disassembled, the liner should be carefully checked. If it is grooved excessively, the liner should be replaced in accordance with manufacturer's recommendations for the specific unit.

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

SAFETY PRECAUTIONS

The following safety precautions must be observed in connection with the operation of pumps:

1. Ensure that all relief valves are tested at the appropriate intervals as required by the Planned Maintenance Subsystem. Ensure that relief valves function at the designated pressure.
2. Never attempt to jack over a pump by hand while the throttle valve to the turbine is open or the power is on. Never jack over a reciprocating pump when the throttle valve or the exhaust valve is open.
3. Do not attempt to operate a pump while either the speed-limiting governor or the constant-pressure governor is inoperable. Be sure that the speed-limiting governor and the constant-pressure governor are properly set.
4. Do not use any boiler feed system pump for any service other than boiler or feedwater service, except in an emergency.

CHAPTER 6

PIPING, VALVES, GASKETS, AND PACKING

As an MM3 and MM2 you will be working with piping, fittings, valves, packing, gaskets, and insulation. You will be responsible for routine maintenance of this equipment in your spaces and possibly throughout the ship. The machinery of a system cannot work properly unless the piping and valves that make up the system are in good working order. The information in this chapter, as it is throughout the book, is of a broad and general nature. You should refer to the appropriate manufacturer's technical manuals and/or ship's plans, information books and plant or valve manuals for specific problems with individual equipment.

PIPING AND TUBING

The Naval Sea System Command defines piping as an assembly of pipe or tubing, valves, fittings, and related components forming a whole or a part of a system for transferring fluids (liquids and gases).

More information about piping systems installation, components, fittings, testing, inspection, safety and cleaning can be found in *NAVSHIPS' Technical Manual,* Chapter 505 (9480)–Piping Systems.

IDENTIFICATION

In commercial usage, there is no clear distinction between pipe and tubing since the correct designation for each tubular product is established by the manufacturer. If the manufacturers call a product pipe, it is pipe; if they call it tubing, it is tubing. In the Navy, however, a distinction is made between pipe and tubing based on the way the tubular product is identified as to size.

There are three important dimensions of any tubular product: outside diameter (OD), inside diameter (ID), and wall thickness. A tubular product is called TUBING if its size is identified by actual measured outside diameter (OD) and by actual measured wall thickness. A tubular product is called PIPE if its size is identified by a nominal dimension called IRON PIPE SIZE (IPS) and by reference to a wall thickness schedule designation.

The size identification of tubing is simple enough, since it consists of actual measured dimensions, but the terms used for identifying pipe sizes may require some explanation. A NOMINAL dimension such as iron pipe size (IPS) is close to–but not necessarily identical with–an actual measured dimension. For example, a pipe with a nominal pipe size of 3 inches has an actual measure outside diameter of 3.50 inches. A pipe with a nominal pipe size of 2 inches has an actual measured outside diameter of 2.375 inches. In the larger sizes (about 12 inches) the nominal pipe size and the actual measured outside diameter are the same. For example, a pipe with a nominal pipe size of 14 inches has an actual measured outside diameter of 14 inches. Nominal dimensions are used to simplify the standardization of pipe fittings and pipe taps and threading dies.

The wall thickness of pipe is identified by reference to wall thickness schedules established by the American Standards Association. For example, a reference to schedule 40 for a steel pipe with a nominal pipe size of 3 inches indicates that the wall thickness of the pipe is 0.216 inch. A reference to schedule 80 for a steel pipe of the same nominal pipe size (3

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inches) indicates that the wall thickness of the pipe is 0.300 inch.

A schedule designation does NOT identify any one particular wall thickness unless the nominal pipe size is also specified. For example, we have seen that a schedule 40 steel pipe of nominal pipe size 3 inches has an actual wall thickness of 0.216 inch. But if we look up schedule 40 for a steel pipe of nominal pipe 4 inches, we will find that the wall thickness is 0.237 inch. These examples are used merely to illustrate the meaning of wall thickness schedule designations. Many other values can be found in pipe tables given in engineering handbooks.

You have probably seen pipe identified as STANDARD (Std), EXTRA STRONG (XS), and DOUBLE EXTRA STRONG (XXS). These designations, which are still used to some extent, also refer to wall thicknesses. However, pipe is manufactured in a number of different wall thicknesses, and some pipe does not fit into the standard, extra strong, and double extra strong classifications. The wall thickness schedules are being used increasingly to identify the wall thickness of pipe because they provide identification of more wall thicknesses than can be identified under the strong, extra strong, and double extra strong classifications.

We have briefly described the standard ways of identifying the size and wall thickness of pipe and tubing. However, you will sometimes see pipe and tubing identified in other ways. For example, you may see some tubing identified by ID rather than by OD. And you may see some pipe identified by nominal pipe size, by OD, by ID, and by actual measured wall thickness.

PIPING MATERIALS

Many different kinds of pipe and tubing are used in shipboard piping systems. Some shipboard applications of pipe and tubing that are of particular interest to MM's are mentioned below.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL PIPE is used for some high-pressure, high-temperature steam systems. The upper limit for the piping is 1500 psig and 1050° F.

SEAMLESS CARBON STEEL TUBING is used in oil, steam, and feedwater lines operating at 775° F and below. Different types of this tubing are available; the type used in any particular system depends on the working pressure of the system.

SEAMLESS CARBON-MOLYBDENUM ALLOY STEEL TUBING is used for feedwater discharge piping, boiler pressure superheated steam lines, and boiler pressure saturated steam lines. Several types of this tubing are available; the type used in any particular case depends on the boiler operating pressure and the superheater outlet temperature. The upper pressure and temperature limits for any class of this tubing are 1500 psi and 875° F.

SEAMLESS CHROMIUM-MOLYBDENUM ALLOY STEEL TUBING is used for high-pressure, high-temperature steam service in modern ships. This type of alloy steel tubing is available with varying percentages of chromium and molybdenum with upper limits of 1500 psig and 1050° F.

WELDED CARBON STEEL TUBING is used in some water, steam, and oil lines where the temperature does not exceed 450° F. There are several types of this tubing; each type is specified for certain services and certain service conditions.

NONFERROUS PIPE and NONFERROUS TUBING are used for many shipboard piping systems and for most shipboard heat exchangers. Nonferrous materials are used chiefly where their special properties of corrosion resistance and high heat conductivity are required. Various types of SEAMLESS COPPER TUBING are used for refrigeration installations, plumbing and heating systems, lubrication systems, and other shipboard systems. COPPER-NICKEL ALLOY TUBING is available in composition 70-30 (70% copper and 30% nickel) and in composition 90-10 (90% copper and 10% nickel). The 70-30 composition is generally used in submarine piping systems and heat exchangers. The 90-10 composition is widely used in surface ships.

Many other kinds of pipe and tubing besides the kinds mentioned here are used in shipboard piping systems. It is important to remember that design considerations control the selection of any particular pipe or tubing for any particular system. Although many kinds of pipe and tubing look almost exactly alike from the outside, they may respond very differently to pressures, temperatures, and other service conditions. Therefore, each kind of pipe and tubing can be used ONLY for specified applications.

PIPING FITTINGS

Piping sections of the proper size and material are connected by various standard fittings, including several types of threaded, bolted, welded, silver-brazed, and expansion joints.

THREADED JOINTS

The threaded joints are the simplest type of pipe fittings. Threaded fittings are not widely used aboard modern ships except in low-pressure water piping systems. The union fittings are provided in piping systems to allow the piping to be taken down for repairs and alterations. Unions are available in many different materials and designs to withstand a wide range of pressures and temperatures. Figure 6-1 shows some commonly used types of unions. The union is used a great deal for joining piping up to 2 inches in size. The pipe ends connected to the union are threaded, silver-brazed, or welded into the tail pieces (union halves); then the two ends are joined by setting up (engaging and tightening up on) the union ring. The male and female connecting ends of the tail pieces are carefully ground to make a tight metal-to-metal

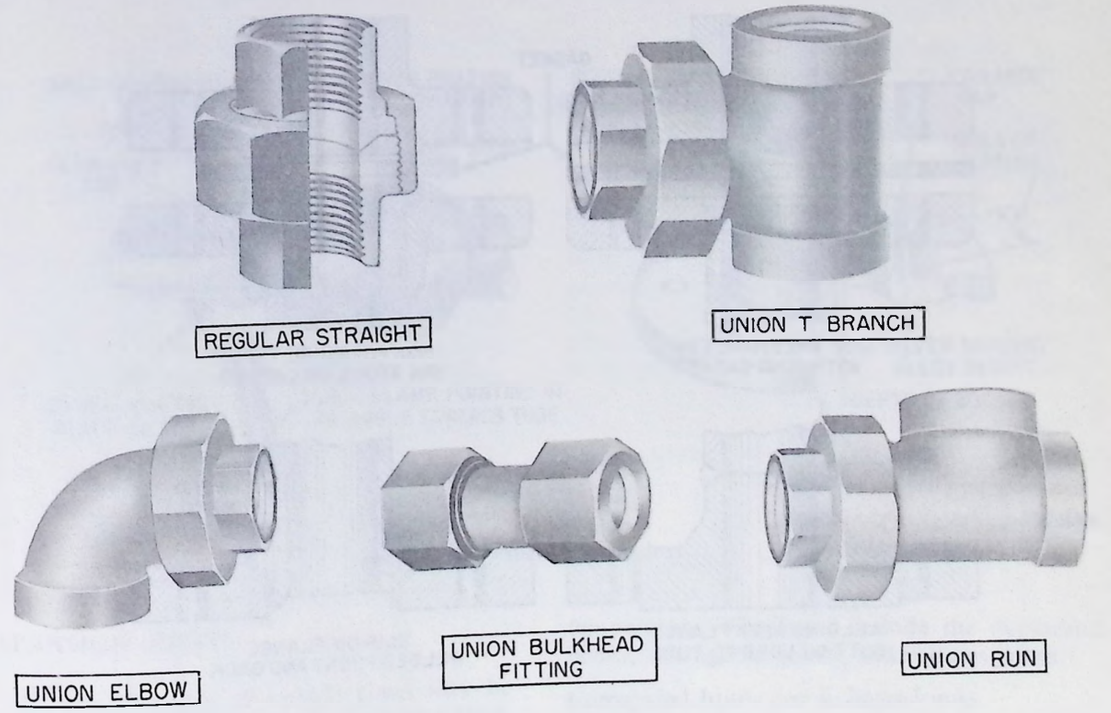


Figure 6-1.—Unions.

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fit with each other. Welding or silver-brazing the ends to the tail pieces prevents contact of the carried fluid or gas with the union threading.

BOLTED FLANGE JOINTS

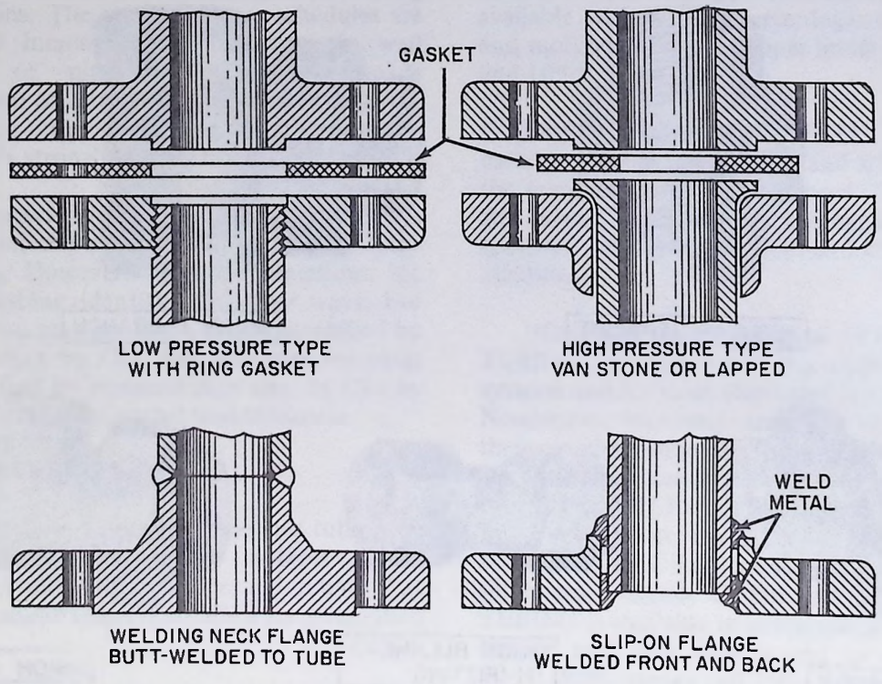
Bolted flange joints (fig. 6-2) are suitable for all pressures now in use. The flanges are attached to the piping by welding, brazing, screw threads (for some low-pressure piping), or rolling and bending into recesses. Those illustrated in figure 6-2 are the most common types of flange joints used. Flange joints are manufactured for all standard fitting shapes such as the tee, cross, elbow and return bend. The Van Stone type and the welded neck-type flange joints are used extensively where piping is subjected to high pressures and heavy expansion strains. The design of the Van Stone flange makes it easier to line up the fastening holes in the two parts of the flange.

WELDED JOINTS

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications which define the materials and techniques. There are three general classes of welded joints—butt-weld, fillet-weld, and socket-weld (fig. 6-3).

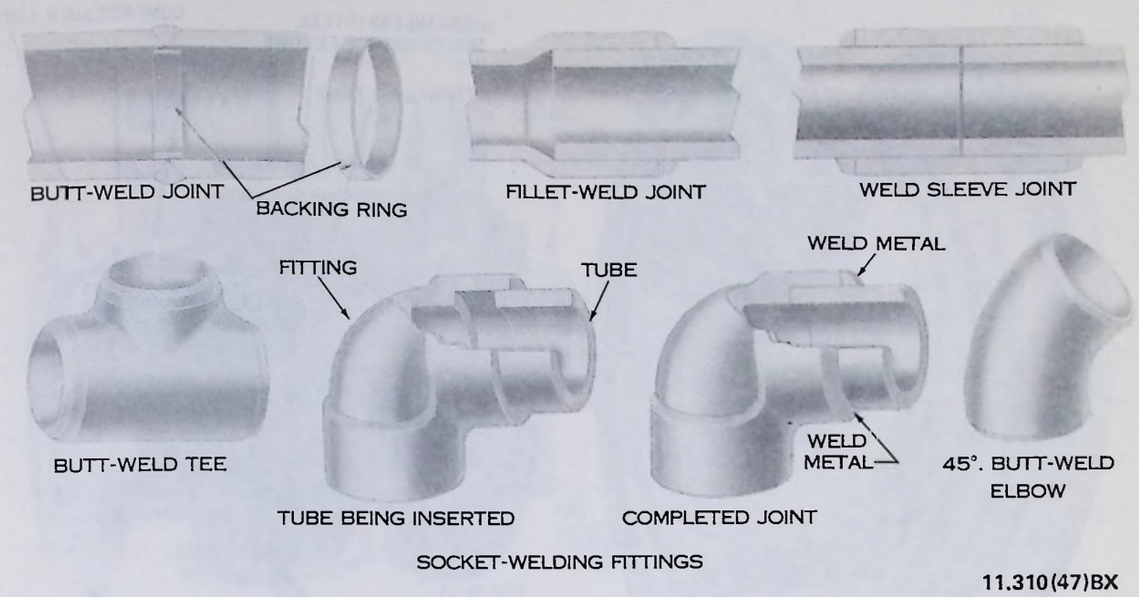
SILVER-BRAZED JOINTS

Silver-brazed joints (fig. 6-4) are commonly used for joining nonferrous piping when the pressure and temperature in the lines make their use practicable—temperature must not exceed 425° F; for cold lines, pressure must not exceed 3,000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the molten metal to fill the few thousandths of an inch annular space between the pipe and the fitting.



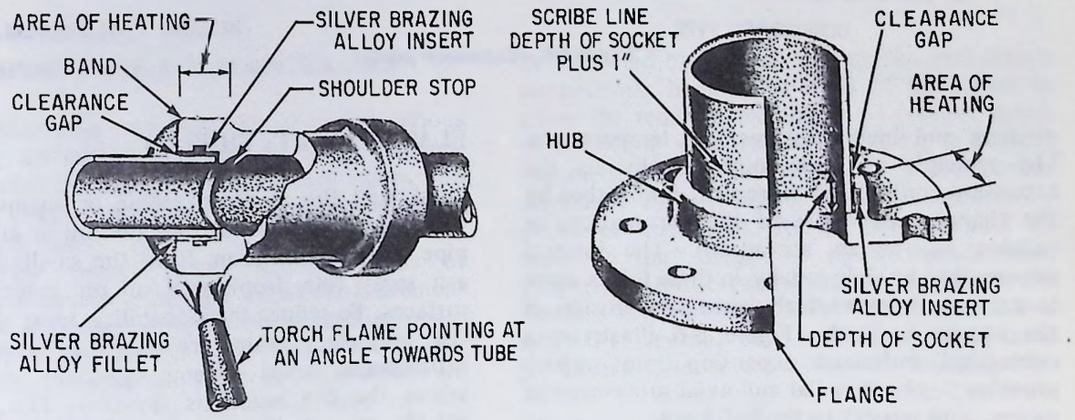
47.55X

Figure 6-2.—Four types of bolted flange piping joints.



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Figure 6-3.—Various types of welded joints.



47.56X

Figure 6-4.—Silver-brazed joints.

EXPANSION JOINTS

Expansion joints of various types may be installed at suitable intervals in long steam lines, because of the expansion and contraction of metal that is subjected to a wide range of temperature. The types include the expansion bends, corrugated joints, and bellows joints.

Corrugated Joints and Bellows Joints

The corrugated and bellows types of expansion joints (fig. 6-5) are used for both

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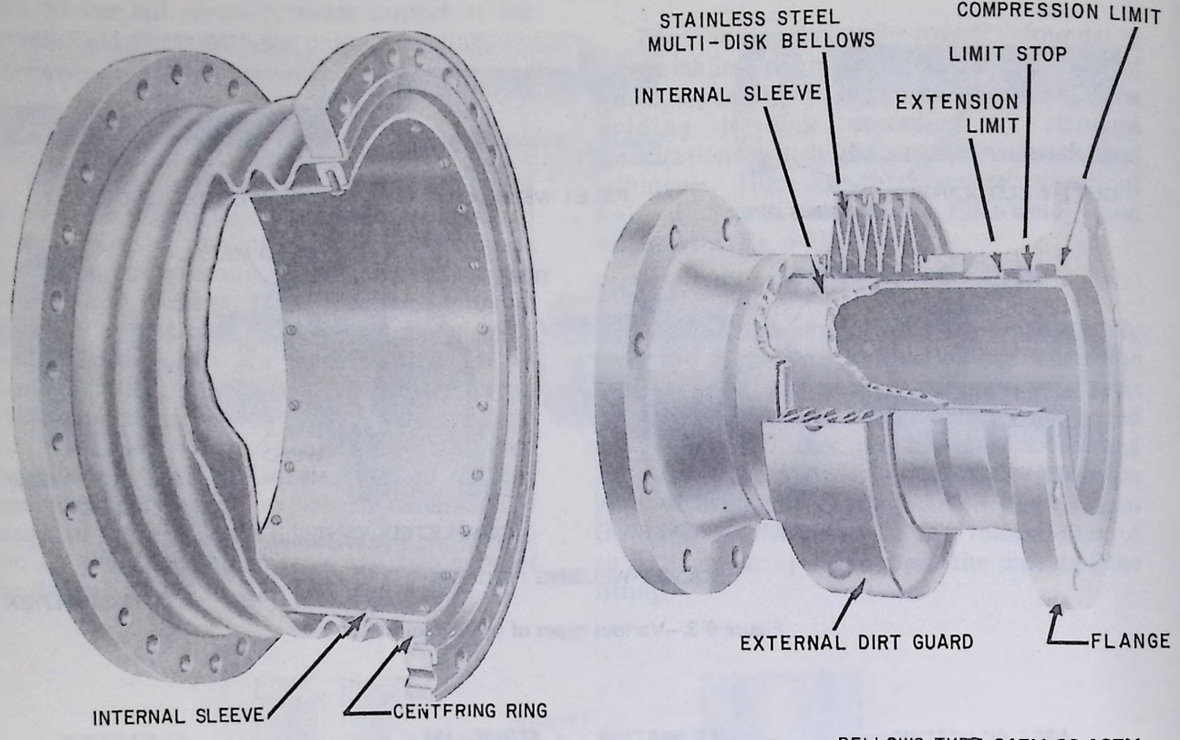


Figure 6-5.—Expansion joints.

medium and high pressures and temperatures. The principle of these joints is obvious; the expansion-contraction movement is absorbed by the changing curvature of the corrugations or bellows (as in an accordion). The internal sleeves, free to slide axially in these joints, serve to prevent excessive turbulence and erosion of the expansion parts. Figure 6-6 illustrates a corrugated bulkhead expansion joint, which provides for both radial and axial movement of piping, with respect to the bulkhead.

Expansion Bends

Expansion bends are employed for high-pressure and high-temperature steam piping in preference to the corrugated or bellows joint. Expansion bends are merely loops of piping of proper length and configuration to take up the changes in pipe length caused by temperature changes. The expansion bends take many shapes—most common are the U-bend, Z-bend and L-bend.

FLANGE SAFETY SHIELDS

A fuel fire in the fireroom or engineroom can be caused by a leak at a fuel oil or lube oil pipe flange connection. Even the smallest leak can spray fine droplets of oil on nearby hot surfaces. To reduce this possibility, spray shields (fig. 6-7) are provided around piping flanges of inflammable liquid systems, especially in areas where the fire hazard is apparent. The spray shields are usually made of aluminized glass cloth and are simply wrapped and wired around the flange.

PIPELINE STRAINERS

Strainers are fitted in many piping lines to prevent the passage of grit, scale, dirt, and other foreign matter. Such matter could obstruct pump or throttle valves, or damage machinery parts. Various types of strainers are used, depending on the service intended.

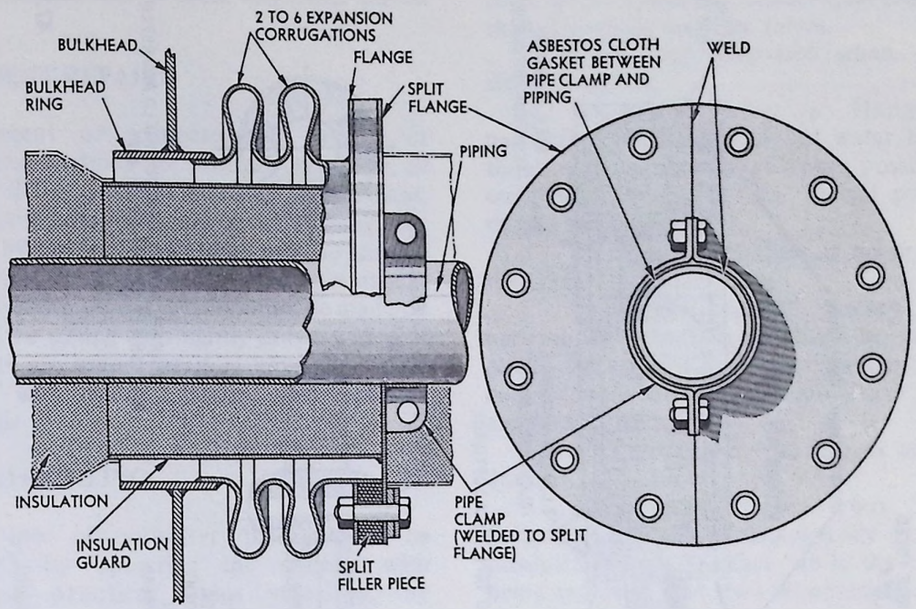


Figure 6-6.—Corrugated bulkhead expansion joint, showing details of installation.

PIPING CARE AND MAINTENANCE

Reasonable care must be given the various piping assemblies, as well as the machinery connected by the piping. All joints, valves, and cocks in the lines must be examined frequently and kept tight.

Where piping passes through decks or bulkheads and a possibility exists for movement of one with respect to the other, stuffing boxes or flexible bulkhead connections are provided—if expansion bends or other offsets are not provided in the piping—to take up the movement. The external surfaces of uncovered and ungalvanized steel or iron piping should be kept properly painted and free of moisture. Copper and brass piping is seldom painted.

LEAKAGE AT JOINT

Continual leakage at a joint where a branch line joins another line is usually due to improper allowance for expansion in one of the lines or to excessive vibration. Oftentimes, these leaks can be corrected by slightly altering the anchorages, connections, hangers, or leads of the piping to allow the required expansion to prevent strain, or by fitting supports to the piping to prevent vibration. Leaky joints may also be due to poor alignment of the piping or to movement of decks or bulkheads. Realignments should be made so that flanges or screw threads meet properly without being forced. Sometimes the flange joints may need to be refaced or distance (shims) pieces may need to be fitted. Small leaks in gaskets should be taken up immediately, before a dangerous blowout results from progressive growth of the leak.

PIPE THREAD LEAKS

Pipe thread leaks should be promptly corrected. Leaky screwed joints that cannot be tightened with a reasonable amount of tightening should be taken apart, cleaned, examined for bad thread conditions, recoated with the appropriate (if any) compound, and

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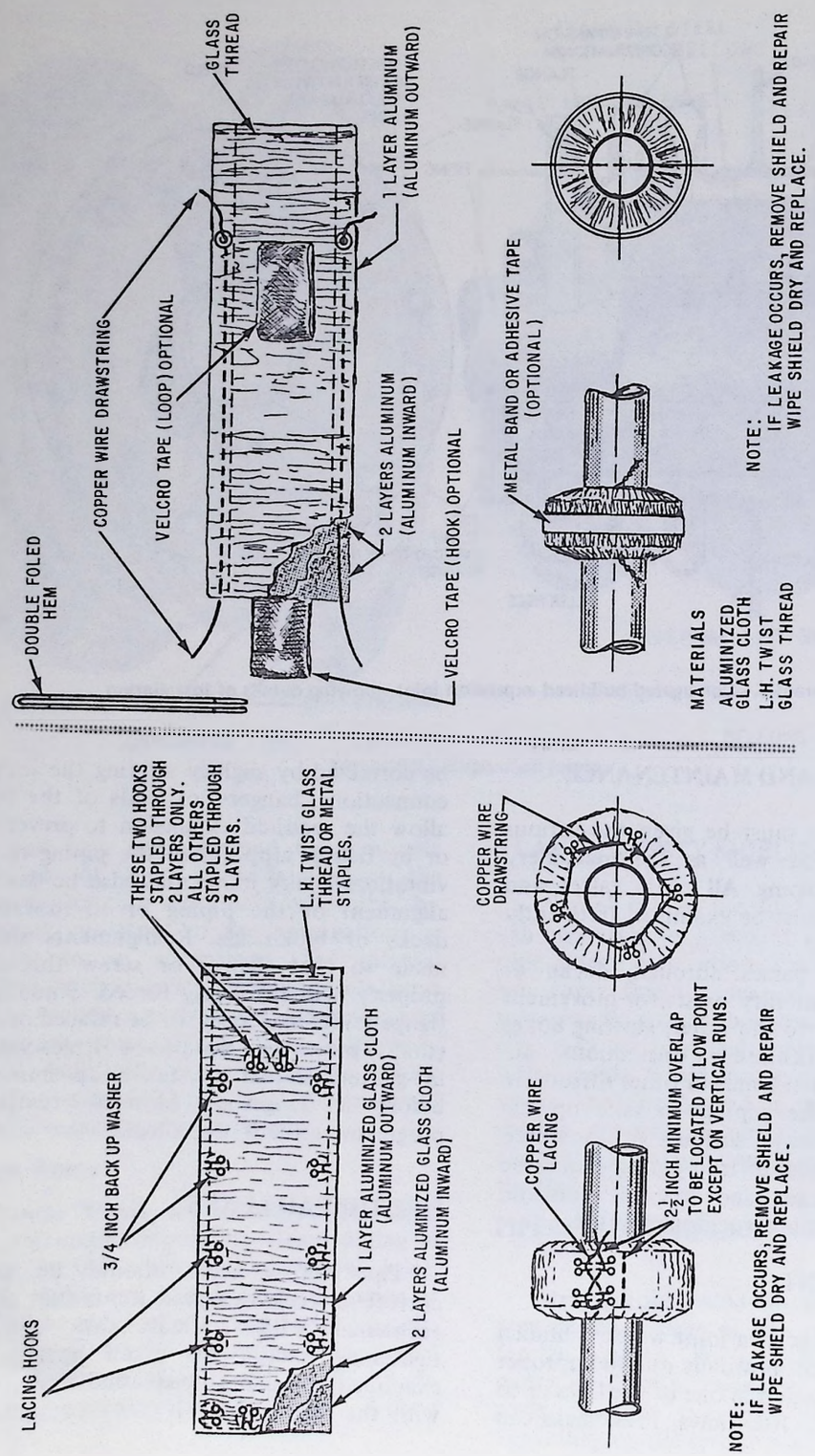


Figure 6-7.—Flange safety shield.

carefully reassembled to avoid any other thread damage.

PERMANENT REPAIRS

Permanent or semipermanent repairs of leaky piping sections are generally made by, or with the aid of Hull Maintenance Technicians. Permanent repairs of copper or brass piping may be made by brazing. Small holes may be plugged with a rivet or a screw plug. Semipermanent repairs of leaky piping sections may be made by wrapping the piping with tightly drawn wire that is soldered or brazed as it is applied. Several layers of wire securely bonded give a strong, tight repair.

SALTWATER PIPING

The life of saltwater piping may be lengthened by operating the systems with minimum practical water velocities; by eliminating grounds from electrical systems, especially d.c. circuits; by eliminating air from the saltwater systems; by promptly correcting any leaks; by insulating with sheet rubber the hangers which support piping other than that made of wrought iron or steel; and by eliminating wire-drawing by fully opening valves where throttling is unnecessary.

Submarine piping systems identified as SUB-SAFE require special precautions and testing during maintenance.

Also, some systems aboard ship may be designated to be maintained Grade "A" clean. Maintenance on these systems must be done with extreme care to maintain a very high level of cleanliness and to prevent introduction of seawater or other contaminants.

PIPING SAFETY PRECAUTIONS

The following are some general safety precautions to be observed concerning piping systems.

1. To prevent water hammer, drain water from steam piping before admitting steam.
2. Before opening large steam valves, open bypasses to warm lines and equalize pressures. If there are no bypasses, "crack" (just slightly back the valve off its seat) the valves.
3. Open trap bypasses when admitting steam to piping.
4. When breaking a flange joint, particularly in steam and hot water lines or in those saltwater lines that have a possible direct connection with the sea, special precautions should be taken.
   a. Ensure that there is no pressure on the line.
   b. Ensure that the valves that cut pressure off the part of the line undergoing repair are secured in such a manner that they cannot be accidentally opened. (Such as tagging and locking)
   c. Ensure that the line is completely drained.
   d. Ensure that two of the flange-securing nuts (diametrically opposite if possible) remain in place while the others are being removed. The two remaining nuts should then be slacked sufficiently to allow breaking the joint. If the line is clear, all the nuts may be removed. This precaution is necessary to prevent accidents such as scalding personnel or flooding compartments.
5. After remaking a steam joint, tighten the nuts according to prescribed methods.
6. NEVER use piping for handholds or footholds.
7. NEVER secure chain falls to piping.
8. NEVER use piping for supporting weights.
9. Secure copper and brass piping in such a manner that contact with bilges is avoided. The brackets should be lined with insulating material to prevent direct contact between piping and any of the ship's structure.

VALVES

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged and are made of either plain steel or alloy steel. Alloy steel valves are used in high-pressure, high-temperature systems; the disks and seats (internal sealing surfaces) of these valves are usually surfaced with a

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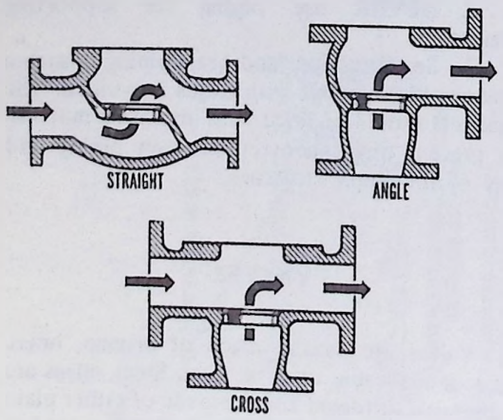
chromium-cobalt alloy known as Stellite. Stellite is extremely hard.

Brass and bronze valves are never used in systems where temperatures exceed 550° F. Steel valves are used for all services above 550° F and in lower temperature systems where internal or external conditions of high pressure, vibration, or shock would be too severe for valves made of brass or iron. Bronze valves are used almost exclusively in systems that carry saltwater. The seats and disks of these valves are usually made of Monel, a metal that has excellent corrosion- and erosion-resistant qualities.

Most submarine seawater valves are made of 70-30 copper-nickel alloy.

STOP VALVES

Stop valves are used to shut off or, in some cases, partially shut off the flow of fluid. Stop valves are controlled by the movement of the valve stem. Stop valves can be divided into four general categories: globe, gate, butterfly and ball valves. Plug valves and needle valves may also be considered stop valves but these valves are covered sufficiently in *Fireman*, NAVEDTRA 10520.



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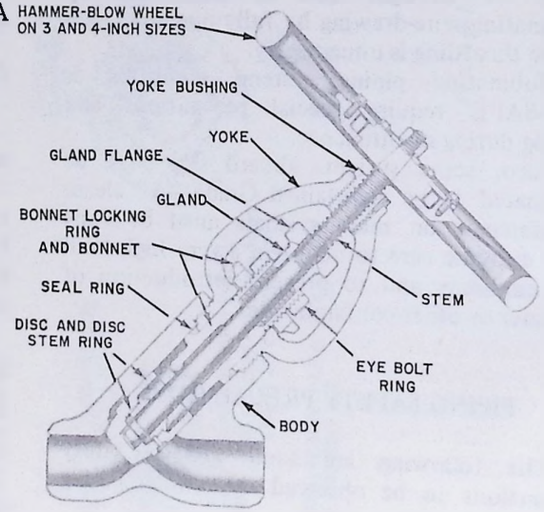
Figure 6-8.—Types of globe valve bodies.

GLOBE VALVES

Globe valves are probably the most common valve in existence. The globe valve derives its name from the globular shape of the valve body. However, positive identification of a globe valve must be made internally because other valve types may also have globular appearing bodies. Globe valve inlet and outlet openings are arranged in several ways to suit varying requirements of flow. Figure 6-8 shows the common types of globe valve bodies; straight flow, angle flow, and cross flow. Figure 6-9 shows a pressure-seal bonnet globe valve with an angled straight-flow type body. This arrangement of the angled valve seat within the valve produces lower fluid turbulence and flow restriction than the standard straight-flow globe valve.

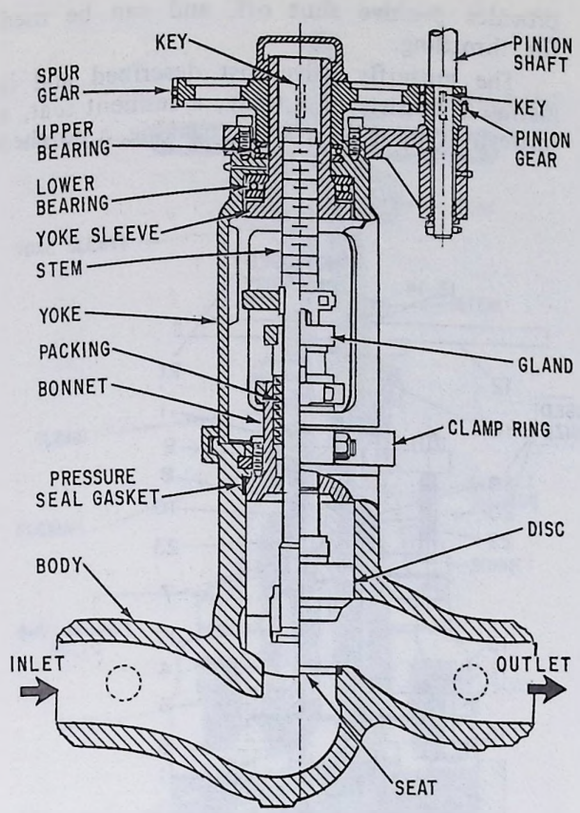
Figure 6-10 shows a gear-operated globe stop valve used as an astern throttle valve in a steam plant.

Globe valves are used extensively throughout the engineering plant and other parts of the ship in a variety of systems.



47.194

Figure 6-9.—1500-pound pressure seal bonnet globe valve.



47.195

Figure 6-10.—Gear-operated globe stop valve.

GATE VALVES

Gate valves are used when a straight line flow of fluid and minimum flow restriction is desired. Gate valves are so named because the part which either stops or allows flow through the valve acts somewhat like the opening or closing of a gate and is called, appropriately, the gate. The gate is usually wedge shaped. When the valve is wide open the gate is fully drawn up into the valve leaving an opening for flow through the valve the same size as the pipe in which the valve is installed. Therefore, there is little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes since the control of flow would be difficult due to valve design and since the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.

Gate valves are classified as either rising-stem or nonrising-stem valves. On the nonrising stem gate valves, shown in figure 6-11, the stem is threaded on the lower end into the gate. As the handwheel on the stem is rotated the gate travels up or down the stem on the threads while the stem remains vertically stationary. This type valve will almost always have a pointer type indicator threaded onto the upper end of the stem to indicate valve position.

The rising stem gate valve, illustrated in figure 6-12, has the stem attached to the gate, and the gate and stem rise and lower together as the valve is operated.

Gate valves used in steam systems have flexible gates. The reason for using a flexible gate is to prevent binding of the gate within the valve when the valve is in the closed position. When steam lines are heated, they will expand, causing some distortion of valve bodies. If a solid gate fits snugly between the seat of a valve in a cold steam system, when the system is heated and pipes elongate, the seats will compress against the gate wedging the gate between them and clamping the valve shut. This problem is overcome by using a flexible gate, which is best described as two circular plates attached to each other with a flexible hub in the middle. This design allows the gate to flex as the valve seat compresses it, thereby preventing clamping.

The major problem associated with flexible gates is that water tends to collect in the body neck; then, under certain conditions the admission of steam may cause the valve body neck to rupture, the bonnet to lift off, or the seat ring to collapse. To prevent this, it is essential that correct warming up procedures are followed. Also, some very large gate valves have a three-position vent and bypass valve installed. This valve allows venting of the bonnet either upstream or downstream of the valve and has a position for bypassing the valve.

Such valves are used as main steam stops on some submarines.

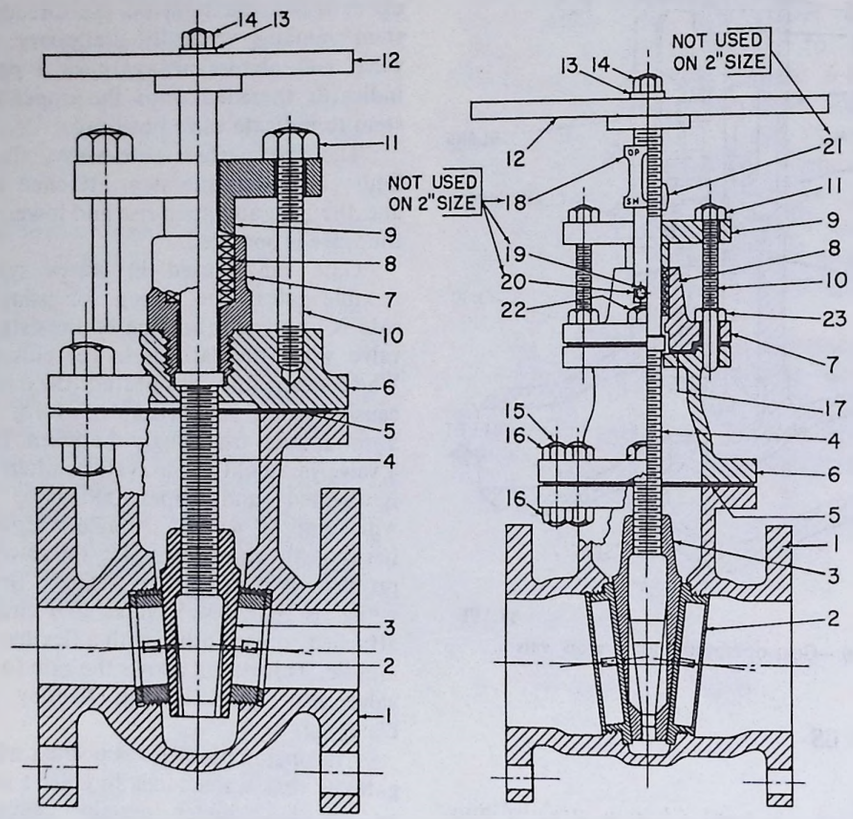
BUTTERFLY VALVES

The butterfly valve, one type of which is shown in figure 6-13, may be used in a variety of

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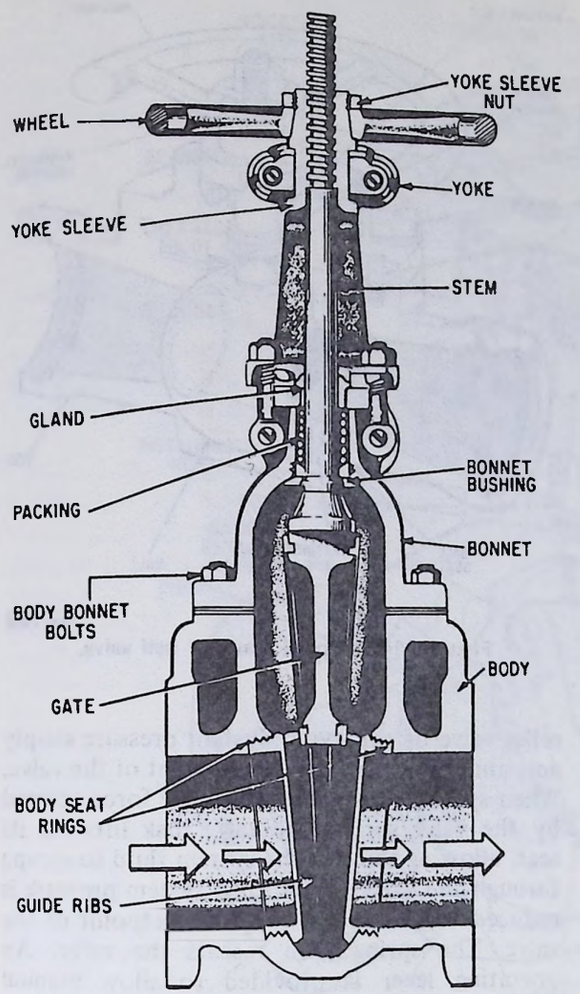
systems aboard ship. These valves can be used effectively in freshwater, saltwater, JP-5, Navy special fuel oil, lube oil, and chill water systems aboard ship. The butterfly valve is light in weight, relatively small, relatively quick-acting, provides positive shut off, and can be used for throttling.

The butterfly valve just described and illustrated consists of a body, a resilient seat, a butterfly-type disk, a stem, packing, a notched



LIST OF PARTS			
PART NO.	NAME OF PART	PART NO.	NAME OF PART
1	BODY	13	HANDWHEEL WASHER
2	SEAT RING	14	HANDWHEEL NUT
3	GATE	15	BONNET STUD
4	STEM	16	BONNET STUD NUT
5	BONNET GASKET	17	STUFFING BOX GASKET
6	BONNET	18	INDICATOR PLATE
7	STUFFING BOX	19	LOCK WASHER
8	PACKING	20	INDICATOR PLATE SCREW
9	GLAND	21	INDICATOR NUT
10	GLAND STUD	22	STUFFING BOX STUD
11	GLAND STUD NUT	23	STUFFING BOX STUD NUT
12	HANDWHEEL		

Figure 6-11.—Cross-sectional views of gate stop valves (nonrising stem type). 38.118

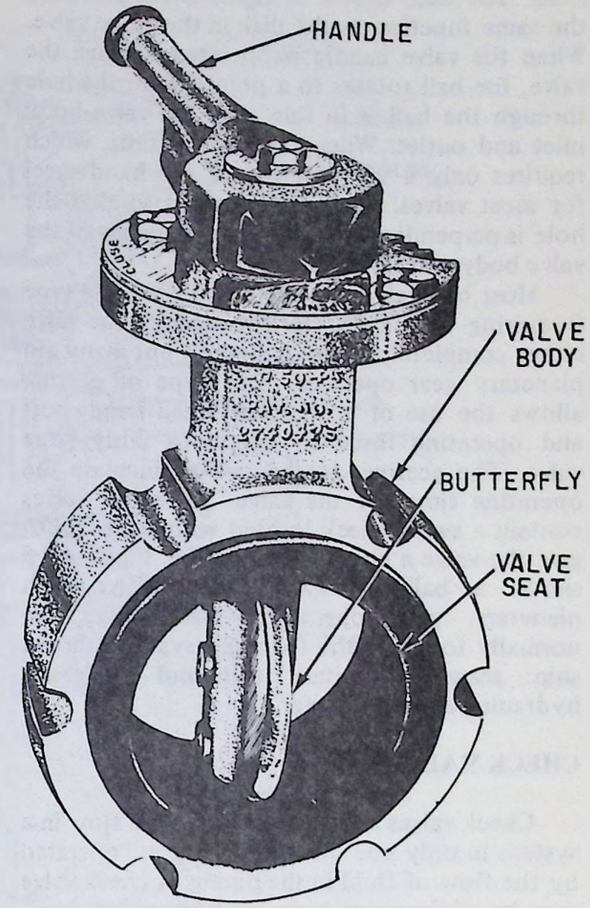


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Figure 6-12.—Cutaway view of gate stop valve (rising stem type).

positioning plate, and a handle. The resilient seat is under compression when it is mounted in the valve body, thus making a seal around the periphery of the disk and both upper and lower points where the stem passes through the seat. Packing is provided to form a positive seal around the stem for added protection in case the seal formed by the seat should become damaged.

To close or open a butterfly valve, it is necessary to turn the handle only one quarter turn to rotate the disk 90°. Some larger



11.318

Figure 6-13.—Butterfly valve.

butterfly valves may have a handwheel that operates through a gearing arrangement to operate the valve. This method is used especially where space limitation precludes the use of a long handle.

Butterfly valves are relatively easy to maintain. The resilient seat is held in place by mechanical means, and neither bonding nor cementing is necessary. Because the seat is replaceable, the valve seat does not require lapping, grinding or machine work.

BALL VALVES

Ball valves, as the name implies, are stop valves that use a ball to stop or start the flow of

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fluid. The ball, shown in figure 6-14, performs the same function as the disk in the globe valve. When the valve handle is operated to open the valve, the ball rotates to a point where the hole through the ball is in line with the valve body inlet and outlet. When the valve is shut, which requires only a 90° rotation of the handwheel for most valves, the ball is rotated so that the hole is perpendicular to the flow openings of the valve body and flow is stopped.

Most ball valves are of the quick-acting type (requiring only a 90° turn to operate the valve either completely open or closed), but many are planetary gear operated. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. The gearing does, however, increase the operating time for the valve. Some ball valves contain a swing check located within the ball to give the valve a check valve feature. Figure 6-15 shows a ball-stop swing check valve with planetary gear operation. Ball valves are normally found in the following systems aboard ship: seawater, sanitary, trim and drain, air, hydraulic, and oil transfer.

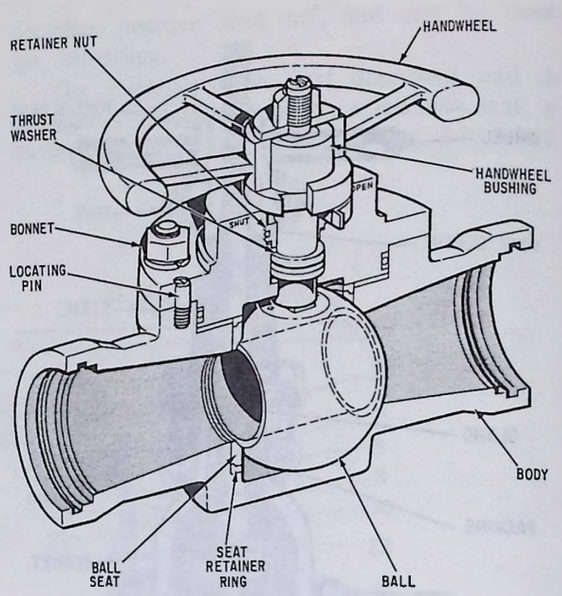


Figure 6-14.—Typical seawater ball valve.

CHECK VALVES

Check valves are used to allow fluid flow in a system in only one direction. They are operated by the flow of fluid in the piping. A check valve may be of the swing type, lift type, or ball type.

SPECIAL PURPOSE VALVES

There are many types of automatic pressure control valves—some of them merely providing an escape for pressures exceeding the normal pressure; some providing only for the reduction of pressure; and some providing for the regulation of pressure.

RELIEF VALVES

Relief valves are automatic valves used on system lines and equipment to prevent inadvertent overpressurization which could be caused in numerous ways. Most relief valves simply lift (open) at a preset pressure and reset (shut) when the pressure drops only slightly below the lifting pressure. Figure 6-16 shows a relief valve of this type. System pressure simply acts under the valve disk at the inlet of the valve. When system pressure exceeds the force exerted by the valve spring, the valve disk lifts off its seat, allowing some of the system fluid to escape through the valve outlet until system pressure is reduced to just below the relief setpoint of the valve. The spring then reseats the valve. An operating lever is provided to allow manual cycling of the relief valve or to gag it open for certain tests. Virtually all relief valves are provided with some type of device to allow manual cycling.

Other types of relief valves are the boiler safety relief valve and the steam generator relief valve. Both of these types of valves are designed to open completely at a specified lift pressure and to remain open completely until a specified reset pressure is reached at which time they go shut. Many different designs of these valves are used, but the same result is achieved.

SENTINEL VALVES

Sentinel valves are simply small relief valves sometimes installed in systems to warn of impending overpressure. Sentinel valves are NOT designed to relieve the pressure of the system; if the situation causing the sentinel valve to lift is not corrected, a relief valve will have to lift to protect the system or component.

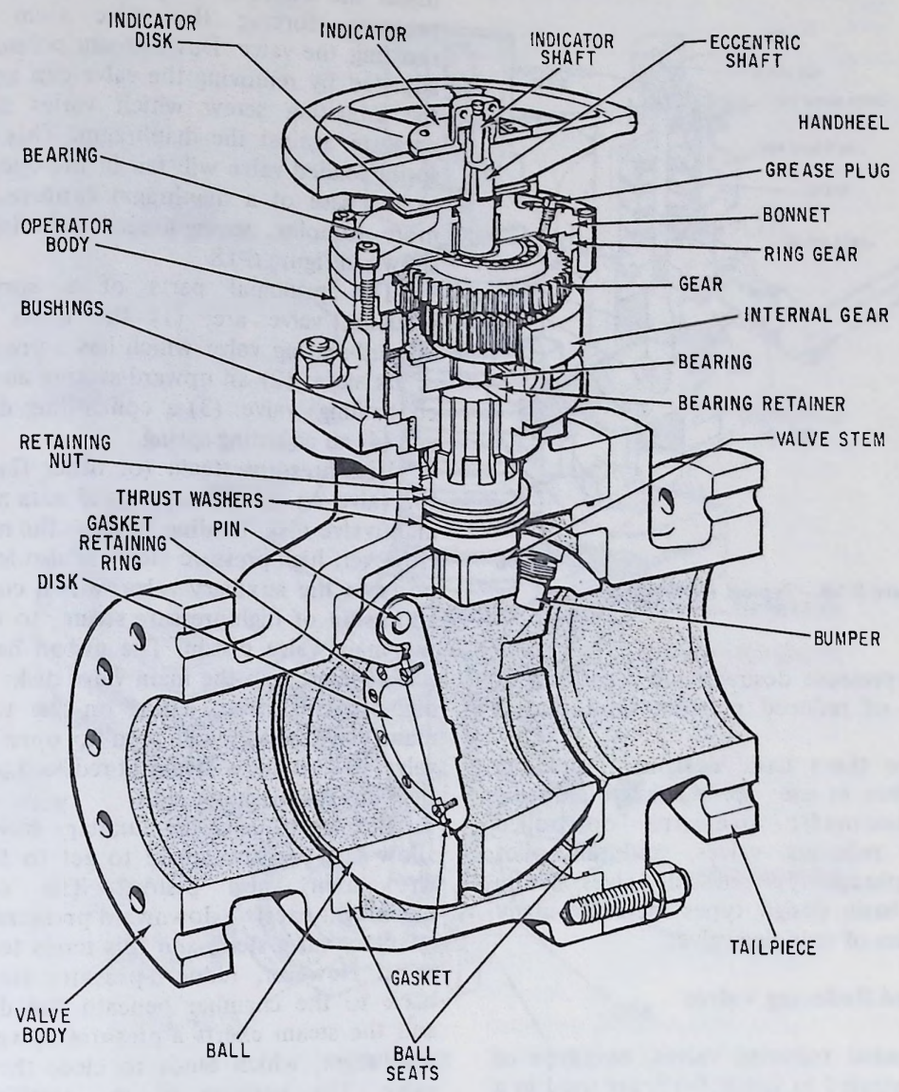


Figure 6-15.—Typical ball stop swing-check valve for seawater service.

PRESSURE REDUCING VALVES

Reducing valves are automatic valves that provide a steady pressure into a system which is at a lower pressure than the supply system. Reducing valves of one type or another are found in steam, air, lube oil, seawater and other systems. A reducing valve can normally be set for any desired downstream pressure within the design limits of the valve. Once 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

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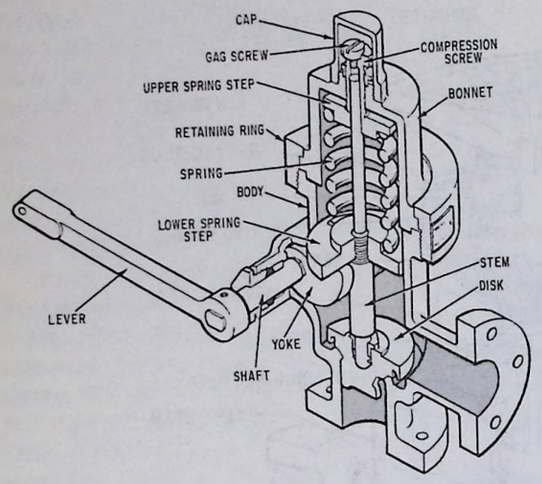


Figure 6-16.—Typical relief valve.

the reduced pressure desired) and regardless of the amount of reduced pressure fluid that is used.

There are three basic designs of pressure reducing valves in use: spring-loaded reducing valves, pneumatic pressure controlled (gas-loaded) reducing valves, and air pilot operated diaphragm-type reducing valves. Within these three basic design types there are many different styles of reducing valves.

Spring-Loaded Reducing Valves

Spring-loaded reducing valves, one type of which is illustrated in figure 6-17, are used in a wide variety of applications. Low-pressure air reducers, distilling plant seawater reducers, some reduced-steam system reducers and others are of this type. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, outlet pressure (the pressure in the reduced pressure system) of the valve forces the disk upward to shut the valve. When outlet pressure drops below the setpoint of the valve, spring pressure overcomes outlet pressure and forces the valve stem downward, opening the valve. As outlet pressure increases, approaching the desired value, the pressure under the diaphragm begins to overcome spring pressure, forcing the valve stem upwards, shutting the valve. Downstream pressure can be adjusted by removing the valve cap and turning the adjusting screw which varies the spring pressure against the diaphragm. This particular spring-loaded valve will fail in the open position in the case of a diaphragm rupture. Another, more complex, spring-loaded reducing valve is shown in figure 6-18.

The principal parts of a spring-loaded reducing valve are: (1) the main valve, an upward-seating valve which has a piston on top of its stem; (2) an upward-seating auxiliary (or controlling) valve; (3) a controlling diaphragm; and (4) an adjusting spring.

High-pressure steam (or other fluid) enters the valve on the inlet side and acts against the main valve disk, tending to close the main valve. However, high-pressure steam is also led through ports to the auxiliary valve, which controls the admission of high-pressure steam, to the top of the main valve piston. The piston has a larger surface area than the main valve disk; therefore, high-pressure steam acting on the top of the main valve piston will tend to open the main valve, and so allow steam at reduced pressure to flow out the discharge side.

But what makes the auxiliary valve open to allow high-pressure steam to get to the top of the main valve piston? The controlling diaphragm exerts a downward pressure upon the auxiliary valve stem, and this tends to open the valve. However, reduced-pressure steam is led back to the chamber beneath the diaphragm, and the steam exerts a pressure upward on the diaphragm, which tends to close the auxiliary valve. The position of the auxiliary valve, therefore, is determined by the position of the controlling diaphragm.

The position of the diaphragm at any given moment is determined by the relative strength of two opposing forces: (1) the downward force exerted by the adjusting spring, and (2) the upward force which is exerted on the underside of the diaphragm by the reduced-pressure steam. These two forces are continually seeking to reach a state of balance, and, because of this, the discharge pressure of steam is kept constant as long as the amount of steam used is kept within the capacity of the valve.

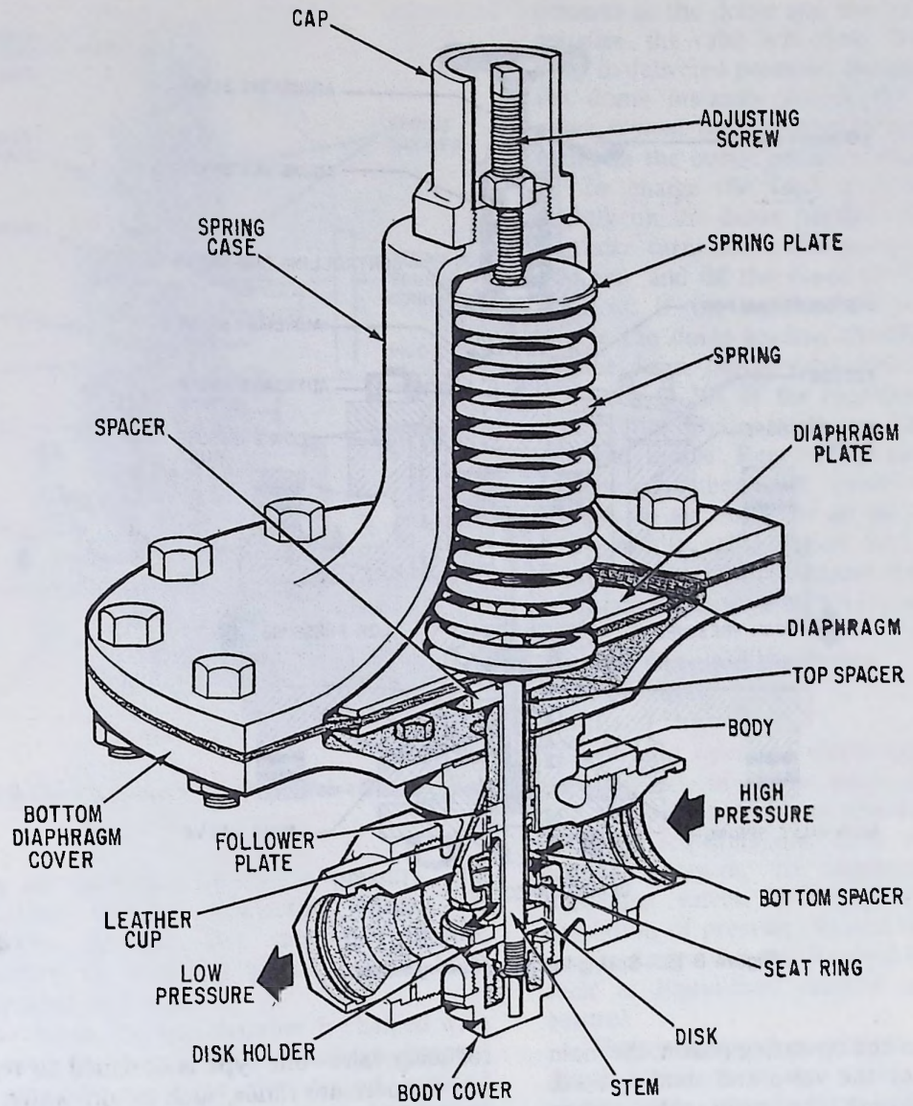
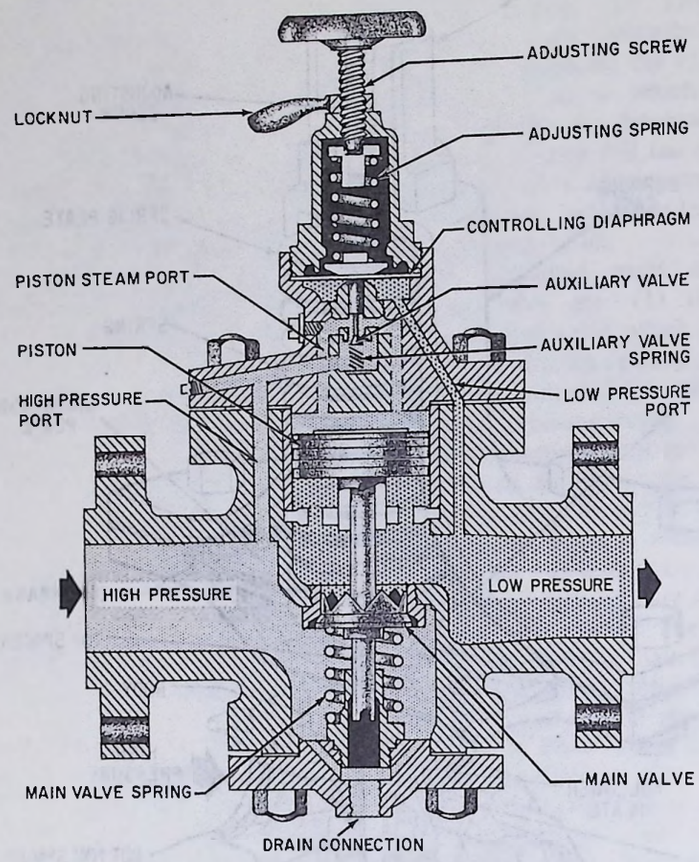


Figure 6-17.—Pressure reducing (spring-loaded) valve.

INTERNAL PILOT-ACTUATED PRESSURE REDUCING VALVE.—The internal pilot-actuated pressure reducing valve, shown in figure 6-19, uses a pilot valve to control the main valve. The pilot valve controls the flow of upstream fluid, which is ported to the pilot valve, to the operating piston which operates the main valve. The main valve is opened by the operating piston and closed by the main valve spring. The pilot valve is opened when the adjusting spring pushes downward on the pilot diaphragm and is closed when downstream pressure, sensed and piped into the valve beneath the pilot diaphragm, exerts a force that exceeds the force of the adjusting spring thereby raising the diaphragm to allow the pilot valve spring to close or throttle the pilot valve. When the pilot valve shuts off or throttles the flow of

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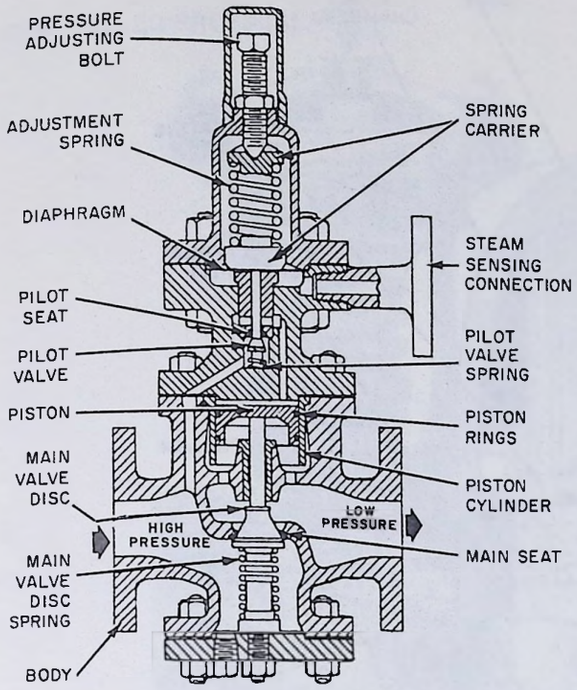
Figure 6-18.—Spring-loaded reducing valve.

upstream fluid to the operating piston, the main valve then pushes the valve and stem upward, throttling or closing the main valve. When downstream pressure drops off, the adjusting spring force, which is acting downward on the diaphragm, will overcome the force of the downstream system pressure, which is acting upward on the diaphragm. This will open the pilot valve, allowing upstream pressure to the top of the operating piston to open the main valve.

Pneumatic Pressure Controlled Reducing Valves

There are two types of the pneumatic-pressure-controlled (or gas-loaded) reducing valve—one type is designed to regulate low-temperature fluids, such as air, water, or oil (fig. 6-20); and the other type is designed to regulate high-temperature fluids, such as steam or hot water. The high-temperature fluid reducer is found only in older ships.

Air-controlled regulators operate on the principle that the pressure of an enclosed gas varies inversely as its volume. A reduction in volume results in an immediate increase in pressure, and an increase in volume results in an immediate decrease in pressure. A relatively small change in the large volume within the dome loading chamber produces only a slight pressure variation, while the slightest variation in the small volume within the actuating chamber



11.322

Figure 6-19.—Reducing valve (Atlas Valve Company).

creates an enormous change in pressure. The restricting orifice connecting these two chambers governs the rate of pressure equalization by retarding the flow of gas from one chamber to the other.

The dome loading chamber is charged with air or other compressible gases (such as nitrogen) at a pressure equal to the desired reduced pressure. When the chamber is loaded and when the loading valve is closed, the dome will retain its charge almost indefinitely. When the regulator is in operation, the trapped pressure within the dome passes into the actuating chamber through the small separation plate orifice and moves the large flexible diaphragm which forces the reverse acting valve off its seat. The pressure entering the regulator is then permitted to flow through the open valve into the reduced pressure line. A large pressure equalizing orifice transmits this pressure directly to the underside of the diaphragm. When the delivered pressure approximates the loading pressure in the dome and the unbalanced forces equalize, the valve will close. With the slightest drop in delivered pressure, the pressure charge in the dome instantly forces the valve open to allow system fluid to pass through and thereby maintain the outlet pressure relatively constant.

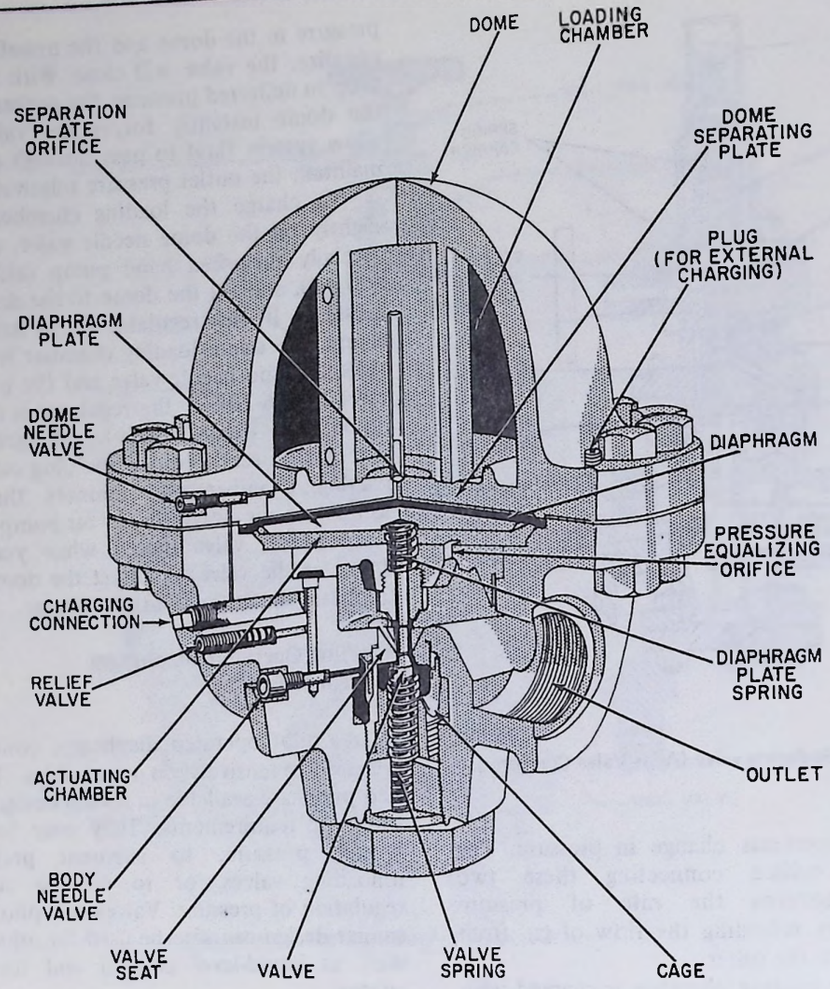
To charge the loading chamber, back off slightly on the dome needle valve, connect the specially furnished hand pump (either 300 or 600 psi), and fill the dome to the desired outlet pressure. If the regulator is to handle a gas, charge the dome loading chamber with this gas via the dome needle valve and the body needle valve (fig. 6-20). If the regulator is to handle a liquid, the dome must be charged from an external source. Remove the plug on the dome loading chamber and connect the external source, an air bottle or an air pump. Keep the body needle valve closed while you use the dome needle valve to adjust the dome pressure to obtain the desired outlet pressure.

Air-Pilot Operated Diaphragm Control Valves

Air-pilot operated diaphragm control valves are used extensively on naval ships. The valves and pilots are available in several designs to meet different requirements. They may be used to reduce pressure, to augment pressure, as unloading valves, or to provide continuous regulation of pressure. Valves and pilots of very similar design can also be used for other services such as liquid-level control and temperature control.

The air-operated control pilot may be either direct acting or reverse acting. A direct acting air-operated control pilot is shown in figure 6-21. In this type of pilot, the controlled pressure—that is, the pressure from the discharge side of the diaphragm control valve—acts on top of a diaphragm in the control pilot. This pressure is balanced by the pressure exerted by the pilot adjusting spring. If the controlled pressure increases and overcomes the pressure exerted by the pilot adjusting spring, the pilot valve stem is forced downward. This action causes the pilot valve to open thereby increasing the amount of operating air pressure going from the pilot to the diaphragm control valve. A reverse-acting pilot has a lever which reverses the

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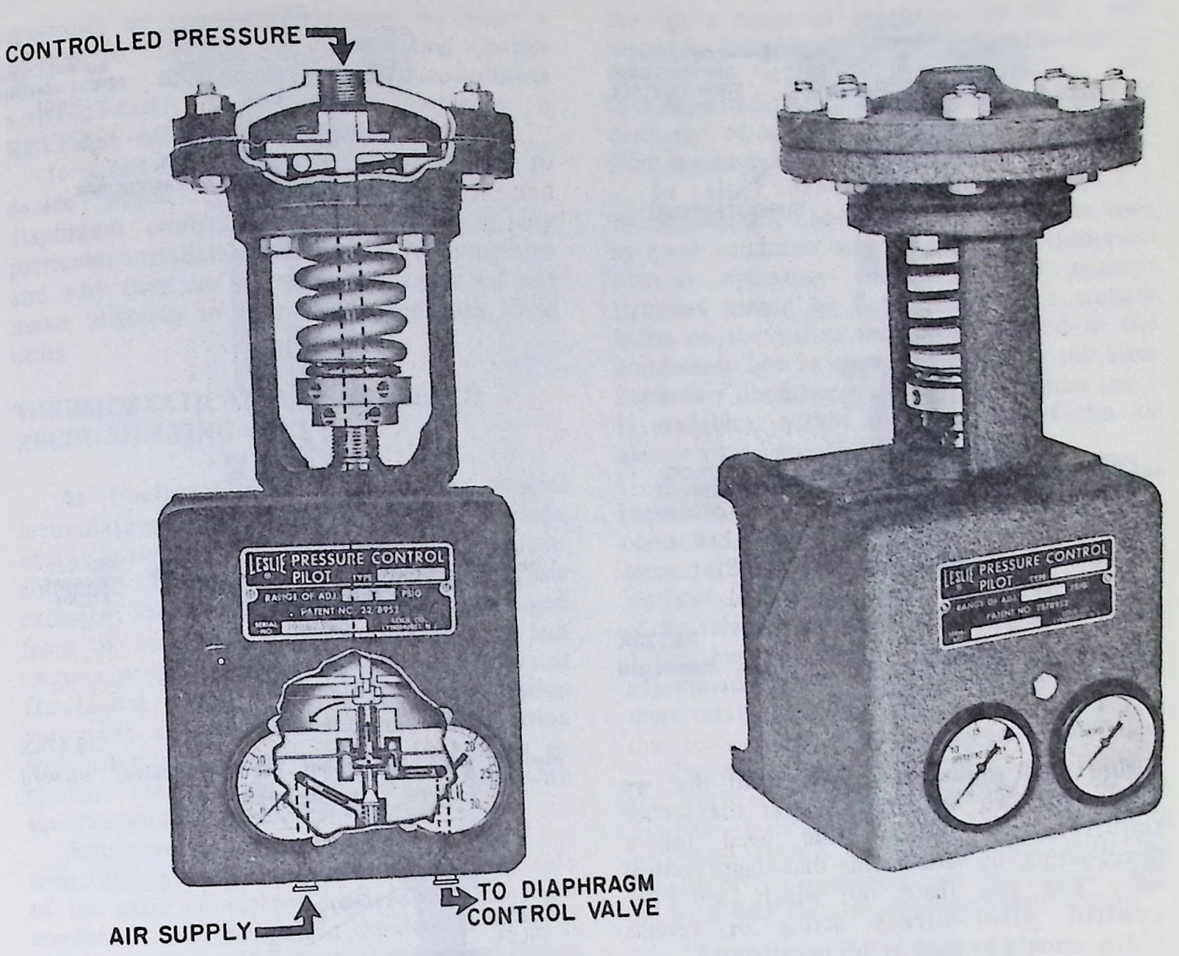
47.60

Figure 6-20.—Pneumatic-pressure-controlled reducing valve for low-temperature service.

pilot action. In a reverse-acting pilot, therefore, an increase in controlled pressure produces a decrease in operating air pressure.

In the diaphragm control valve, operating air from the pilot acts on the valve diaphragm. The superstructure, which contains the diaphragm, is direct acting in some valves and reverse acting in others. If the superstructure is direct acting, the operating air pressure from the control pilot is applied to the TOP of the valve diaphragm. If the superstructure is reverse acting, the operating air pressure from the pilot is applied to the UNDERSIDE of the valve diaphragm.

Figure 6-22 shows a very simple type of direct-acting diaphragm control valve with operating air pressure from the control pilot applied to the top of the valve diaphragm. Since the valve in the figure is a downward seating valve, any increase in operating air pressure pushes the valve stem downward and tends to close the valve.



38.121X

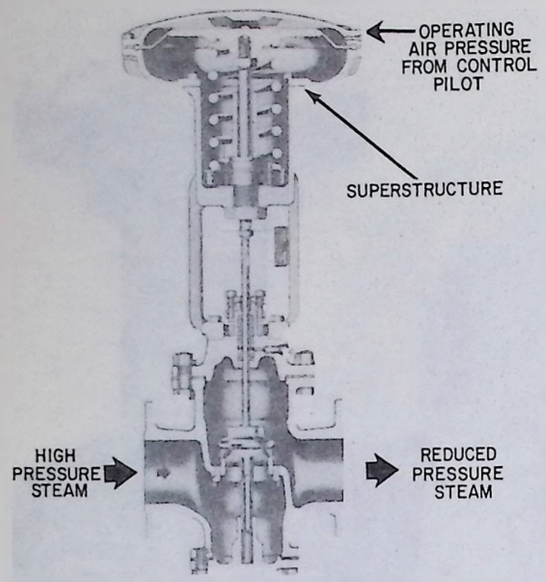
Figure 6-21.—Air-operated control pilot.

Now look at figure 6-23. This is also a direct-acting valve with operating air pressure from the control pilot applied to the top of the valve diaphragm. But the valve shown in figure 6-23 is more complicated than the one shown in figure 6-22. The valve shown in figure 6-23 is an upward seating valve rather than a downward seating valve. Therefore, any increase in operating air pressure from the control pilot tends to OPEN this valve rather than to close it.

As we have seen, the air-operated control pilot may be either direct acting or reverse acting. The superstructure of the diaphragm control valve may be either direct acting or reverse acting. And the diaphragm control valve may be either upward seating or downward seating. These three factors, as well as the purpose of the installation, determine how the diaphragm control valve and its air-operated control pilot are installed in relation to each other.

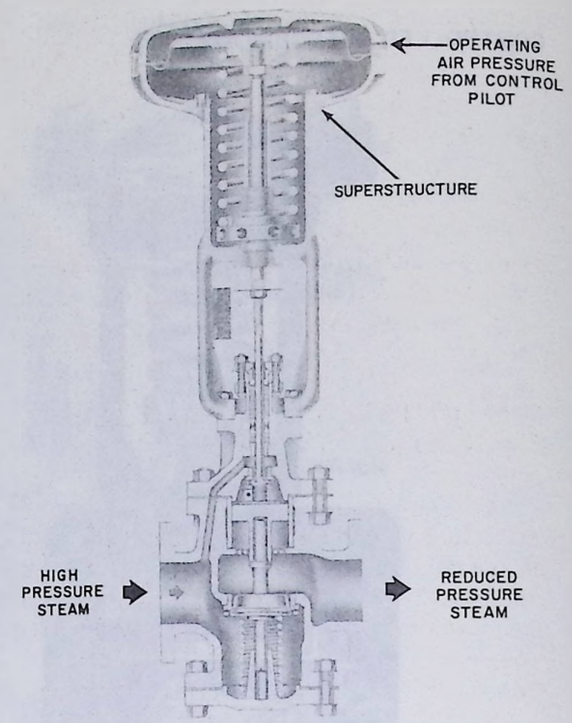
To see how these factors are related, let's consider an installation in which a diaphragm control valve and its air-operated control pilot are used to supply reduced-steam pressure.

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38.123X

Figure 6-22.—Diaphragm control valve, downward seating type.

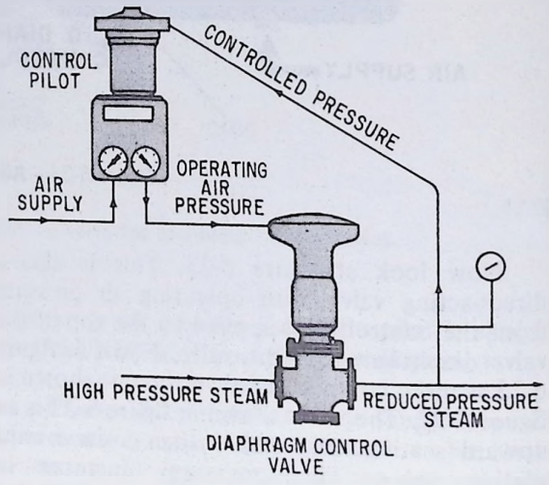


38.124X

Figure 6-23.—Diaphragm control valve, upward seating type.

Figure 6-24 shows one arrangement that we might use. We will assume that the service requirements indicate the need for a direct-acting, upward-seating diaphragm control valve. Can you figure out which kind of a control pilot—direct acting or reverse acting—should be used in this installation?

Let's try it first with a direct-acting control pilot. As the controlled pressure (discharge pressure from the diaphragm control valve) increases, increased pressure will be applied to the diaphragm of the direct acting control pilot. The valve stem will be pushed downward and the valve in the control pilot will be opened, thus sending an increased amount of operating air pressure from the control pilot to the top of the diaphragm control valve. The increased operating air pressure acting on the diaphragm of the valve will push the stem downward and, since this is an upward seating valve, this action will OPEN the diaphragm control valve still wider. Obviously, this won't work—for this application, an INCREASE in controlled pressure must result in a DECREASE in



38.125

Figure 6-24.—Arrangement of control pilot and diaphragm control valve for supplying reduced-steam pressure.

operating air pressure. Therefore, we made a mistake in choosing the direct-acting control pilot. For this particular pressure-reducing application, we should choose a REVERSE-ACTING control pilot.

It is not likely that you will be required to decide which type of control pilot and diaphragm control valve are needed in any particular installation. But you must know how and why they are selected so that you will not make mistakes in repairing or replacing these units.

THERMOSTATICALLY CONTROLLED RECIRCULATING VALVES

At fractional power, or cruising power, recirculating condensate from the discharge side of the main air ejector condenser to the main condenser is essential. Recirculation prevents excessive loss of feedwater (as vapor discharged from the air ejector after condenser vent) and ensures proper operation of the air ejectors at fractional power. To make recirculation automatic and to avoid excessive recirculation with attendant excessive loss of heat, most air ejector recirculating lines are fitted with thermostatically controlled valves.

Excessive heat loss can be avoided by recirculating condensate from the discharge side of the main air ejector condenser to the main condenser. The air ejector condensers must be supplied with cooling water (condensate) during their operation. A hand-controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used when the thermostatic valve is inoperative.

Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve. The thermostatic recirculating valves are actuated by the temperature of the condensate discharged from the air ejector after condenser. A rise in the water temperature, above the temperature at which the valve is set, results in automatic opening of the valve and recirculation of the heated water back to the condenser and through the air ejector again. The thermostatically controlled recirculating valves are adjusted through a range of approximately 40° F and should be individually set to open at the highest temperature at which the air ejectors will operate without loss of condenser vacuum or discharge of an appreciable amount of vapor from the air ejector after condenser vent.

In the interest of economy, the thermostatically controlled valve should be kept in good condition and properly set. Under all normal operating conditions, the manual bypasses should be kept closed. The control bulbs of the valves should be located in the condensate line as close as possible to the after condenser discharge, or preferably (when space is available), within the last pass of the air ejector after condenser water chest.

Figure 6-25 illustrates a thermostatic recirculating valve. This type of thermostatically controlled recirculating valve is also used on some distilling plants to control recirculation of seawater to maintain shell temperature. Failure of the valve to maintain the cooling water at the desired temperature is an indication of improper adjustment. It may also be an indication that the thermostatic elements of the valve are leaking or that some other portion of the valve has failed.

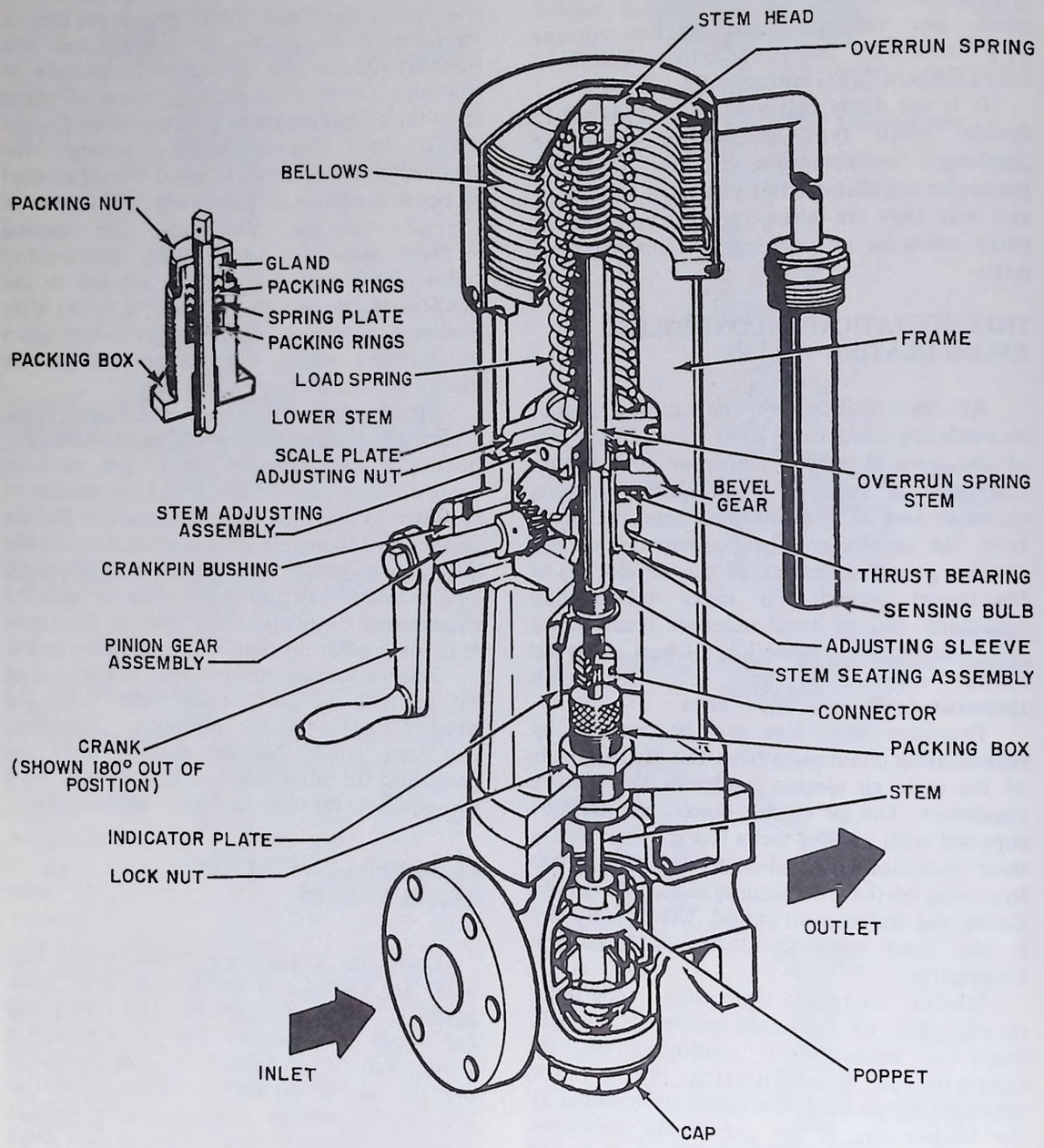
The main cause of improper adjustment of the valve is the lack of instructions for the proper adjustment procedure. Operating personnel should become familiar with the procedure for adjustment of this type of valve by consulting the manufacturer's instructions.

COMBINED EXHAUST AND RELIEF VALVES

Combined exhaust and relief valves (fig. 6-26) are used for steam exhaust from some auxiliary turbines such as the main feed pump and forced draft blowers. The valves provide a startup feature for lighting off the turbine in that the valve allows startup turbine exhaust to pass to the auxiliary exhaust system without allowing auxiliary exhaust steam to flow back into the turbine. The auxiliary valve in the combined valve provides a safety feature for turbine maintenance.

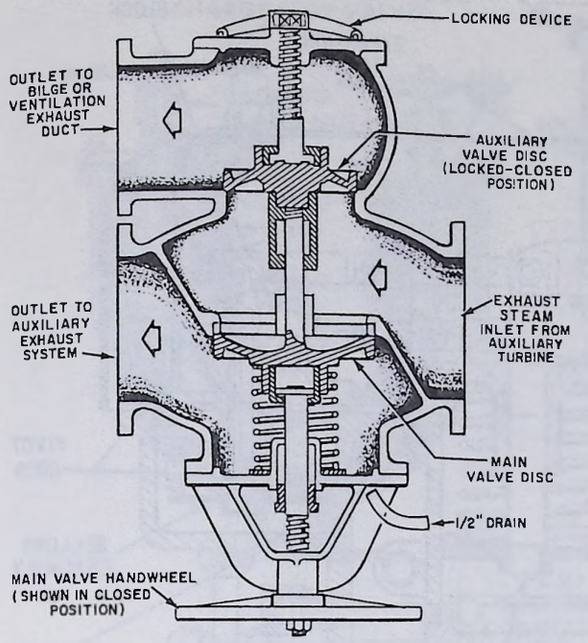
The combined exhaust and relief valve has three positions: relief position, normal operating position, and safety position.

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47.175

Figure 6-25.—Thermostatic recirculating valve.



47.200

Figure 6-26.—Typical combined exhaust and relief valve.

Relief Position

The relief position is for turbine startup. With the auxiliary valve locked shut, the main valve handwheel is turned in (clockwise) and seated against the bonnet yoke. (Contact of the handwheel against the bonnet yoke prevents gagging of the main valve disk; for this reason it is extremely important that the handwheel retaining nut be kept tightly secured to the valve stem at all times.) The spring-loaded main disk prevents backflow, but has sufficient clearance to open with pressure and protect turbine casing during startup.

Normal Operating Position

The normal operating position is to be used as soon as the turbine is started up. The main valve handwheel is backed out all the way (counterclockwise) pulling the main valve disk open and backseating it against the bonnet. The main valve is now wide open with minimum backpressure on the turbine.

Safety Position

The safety position of the valve is used during turbine overhaul. First the valve is put into the relief position, then the auxiliary valve is unlocked and backed out (with a wrench). This pulls up and locks the main valve disk against its seat, at the same time opening the auxiliary valve to provide an emergency steam escape from the turbine. The auxiliary valve is open for INADVERTENT startup ONLY. Full turbine flow may possibly overpressurize the turbine casing.

HYDRAULICALLY OPERATED GLAND SEAL REGULATOR

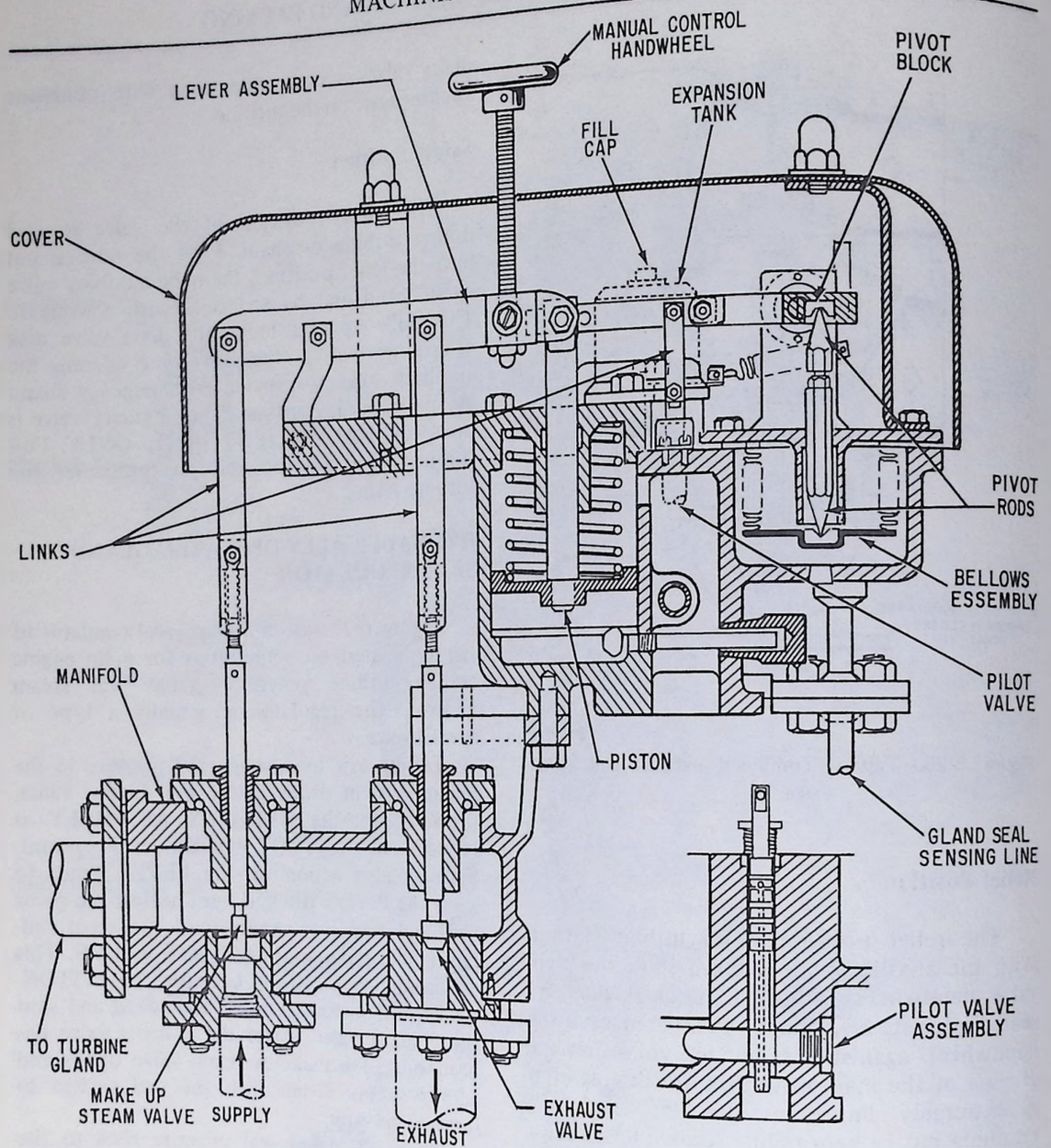
Figure 6-27 shows a gland seal regulator of the type used on some ships for main engine and/or turbine generator gland seal steam control. The regulator is actually a type of special valve.

During low load, when the pressure in the sealing system drops below the desired value, pressure on the BELLOWS ASSEMBLY is reduced and the PIVOT RODS move downward. Spring-loaded action on the LEVER tends to keep the PIVOT BLOCK hard against the pivot rod, and the lever moves with the pivot rod, raising the links and the PILOT VALVE. This action drains oil from beneath the PISTON, causing the piston to move downward and shut the exhaust valve. After the exhaust valve has been shut, the makeup steam valve opens and admits supply steam into the seal system to increase pressure.

When the gland seal pressure rises to the desired value, the reverse of the above events takes place. The increased pressure on the bellows raises the pivot rods and thus causes the pilot valve to admit oil to the piston. The piston moves upward to shut the makeup steam valve, after which the exhaust valve opens.

In case of a failure of the bellows, the pivot rods move downward to their furthest travel, and the pilot valve is raised to dump oil pressure from under the piston. The piston moves downward to shut the exhaust valve and to open

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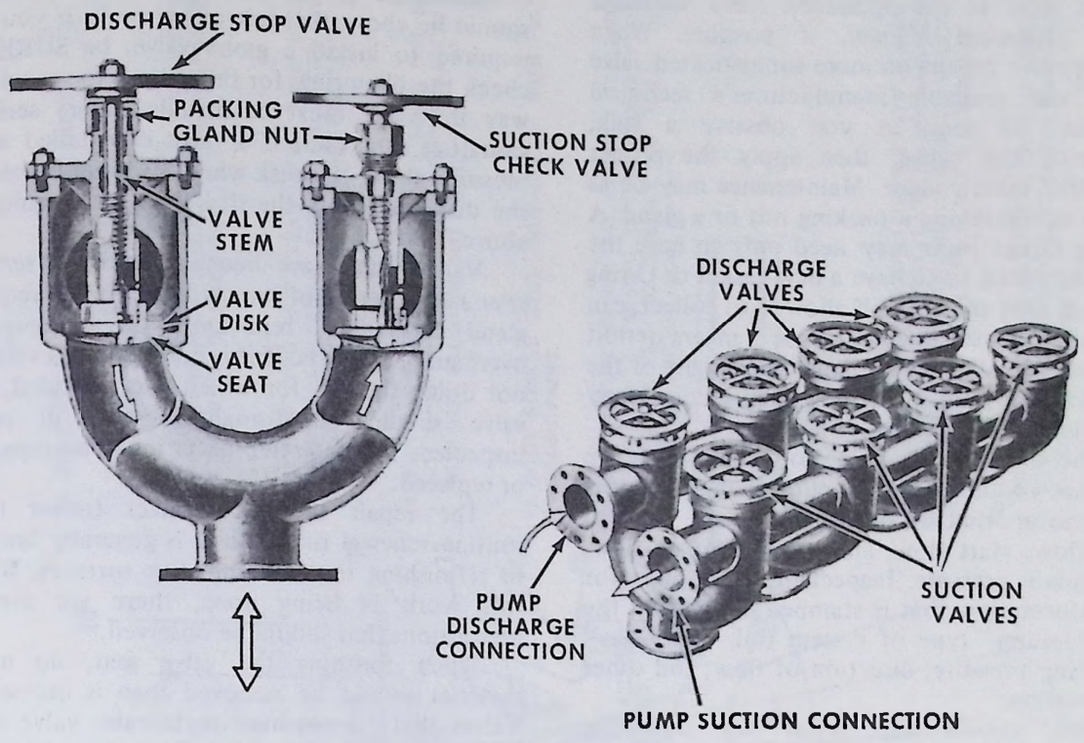
47.201

Figure 6-27.—Hydraulic steam seal regulator.

the makeup steam valve. This action provides a supply of gland seal to the shaft packing. The position of the valves can then be controlled manually by means of the control knob.

VALVE MANIFOLDS

Sometimes it is necessary to take suction from any one of many sources and discharge it to another unit or units of either the same or another group. A valve manifold is used for this type of operation. An example of such a manifold (fig. 6-28) is the fuel oil filling and transfer system where provision must be made for the transfer of oil from any tank to any other tank, to the service system, or to another ship. If, for example, the purpose is to transfer



47.63X

Figure 6-28.—Valve manifold showing cutaway view of the valves and typical combination of suction and discharge valves.

oil from tank No. 1 to tank No. 4, the discharge valve for tank No. 4 and the suction valve from tank No. 1 are opened, and all other valves closed. Fuel oil can now flow from tank No. 1, through the suction line, through the pump, through the discharge valve, and into tank No. 4. The manifold suction valves are often of the stop-check type to prevent draining of pumps when they are stopped.

REMOTE-OPERATED VALVES

Remote operating gear is installed to provide a means of operating certain valves from distant stations. Remote operating gear may be mechanical, hydraulic, pneumatic, or electric.

Some remote operating gear for valves is used in normal operation of valves. For example, the main engine throttle valves are opened and closed by a reach rod or series of reach rods and gears. Reach rods may be used to operate engineroom valves in instances where the valves are difficult to reach from operating stations.

Other remote operating gear is installed as emergency equipment. Some split-plant valves, main drainage valves, and main condenser injection and overboard valves are equipped with remote operating gear. These valves can be operated normally or in an emergency they may be operated from remote stations. Remote operating gear also includes a valve position indicator to show whether the valve is open or closed.

MAINTENANCE AND REPAIR OF VALVES

Preventive maintenance is the best way to extend the service life of valves and fittings.

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Always refer to the applicable *Navy Standard Valve Technical Manual*, if possible. When making valve repairs on more sophisticated valve types, use available manufacturer's technical manuals. As soon as you observe a leak, determine the cause, then apply the proper corrective maintenance. Maintenance may be as simple as tightening a packing nut or a gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, can ultimately cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and the fluid in these sagging sections may strain joints to the point of leakage.

Whenever you are going to install a valve, be sure that you know the function that the valve is to perform—that is, whether it must prevent back flow, start flow, stop flow, regulate flow, or regulate pressure. Inspect the valve body for the information that is stamped upon it by the manufacturer: type of system (oil, water, gas); operating pressure; direction of flow; and other information.

You should also know the operating characteristics of the valve, the metal from which it is made, and the type of end connection with which it is fitted. Operating characteristics and the material are factors that affect the length and kind of service that a valve will give; end connections indicate whether or not a particular valve is suited to the installation.

Valves should be installed in accessible places and with enough headroom to allow for full operation. Install valves with stems pointing upward, if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). If the valve is installed with the stem pointing downward, sediment will collect in the bonnet and score the stem. Also, in a line that is subject to freezing temperatures, liquid that is trapped in the valve bonnet may freeze and rupture it.

Globe valves may be installed with pressure either above the disk or below the disk, depending on which method will be best for the operation, protection, maintenance, and repair of the machinery served by the system. The question of what would happen if the disk became detached from the stem is a major consideration in determining whether pressure should be above the disk or below it. If you are required to install a globe valve, be SURE to check the blueprints for the system to see which way the valve must be installed. Very serious casualties can result if a valve is installed with pressure above the disk when it should be below the disk, or below the disk when it should be above.

Valves that have been in constant service over a long period of time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If it is known that a valve is not doing the job for which it is intended, the valve should be dismantled and all parts inspected. All defective parts must be repaired or replaced.

The repair of globe valves (other than routine renewal of packing) is generally limited to refinishing the seat and disk surfaces. When this work is being done, there are certain precautions that should be observed.

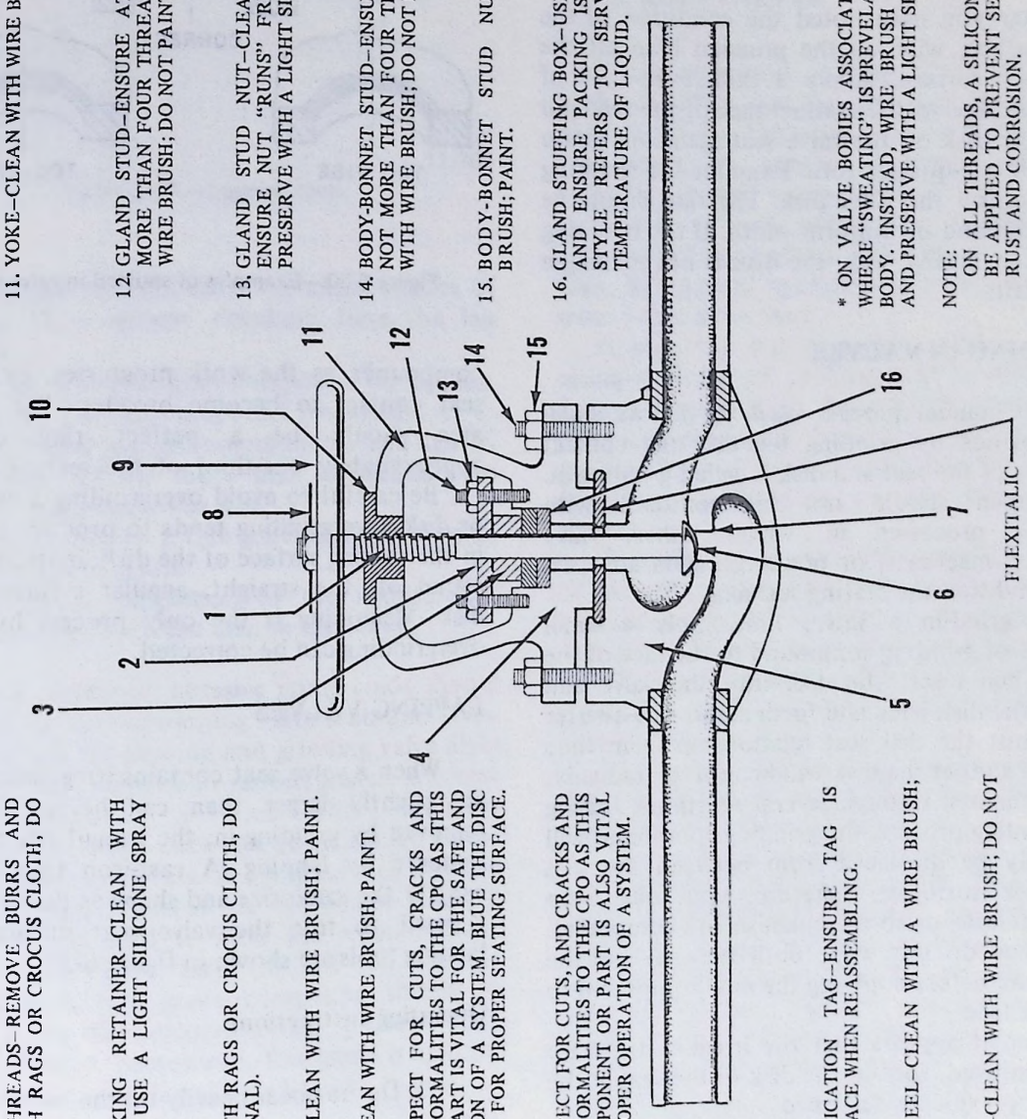
When finishing the valve seat, no more material should be removed than is necessary. Valves that do not have replaceable valve seats can be refinished only a limited number of times.

Before you do any repair to the seat and disk of a globe valve, check the valve disk to make certain that it is secured rigidly to and is square on the valve stem. Also, check to be sure that the stem is straight. If the stem is not straight, the valve disk cannot seat properly. Carefully inspect the valve seat and valve disk for evidence of wear, for cuts on the seating area, and for improper fit of the disk to the seat. If the disk and the seat appear to be in good condition, they should be spotted-in to find out whether they actually are in good condition.

Figure 6-29 shows a checkoff diagram for performing a routine inspection and minor maintenance of a globe valve.

SPOTTING-IN VALVES

The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of prussian blue evenly over the entire machined face surface of the disk. Then



1. STEM & STEM THREADS–REMOVE BURRS AND PAINT. CLEAN WITH RAGS OR CROCUS CLOTH, DO NOT PAINT.
2. STRONGBACK/PACKING RETAINER–CLEAN WITH WIRE BRUSH AND USE A LIGHT SILICONE SPRAY LUBRICANT.
3. GLAND–CLEAN WITH RAGS OR CROCUS CLOTH, DO NOT PAINT, (INTERNAL).
4. VALVE BONNET–CLEAN WITH WIRE BRUSH; PAINT.
5. VALVE BODY*–CLEAN WITH WIRE BRUSH; PAINT.
6. VALVE DISC–INSPECT FOR CUTS, CRACKS AND REPORT ANY ABNORMALITIES TO THE CPO AS THIS COMPONENT OR PART IS VITAL FOR THE SAFE AND PROPER OPERATION OF A SYSTEM. BLUE THE DISC AND CHECK SEAT FOR PROPER SEATING SURFACE.
7. VALVE SEAT–INSPECT FOR CUTS, AND CRACKS AND REPORT ANY ABNORMALITIES TO THE CPO AS THIS PARTICULAR COMPONENT OR PART IS ALSO VITAL FOR SAFE AND PROPER OPERATION OF A SYSTEM.
8. VALVE IDENTIFICATION TAG–ENSURE TAG IS READABLE. REPLACE WHEN REASSEMBLING.
9. VALVE HANDWHEEL–CLEAN WITH A WIRE BRUSH; DO NOT PAINT.
10. STEM BUSHING–CLEAN WITH WIRE BRUSH; DO NOT PAINT.
11. YOKE–CLEAN WITH WIRE BRUSH; PAINT.
12. GLAND STUD–ENSURE AT LEAST ONE BUT NOT MORE THAN FOUR THREADS VISIBLE; CLEAN WITH WIRE BRUSH; DO NOT PAINT.
13. GLAND STUD NUT–CLEAN WITH WIRE BRUSH; ENSURE NUT "RUNS" FREELY ON GLAND STUD; PRESERVE WITH A LIGHT SILICONE LUBRICANT.
14. BODY-BONNET STUD–ENSURE AT LEAST ONE BUT NOT MORE THAN FOUR THREADS VISIBLE; CLEAN WITH WIRE BRUSH; DO NOT PAINT.
15. BODY-BONNET STUD NUT–CLEAN WITH WIRE BRUSH; PAINT.
16. GLAND STUFFING BOX–USE CORRECT STYLE SIZE AND ENSURE PACKING IS CUT PROPERLY. THE STYLE REFERS TO SERVICE OF VALVE AND TEMPERATURE OF LIQUID.

* ON VALVE BODIES ASSOCIATED WITH S/W SYSTEMS WHERE "SWEATING" IS PREVELANT, DO NOT PAINT THE BODY. INSTEAD, WIRE BRUSH TO REMOVE VETIGRIS AND PRESERVE WITH A LIGHT SILICONE LUBRICANT.

NOTE:
ON ALL THREADS, A SILICONE LUBRICANT SHOULD BE APPLIED TO PREVENT SEIZING AND TO RETARD RUST AND CORROSION.

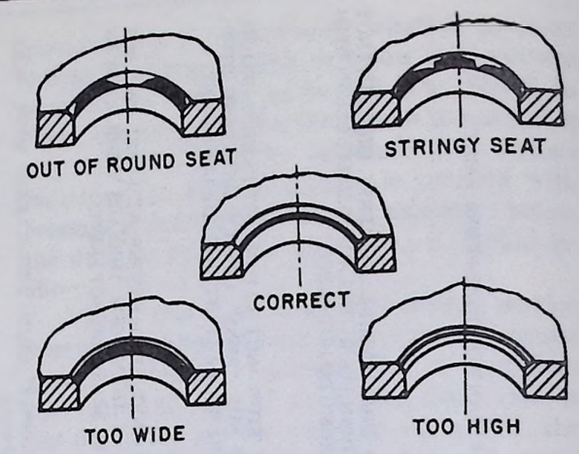
47.202

Figure 6-29.—Valve maintenance checkoff diagram.

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insert the disk into the valve and rotate it one-quarter turn, using a light downward pressure. The prussian blue will adhere to the valve seat at those points where the disk makes contact. Figure 6-30 shows the appearance of a correct seat when it is spotted-in; it also shows the appearance of various kinds of imperfect seats.

After you have noted the condition of the seat surface, wipe all the prussian blue off the disk face surface. Apply a thin, even coat of prussian blue to the contact face of the seat and place the disk on the valve seat again and rotate the disk one-quarter turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not making a proper fit.



8.71

Figure 6-30.—Examples of spotted-in valve seats.

GRINDING-IN VALVES

The manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk is called grinding-in. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about one-quarter turn; shift the disk-seat relationship from time to time so that the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, you must stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one-third of the seating surface.

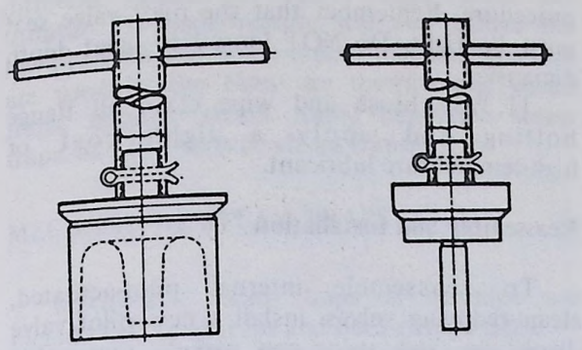
Be careful to avoid overgrinding a valve seat or disk. Overgrinding tends to produce a groove in the seating surface of the disk; it also tends to round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

LAPPING VALVES

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, the irregularities can be removed by lapping. A cast-iron tool (lap) of exactly the same size and shape as the valve disk is used to true the valve seat surface. Two lapping tools are shown in figure 6-31.

Operating Instructions

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the valve seat occasionally so that the lap will gradually and slowly rotate around the entire seat circle.



11.353

Figure 6-31.—Lapping tools.

4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use clean compound for lapping.
6. Replace the compound frequently.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth, even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. Upon completion of the lapping job, spot-in and grind-in the disk to the seat.

Only approved abrasive compounds should be used for reconditioning valve seats and disks. Compounds for lapping and grinding valve disks and seats are supplied in various grades. A coarse grade compound is used when extensive corrosion or deep cuts and scratches are found on the disks and seats. A compound of medium grade is used to follow up the coarse grade; it may also be used to start the reconditioning process on valves that are not too severely damaged. A fine grade compound should be used when the reconditioning process nears completion. A microscopic-fine grade is used for finish lapping and for all grinding-in.

REFACING VALVES

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. However, the lathe, rather than the reseating machine, should be used for refacing all valve disks and all hard-surfaced valve seats.

Work that must be done on a lathe or with a power grinder should be turned over to shop personnel.

REPACKING VALVES

If the stem and packing of a valve are in good condition, you can normally stop packing gland leaks by tightening up on the packing. You must be careful, however, to avoid excessive thread engagement of the packing gland studs (if used) and to avoid tightening old, hardened packing which will cause the valve to seize. Subsequent operation of such a valve may score or bend the stem.

Coils, rings and corrugated ribbon are the common forms of packing used in valves. The form of packing to be used in repacking a particular valve will depend on the valve size, application and type. (Additional information concerning packing is covered later in this chapter.)

Basically, valve repacking involves removal of the old packing (this must be done carefully to avoid scoring of the gland or stem), inspecting and cleaning the valve stem and gland, and installing new packing. Adding the new packing is not difficult but must be done properly or the valve will leak or bind.

When using ring packing, cut the packing so the ends fit flush and stagger the splits from each other to prevent leakage.

Some special purpose valves are provided with pre-cut packing available through the supply system, which must be soaked in pure (distilled) water for several hours prior to installation. Many valves require the use of packing pushers (either wooden or brass bushings) to ensure that the bottom rings of packing get compressed properly. These packing pushers fit into the packing gland stuffing box and the gland is tightened up with the pushers inside. After compression of the packing, the gland and pushers are removed and more packing is added. Different lengths of packing pushers are required to provide for the decreasing depths of the gland stuffing box as packing is added.

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INTERNAL PILOT-ACTUATED, STEAM-REDUCING VALVES

Internal pilot-actuated, steam-reducing valves should be isolated, removed, and disassembled in accordance with manufacturer's instructions.

Preventive Maintenance

When valves are disassembled, the most important preventive maintenance procedures are as follows:

1. Clean the parts with solvent. Remove foreign materials with crocus cloth, except for nonmetallic parts. Check the main and pilot valves to ensure that they move freely in their guides and are properly seated.
2. Clean the guide stems and bushings with crocus cloth.
3. Inspect the guide stems at the junction with the valve disk by using dye penetrant for fatigue cracks. Replace if necessary.
4. Inspect the seating surfaces for damage. Fine cracks or small pits can be removed by handlapping the disk to seat with an appropriate, very fine lapping compound. If the seating surfaces are badly wire-drawn, scored, or pitted, replace the disk and seat or reface the seating surfaces.
5. Clean the cylinder liner, where applicable, with crocus or very fine aluminum oxide cloth. Badly scored liners should be rehoned or replaced. In honing, an I.D. variation of 0.005 inch over the standard dimension shown on the drawing is permissible.
6. Inspect the piston seals for damage and, if piston rings are used, they should move and expand freely in grooves; replace if damaged or distorted.
7. Handlap the pilot valve and clean the guiding surfaces with crocus cloth.
8. Run soft copper wire through control ports to clean out dirt, and blow out with compressed air.
9. Inspect all flange seating surfaces for signs of wire drawing. Remachine if necessary.
10. Check the pilot valve stem clearance after tightening the pilot valve seat. Refer to the applicable technical manual for the prescribed procedure. Remember that the pilot valve seat must be tight. Do NOT loosen to meet depth dimension.
11. Wire brush and wipe clean all flange bolting and apply a light coat of high-temperature lubricant.

Reassembly and Installation

To reassemble internal pilot-actuated, steam-reducing valves, install a new pilot valve diaphragm, and, using new gaskets, reassemble the valve.

The installation and adjustment procedure for internal pilot-actuated, steam-reducing valves is as follows:

1. Reinstall the valve in the line.
2. Back off the adjusting screw to release compression on the adjusting spring.
3. Open the stop valve in the remote impulse line, where applicable.
4. Slowly, open wide the inlet stop valve. On high capacity valves, use the bypass to bring the system up to slightly under the desired pressure setting.
5. Fully open any stop valves between the regulator outlet and the discharge pressure gage. (The gage should be ahead of the outlet stop valve.) Partially open the outlet stop valve. Where possible, the flow through the regulator should be throttled by using a valve downstream of the discharge pressure gage so that the regulator may be set at a low flow condition.
6. Slowly, turn down on the adjusting screw until the desired downstream pressure is shown on the discharge pressure gage.
7. Secure the bypass valve.
8. Slowly, bring up the regulator to full flow and check the regulation.
9. To change the outlet pressure, turn the adjusting screw clockwise to increase the pressure and counterclockwise to decrease the pressure.

STEAM TRAPS

Steam traps are installed in steam lines to drain condensate from the lines without allowing the escape of steam. There are many

different designs of steam traps; some are suitable for high-pressure use and others for low-pressure use. Some types of steam traps that are used in the Navy are thermostatic steam traps, impulse steam traps, bimetallic steam traps, and orifice-type steam traps.

MECHANICAL STEAM TRAPS

Mechanical steam traps in common use include ball float traps and bucket type traps.

The operation of the bucket type steam trap, shown in figure 6-32, is controlled by the condensate level in the trap body. The bucket floats as condensate enters the trap body. The valve is connected to the bucket in such a way that the valve closes as the bucket rises. As condensate continues to flow into the trap body, the valve remains closed until the bucket is full. When the bucket is full, it sinks and thus opens the valve. The valve remains open until enough condensate has blown out to allow the bucket to float, thus closing the valve.

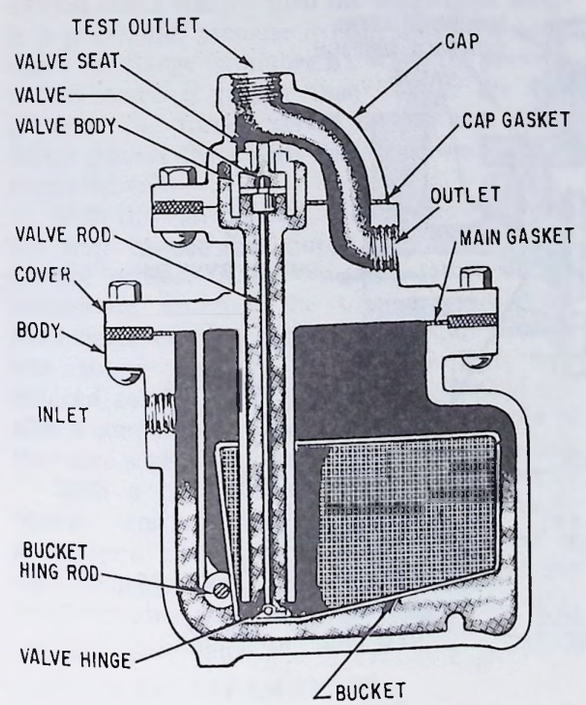


Figure 6-32.—Bucket type steam trap.

Figure 6-33 illustrates a ball-float type steam trap. This trap works much in the same way as the bucket trap. Condensate and steam enter the body of the trap and the condensate collects at the bottom. As the condensate level rises, the ball float rises until it is raised enough to open the outlet valve of the trap. When the outlet valve opens, the condensate flows out of the trap into the drain system and the float level drops, shutting off the valve until the condensate level rises again.

THERMOSTATIC STEAM TRAPS

There are several types of thermostatic steam traps. In general, these traps are more compact and have fewer moving parts than most mechanical steam traps. The operation of a bellows type thermostatic trap is controlled by expansion of the vapor of a volatile liquid, enclosed in a bellows type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, thus causing expansion of the bellows. The valve is attached to the bellows in such a way that the valve closes when the bellows expands. The valve remains closed, trapping steam in the trap body. As the steam cools and condenses, the bellows cools and

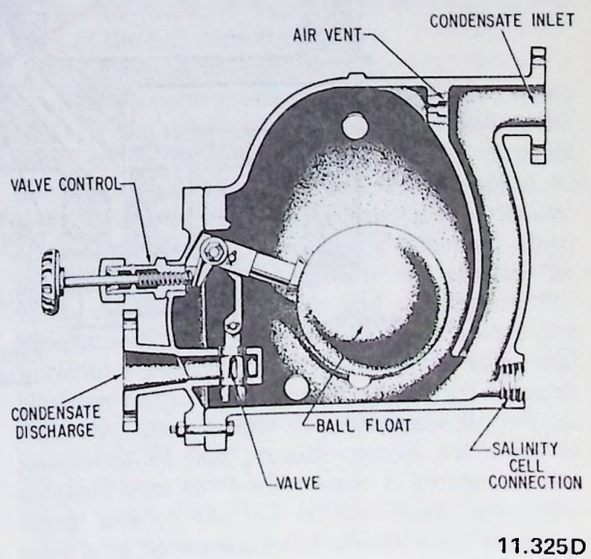


Figure 6-33.—A ball float steam trap.

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contracts, thereby opening the valve and allowing the condensate to drain.

IMPULSE STEAM TRAPS

Impulse steam traps of the type shown in figure 6-34 are commonly used in steam drain collecting systems aboard ship. Steam and condensate pass through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk.

The impulse type steam trap operates on the principle that hot water under pressure tends to flash into steam when the pressure is reduced. So that you understand how this principle is utilized, let's consider the arrangement of parts shown in figure 6-34 and see what happens to the flow of condensate under various conditions.

The only moving part in the steam trap is the disk, which is rather unusual in design. Near the top of the disk there is a flange that acts as a piston. As you can see in the inset in figure 6-34 the working surface above the flange is larger than the working surface below the flange; the importance of having this larger effective area above the flange is brought out later in this discussion.

A control orifice runs through the disk from top to bottom, being considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the flange) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the flange and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first cut in, (put in service) pressure from the inlet (chamber A) acts against the underside of the flange and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat, and, at the same time, a small amount of condensate (called CONTROL FLOW) flows up past the

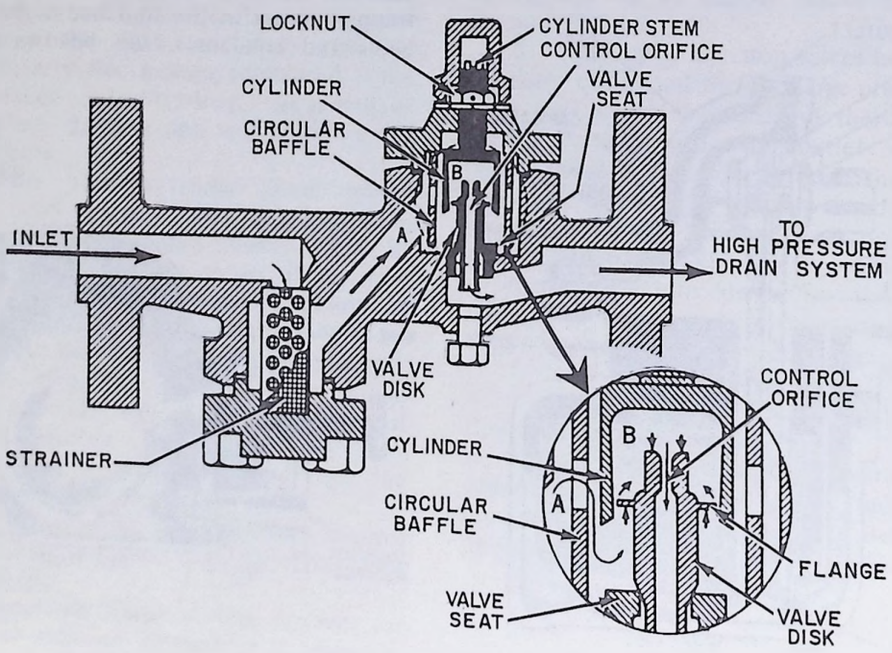


Figure 6-34.—Impulse steam trap. 38.126

flange and into chamber B. The control flow discharges through the control orifice, into the outlet side of the trap, and the pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the flange until a balanced position is reached in which the total force exerted above the flange is equal to the total force exerted below the flange. It is important to note that there is still a PRESSURE DIFFERENCE between chamber A and chamber B. The FORCE is equalized because the effective area above the flange is larger than the effective area below the flange. The difference in working area is such that the valve maintains an open, balanced position when the pressure in chamber B is 86% of the pressure in chamber A.

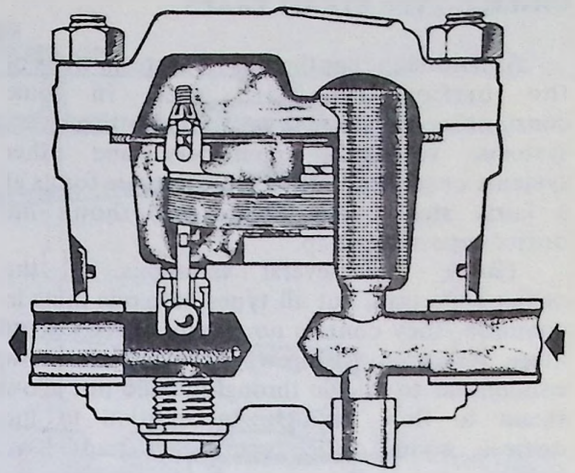
As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low pressure area. Since the steam has a much larger volume than the water from which it is generated, pressure is built up in the space above the flange (chamber B). When the pressure in this space is greater than 86% of the inlet pressure, the force exerted on the top of the flange pushes the entire disk downward and so closes the valve.

With the valve closed, the only flow through the trap is past the flange and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing into steam. Pressure in chamber B is thus reduced to the point that the valve opens and allows condensate to flow through the orifice in the valve seat. Thus the entire cycle is repeated.

With a normal condensate load the valve opens and closes at frequent intervals, discharging a small amount of condensate at each opening. With a heavy condensate load, the valve remains wide open and allows a heavy, continuous discharge of condensate.

BIMETALLIC STEAM TRAPS

Bimetallic steam traps of the type shown in figure 6-35 are used in many ships to drain



147.104X

Figure 6-35.—Bimetallic steam trap.

condensate from main steam lines, auxiliary steam lines, and other steam components. The main working parts of this steam trap are a segmented bimetallic element and a ball-type check valve.

The bimetallic element consists of several bimetallic strips fastened together in a segmented fashion, as shown in figure 6-35. One end of the bimetallic element is fastened rigidly to a part of the valve body; the other end, which is free to move, is fastened to the top of the stem of the ball-type check valve.

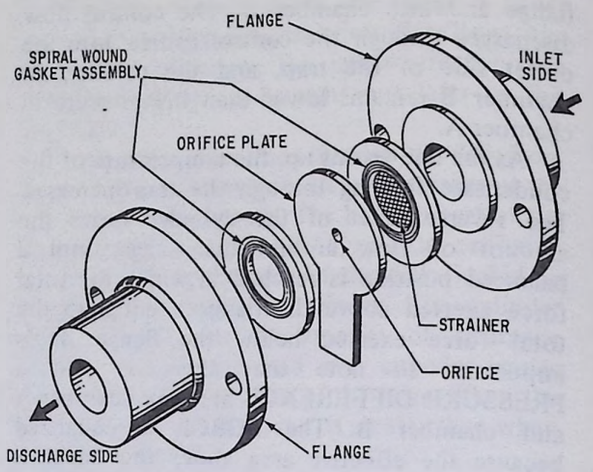
Line pressure acting on the check valve tends to keep the valve open. When steam enters the trap body, the bimetallic element expands unequally because of the different response to temperature of the two metals; the bimetallic element deflects upward at its free end, thus moving the valve stem upward and closing the valve. As the steam cools and condenses, the bimetallic element moves downward, toward the horizontal position, thus opening the valve and allowing some condensate to flow out through the valve. As the flow of condensate begins, an unbalance of line pressure across the valve is created; since the line pressure is greater on the upper side of the ball of the check valve, the valve now opens wide and allows a full capacity flow of condensate.

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ORIFICE-TYPE STEAM TRAPS

Aboard ship, continuous-flow steam traps of the orifice type are used in some constant-service steam systems, oil heating steam systems, ventilation preheaters, and other systems or services in which condensate forms at a fairly steady rate. Figure 6-36 shows one orifice-type steam trap.

There are several variations of the orifice-type trap, but all types have one thing in common—they contain no moving parts. One or more restricted passageways or orifices allow condensate to trickle through but do not allow steam to flow through. In addition to the orifices, some orifice-type steam traps have baffles.



47.203

Figure 6-36.—Constant-flow drain orifice.

MAINTENANCE OF STEAM TRAPS

A strainer is installed just ahead of each steam trap. The strainer must be kept clean and in good condition to keep scale and other foreign matter from getting into the trap. Scale and sediment can clog the working parts of a steam trap and seriously interfere with the working of the trap.

Steam traps that are not working properly can waste a large amount of steam and can cause operating trouble in vital systems and machinery.

One way to check on the operation of a steam trap is to listen to it. If the trap is leaking, you will probably be able to hear it blowing through. Another way to check the operation of steam traps is to check the pressure in the drain system. A leaking steam trap causes an unusual increase in pressure in the drain system. When this condition is observed, the defective trap can be located by cutting out (isolating from the system) traps, one at a time, until the pressure in the drain system returns to normal.

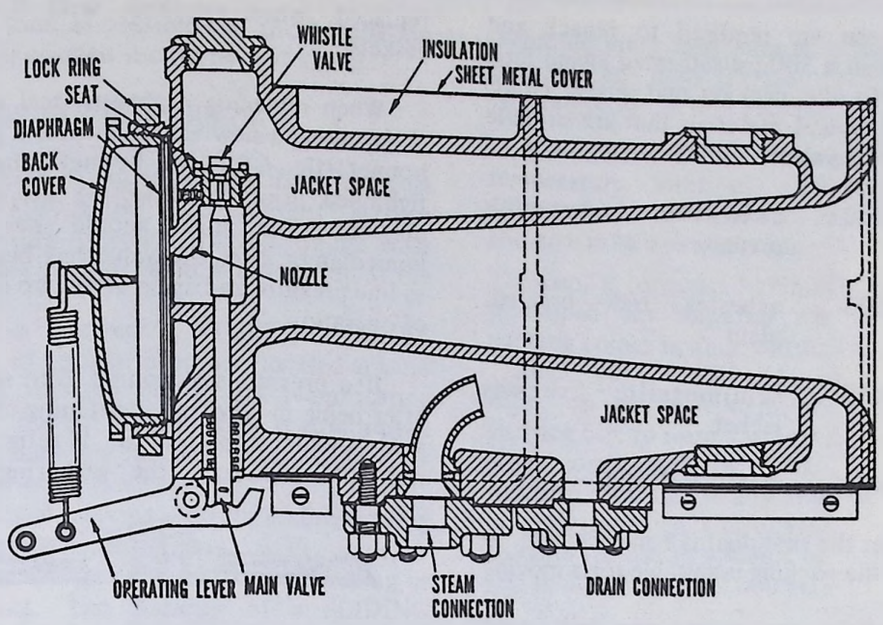
Defective steam traps should be disassembled, cleaned, and inspected. After determining the cause of the trouble, repair or replace parts as required. In some steam traps, the main working parts can be replaced as a unit; in others, you may have to grind in a seating surface, replace a disk, or perform other repairs. Defective trap discharge valves should be reseated. Always install new gaskets when reassembling a steam trap.

STEAM WHISTLES

Since you will have to maintain, and occasionally repair, the steam whistles installed on your ship, you should know something about their construction and how they work.

The steam whistle illustrated in figure 6-37 is of the diaphragm type and is typical of the steam whistles used on modern ships. When the operating lever is pulled, the valve opens and admits steam through the orifice. This steam forces the spring-metal diaphragm disks to the left. As the disks attempt to spring back against the nozzle, they vibrate and produce an audible sound. The steam passes out around the nozzle and through the horn. Condensate leaks off through the drain connection. Before the whistle is used, the drain should be opened.

To ensure against damage, a steam separator (located below decks) is installed in the steam line to the whistle. The separator removes condensate from the steam by imparting a whirling motion to the steam when it passes on its way to the whistle. The whirling motion is set up by stationary curved baffles and guide vanes.



47.64X

Figure 6-37.—Sectional view of a diaphragm-type steam whistle.

Water is removed from the steam by the centrifugal motion imparted to the steam by the baffles and guide vanes.

When a ship is in port, the steam lines to the whistle should be secured. About an hour prior to getting underway, the whistle steam lines should be turned on with all drains open and traps in operation for at least 30 minutes to ensure proper heating and removal of condensate. AT NO TIME, while underway, should the whistle steam lines be secured.

PACKING AND GASKET MATERIALS

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines and to seal connections that slide or rotate under operating conditions. There are many types and forms of packing and gasket materials available commercially. To simplify the selection of packing and gasket materials commonly used in naval service, the Naval Sea Systems Command has prepared a packing and gasket chart (Mechanical Standard Drawing B-153) showing the symbol numbers and the recommended applications of all types and kinds of packing and gasket materials. This chart is usually posted in the engineering spaces or the Logroom.

The symbol number used to identify each type of packing and gasket consists of a four-digit number. The first digit indicates the class of service with respect to fixed and moving joints; the numeral 1 indicates a moving joint (moving rods, shafts, valve stems) and the numeral 2 indicates a fixed joint (flanges, bonnets). The second digit indicates the material of which the packing or gasket is primarily composed—asbestos, vegetable fiber, rubber, metal, etc. The third and fourth digits indicate the different styles or forms of the packing or gaskets made from the material.

Practically all shipboard packing and gasket problems can be solved by selecting the correct material from the listings on the packing and gasket chart. The following examples show the kind of information that you can get from the packing and gasket chart.

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Suppose you are required to repack and install a valve in a 300-psi saturated steam line. By referring to the packing and gasket chart, you will find several materials that are suitable for repacking the valve:

Symbol 1100 . . . asbestos, rod, high pressure

Symbol 1103 . . . asbestos, rod, braided, plain

Symbol 1400 . . . semimetallic asbestos jacket

Symbol 1430 . . . metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

For installing the valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following materials:

Symbol 2150 . . . asbestos, sheet, compressed

Symbol 2151 . . . asbestos, metallic cloth, sheet

Symbol 2410 . . . gaskets, metallic-asbestos, spiral-wound

In addition to the Naval Sea Systems Command chart, most ships have a packing and gasket chart made up specifically for each ship. The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping system, machinery, and hull fittings.

RENEWING BONNET GASKETS AND SEAL RINGS IN VALVES

Care must be taken in reassembling valves with gaskets under the bonnets to ensure an even compression of the gasket, to prevent misalignment. Bonnet gaskets should be replaced, when required, with Symbol 2410 gaskets.

When replacing a pressure-seal ring (gasket) or installing a new valve that has a pressure-seal bonnet (fig. 6-38), the bonnet joint should be tightened prior to subjecting the valve to line pressure. The joint should be retightened immediately after the valve has been subjected to line pressure and again after two or three days of operation.

If a pressure-seal bonnet joint starts to leak after being in service, retightening of the bonnet studs should stop the leak. If retightening does not stop the leak, the seal ring should be

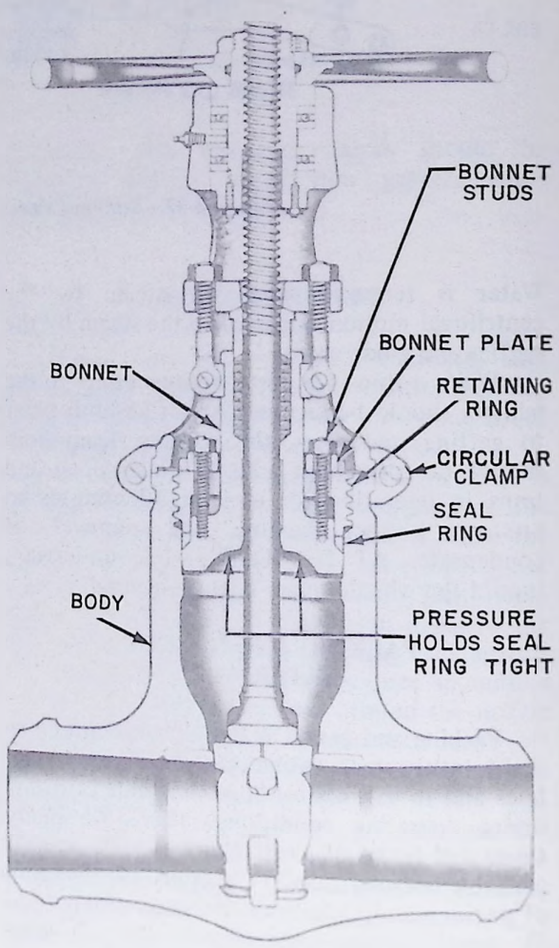


Figure 6-38.—Pressure-seal bonnet.

replaced as soon as possible and the installation procedure mentioned should be performed.

PACKING OF MOVING JOINTS

The packing of moving joints offers the most difficulty. The seals must prevent leakage without causing excessive friction, undue wear of the moving part, or rapid deterioration of the packing.

Packing is inserted in STUFFING BOXES that consist of annular chambers located around valve stems, rotating shafts, and reciprocating pump rods. The packing material is compressed to the necessary extent and held in place by gland nuts or other devices.

The types of packing used for sealing moving joints illustrated in figure 6-39 depends primarily on whether the seal is for a sliding or rotating joint. The packing of a SLIDING JOINT may be one of a large variety of types. High-pressure asbestos rod packing was formerly used exclusively for sealing steam joints (rods, valve stems, etc). This type has been superseded to a large extent, however, by WIRE-INSERTED SQUARE-BRAIDED ASBESTOS, (for pressures up to 400 psi and temperatures up to 700° F) and by PLASTIC NONMETALLIC ASBESTOS ENCASED IN A BRAIDED WIRE COVERING (for pressures up to 650 psi and temperatures up to 850° F).

The sealing of ROTATING JOINTS is a more difficult problem than that of sliding joints. With this type of joint, it is possible for the packing to create enough friction to prevent the machine from operating. In the sliding joint, the heat of friction created by the packing is dissipated through the moving part of the joint. This does not happen in the rotating joint, where the friction heat builds up on the wearing faces of the packing and the shaft, unless other means are provided for its dissipation. Packings composed of materials with high heat conductivity properties, along with an allowance for leakage, take care of this heat dissipation in rotating joints. It is very important, however, that pressure applied to the packing be kept at the minimum which keeps the leakage within the allowable limits.

A relatively new material used for sealing the packing glands of all freshwater pumps, including main feed pumps, is asbestos packing impregnated with Teflon (TFE), commonly referred to as "Teflon Packing."

CAUTION: Teflon packing has an operating temperature limit of 500° F. Above this temperature, the material may "breakdown" and give off a poisonous gas.

Also, a corrugated ribbon packing has been developed for universal use on valves. This packing comes in four widths (1 inch, 3/4 inch, 1/2 inch, and 1/4 inch) and is easily cut to length, rolled on the valve stem, and pushed into the stuffing box to form a solid, endless packing ring when compressed (fig. 6-40). The packing does not turn rock hard at any temperature, therefore is easily removed. Corrugated ribbon packing is suitable for use in systems of high temperatures (up to 1200° F and 2,000 psi).

Installation of Rod Packing

In the installation of rod packing, care must be taken both to use the proper packing material and to detect and correct any deficiencies existing in the joint itself. The best grade of packing cannot seal a rod effectively if:

1. The rod is bent, scored, or rusty.
2. The gland is cocked.
3. The stuffing box and gland are scored or nicked.
4. The gland is out of alignment with the shaft.
5. All the old, hard, dry packing is not removed.
6. The threads on the gland studs are burred to the extent that the setting up of the gland nuts is prevented.

Whenever a stuffing box is broken down, the box, gland, rod, and studs should be carefully inspected to determine whether any of the above conditions exist. The packing of any moving joint should NEVER be jammed tight with a wrench, as this increases the friction and causes wear of both the packing and the rod.

When installing packing rings in stuffing boxes of moving rods, be sure that the ends of the rings are cut square, not beveled. Leave enough clearance between the ends of the rings

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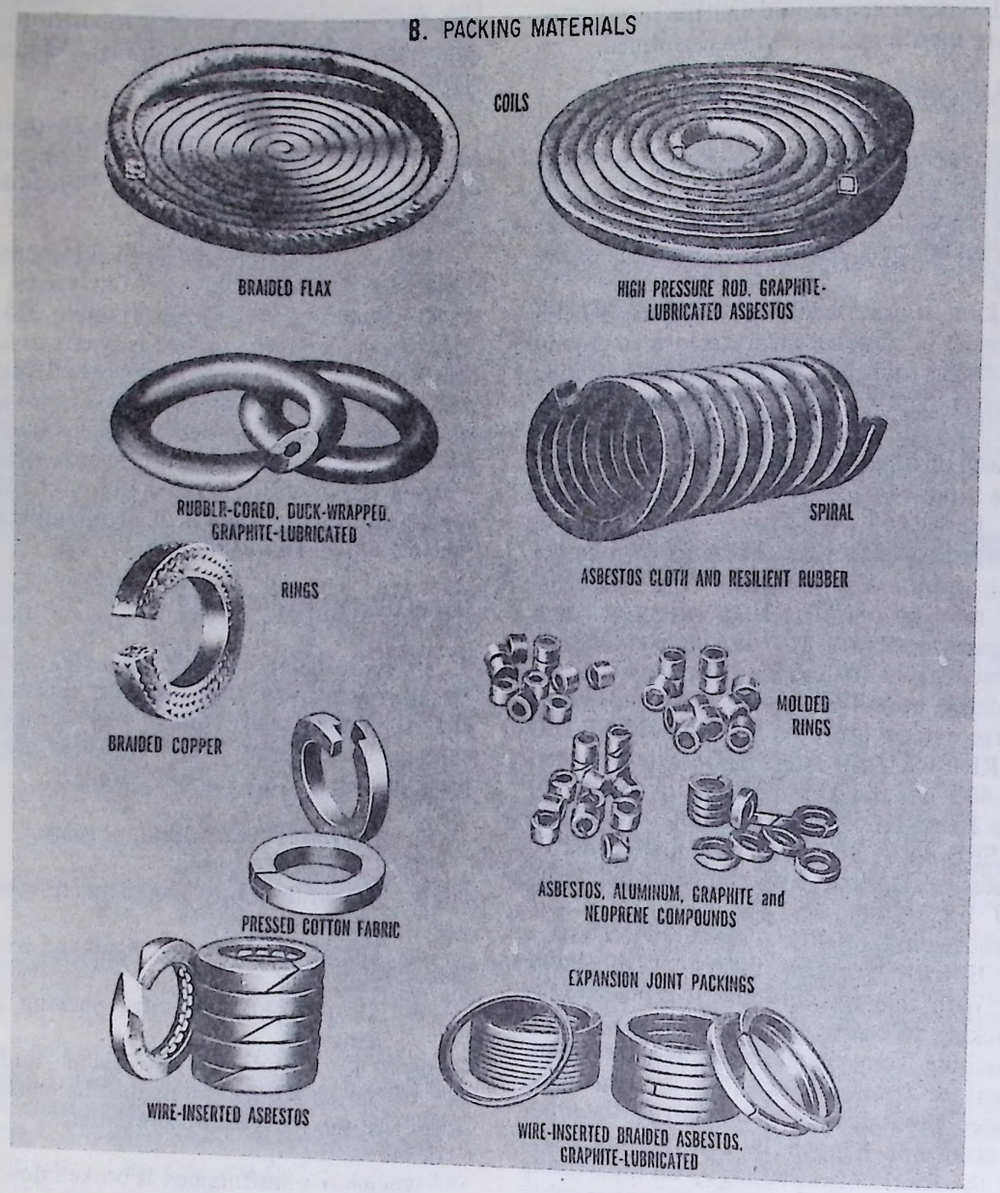
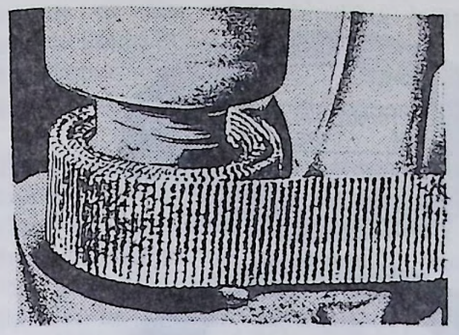


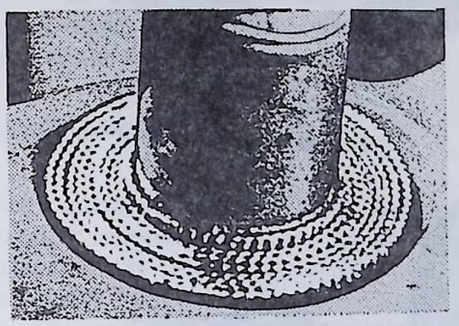
Figure 6-39.—Types of packing. 5.35X

to allow for elongation when the packing is set up. After all possible causes of faulty sealing have been corrected, install the cut rings in the box one at a time with the joints staggered. Insert the gland, draw it up with a wrench, and then back it off until it is finger tight. A slight leakage will occur during the time the packing is adjusting itself to the rod and box. As the packing expands, further backing off on the nuts may be necessary.

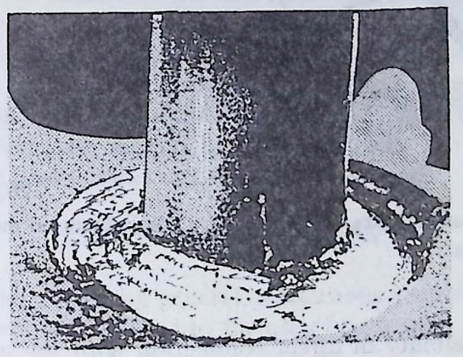
Hydraulic rod packing, such as tuck, and rock hard, must be soaked in water for approximately 12 hours to allow for swelling, before cutting and fitting in a pump plunger. Step-type joints are best. When it is necessary in an emergency to use this packing dry, be sure to allow enough clearance to provide for the swelling which will occur after the packing has absorbed moisture.



(A) CORRUGATED RIBBON PACKING ROLLED AROUND STEM



(B) STUFFING BOX FILLED (BEFORE COMPRESSION)



(C) COMPRESSED RINGS IN STUFFING BOX

47.205

Figure 6-40.—Corrugated ribbon packing.

NOTE: Regardless of how good the packing material may be, if the surface of the shaft passing through the stuffing box is scored or damaged in any way, the packing will not last long. When replacing packing, carefully inspect the shaft in the area where it passes through the stuffing box as well as the interior of the stuffing box itself. Operating requirements and time permitting, take whatever steps are necessary to ensure that the packing will make contact with the straightest, smoothest possible surface. (You may have to have the shaft repaired and refinished, or replaced.)

PACKING OF FIXED JOINTS

At one time, fixed steam joints could be satisfactorily sealed with gaskets of compressed asbestos sheet packing (fig. 6-41A), but the 15% rubber content of the packing makes it unsatisfactory for modern high-temperature steam equipment. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines. The following two types of metallic or semimetallic gaskets are in use in present day high-temperature, high-pressure installations:

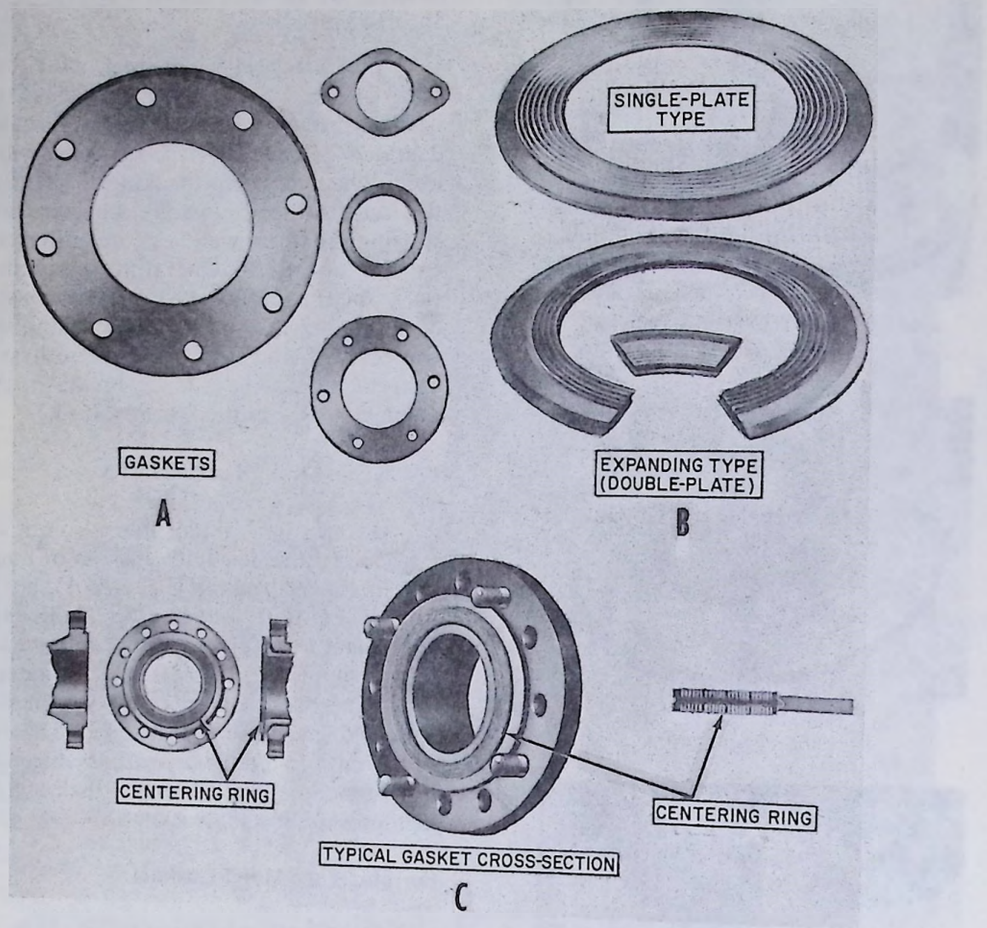
Serrated-Face Metal Gaskets

Serrated-face metal gaskets (fig. 6-41B), made of steel, Monel, or soft iron, have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency, and line pressure tends to force the serrated faces tighter against the adjoining flange. The gaskets shown are two variations.

Spiral-Wound Metallic-Asbestos Gaskets

Spiral-wound metallic-asbestos gaskets (fig. 6-41C) are composed of interlocked piles of preformed corrugated metal and asbestos strips, spirally wound, called a FILLER and a solid metal outer or centering ring, sometimes called a RETAINING RING. The filler piece is replaceable. When renewal of a gasket is required, this piece should be removed from the

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Figure 6-41.—Fixed joint gaskets. A. Sheet asbestos gaskets. B. Serrated-face metal gaskets. C. Spiral-wound metallic-asbestos gaskets.

retaining metal ring and replaced with a new refill. The solid metal retaining outer ring should not be discarded unless it is damaged. The gasket is then placed into a retainer or centering ring. The solid steel centering ring also acts as reinforcement to prevent blowouts. The gaskets can be compressed to the thickness of the centering ring.

When renewing a gasket in a flanged joint, you must exercise special precautions when breaking the joint, particularly in steam and hot water lines, or in saltwater lines which have a possibility of direct connection with the sea. Be sure that:

1. There is no pressure on the line.
2. The line pressure valves including the bypass valves, are firmly secured, wired closed, and tagged.
3. The line is completely drained.
4. At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed, then slackened to allow breaking of the joint, and removed after the line is clear.

5. Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines.
6. Proper ventilation is ensured before joints are broken in closed compartments.

These precautions may prevent serious explosions, severe scalding of personnel, or flooding of compartments. All sealing and bearing surfaces should be thoroughly cleaned for the gasket replacement. The gasket seats should then be checked with a surface plate, and scraped as necessary, to afford uniform contact. All damaged bolt studs and nuts should be replaced. In flanged joints which have raised faces, the edges of gaskets may extend beyond the edge of the raised face.

Plain Full-Faced Gasket

When cutting a plain full-faced gasket from compressed asbestos sheet, lay an appropriate size piece of the asbestos sheet on the flange. Scribe in the bolt holes and flange circle lines with light blows of a ball-peen hammer. Using a gasket punch, about 1/16 inch larger in diameter than the bolts, cut the bolt holes into the gasket material. Use a piece of hardwood as the supporting and backing surface for the material while punching it to prevent damage to the lips of the punch. After the holes have been punched, use shears or a sharp knife to cut the center and outside circles to form the ring.

PACKING PRECAUTIONS

The following general precautions should be observed with regard to the use of packing:

1. Do NOT use metallic or semimetallic packing on bronze or brass shafts, rods, plungers, or sleeves. If these materials are used, scoring may result. Use a braided packing that is lubricated throughout or a nonmetallic plastic packing in the center of the box with an end ring of the braided packing at each end of the box.
2. Do NOT use a packing frictioned with rubber or synthetic rubber of any kind on rotary or centrifugal shafts. Such packing will overheat.
3. Do NOT use braid-over-braid packing on rotary or centrifugal shafts. The outer layer will wear through quickly and eventually the packing will become rags.
4. Do NOT use packing with a rubber binder on rotary type compressors. It will swell and bind, thereby developing excessive frictional heat. The use of flexible metallic packing is recommended, or a lead-base plastic packing alternated with the flexible metallic packing can be used.
5. On hydraulic lifts, rams, and accumulators use a V-type packing or O-ring. For water, this packing should be frictioned with crude, reclaimed, or synthetic rubber. For oils, the packing should be frictioned with oil-resistant synthetic rubber.
6. Do NOT use a plastic packing, such as Symbol 1433 or 1439, alone on worn equipment or out-of-line rods; it will not hold. A combination of 1433 with end rings of plain braided asbestos (1103) or of flexible metallic packing (1430) may be satisfactory for temporary service until defective parts can be repaired or replaced.
7. Do NOT use a soft packing against thick or sticky liquids or against liquids having solid particles. This packing is too soft to hold back liquids, such as cold boiler fuel oil, and usually gets torn. Some of the solid particles, which may be suspended in these liquids, embed themselves in the soft packing, thereafter acting as an abrasive on the rod or shaft. Flexible metallic packing is best for these conditions.

INSULATION

The purpose of insulation is to retard the transfer of heat FROM piping that is hotter than the surrounding atmosphere or TO piping that is cooler than the surrounding atmosphere. Insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also serves to protect personnel from being burned by coming in contact with hot surfaces. Piping insulation represents the composite piping covering which consists of the insulating material, lagging, and fastening. The INSULATING MATERIAL offers

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resistance to the flow of heat; the LAGGING, usually of painted canvas, is the protective and confining covering placed over the insulating materials; and the FASTENING attaches the insulating material to the piping, and to the lagging.

Insulation covers a wide range of temperatures, from the extremely low temperatures of the refrigerating plants to the very high temperatures of the ship's boilers. No one material could possibly be used to meet all the conditions with the same efficiency.

INSULATION MATERIALS

The following QUALITY REQUIREMENTS for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

1. Low heat conductivity
2. Noncombustibility
3. Lightweight
4. Easy molding and installation capability
5. Moisture repellent
6. Noncorrosive, insoluble and chemically inactive
7. Composition, structure and insulating properties unchanged by temperatures at which it is to be used
8. Once installed, should not cluster, become lumpy, disintegrate or build up in masses from vibration
9. Vermin proof
10. Hygenically safe to handle

Insulating material is available in preformed pipe coverings, blocks, batts, blankets, and felts. Chapter 635 of the *NAVSHIPS' Technical Manual* contains all of the insulating materials, their application and precautions.

Insulating Cements

The insulating cements are composed of a variety of materials, differing widely among themselves as to heat conductivity, weight, and other physical characteristics. Typical of these variations are the asbestos cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high temperature insulating materials, but they are valuable for patchwork emergency repairs and for covering small irregular surfaces (valves, flanges, joints, etc). The cements are also used for a surface finish over block or sheet forms of insulation, to seal joints between the blocks and to provide a smooth finish over which asbestos or glass cloth lagging may be applied (fig. 6-42).

REMOVABLE TYPE INSULATION

Removable type insulation is usually installed in the following locations:

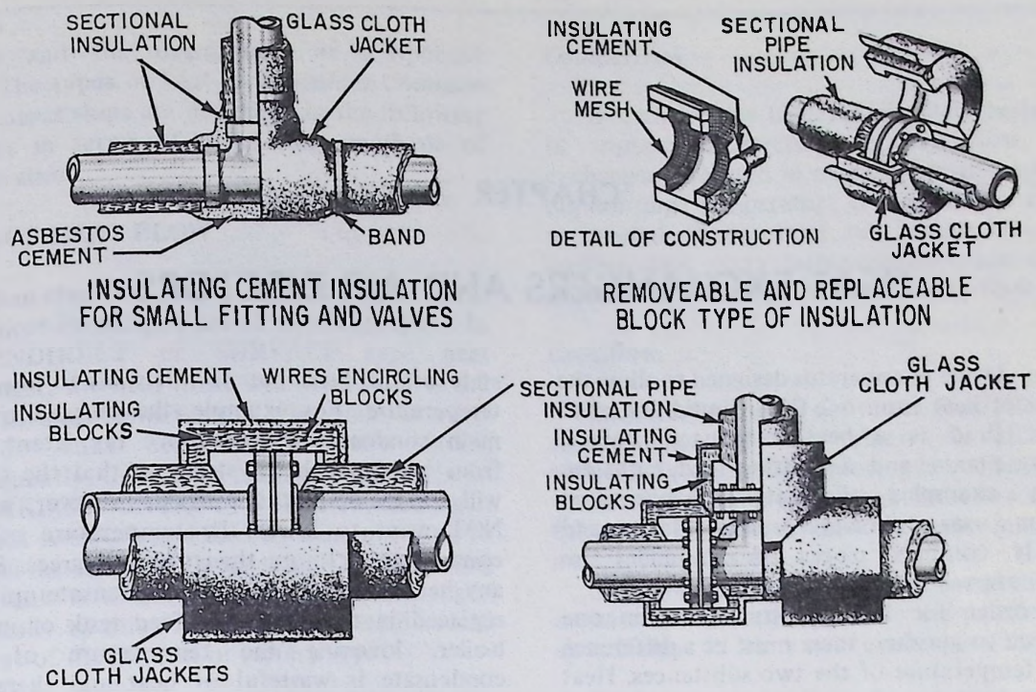
1. Manhole covers, inspection openings, turbine casing flanges, drain plugs, strainer cleanouts, and spectacle flanges.
2. Flanged pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul.
3. Valve bonnets of valves larger than 2 inches, IPS, that operate at 300 psi and above, or at 240° F and above.
4. All pressure reducing and pressure regulating valves, pump pressure governors, and strainer bonnets.

For a small unit of machinery or equipment such as an auxiliary turbine, where it would be difficult to install both permanent insulation over the casing and removable and replaceable covers over the casing flanges, the entire insulation may be made removable and replaceable. Covers should fit accurately and should project over adjacent permanent insulation.

GENERAL INSULATION PRECAUTIONS

The following general precautions should be observed with regard to the application and maintenance of insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to



47.68X

Figure 6-42.—Permanent type insulation of pipe fittings, flanges, and valves.

damage, use sheet metal lagging. Flanges and joints should be cuffed with 6-inch lagging.

3. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation fully as much as it is in the case of electrical insulation. Any dampness increases the conductivity of all heat-insulating materials.

4. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting, otherwise a considerable quantity of heat will be lost via conduction through the support.

5. Sheet metal covering should be kept bright and not painted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.

6. Once installed, heat insulation requires careful inspection, upkeep, and repair. Lagging and insulation removed to make repairs should be replaced just as carefully as when originally installed. When replacing insulation, make certain that the replacement material is of the same type as had been used originally.

7. Insulate all flanges with easily removable forms which can be made up as pads of insulating material, wired or bound in place, and the whole covered with sheet metal casings which are in halves, and easily removable.

The main steam, auxiliary steam, auxiliary exhaust, feedwater, and steam heating piping systems are lagged to hold in the heat. The circulating drainage, fire, and sanitary piping systems are lagged to prevent condensation of moisture on the outside of the piping.

8. Asbestos Control: Inhalation of excessive quantities of asbestos filler can produce severe lung damage in the form of disabling or fatal fibrosis of the lungs. Asbestos has also been found to be a causal factor in the development of cancer of the membrane lining the chest and abdomen. Lung damage and disease usually develop slowly and often do not become apparent until years after the initial exposure. If your future plans include a long and healthy Navy retirement, you have no business doing asbestos lagging ripout without a respirator or even staying in the area of the ripout if you are unprotected.

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CHAPTER 7

HEAT EXCHANGERS AND AIR EJECTORS

Any device or apparatus designed to allow the transfer of heat from one fluid (liquid or gas) to another fluid is a heat exchanger. Boilers, distilling plants, and deaerating feed tanks are primary examples of heat exchangers; in common usage, however, these large and relatively complex pieces of equipment are seldom referred to as heat exchangers.

In order for heat to transfer from one substance to another, there must be a difference in the temperature of the two substances. Heat flow or heat transfer can occur only from a substance that is at a higher temperature to a substance that is at a lower temperature. When two objects at different temperatures are placed in contact with each other, or near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat transfer occurs at a faster rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero.

In some heat exchangers we want to RAISE THE TEMPERATURE of one fluid. Fuel oil heaters, combustion air preheaters, lube oil heaters, and many other heat exchangers used aboard ship serve this function.

In other heat exchangers we want to LOWER THE TEMPERATURE of one fluid. Lube oil coolers, boiler water sample coolers, and desuperheaters are examples of this type of heat exchanger.

In condensers, we want to REMOVE LATENT HEAT from a fluid to make it change from a gas to a liquid. Very often, we want to remove the latent heat without removing any sensible heat—that is, we want to change the state of the fluid but do not want to lower its temperature. For example, the purpose of the main condenser is to remove the latent heat from turbine exhaust steam so that the steam will condense. In this process, however, we do NOT want to lower the temperature of the condensate by more than a few degrees. Since any heat removed from the condensate must be replaced in the deaerating feed tank or in the boiler, lowering the temperature of the condensate is wasteful of heat and therefore wasteful of fuel. In addition, the hotter the condensate the less oxygen it can absorb.

In some heat exchangers, we want to ADD LATENT HEAT to a fluid to make it change from a liquid to a gas. The generating part of a boiler is a good example of this type of heat exchanger. Since it is impossible to raise the temperature of the steam as long as it is in contact with the water from which it is being generated, the steam does not increase in temperature until it has been drawn off into another heat exchanger (the superheater).

In this chapter you will learn about the heat exchangers that you will encounter in the engineroom. These include the main and auxiliary condenser, air ejector condensers, air coolers, lube oil coolers, and deaerating feed tanks.

CLASSIFICATION OF HEAT EXCHANGERS

Heat exchangers may be classified according to the path of heat flow, the relative direction of the flow of the fluids, the number of times that either fluid passes the other fluid, and the general construction features such as the type of

surface and the arrangement of component parts. The types of heat exchangers in common use in naval ships are described in the following sections in terms of these basic methods of classification.

PATH OF HEAT FLOW

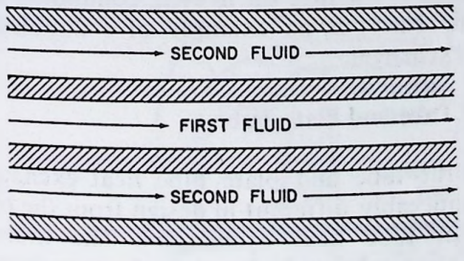
When classified according to the path of heat flow, heat exchangers are of two basic types. In the INDIRECT or SURFACE type heat exchanger, the heat flows from one fluid to the other through some kind of tube, plate, or other surface that separates the two fluids; consequently, there is no mixing of the fluids. In the DIRECT-CONTACT type heat exchanger, the heat is transferred directly from one fluid to another as the two fluids mix. The deaerating feed tank is a direct contact heat exchanger; practically all other heat exchangers used aboard ship are of the indirect or surface type.

DIRECTION OF FLUID FLOW

In surface heat exchangers the fluids may flow parallel to each other, counter to each other or at right angles to each other (crossflow).

Parallel Flow

In parallel flow (fig. 7-1) both fluids flow in the same direction. If a parallel flow heat exchanger has a lengthy heat transfer surface, the temperatures of the two fluids will be practically equal as the fluids leave the heat exchanger.



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Figure 7-1.—Parallel flow in heat exchanger.

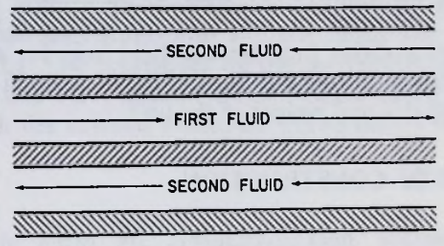
Counterflow

In counterflow (fig. 7-2) the two fluids flow in opposite directions. Counterflow heat exchangers are used in many applications which require large temperature changes in the cooled or heated fluids. Fuel oil heaters, lube oil coolers, and many internal-combustion engine coolers are examples of the counter-flow type.

Crossflow

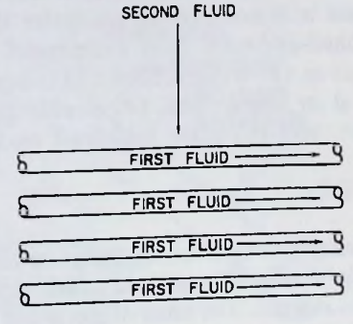
In crossflow (fig. 7-3) one fluid flows at right angles to the other. Crossflow is particularly useful for removing latent heat, thus condensing a vapor to a liquid. Crossflow is used for most condensers, including the main and auxiliary condensers.

Counterflow and crossflow heat exchangers are more commonly used than the parallel flow aboard ship. In many heat exchangers, the types



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Figure 7-2.—Counterflow in heat exchanger.



98.32

Figure 7-3.—Crossflow in heat exchanger.

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of flow are combined in various ways so that it is not always easy to determine whether the flow is basically parallel, counter, or cross.

NUMBER OF PASSES

Surface heat exchangers may be classified as SINGLE-PASS units if one fluid passes another only once, or as MULTIPASS units if one fluid passes another more than once. Multipass flow may be obtained either by the arrangement of the tubes and the fluid inlets and outlets or by the use of baffles to guide a fluid so that it passes the other fluid more than once before it leaves the heat exchanger.

TYPE OF SURFACE

Surface heat exchangers are known as PLAIN SURFACE units if the surface is relatively smooth, or as EXTENDED SURFACE units if the surface is fitted with rings, fins, studs, or some other kind of extension. The main advantage of the extended surface is that the extensions increase the heat transfer area without requiring any substantial increase in the overall size and weight of the unit.

TYPE OF CONSTRUCTION

Surface heat exchangers are often given names that indicate general features of design and construction. Basically, all surface heat exchangers are of SHELL-AND-TUBE construction. However, the shell-and-tube arrangement is modified in various ways and in some cases it is not easy to recognize the basic design. Shell-and-tube heat exchangers include such types as (1) straight tube, (2) U-bend tube, (3) helical or spiral tube, (4) double tube, (5) strut tube, and (6) plate tube heat exchangers.

Straight Tube

In straight tube heat exchangers, the tubes are usually arranged in a bundle and enclosed in a cylindrical shell. The ends of the tubes may be expanded into a tube sheet at each end of the bundle, or they may be expanded into one tube sheet and packed and ferruled into the other. The ferrules allow the tube to expand and contract slightly with temperature changes.

U-Bend Tube

U-bend tube heat exchangers, sometimes called RETURN BEND heat exchangers, consist of a bundle of U-shaped tubes inside a shell. Since the tubes are U-shaped, there is only one tube sheet. The shape of the tubes provides sufficient allowance for expansion and contraction.

Helical or Spiral Tube

Helical or spiral tube heat exchangers have one or more coils of tubing installed inside a shell. The tubes may communicate with headers at each end of the shell, or, in the case of relatively simple units such as boiler water sample coolers, the ends of the tubing may pass through the shell and serve as the inlet and the outlet for the fluid that flows through the coil of tubing.

Double Tube

Double tube heat exchangers have one tube inside another. One fluid flows through the inner tube and the other fluid flows between the outer and the inner tubes. The outer tube may thus be regarded as the shell for each inner tube. The shells, or outer tubes, are usually arranged in banks and are connected at one end by a common tube sheet with a partitioned cover that serves to direct the flow. Many double-tube heat exchangers are of U-bend construction to allow for expansion and contraction. The sectional G-fin fuel oil heater, commonly used by the Navy, is an example of a double-tube heat exchanger.

Strut Tube and Plate Tube

Strut tube and plate tube heat exchangers are noticeably different in design from the other shell-and-tube heat exchangers. The tubes in both strut tube and plate tube heat exchangers consist of pairs of flat, oblong strips; one fluid flows inside the tubes and the other flows around the outside. Strut tube and plate tube heat exchangers are used primarily as water coolers and lubricating oil coolers in internal-combustion engines; they are also used as lube oil coolers for some small auxiliary turbines.

STEAM CONDENSERS

A condenser is a type of heat exchanger used to remove latent heat from a vapor, thereby changing the vapor to a liquid. There are main condensers and auxiliary condensers. Since the main condenser of a steam plant is one of the most important units in the plant, we shall discuss it in some detail.

MAIN CONDENSERS

The main condenser is the heat receiver of the thermodynamic cycle–that is, it is the heat "sink," or lowest temperature receiver, of the main propulsion plant. In simpler terms, exhaust steam from the low-pressure (LP) turbines enters the main condenser where the steam's latent heat is removed by the circulating (cooling) water.

The main condenser is also the means by which feedwater is recovered and returned to the feed system. If we imagine a shipboard propulsion plant in which there is no main condenser and the turbines exhaust to atmosphere, and if we consider the vast quantities of freshwater that would be required to support even one boiler generating 150,000 pounds of steam per hour, it is immediately apparent that the main condenser serves a vital function in recovering feedwater.

One type of main condenser system is illustrated in figure 7-4. There are two separate circuits involved in the condensation of steam in a condenser of this type–the vapor condensate system and the cooling water circuit.

Vapor-Condensate Circuit

The first circuit is the vapor-condensate circuit where exhaust steam from the propulsion turbines is condensed as it comes in contact with tubes through which "cool" seawater is flowing. The condensate then falls to the bottom of the condenser, drains into a space called the HOT WELL, and is removed by the condensate pump. Air and other noncondensable gases, which enter with the exhaust steam, are drawn off by the air

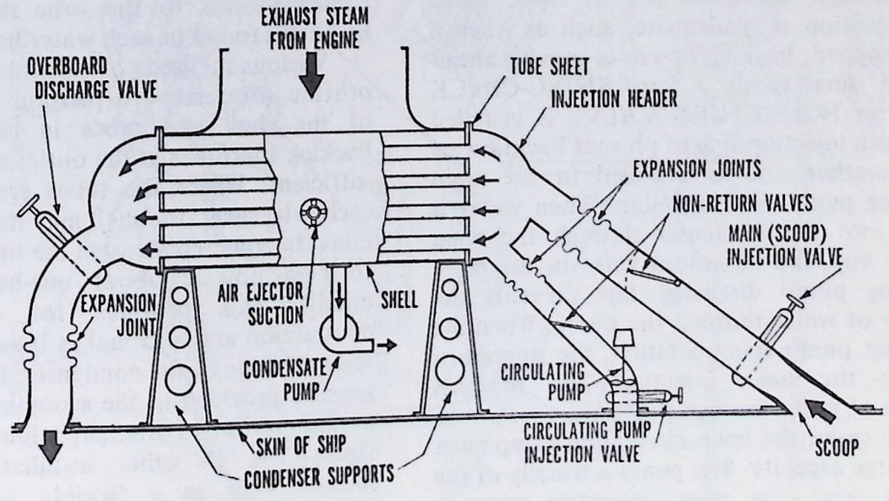


Figure 7-4.–Schematic arrangement of a main condensing system.

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ejector through an AIR EJECTOR SUCTION OPENING in the shell above the condensate level.

Cooling Water Circuit

The second circuit in the condenser is the cooling water circuit. During normal operation, seawater flow through the condenser is provided automatically by means of the INJECTION SCOOP. The scoop, located below the waterline, and the forward motion of the ship (at a certain speed) cause seawater to flow through the condenser. A major advantage of scoop injection is that it provides a flow of cooling water at a rate that is controlled by the speed of the ship and, hence, is automatically correct for various conditions. Scoop injection is standard for naval combatant ships, except submarines, and for many of the auxiliary ships. STRAINER BARS are installed in the sea chest to strain out debris which could foul the piping and the condenser tubes. The injection and overboard discharge lines are provided with expansion joints to prevent undue strains which could result from a change in either the temperature or the working of the hull.

Circulating Pump

A main circulating pump provides a flow of water through the condenser at times when scoop injection is inadequate, such as when a ship is stopped, backing down, or moving ahead at a very slow speed. A large SWING-CHECK VALVE or NONRETURN VALVE is installed in the main injection line to prevent backflow of water; another one is installed in the main circulating pump discharge line. When water is flowing into the condenser through the main injection line, the nonreturn valve in the main circulating pump discharge line prevents the backflow of water through the pump. When the circulating pump is in operation, the nonreturn valve in the main injection line prevents backflow of water through that line.

In all cases, the main circulating pump must have a large capacity. The pump is usually of the propeller type. The main circulating pump is provided with a bilge suction line so that it can be used to pump water overboard in case of serious flooding in the engineroom.

Construction

To ensure proper maintenance of a condenser, there are certain installation and construction features which you should understand. Most installations suspend the condenser from the turbine rather than have the condenser support the turbine. This provision allows for greatly reduced weight and makes use of an expansion joint between the turbine and the condenser unnecessary.

All main condensers that have scoop injection are of the straight-tube, single-pass type; they are usually of the general construction shown in figure 7-5.

A main condenser may contain from 2,000 to 10,000 copper-nickel alloy tubes, usually of 5/8-inch diameter. The length of the tubes and the number of tubes depend on the size of the condenser, and this, in turn, depends on the capacity requirements. The tube ends are usually expanded into the tube sheet at the inlet end and are flared after expansion. The outlet tube ends are either expanded or packed and ferruled into the tube sheet. Condensers having tubes ferruled into each tube sheet are found in some older ships.

The tube sheets serve as partitions between the saltwater circuit and the vapor-condensate circuit. Access to the tube sheets is through manholes found in each water box.

Various methods of construction are used to provide for relative expansion and contraction of the shell and tubes in main condensers. Packing the tubes at the outlet end is sometimes sufficient. Where the tubes are expanded into each tube sheet, the shell may have an expansion joint. In some condensers the tubes are arranged to bow upward about one-half inch at the middle; this provides for expansion and contraction and also makes it easier to drain the saltwater side of the condenser. Expansion joints are also provided in the scoop injection line and in the overboard discharge lines, as shown in figure 7-4. In other installations additional means, such as a flexible support foot or lubricated sliding feet, are provided to compensate for expansion and contraction

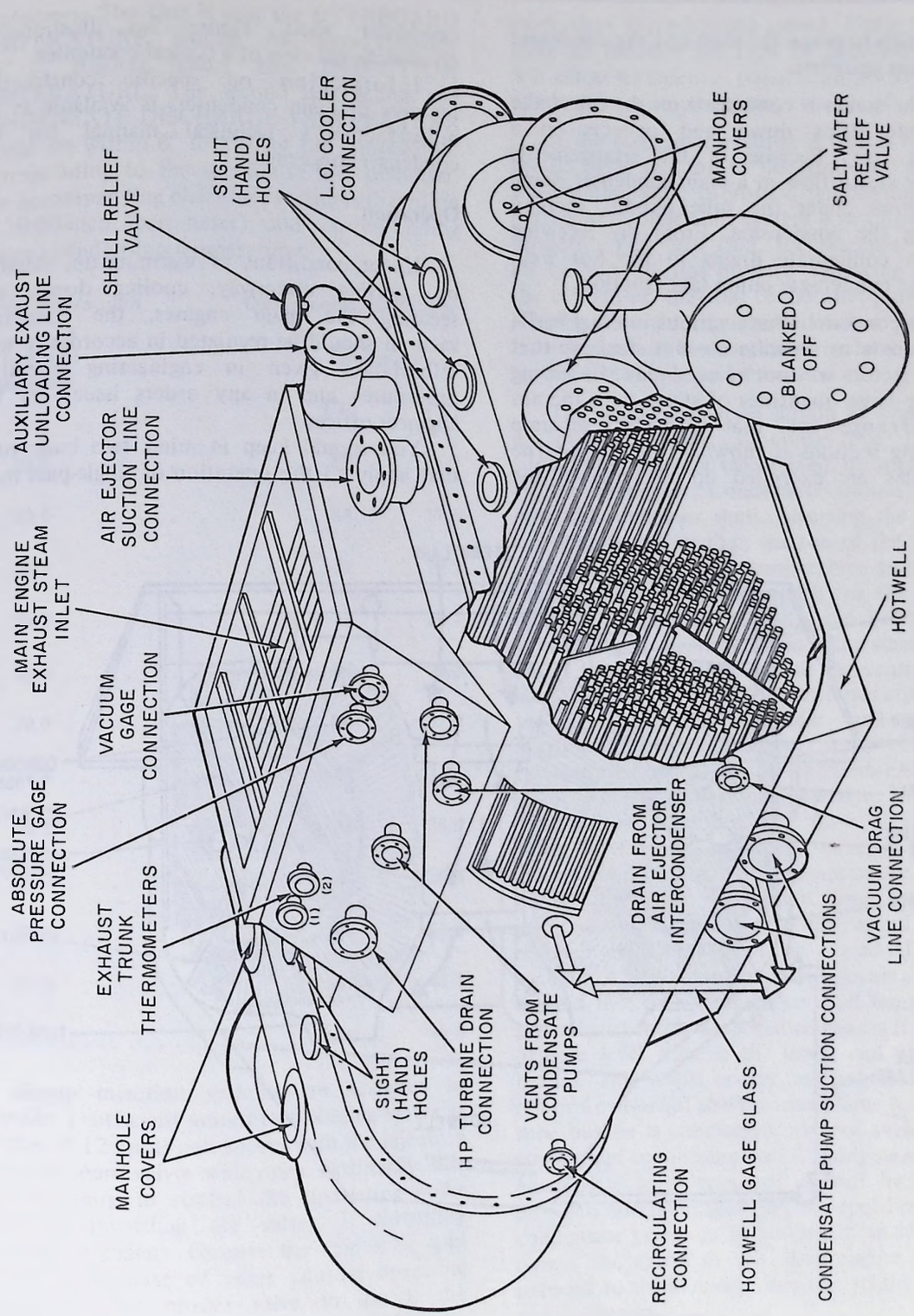


Figure 7-5.–Cutaway view of a main condenser.

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differentials between the shell and the condenser supporting structure.

As the steam is condensed on the tubes, the condensate drips down and collects on a receiving tray. Because of the arrangements made for steam flow in a main condenser, some steam flows under the tube bundle, thereby reheating the condensate. From the receiving tray the condensate drains to the hot well, where the condensate pump takes suction.

Main condensers have various internal baffle arrangements to separate air and steam so that the air ejectors will not be overloaded by having to pump large quantities of steam with the air. One arrangement that provides separate air-cooling sections is shown in figure 7-6. The air baffles are extended up the side of the condenser shell. Figure 7-6 illustrates a cross-sectional view of a typical condenser.

Information on specific construction features of main condensers is available in the manufacturer's technical manual for the condenser concerned.

Operation

Under conditions of warming up, standing by, getting underway, cooling down, and securing the main engines, the condenser vacuum should be regulated in accordance with information given in engineering operating procedures and in any orders issued by the engineer officer.

You should keep in mind two basic rules that apply to the operation of single-pass main

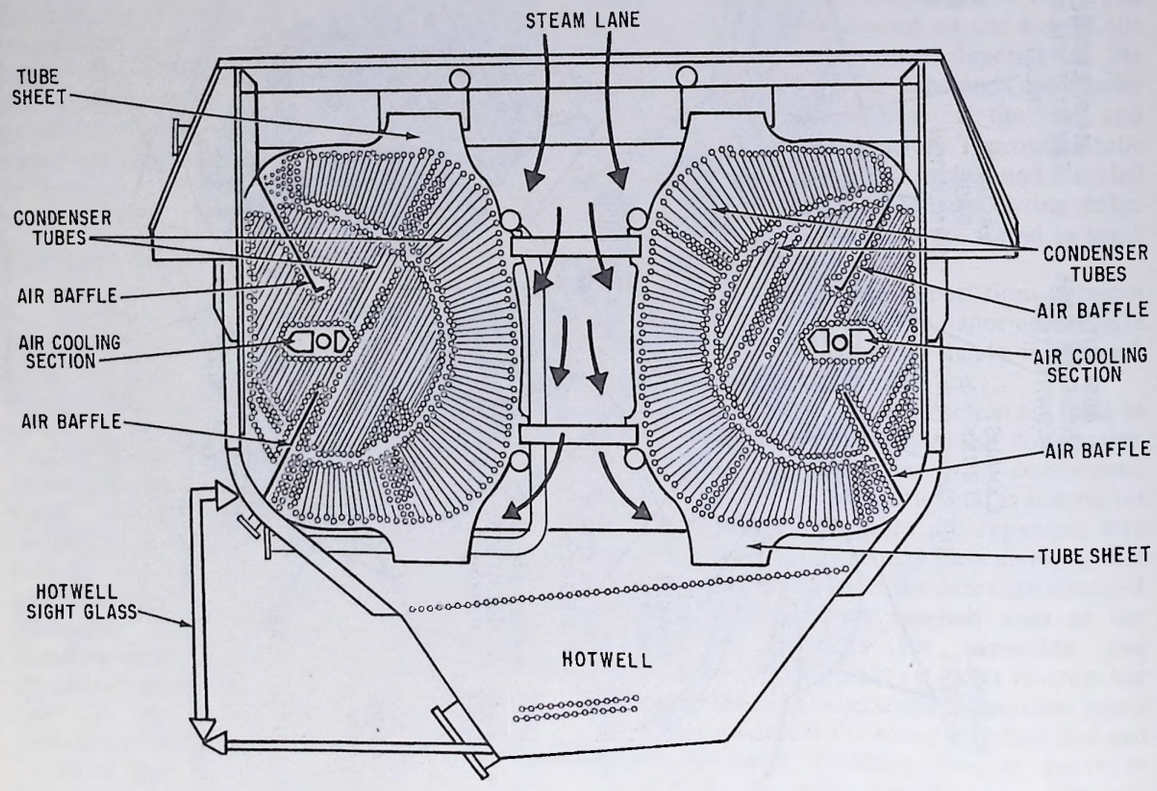


Figure 7-6.—Cross sectional view of internals of a main condenser.

condensers. The first is that the OVERBOARD TEMPERATURE should be approximately 10° F higher than the INJECTION TEMPERATURE. The second rule is that the CONDENSATE DISCHARGE TEMPERATURE should be within 0° to 2° F of the temperature corresponding to the vacuum in the condenser. The accompanying chart lists vacuums (based on a 20.00-inch barometer) and corresponding (steam) condensing temperatures.

Condenser Vacuum (Inches of Mercury)	Corresponding Saturation Temperature	
	(°F)	(°C)
29.6	53	11.7
29.4	64	17.8
29.2	72	22.2
29.0	79	26.1
28.8	85	29.3
28.6	90	32.2
28.4	94	34.4
28.2	98	36.6
28.0	101	38.3
27.8	104	40.0
27.6	107	41.7
26.5	120	48.9

Scoop injection systems are designed to provide a sufficient amount of cooling water at speeds of 12 knots and above, with the injection and overboard valves wide open. Ordinarily, it is not necessary to control the circulating water flow by throttling the valves. If throttling becomes necessary because the ship is in cold waters or because of other unusual operating conditions, the proper valve to use is the overboard valve; the valve should NEVER be more than three-fourths closed. Using the inlet valve to throttle the flow of circulating water will cause turbulence, possible air pockets in the condenser, and consequent erosion of the tubes.

If the condenser vacuum is not as high as it should be in relation to the condenser load and the cooling water overboard temperature, some part of the condensing system is not functioning properly. You may find, for example, that the air ejectors are not properly removing air from the condenser, that the condensate pump is not keeping the right condensate level, or that there is an air leak in the condenser or in some other part of the system under vacuum.

The condensate level should be kept as low as possible while a continuous flow of condensate is being maintained through the air ejector condenser. Condensate should not rise into the condenser shell. Allowing the level to rise slightly higher than the top of the hot well causes the condensate temperature to be lower than normal because the path for the flow of reheating steam is partially blocked by the condensate. (Reheating steam is the steam which enters the hot well by way of the central steam lane. The central steam lane extends completely through the tube bundle and provides longitudinal distribution of steam from the exhaust inlet directly to the condenser hot well.) If the condensate level is allowed to rise to the bottom row of tubes, the flow of reheating steam is further restricted, causing an even greater drop in condensate temperature. At this point, the high condensate level begins to interfere with the flow of air toward the air removal areas, thus causing a gradual loss of vacuum. A rapid loss of vacuum, accompanied by a rapid increase in condenser shell temperature and exhaust trunk temperature, results if the condensate level rises to the lower end of the air baffles. This result occurs not only because air removal ceases but also because a large part of the tube bundle is submerged and not available for cooling and condensing the incoming steam. If the condensate level rises and cannot be brought down to normal immediately by speeding up the condensate pump or by cutting in an additional pump, the speed of the main engine must be reduced to avoid serious damage to the turbine and condenser.

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An adequate flow of circulating water must be provided continuously to an operating condenser. The circulating water cools the steam and causes it to condense. Failure of the circulating water supply causes overheating of the condenser and loss of vacuum. Unless the situation is corrected immediately, steam pressure may build up to a point that the condenser shell might rupture.

Causes of insufficient circulating water are:

1. Condenser tubes clogged with foreign matter such as fish, seaweed, or mud.
2. Obstruction of injection or discharge sea chests, piping, or valves.
3. Injection or overboard valves not properly adjusted.
4. Inefficient or inoperative circulating pump.
5. Obstructed air vents (condenser vapor bound).
6. Faulty nonreturn valves (flappers) in scoop injection lines or in main circulating pump discharge lines.

Steam or air connections are provided to clear foreign matter from sea chests. Sometimes, however, thick accumulations of marine growth on or around sea valve openings cannot be blown clear. When maximum pressure fails to clear a sea chest, the obstruction must be removed by a diver.

To minimize air erosion of the tubes and to avoid air-binding, air vents must be kept open under all operating conditions where air is vented overboard through the hull or where the inlet water chest is vented to the discharge water chest or piping. Vents that are piped to the bilges should be kept slightly open at all times when the condenser is in use. As long as a trickle of water escapes, the unit will not become air bound and the circulating water flow will not be obstructed.

Main condenser circulating pumps are provided with a bilge suction which has a large potential capacity available for pumping engineroom bilges.

If a main circulating pump operates on bilge suction, it should be started the same as for main condenser circulating service; then, the main injection valve should be gradually closed and the bilge suction valve should be opened. When the pump is operating on a high suction lift (as when pumping bilges), the speed should be reduced, if possible, to approximately two-thirds of rated speed.

AUXILIARY CONDENSERS

Condensers into which turbogenerators exhaust are generally referred to as auxiliary condensers. Although much smaller than main condensers, auxiliary condensers operate on the same principle. In an auxiliary condenser, however, the cooling water is pumped through the condenser at all times instead of being scoop injected. Also, most auxiliary condensers are of two-pass rather than single-pass construction. Figure 7-7 shows a two-pass auxiliary condenser; the seawater chest is divided into an inlet chamber and a discharge chamber. In other construction features, including the metals used, auxiliary condensers are similar to main condensers.

Auxiliary exhaust steam, beyond that required for units such as the deaerating feed tank and the distilling plants, may be directed either to the auxiliary condenser or to the main condenser. When in port, the auxiliary exhaust goes only to the auxiliary condenser. When getting underway, the exhaust goes to the auxiliary condenser until vacuum in the main condenser is sufficiently high.

MAINTENANCE OF STEAM CONDENSERS

Heat exchangers and associated equipment should be tested and inspected periodically to ensure that they are operating efficiently. Preventive maintenance is much more economical than corrective maintenance. All preventive maintenance should be conducted in accordance with the 3-M system.

Air Leaks

The desired condenser vacuum cannot be maintained if the condenser leaks. Leaks at flanged joints and through porous castings can usually be stopped temporarily with an application of shellac when the condenser is under vacuum. Leaks around valve stems can

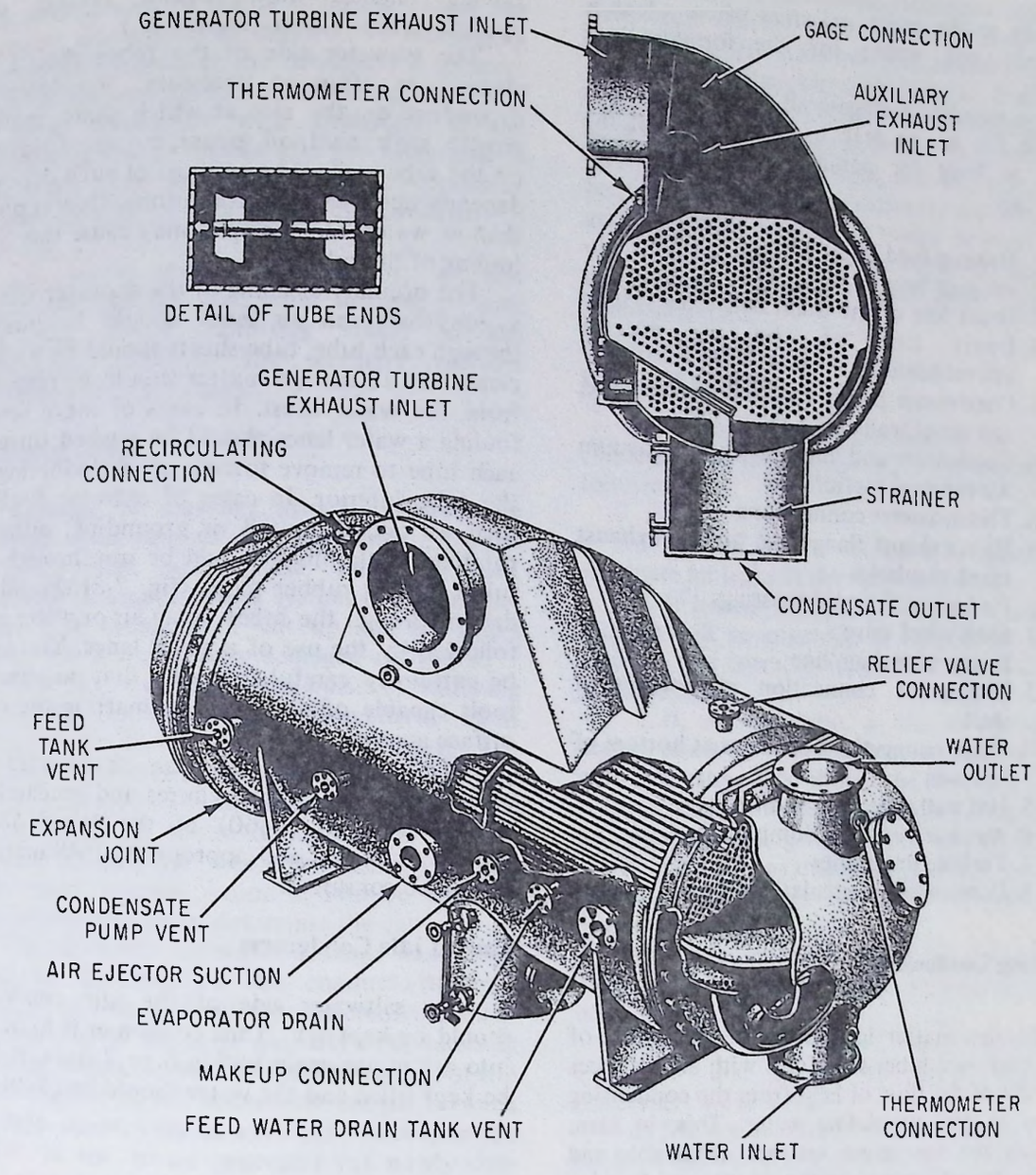


Figure 7-7.—Auxiliary condenser (turbogenerator).

sometimes be eliminated by tightening the packing. Small leaks around porous castings, flange nuts, valve stems, etc, can sometimes (but not always) be located by the candle test. Hold a lighted candle close to areas where leaks are suspected and see whether the flame flickers. A more reliable means of locating condenser air leaks is the soapsuds test while the steam side of the condenser is under pressure. Remove one of the thermometer wells and install a pressure gage and line. Now subject the steam side of the condenser to a specified pressure. Apply

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soapsuds to the units and areas where a leak is suspected and watch for the formation of bubbles.

You should investigate all places where it is possible for an air leak to exist. Some of the places to look for possible leaks include the following:

1. Makeup feed line
2. All gage lines
3. Drain line of the drain collecting system
4. Drain line of the air ejector intercondenser
5. Condensate pump suction line, vent line, and gland sealing system
6. Condensate and vent lines under vacuum
7. Air-removal suction line
8. Thermometer connections
9. Main exhaust flange and turbine exhaust trunk manholes
10. Fittings with porous castings
11. Shell relief valve
12. Evaporator drain line
13. Boiling-out connection at bottom of shell
14. Drain connections or plates at bottom of hot well
15. Hot well gage glass and fittings
16. Auxiliary exhaust dumping line
17. Turbine drain lines
18. Condensate recirculating line

Cleaning Condensers

Foreign matter lodged on the steam side of the condenser tubes interferes with and reduces the rate of the flow of heat from the condensing steam to the circulating water. This, in turn, reduces the maximum vacuum obtainable and lowers the efficiency of the condenser. Foreign matter lodged on the seawater side of the tubes is detrimental to the tubes in addition to slowing down the transfer of heat. Frequent visual inspections provide the only safe means of knowing the conditions of condenser fouling.

Grease and dirt on the steam side of a condenser may be boiled out with a solution of trisodium phosphate. Normally, though, this boiling-out process should not be necessary more than once every overhaul. (Condensers serving engines may require boiling out operations much more frequently.)

The seawater side of the tubes should be cleaned as often as necessary, the intervals dependent on the rate at which slime, marine growth, scale, mud, oil, grease, etc, are deposited on the tube walls. The amount of such deposits depends upon existing conditions. Operation in shallow water, for example, may cause this type fouling of the tubes.

For ordinary cleaning of the seawater side of a condenser, an air lance should be pushed through each tube, tube sheets should be washed clean, and all foreign matter should be removed from the water chest. In cases of more severe fouling a water lance should be pushed through each tube to remove foreign matter adhering to the tube interior. In cases of extreme fouling, such as caused by oil or grounding, either a rotating bristle brush should be run through the tubes or soft rubber plugs (fig. 7-8) should be driven through the tubes by an air or water gun, followed by the use of a water lance. You must be extremely careful to ensure that no abrasive tools capable of scratching or marring the tube surface are used.

In cleaning either the steam or seawater side of a condenser, the procedures and precautions in Chapter 254 (9460) of the *Naval Ships' Technical Manual* and appropriate PMS material should be consulted.

Care of Idle Condensers

The saltwater side of the idle condenser should be kept dry. If the condenser is to be put into active use again within 6 or 7 days, it may be kept filled and the water should be circulated

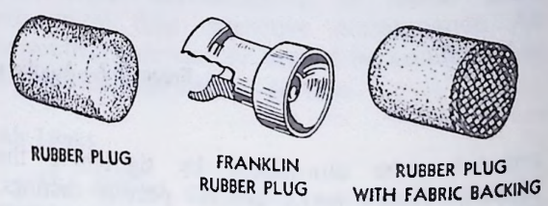


Figure 7-8.—Types of rubber plugs used for cleaning condenser tubes.

daily. One exception should be noted: when the ship is anchored in highly polluted waters, the seawater side should be drained and thoroughly washed out whenever the condenser is secured. Some ships are required to fill the saltwater side of their condensers with freshwater if the condensers are to remain idle for more than a few days. The steam side of the condenser should always be dry when the condenser is secured.

To avoid possible damage to an idle condenser and the associated turbine, be sure that the valves admitting steam to the condenser, such as the auxiliary exhaust dumping valve, are closed.

Saltwater Leaks

Leakage of seawater into the condensate through even one of the thousands of tubes installed will contaminate the feedwater. Seawater leakage into the system is serious; the entire feed system will salt up and the ship's boilers will become badly damaged as a result.

You may learn that a leak exists by watching the salinity indicator (described in chapter 10 of this manual). The indicator, usually located at a position convenient to the main control station in the engineroom, must be kept in operative condition at all times. Salinity cells must be checked frequently. When the salinity reading goes above normal, action should be taken as soon as practicable to determine the cause.

Objectionable saltwater leakage cannot always be detected by the conductivity type salinity indicators installed in the condensate system because of the large quantity of condensate which generally flows. The first indications of seawater leakage in the active tube length between the tube sheets may be a chloride buildup in the boiler, in the steam generator (of newly constructed plants), or, when the plant has been secured, in the hot well of the idle condenser.

A careful investigation must ensure that the source of chloride contamination is not in the piping connected to the condenser rather than in the condenser tubes. Special attention should be given to those sections of the condensate, drain, or makeup feed piping, normally under vacuum and located in the bilge area. Experience has demonstrated that leakage of bilge water into joints of this piping may occur and may not be detected until after considerable time and effort have been devoted to a search for a tube leak. Therefore, a SHIPALT has been issued to remove as much of this piping as practicable. If any such pipes and joints are located in the bilge area, all such piping should be uncovered by lowering the level of water in the bilges, and all joints should be inspected while the condenser and the piping are filled with freshwater under pressure when one of the leakage detection methods, described in Chapter 254 (9460) of *Naval Ships' Technical Manual,* is used.

CONDENSER SAFETY PRECAUTIONS

The following safety precautions apply to all condensers in the engineering plant and must be followed:

1. Always be on the alert to detect and eliminate air leaks in the vacuum system.
2. If a large air leak occurs, the condenser vacuum will be immediately reduced by a large amount, and corrective measures must be taken immediately.
3. If, at any time, a loss of vacuum is accompanied by a hot or flooded condenser, the unit exhausting into it must be slowed down or stopped until the condensing unit is again put into proper working order. Condenser shell relief valves must be examined and lifted by hand before a condenser is tested or put into operation.
4. Condenser water chests of surface ships must NOT be subjected to a pressure in excess of 15 psig.
5. Water chest relief valves must be examined and lifted by hand whenever condensers are secured.
6. The condensate level in condensers must be kept as low as possible under all operating conditions. Ensure that condensate does not collect in condensers and overflow into turbines or engines. The steam side of idle condensers must be kept drained and dry.
7. Ensure that sufficient circulating water flow is continuously provided when a condenser is in operation.
8. The saltwater side of operating condensers must be kept free of air.
9. No permanent connection shall be retained between any condenser and a water

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supply system which could subject the seawater side to a pressure of more than 15 psig.

10. Every effort must be made to ensure that seawater is NOT fed into the feed system. The condensate from each main condenser must be electrically tested every 15 minutes underway and every 30 minutes while standing by. Auxiliary condenser condensate must be tested every 30 minutes. Salinity indicator systems must be in continuous operation when there is flow in the condensate system.

11. Idle condensers must be kept dry and clean whenever practical, especially in polluted waters.

12. All valves admitting steam to an idle condenser must be closed.

13. Before opening the saltwater side of a condenser, all sea openings must be tightly shut and secured against accidental opening.

14. NEVER bring an open flame or anything that will cause a spark close to a freshly opened condenser until it has been thoroughly blown out with steam or air. Hydrogen and/or methane (sewer) gases may be present. These and other safety precautions are contained in Chapter 254 (9460) of *Naval Ships' Technical Manual.*

OTHER HEAT EXCHANGERS

Some of the variety of heat exchangers in use aboard ship are discussed throughout this manual in relation to the specific systems of which they are a part. Information on some of the other shipboard heat exchangers is given in the following sections.

DEAERATING FEED TANKS

The deaerating feed tank (DFT) serves three purposes: (1) to free the condensate of oxygen and other noncondensable gases, (2) to heat the feedwater, and (3) to act as a reservoir in which to store water to take care of fluctuations in feedwater demand or condensate supply.

The DFT has spray nozzles that "scrub" the feedwater free of air. The feedwater is heated by direct contact with auxiliary exhaust steam. The DFT is usually designed to operate at a pressure of approximately 15 psig and to heat the water to between 240° and 250° F. The water is kept just under its boiling point at the operating pressure so that it will not flash into steam. In FF 1052/1078 class ships, the DFT has a feedwater cooler connected between the feedwater outlet and the inlet of the main feed booster pump. Before the condensate (from the main condensate system) enters the DFT, it is directed to pass through the feedwater cooler. In this way, the condensate is preheated and the temperature of the feedwater is reduced to the point that it should not flash into steam when entering the suction side of the main feed booster pump.

One type of DFT is shown in figure 7-9. Condensate enters the DFT through an inlet pipe and flows into the spray manifold. The spray manifold contains a number of spring-loaded poppet type spray valves designed to form the flow stream first into conical sheets, then into jet streams, and finally into fine particles directly in contact with steam. Thus the condensate is heated to approximately the steam temperature. The efficient heating and counterflow patterns of the steam and water in the spray chamber release all but a small amount of oxygen and other dissolved gases. The water spray surface is partially enclosed by baffles to maintain this strict counterflow relationship and to provide a zone for cooling the released gases prior to their ventilation from the tank.

The spray is directed into the water collection cone. The water in the cone drains by gravity through a downtake pipe to the deaerating compartment from which it is drawn up into the steam scrubbing and mixing passage by the eductor action of steam leaving the steam passage. This high velocity steam and water mixture is jetted from the water passage through the baffle space and strikes on the conical impingement baffle. The baffle deflects the flow of water downward into the storage section of the DFT. The water is now deaerated, heated, and ready to be pumped to the boiler.

The steam from the auxiliary exhaust line, in order to enter the initial heating chamber, must break through the baffle section; in so doing, the steam carries with it any gases released from the water by the jet action of the steam, thereby preventing gas accumulation above the deaerated water in the storage compartment. After starting its upward travel, the steam and released gases

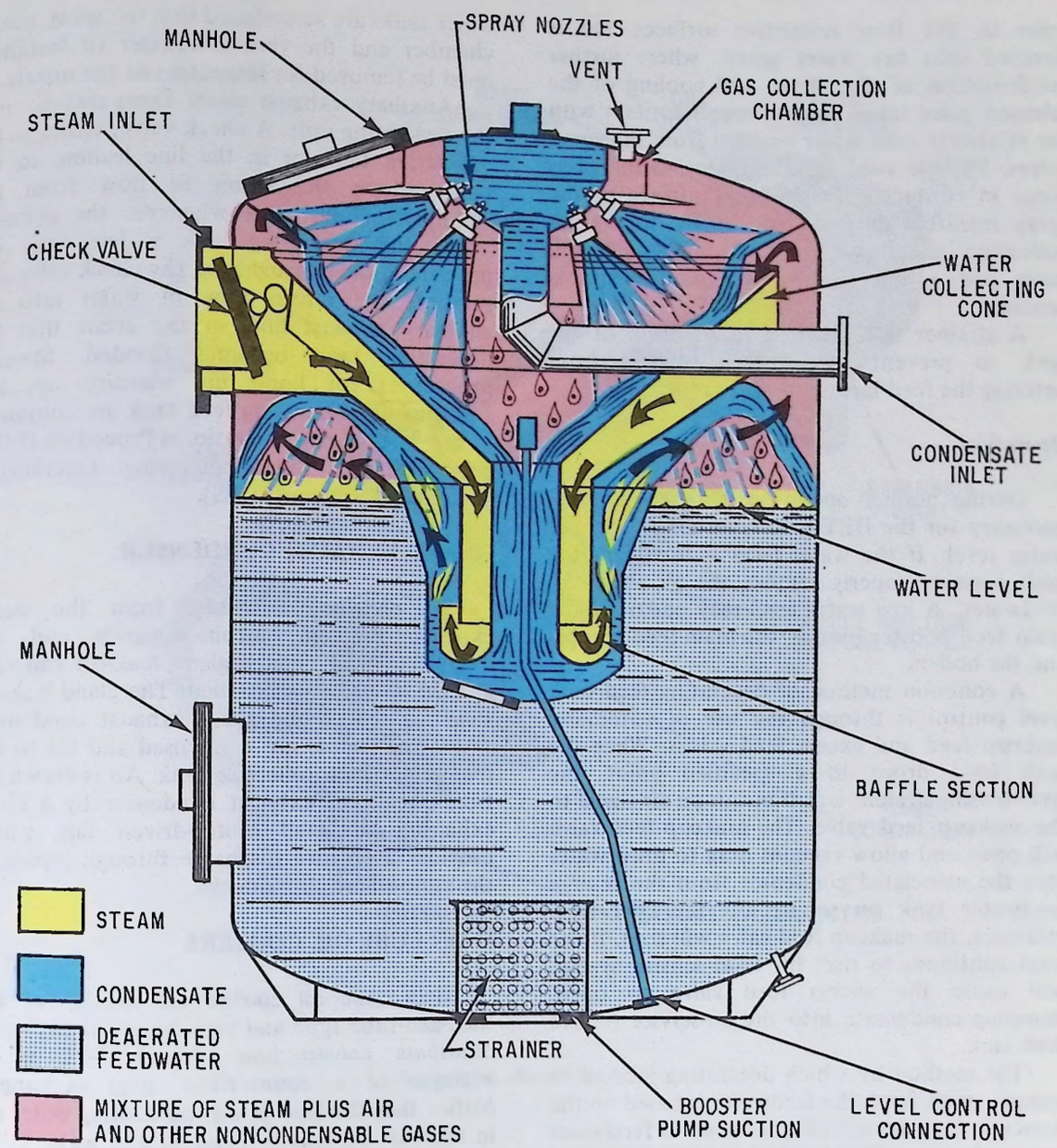


Figure 7-9.—Deaerating feed tank.

break through the water film into the spray chamber and come in direct contact with relatively cold water entering the spray chamber through the springloaded spray valves. The spray chamber is where the initial heating and deaeration take place.

The major portion of the steam entering the spray chamber is condensed. The uncondensed steam and gases released from the water pass along the spray water surfaces within the confines of the flow restrictive surfaces. The steam and gas mixture passes through a series of

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holes in the flow restrictive surfaces and is directed into the water spray, where further condensation of the steam and cooling of the released gases takes place through contact with the relatively cold water emitted from the spray valves. Further cooling takes place as the gases come in contact with the cold surface of the spray manifold during their passage to the gas collection chamber from which the released gases and a trace of uncondensed steam is vented.

A strainer is located in the bottom of the tank to prevent any foreign matter from entering the feed booster pump suction.

Operation

During normal operation, the only control necessary for the DFT is to maintain the proper water level. If the water level is too high, the tank cannot properly remove the air from the feedwater. A low water level may endanger the main feed booster pumps, the main feed pumps, and the boilers.

A common method of deaerating feed tank level control is through the use of automatic makeup feed and excess feed valves. When the tank level drops to a specified point, the level-sensing system will transmit an air signal to the makeup feed valve. The makeup feed valve will open and allow vacuum drag to draw water into the associated condenser from the reserve feedwater tank on service. As the DFT level increases, the makeup feed valve will shut. If the level continues to rise; the level sensing system will cause the excess feed valve to open, dumping condensate into the on-service reserve feed tank.

The method by which deaerating feed tanks remove gases from the feedwater is based on the principle that the solubility of gases in feedwater approaches zero when the water temperature approaches the boiling point. During operation, water is sprayed so that it comes in contact and mixes with the steam from the auxiliary exhaust line. The quantity of steam must always be proportional to the quantity of water, otherwise, faulty operation or a casualty will result.

In most deaerating feed tanks, the manhole provides access for inspection of spray nozzles; other tanks are so designed that the spray nozzle chamber and the vent condenser (if installed) must be removed for inspection of the nozzle.

Auxiliary exhaust steam flows directly into the deaerating unit. A check valve, either in the deaerating tank or in the line leading to the tank, allows the steam to flow from the auxiliary exhaust line whenever the pressure inside the deaerating tank is less than the pressure in the exhaust line. The check valve also prevents the return flow of water into the auxiliary exhaust line, in the event that the deaerating tank becomes flooded. Specific procedures for lining up, warming up, and securing and deaerating feed tank are contained in the Engineering Operational Procedure (EOP) subsystem of the Engineering Operational Sequencing System (EOSS).

GLAND EXHAUST CONDENSER

To recover condensate from the steam expelled by the turbine glands and the deaerating feed tank, a gland leak-off and vent and drain system is installed. The gland leak-off steam is led to the gland exhaust condenser, where the vapors are condensed and led to the freshwater drain collecting tank. Air is drawn off from the gland exhaust condenser by a gland exhauster, a small motor-driven fan, which provides a positive discharge through piping to the atmosphere above decks.

MAIN LUBE OIL COOLERS

Main lube oil coolers are usually of the shell-and-tube type and may be of single-pass or multipass construction. Figure 7-10 is an example of a counterflow heat exchanger. Notice that the flow of oil and cooling water are in opposite directions. (The oil and water inlets and outlets are at opposite ends of the unit.) The size of an oil cooler depends on the quantity of heat that must be removed per unit of time from the lube oil in order to maintain proper bearing temperature.

The lube oil cooler consists of a cylindrical shell with a header at each end. Inside the shell is a bundle of straight, copper-nickel tubes through which the cooling water flows from one header to the other. Hot lube oil enters at the

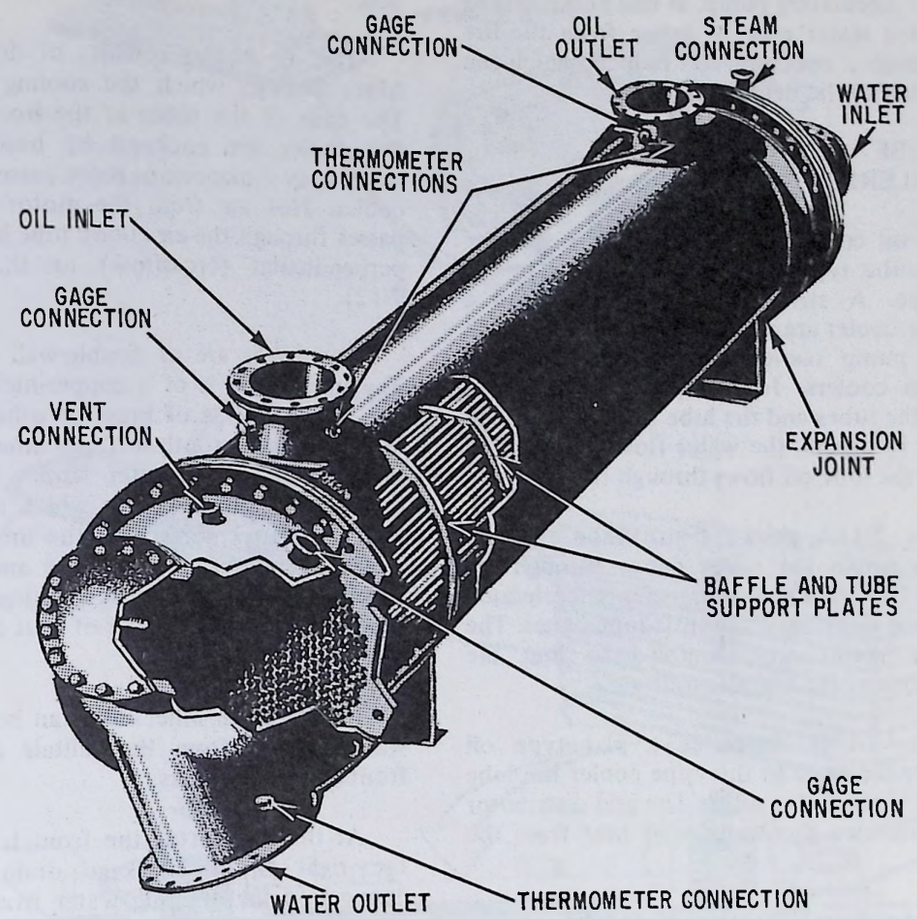


Figure 7-10.—Main lube oil cooler.

top of the shell, at the end opposite the water outlet, and flows across the tubes and around the annular jacket. The cooled oil comes out of the top of the cooler at the other end, near the water inlet. The baffles and tube support plates direct the oil flow.

In older ships, a bypass valve is installed in the oil inlet line to the cooler. The purpose of this bypass is to isolate the cooler in the event of a cooler casualty.

TURBOGENERATOR LUBE OIL COOLERS

Turbogenerator lube oil coolers are similar to main lube oil coolers in construction but much smaller in size. A three-way selector valve is placed in the oil line to route oil through the cooler or to bypass oil around the cooler. Each turbogenerator is served by a single lube oil cooler.

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Seawater is pumped through the turbogenerator lube oil cooler by the auxiliary condenser circulating pump. If this pump should fail, cooling water may be taken from the fire main through a cooling water reducer which can be regulated to the desired pressure.

PUMP LUBE OIL COOLERS

Lube oil coolers for pumps may be of the shell-and-tube type, the strut-tube type, or the plate type. A strut-tube type cooler and a plate-type cooler are shown in figure 7-11. Small lube oil pump coolers are usually multitube single-pass coolers. In some, the water flows through the tubes and the lube oil flows through the shell; in others, the water flows through the shell and the lube oil flows through the tube.

Figure 7-11A shows a strut-tube type oil cooler in which the water passes through the tubes. In this cooler, heat transfer is accelerated by stamped dimples in the strut-tube plates. The strut-tube plates are assembled so that the convex sides of the dimples touch.

Figure 7-11B illustrates a plate-type oil cooler for a pump. In this type cooler the lube oil passes through the tubes. The grid distributor strip accelerates the transfer of heat from the tubes.

Strut-tube coolers and plate-tube coolers have replaceable core assemblies, and several spare core assemblies are usually carried aboard ship. In practically all cases of failure of these types of coolers, core replacement is all that is required to correct the trouble. It is seldom necessary to replace the entire cooler.

AIR COOLERS

Air coolers are installed on shipboard propulsion motors and generators to keep them from overheating. The air cooler is connected to the air intake and air discharge openings of the motor or generator by suitable ducts. The only characteristic difference between a lube oil cooler and a propulsion motor or generator air cooler is that the latter is of double-tube construction with the outer tubes having high fins.

The air cooler consists of double-wall fin tubes through which the cooling water flows. The ends of the tubes at the front and rear of the cooler are enclosed by headers. Cooling water may make one or more passes through the cooler. Hot air from the motor or generator passes through the air cooler tube bank in a path perpendicular (crossflow) to the tubes (fig. 7-12).

The tubes are of double-wall construction. The inner tube is of a copper-nickel alloy and the outer tube is of brass or other nonferrous material. The smooth-surfaced inner tube carries the water. The outer tube has internal longitudinal ribs or lands which make contact with the outer surface of the inner tube. The internal ribs of the outer tube and the cooling fins mounted on the outside surface of the outer tube facilitate the transfer of heat to the cooling water.

Failure of an inner tube can be detected by water leakage from the telltale drains in the front and rear headers.

At the bottom of the front header, and to the right of the leakage drain plug, is a connection for draining water from the cooler. At the top of the front and rear header is a vent plug. These air relief plugs should be removed whenever the cooler, after having been drained of water, is to be refilled. The plugs should be removed from the telltale drain system to allow detection of leaks from the tube section of the cooler.

AIR EJECTORS

The function of an air ejector is to remove air and other noncondensable gases from the condenser. (Some ships use vacuum pumps instead of air ejectors to perform this function.) An air ejector is a jet pump. The flow through the air ejector is maintained by a jet of high velocity steam passing through a nozzle (fig.

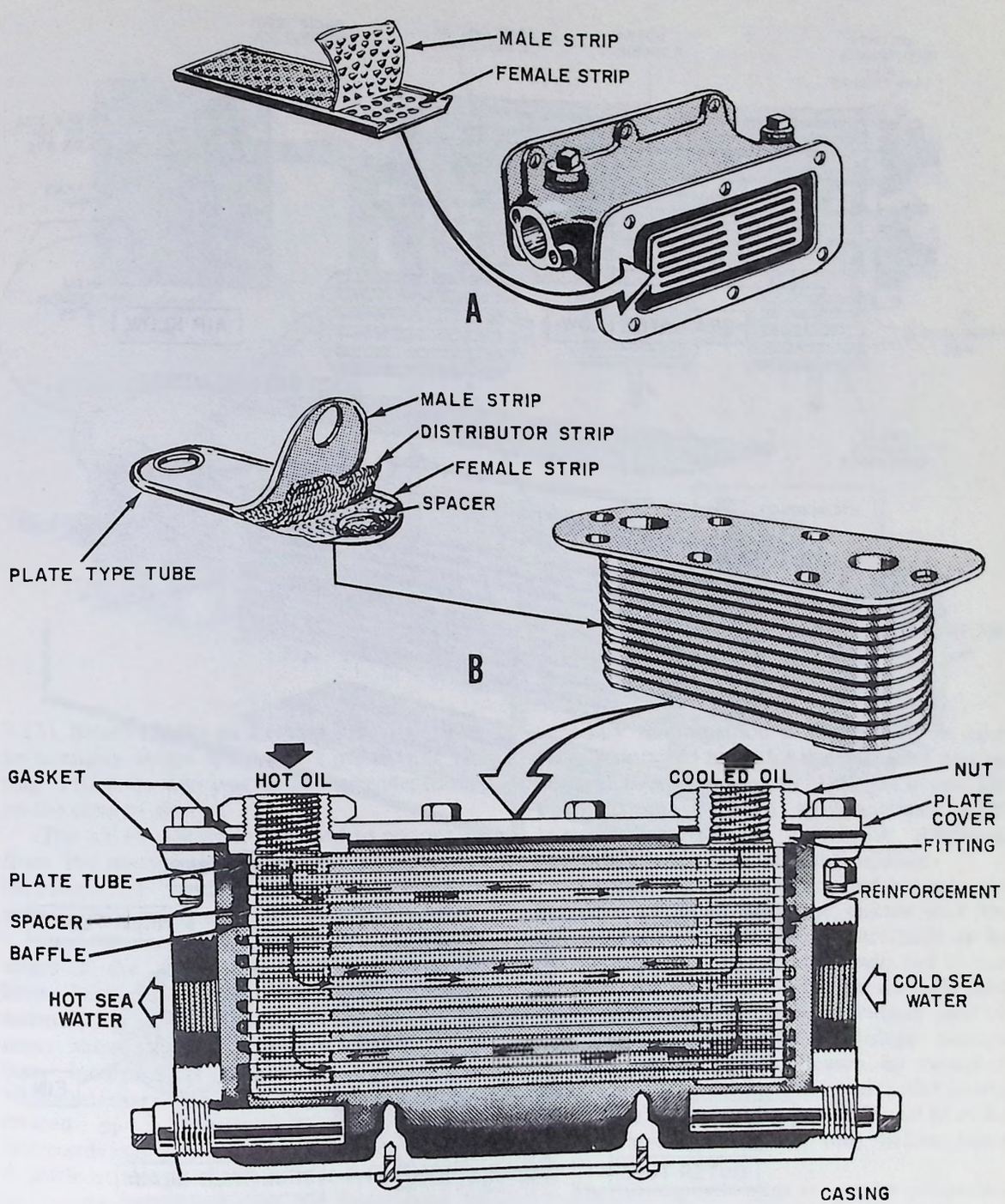
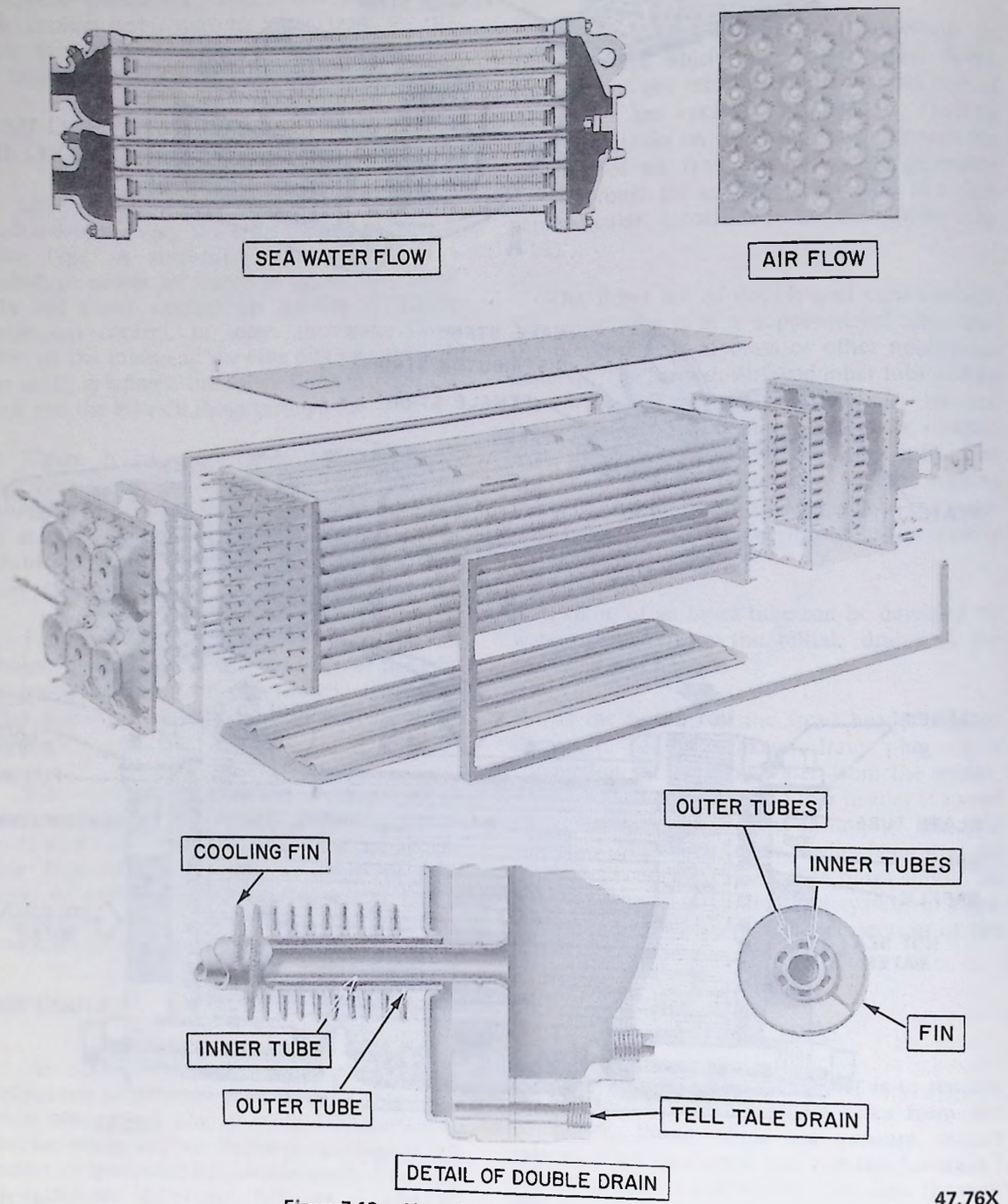


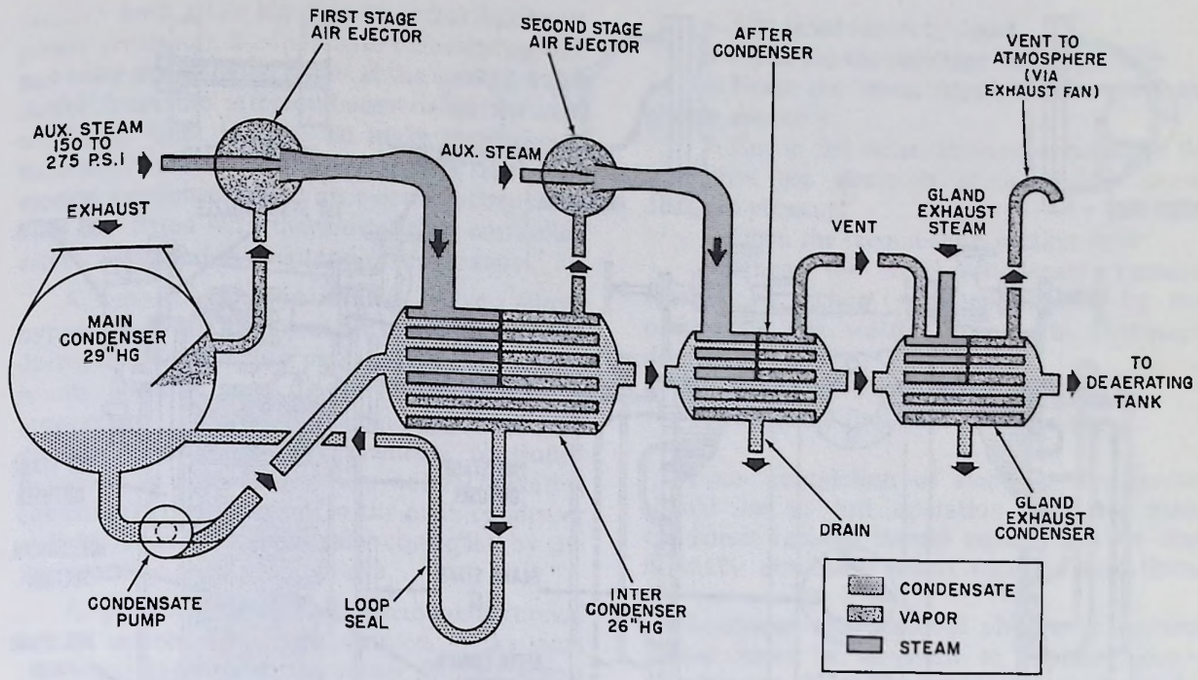
Figure 7-11.—Oil coolers for pumps. A. Strut-tube type oil cooler. B. Plate-type oil cooler.

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Figure 7-12.—Air cooler for a motor or generator.



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Figure 7-13.—Flow diagram of a two-stage air ejector.

7-13). Steam for the air ejectors is supplied from an auxiliary steam system at a pressure of 135 psig, 150 psig, 180 psig or 275 psig, depending on the class of ship.

The air ejector assembly used to remove air from the main condenser usually consists of a first-stage air ejector, an intercondenser, a second-stage air ejector, and an aftercondenser.

In most ships, however, the first and second stages of the air ejectors and their condensers have been combined into one complete assembly, such as is shown in figure 7-14. In many ships, the gland exhaust condenser has been incorporated within the shell of the aftercondenser. The shell is rectangular and is divided by a longitudinal plate into the intercondenser and the aftercondenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the aftercondenser section.

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

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

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster), which provides a positive discharge through piping to the atmosphere above decks. This is necessary to avoid filling the engineroom

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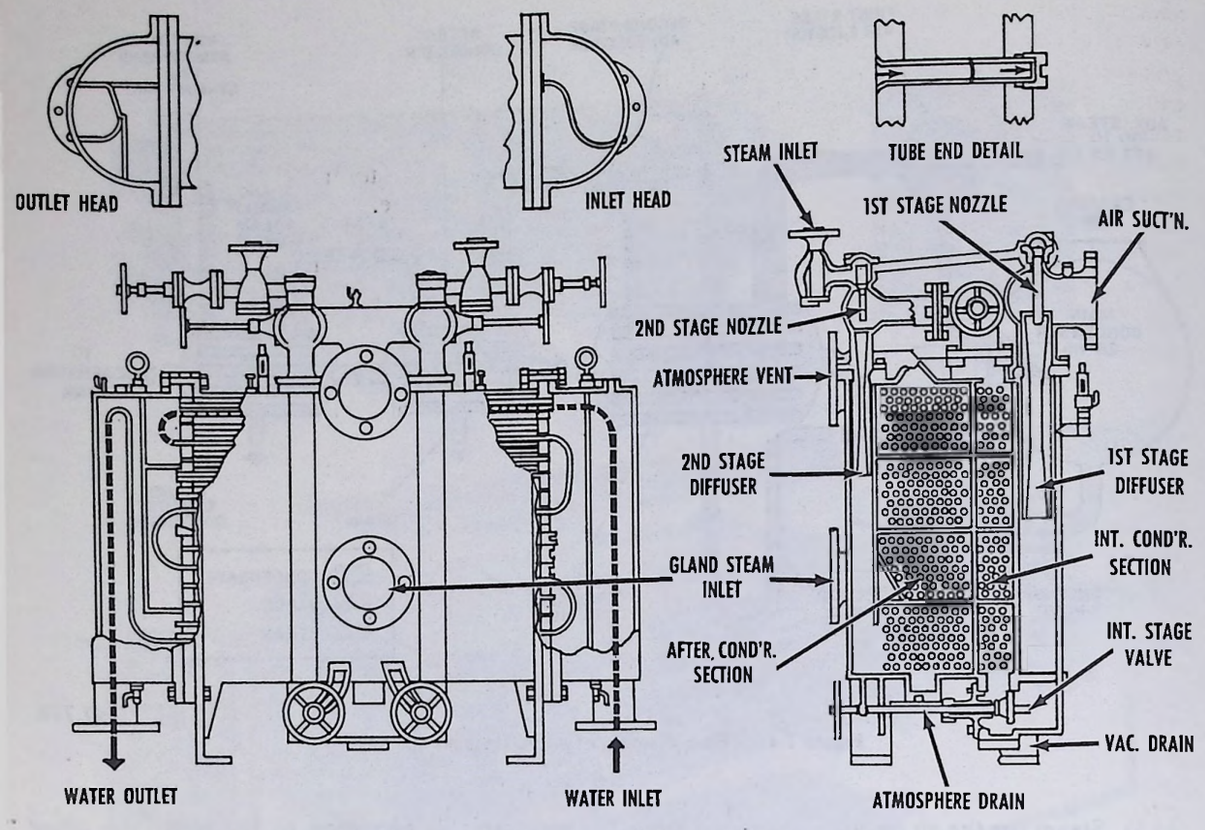


Figure 7-14.—A main air ejector and condenser assembly.

with steam, if the air ejector cooling water supply should fail, thereby allowing the steam to pass through the intercondenser and the aftercondenser without being condensed.

PRINCIPLES OF OPERATION

The first-stage air ejector takes suction on the main condenser and discharges the steam-air mixture to the intercondenser where the steam content of the mixture is condensed. The resulting condensate drops to the bottom of the intercondenser shell, and from there it drains to the main condenser through a U-shaped loop seal line. The air passes to the second-stage air ejector suction.

In the second-stage air ejector, another jet of steam is used. The steam-air mixture is now discharged into the aftercondenser, where the steam is condensed, and the air is vented to the atmosphere. (Normally, the air is vented to the atmosphere by way of the gland exhaust condenser; however, in some installations air is vented directly to the atmosphere from the air ejector aftercondenser).

Condensate from the main condenser is used as the cooling water in the air ejector intercondenser and aftercondenser. The air ejectors remove air only from the condenser, not from the condensate.

The intercondenser is under vacuum of approximately 26 inches of mercury. The aftercondenser is at approximate atmospheric pressure.

To assure sufficient cooling water for proper operation of the air ejectors when raising

vacuum both while standing by and at fractional power (cruising), a condensate recirculating line and valve are installed either at the cooling water outlet from the aftercondenser or on the vent condenser inlet header. To make recirculation automatic and to avoid overheating of the air ejector condenser, most air ejector recirculating lines are fitted with thermostatically controlled valves, discussed in chapter 6 of this manual.

A manually controlled valve allows bypassing of the thermostatic recirculating valve during the warming-up period. This bypass valve is also used in case the thermostatic valve is inoperative. When the required condenser vacuum is obtained, the manually controlled bypass valve is secured. Under normal operating conditions, recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve.

As previously noted, the condensate formed in the intercondenser is returned to the main condenser through the loop seal. If there were a direct connection between the intercondenser and the main condenser, the vacuum would be equalized in the two condensers. Since the main condenser carries a higher vacuum than the intercondenser, it is necessary that some form of seal be maintained in this drain line to prevent this equalization of vacuum. A water level in the U-shaped loop seal line provides this seal.

Operating procedures for lining up, starting, shifting and securing air ejectors for the main and auxiliary condensers are outlined in the Engineering Operation Procedures (EOP) subsystem of the Engineering Operational Sequencing System (EOSS). The following is a summary of those procedures.

STARTING AIR EJECTORS

The procedure for starting the air ejectors is usually as follows:

1. Start circulation of condensate cooling water through the air ejector condenser.
2. Open the valves in the drain lines, from the intercondensers and the aftercondensers.
3. Check the valves in the pressure and vacuum gage lines to be sure they are open.
4. Lift relief valves by hand.
5. Open the second-stage discharge valve.
6. Drain the steam supply lines to the air ejector assembly.
7. Cut in the steam to the second stage. Be sure that the steam is at or slightly above designed pressure.
8. Open the second-stage suction valve.
9. When the main condenser vacuum reaches 20 inches (or when ordered by the officer of the watch), open the first-stage discharge valve.
10. Cut in the steam to the first stage.
11. Open the first-stage suction valve.

Upon completion of step 11, the ejector should be in full operation and the main condenser vacuum should rapidly rise to that normally obtainable under standby conditions.

Discharge valves should always be opened before steam is admitted to the air ejector nozzles, and the steam supply should always be shut off before the discharge valves are closed.

After an air ejector has been started properly, it requires very little attention. It is necessary to (1) supply dry steam at designed pressure, (2) provide sufficient cooling water through the air ejector condenser tubes, (3) maintain proper drainage of the intercondenser and the aftercondenser, and (4) maintain a proper water level in the loop seal line.

SHIFTING AIR EJECTORS

If it becomes necessary or desirable to shift from one two-stage ejector unit to another while an air ejector unit is in operation, the procedure usually is as follows:

1. Open the discharge valve of the standby second stage.
2. Open the second-stage steam inlet valve.
3. Open the second-stage suction valve.
4. Open the first-stage discharge valve.
5. Open wide the steam inlet valve to the first-stage nozzle.
6. Open wide the suction valve of the first-stage element.

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At this point both two-stage units are in operation in parallel. The following procedure applies to the air ejector unit to be secured:

1. Close the suction valve of the first stage.
2. Close the steam supply valve to the first stage.
3. Close the discharge valve of the first stage.
4. Close the suction valve of the second stage.
5. Close the steam to the second stage.
6. Close the discharge valve of the second stage.

This completes the operation. If the turbine (and consequently the condenser) is operating at a low or medium rate when the air ejectors are shifted, it may be necessary to recirculate condensate during the time when both two-stage units are in service in order to provide sufficient cooling water for the intercondenser and aftercondenser. If sufficient cooling water is not provided or if the valves are opened and closed in the wrong order, a loss of vacuum will result and there is a possibility of putting excessive pressure on the air ejector condensers.

SECURING AIR EJECTORS

When securing an air ejector assembly, proceed as follows:

1. Close the first-stage suction valve.
2. Close the first-stage steam inlet valve.
3. Close the first-stage discharge valve.
4. Close the second-stage suction valve.
5. Close the second-stage steam inlet valve.
6. Close the second-stage discharge valve.
7. Close the intercondenser and aftercondenser drains.

CARE AND MAINTENANCE OF AIR EJECTORS

If an air ejector fails to maintain the proper vacuum, the cause may be traced to one of the following difficulties.

Faulty Steam Pressure

If the pressure fluctuates and falls below standard, raise it to a point not more than 15 psi above the designed pressure. A pressure that is too high can cause a reduced capacity, may overload the condenser units, and will cause an uneconomical quantity of steam to be used.

Clogged Steam Strainers

Strainers provided ahead of the nozzles must be clean. (NOTE: It is possible to clean or replace steam strainers as well as the nozzles of an air ejector assembly while the rest of the unit is in operation. It is necessary to isolate the unit that is to be opened from the rest of the assembly, by closing the steam supply valve and interstage valves of the unit, to avoid burns being suffered by personnel engaged in this work.) Strainers should be cleaned in accordance with the 3-M System or the manufacturer's instructions.

Insufficient Cooling Water

If enough cooling water is not circulated through the air ejector intercondenser and aftercondenser, a loss in vacuum results because the water becomes heated and will not condense the steam content of the air-vapor mixture entering the intercondenser. The second-stage ejector becomes overloaded because, instead of handling only air, it must also handle some steam that was not condensed in the intercondenser. Watch the temperature of the cooling water at the cooling water outlet, and keep it at the temperature designated by the manufacturer.

Leakages

Air leakages through the suction or discharge valves result in a loss of vacuum due to overloading of the air ejector. Leaks in valve glands, gasketed joints, relief or sentinel valves, etc. will have the same results.

Flooding of the intercondenser or aftercondenser shell with the condensate, whether caused by leaking tubes in the intercondenser or aftercondenser or by improper

drainage, will interrupt the removal of air and cause loss of vacuum.

Tube joint leakage can be remedied by repacking the tube ends with new packing rings.

Fouled Nozzles

Erosion or fouling of air ejector nozzles indicates that wet steam is being admitted to the equipment. The faulty nozzles make it impossible to operate the ejector under a high vacuum. In some instances, the nozzles may be clogged with grease, boiler compound, or some other deposit which will decrease the jet efficiency. If there are grease deposits, the nozzles should be cleaned by soaking them in an approved solvent.

Unstable Loop Seal

An air leak in the U-shaped loop seal that is provided for draining the intercondenser causes an unstable seal. Occasionally, a violent roll of the ship may cause the water in the seal to siphon out into the condenser. A connection on the condensate line is provided for filling the loop seal line.

AIR EJECTOR SAFETY PRECAUTIONS

The following safety precautions should be observed for air ejectors:

1. When starting an air ejector, always open the discharge valves before admitting steam to the nozzles. When securing an air ejector, always close tightly the steam supply valves to the nozzles before closing the discharge valves.
2. Before starting an air ejector, always drain the steam supply line, open the drain valves in the intercondenser and aftercondenser drain lines and be sure the atmospheric vent line is clear.
3. Should retubing or any other major repairs to an air ejector assembly be necessary, all parts should be hydrostatically tested following reassembly.

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CHAPTER 8

LUBRICATION AND ASSOCIATED EQUIPMENT

Lubrication reduces friction between moving parts by substituting fluid friction for sliding or rolling friction. Without lubrication, it is difficult to move a 100-pound weight across a rough surface; however, with lubrication and with proper attention to the design of bearing surfaces, it is possible to move a 1,000,000-pound load with a motor that is small enough to be held in the hand. By reducing friction, lubrication reduces the amount of energy required to perform mechanical actions and also reduces the amount of energy that is dissipated as heat.

Lubrication is a matter of vital importance throughout the shipboard engineering plant. Moving surfaces must be steadily supplied with the proper kinds of lubricants. Lubricants must be maintained at specified standards of purity and at designed pressures and temperatures in the lubrication systems. Without adequate lubrication, many units of shipboard machinery would quite literally grind to a screeching halt.

The lubrication requirements of shipboard machinery are met in various ways, depending on the nature of the machinery. In this chapter we shall discuss the basic principles of lubrication, the lubricants used aboard ship, the lubrication systems installed for many shipboard units, and the devices used to maintain lubricating oils in the required condition of purity.

FRICTION

The friction that exists between a body at rest and the surface upon which it rests is called STATIC friction. The friction that exists between moving bodies (or between one moving body and a stationary surface) is called KINETIC friction. Static friction, in addition to inertia, must be overcome to PUT any body in motion. Static friction is greater than the kinetic friction, which must be overcome to KEEP the body in motion.

There are three types of kinetic friction: sliding friction, rolling friction, and fluid friction. Sliding friction exists when the surface of one solid body is moved across the surface of another solid body. Rolling friction exists when a curved body such as a cylinder or a sphere rolls upon a flat or curved surface. Fluid friction is the resistance to motion exhibited by a fluid.

Fluid friction exists because of the cohesion between particles of the fluid and the adhesion of fluid particles to the object or medium which is tending to move the fluid. If a paddle is used to stir a fluid, for example, the cohesive forces between the molecules of the fluid tend to hold the molecules together and thus prevent motion of the fluid. At the same time, the adhesive forces of the molecules of the fluid cause the fluid to adhere to the paddle and thus create friction between the paddle and the fluid. Cohesion is the molecular attraction between particles which tends to hold a substance or a body together; adhesion is the molecular attraction between particles which tends to cause unlike surfaces to stick together. From the point of view of lubrication, adhesion is the property of a lubricant which causes it to stick (or adhere) to the parts being lubricated; cohesion is the property which holds the lubricant together and enables it to resist breakdown under pressure.

Cohesion and adhesion are possessed by different materials in widely varying degrees. In general, solid bodies are highly cohesive but only

slightly adhesive. Most fluids are quite highly adhesive but only slightly cohesive; however, the adhesive and cohesive properties of fluids vary considerably.

FLUID LUBRICATION

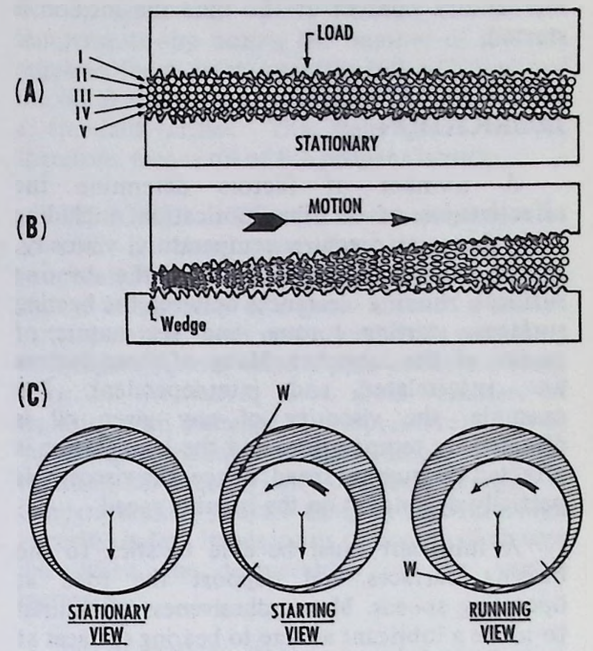
A liquid is used for most lubrication requirements because, in an enclosed space, a liquid is incompressible. Were it not for this incompressibility, it would not be possible to separate moving metal surfaces from each other (prevent metal-to-metal contact). As long as the lubricant film remains unbroken, sliding friction and rolling friction are replaced by fluid friction.

In any process involving friction, some power is consumed and some heat is produced. Overcoming sliding friction consumes the greatest amount of power and produces the greatest amount of heat. Overcoming fluid friction consumes the least power and produces the least amount of heat.

LANGMUIR THEORY

A presently accepted theory of lubrication is based on the Langmuir theory of the action of fluid films of oil between two surfaces, one or both of which are in motion. Theoretically, there are three or more layers or films of oil existing between two lubricated bearing surfaces. Two of the films are boundary films (indicated as I and V in fig. 8-1A), one of which clings to the surface of the rotating journal and one of which clings to the stationary lining of the bearing. Between these two boundary films are one or more fluid films (indicated as II, III, and IV in fig. 8-1A). The number of fluid films shown in the illustration is arbitrarily selected for purposes of explanation.

When the rotating journal is set in motion (fig. 8-1B), the relationship of the journal to the bearing lining is such that a wedge of oil is formed. The oil films II, III, and IV begin to slide between the two boundary films, thus continuously preventing contact between the two metal surfaces. The principle is again illustrated in figure 8-1C, where the position of the oil wedge W is shown with respect to the



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Figure 8-1.—Oil film lubrication. (A) Stationary position, showing several oil films; (B) surface set in motion, showing principle of oil wedge; (C) principle of (A) and (B) shown in a journal bearing.

position of the journal as it starts and continues in motion.

The views shown in figure 8-1C represent a journal or shaft rotating in a solid bearing. The clearances are exaggerated in the drawing to illustrate the formation of the oil film. The shaded portion represents the clearance filled with oil. The film is in the process of being squeezed out while the journal is at rest, as shown in the stationary view. As the journal slowly starts to turn and the speed increases, oil adhering to the surfaces of the journal is carried into the film, increasing the film thickness and tending to lift the journal as shown in the starting view. As the speed increases, the journal takes the position shown in the running view. Changes in temperature, with consequent changes in oil viscosity, cause changes in the film thickness and in the position of the journal.

If conditions are correct, the two surfaces are effectively separated, except for a possible

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momentary contact at the time the motion is started.

FACTORS AFFECTING LUBRICATION

A number of factors determine the effectiveness of oil film lubrication, including such things as pressure, temperature, viscosity, speed, alignment, condition of the bearing surfaces, running clearances between the bearing surfaces, starting torque, and the nature of purity of the lubricant. Many of these factors are interrelated and interdependent. For example, the viscosity of any given oil is affected by temperature, and the temperature is affected by running speed; hence, the viscosity is partially dependent on the running speed.

A lubricant must be able to stick to the bearing surfaces and support the load at operating speeds. More adhesiveness is required to make a lubricant adhere to bearing surfaces at high speeds than at low speeds. At low speeds, greater cohesiveness is required to keep the lubricant from being squeezed out from between the bearing surfaces.

Large clearances between bearing surfaces require high viscosity and cohesiveness in the lubricant to ensure maintenance of the lubricating oil film. The larger the clearance, the greater must be the lubricant's resistance to being pounded out, with consequent destruction of the lubrication oil film.

High unit load on a bearing requires high viscosity of the lubricant. A lubricant subjected to high loading must be sufficiently cohesive to hold together and maintain the oil film.

LUBRICANTS

Although there is growing use of synthetic lubricants, the principal source of the oils and greases used by the Navy is still petroleum. By various refining processes lubricating oils are extracted from crude petroleum and blended, sometimes with additives (chemical compounds), into a multiplicity of products to meet a wide range of lubrication requirements and applications.

Types of Lubricating Oils

Lubricating oils approved for shipboard use are limited to those grades and types deemed essential to provide proper lubrication under all anticipated operating conditions.

For diesel engines, it is necessary to use a detergent-dispersant type additive oil to keep the engines clean. In addition, these lubricating oils must be fortified with oxidation inhibitors and corrosion inhibitors to allow long periods between oil changes and to prevent corrosion of bearing materials.

For steam turbines, it is necessary to have an oil of high initial film strength. This oil is then fortified with antifoaming additives and additives that inhibit oxidation and corrosion. In addition, it is necessary to use extreme pressure (EP) additives to enable the oil to carry the extremely high loading to which it is subjected in the reduction gear.

For the hydraulic systems in which petroleum lubricants are used, and for general lubrication use, the Navy uses a viscosity series of oils reinforced with oxidation and corrosion inhibitors and antifoam additives. The compounded oils, which are mineral oils with additives, are still used in deck machinery and in the few remaining steam plants that utilize reciprocating steam engines.

Many special lubricating oils are available for a wide variety of services. These are listed in the Federal Supply Catalog. Among the most important specialty oils are those used for lubricating refrigerant compressors. These oils must have a very low pour point and must be maintained with a high degree of freedom from moisture.

The principal synthetic lubricants currently in naval use are (1) a phosphate-ester type fire-resistant hydraulic fluid, used chiefly in the deck-edge elevators of carriers, and (2) a water-base glycol hydraulic fluid, used chiefly in the catapult retracting gears.

Classification of Lubricating Oils

The Navy identifies lubricating oils by symbols. Each identification number consists of four digits and, in some cases, appended letters.

The first digit indicates the class of oil according to type and use; the last three digits indicate the viscosity of the oil. The viscosity digits are actually the number of seconds required for 60 milliliters of the oil to flow through a standard orifice at a specified temperature. Symbol 3080, for example, indicates that the oil is in the 3000 series and that a 60-ml sample flows through a standard orifice in 80 seconds when the oil is at a specified temperature (210° F, in this instance). To take another example, symbol 2135 TH indicates that the oil is in the 2000 series and that a 60-ml sample flows through a standard orifice in 135 seconds when the oil is at a specified temperature (130° F, in this case).

The leters H, T, TH, or TEP added to a basic symbol number indicate that the oil contains additives for special purposes.

Lubricating Oil Characteristics

Lubricating oils used by the Navy are tested for a number of characteristics, including viscosity, pour point, flashpoint, fire point, auto-ignition point, neutralization number, demulsibility, and precipitation number. Standard test methods are used for making all tests. The characteristics of lube oil are briefly explained in the following paragraphs.

VISCOSITY.–The viscosity of an oil is its tendency to resist flow or change of shape. A liquid of high viscosity flows very slowly. In variable climates automobile owners, for example, change oils in accordance with prevailing seasons because heavy oil becomes too sluggish in cold weather, and light oil becomes too fluid in hot weather. The higher the temperature of an oil, the lower its viscosity becomes; lowering the temperature increases the viscosity. The high viscosity or stiffness of the lube oil on a cold morning makes an automobile engine difficult to start.

If an oil of a higher viscosity is used under such conditions, the increased internal friction will raise the temperature and reduce the viscosity of the oil. The viscosity must always be high enough to keep a good oil film between the moving parts–otherwise, there will be increased friction, power loss, and rapid wear on the parts. Oils are graded by their viscosities at a certain temperature–by noting the number of seconds required for a given quantity (60 milliliters) of the oil at the given temperature to flow through a standard orifice. The right grade of oil, therefore, means oil of the proper viscosity.

VISCOSITY INDEX.–The viscosity index of an oil is based on the slope of the temperature-viscosity curve–on the rate of change in viscosity of a given oil with a change in temperature, with other conditions remaining unchanged. A low index figure denotes a steep slope of the curve, or a great variation of viscosity with a change in temperature; a higher index figure denotes a flatter slope, or lesser variation of viscosity with identical changes in temperatures. If you are using an oil with a high viscosity index, its viscosity or body will change less when the temperature of the engine increases.

POUR POINT.–The pour point of an oil is the lowest temperature at which the oil will barely flow from a container. At a temperature below the pour point, oil congeals or solidifies. A low pour point is an essential characteristic of lube oils used in cold weather operations. (NOTE: The pour point is closely related to the viscosity of the oil. In general, an oil of high viscosity will have a higher pour point than an oil of low viscosity.)

FLASHPOINT.–The flashpoint of an oil is the temperature at which enough vapor is given off to flash when a flame or spark is present. The minimum flashpoints allowed for Navy lube oils are all above 315° F, and the temperatures of the oils are always far below that under normal operating conditions.

FIRE POINT.–The fire point of an oil is the temperature at which the oil will continue to burn when ignited.

AUTO-IGNITION POINT.–The auto-ignition point of an oil is the temperature at which the flammable vapors given off from the oil will burn without the application of a spark or flame. For most lubricating oils, this temperature is in the range of 465° to 815° F.

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NEUTRALIZATION NUMBER.—The neutralization number of an oil is the measure of the acid content and is defined as the number of milligrams of potassium hydroxide (KOH) required to neutralize 1 gram of the oil. All petroleum products deteriorate (oxidize) in the presence of air and heat; the products of this oxidation include organic acids, which, if present in sufficient concentration, have harmful effects on alloy bearings at high temperatures, galvanized surfaces, and the demulsibility of the oil with respect to freshwater and seawater. This last effect, in turbine installations, may result in the formation of sludge and emulsions too stable to be broken by the means available. An increase in acidity is an indication that the lubricating oil is deteriorating.

DEMULSIBILITY.—The demulsibility, or emulsion characteristic, of an oil is its ability to separate cleanly from any water present—an important factor in forced-feed systems. It is especially important to keep water (fresh or salt) out of oils.

PRECIPITATION NUMBER.—The precipitation number of an oil is a measure of the amount of solids classified as asphalts or carbon residue contained in the oil. The number is reached by diluting a known amount of oil with naphtha and separating the precipitate by centrifuging—the volume of separated solids equals the precipitation number. The test is a quick means of determining the presence of foreign materials in used oils. An oil with a high precipitation number may cause trouble in an engine by leaving deposits or by plugging up valves and pumps.

Lubricating Greases

Some lubricating greases are simple mixtures of soaps and lubricating oils. Others are more exotic liquids such as silicones and dibasic acid esters, thickened with metals or inert materials to provide adequate lubrication. Requirements for oxidation inhibition, corrosion prevention, and extreme pressure performance are met by incorporating special additives.

Lubricating greases are supplied in three grades: soft, medium, and hard. The soft greases are used for high speeds and low pressures; the medium greases are used for medium speeds and medium pressures; the hard greases are used for slow speeds and high pressures.

Classification of Greases

Navy specifications have been drawn to cover the several grades of lubricating greases. The grades most common in engineroom use are as follows:

BALL AND ROLLER BEARING GREASE, MIL-G-24508.—Ball and roller bearing grease is for general use in equipment designated to operate at temperatures up to 300° F. For temperature applications above 300° F, high temperature, electric-motor, ball and roller bearing grease (MIL-L-15719) shall be used.

EXTREME PRESSURE GREASE, MIL-G-17740.—Extreme pressure grease has antirust properties and is suitable for lubrication of semi-enclosed gears, or any sliding or rolling metal surfaces where loads may be high and where the equipment may be exposed to salt spray or moisture. It is intended for use in a temperature range of 0° to 140° F.

GRAPHITE GREASE, VV-G-671.—Graphite grease may be applied with compression grease cups to bearings operating at temperatures not to exceed 150° F. The three grades of this grease are:

Grade 1 Soft	For light pressures and high speeds
Grade 2 Medium	For medium pressures and medium speeds
Grade 3 Medium Hard	For high pressures and slow speeds

LUBRICATING SYSTEMS

MAIN LUBRICATING OIL SYSTEMS

Main lubricating oil systems in steam-driven ships provide lubrication for the turbine bearings

and the reduction gears. In some ships, the main lube oil system also provides control oil for operation of the main engine throttle control system and hydraulic gland seal regulators.

The main lube oil system generally includes a filling and transfer system, a purifying system, and separate service systems for each propulsion plant.

Most ships have three positive displacement pumps for main lube oil service. One pump is an attached pump driven by either the propulsion shaft or the quill shaft of the reduction gear. This pump provides main lube oil service when the main engines are turning fast enough for the pump to supply the required pressure. The other two pumps may be either both electric-motor driven or a combination of one turbine-driven and one electric-motor driven. These pumps are used for light off, getting underway, and as standby pumps.

Some ships have automatic features which provide for electric pumps to start and stop or shift speeds at various pressures and shaft rpm's. This arrangement automatically provides sufficient main lube oil pressure for all operating conditions.

Some ships (most submarines) have only two electric-motor driven main lube oil pumps. One pump is supplied by a.c. electrical power and the other by d.c. electrical power. One pump is always in standby for the running pump and will automatically start if oil pressure drops below a specified value.

Lube oil pressures which provide control features for the main lube oil system (such as alarms, pump standby features, etc) are monitored at the bearing farthest from the lube oil supply (main lube oil pumps); this is known as the "most remote bearing."

In a typical lube oil system (fig. 8-2) the lube oil is discharged from the pumps into the main lube oil STRAINERS. The strainers (fig. 8-3) are of the duplex basket type and are designed so that one strainer can be open for cleaning and inspection while the other is on service. Most of the strainers contain a removable magnetic element (not shown) in each basket to remove ferrous (magnetic)

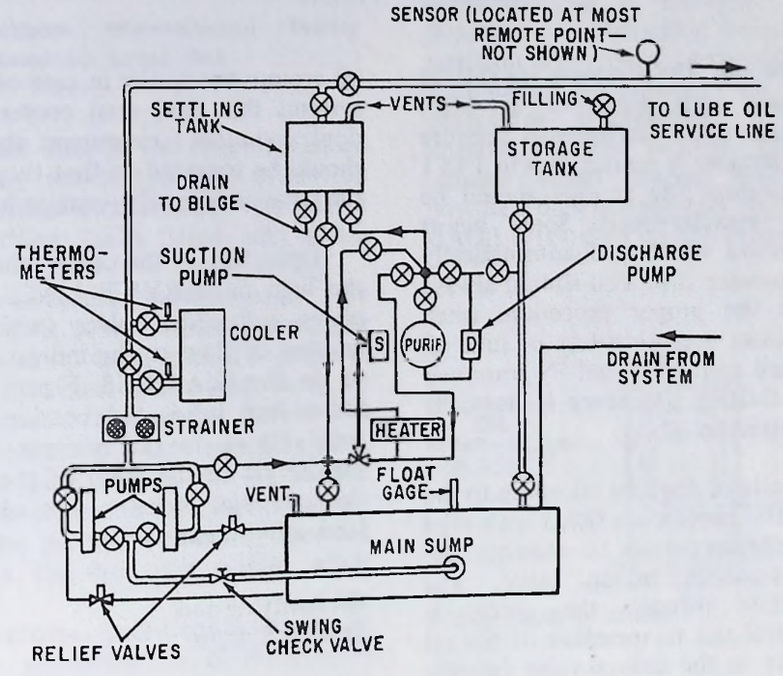
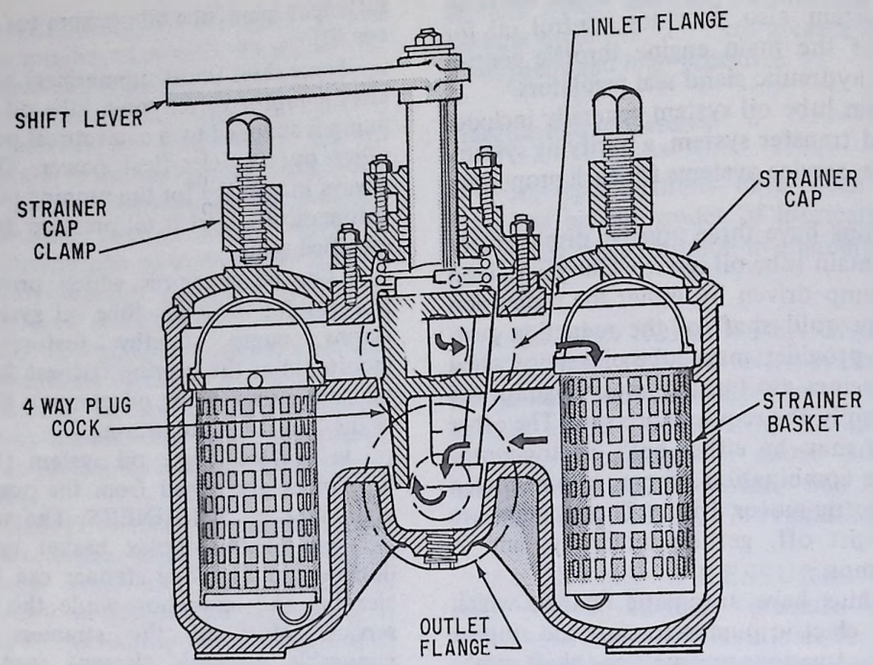


Figure 8-2.—Typical lube oil system.

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Figure 8-3.—Duplex strainer.

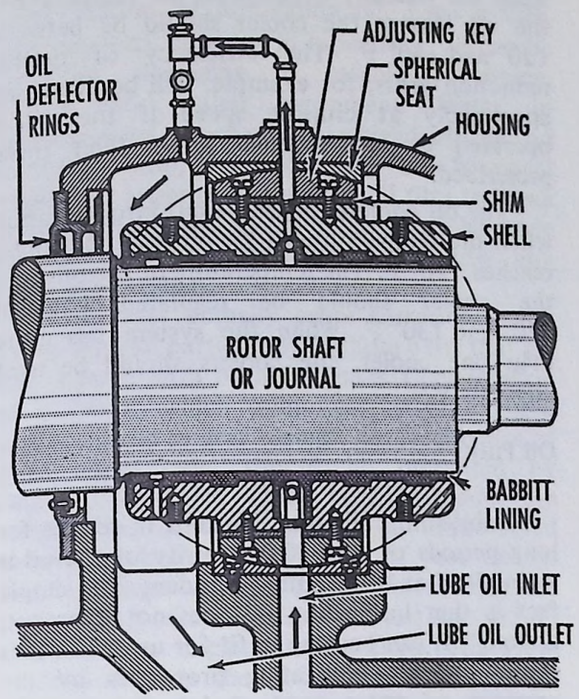
particles from the oil. The strainers are shifted and cleaned once each watch or as ship's instructions dictate. If the differential pressure (d/p) across the strainer in service rises to 1 to 1 1/2 psi above normal, the strainer should be shifted to the standby unit. Some newer strainers have valves which will automatically shift with an excessive d/p. You should always carefully follow the proper procedure when shifting the strainers because a loss of lube oil and/or fire hazard can be caused by improper operation. The shifting procedure is normally posted near the strainer.

From the strainers, the lube oil passes to the OIL COOLER. The coolers are fitted with inlet and outlet oil thermometers to monitor the amount of cooling taking place. The cooling-water flow through the cooler is adjusted to control the temperature of the oil leaving the cooler to the desired value (usually between 120° to 130° F). Some coolers are provided with bypasses to allow bypassing the oil around the cooler in case of tube failure. On systems that have dual coolers (similar to the duplex strainer arrangement above), the coolers should be operated so that they both get about the same number of operating hours.

Upon leaving the cooler, the oil goes on into the lube oil SERVICE LINES, through orifice plates or needle valves (which regulate the amount of flow to the individual bearings) and on to the BEARINGS. Figure 8-4 illustrates a forced-feed lubricated bearing. In addition to supplying oil to the bearings, the service lines provide oil to the teeth of the reduction gears through spray nozzles. The oil then all drains back into the main sump.

Oil Purifying and Settling System

The oil purifying and settling functions of the forced-feed system include a centrifugal oil



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Figure 8-4.—Adjustable spherical-seated bearing lubricated by forced feed.

purifier (discussed later in the chapter), an oil heater for raising the temperature of the oil entering the purifier (to facilitate removal of water), and settling tanks fitted with steam heating coils.

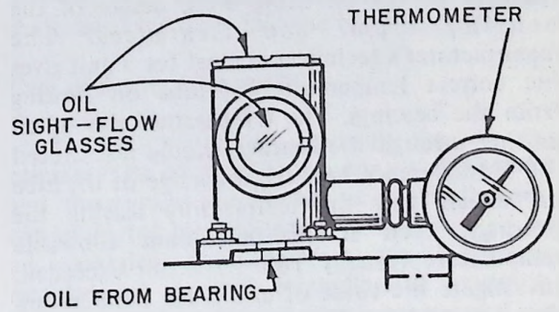
The oil is normally purified while the lubricating system is in operation. The purifier takes oil from a sump tank; after it is purified, the oil is discharged back to the same sump. In some ships, oil from the smaller forced-feed systems is drained and put into a settling tank, from which the purifier may take a suction when it is not employed in purifying oil of the main system. The purifier is normally operated 12 hours a day for the main system, while underway.

If the oil becomes badly contaminated by water or other impurities or if it becomes emulsified, the mixture is pumped up to the SETTLING TANKS. Here the oil is heated by the steam coils. After several hours of heating, the impurities will have settled and can be drawn off through the drains at the bottom of the tanks. The remaining oil is then passed through the purifier and discharged back to the sump. Purification of the main sump oil, by heating and settling, can be done only in port because all the oil must be pumped out of the main engine sump. This should be done as soon as possible after securing to take advantage of the heat accumulated by normal engine operation.

Oil Check Fittings

Various means are provided for maintaining a continuous check on the supply of oil to bearings and on the temperature of oil flowing from the bearings. In modern turbines and reduction gears, a THERMOMETER and a bull's eye SIGHT-FLOW fitting are installed in the return line leading from the individual bearing. A combined sight-flow and thermometer fitting (fig. 8-5) is one type installed.

The thermometers are sometimes of the distant-reading type—with the recording bulbs connected to a dial-type indicator or a temperature monitoring panel. In some new construction ships (especially those with automated propulsion) the bearings have resistance temperature detectors (RTD's) installed in the bearing itself to remotely indicate actual bearing temperature and to provide a high temperature alarm. A PRESSURE GAGE is installed on the header from which oil



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Figure 8-5.—Combined lube oil sight-flow and thermometer fixture.

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is fed to the bearing and gears to permit monitoring for correct supply pressure.

Oil Pressures

The pressures to be carried at the various parts of the lubrication system differ with the type of installation. Pressure at the service pumps should be such that the pressure at the most remote bearing is in accordance with the manufacturer's specification. A higher pressure than this will cause the bearings to become flooded and the oil to foam. Pressures shown by the oil gages on the main gage board should indicate the actual pressure at the low-pressure alarm connections to the system. Sudden increases in pressure at the pump (usually due to a clogged strainer or pipeline or to startup of a standby pump) should prompt an immediate check of oil flow at the bearings. The trouble should be located and corrected at once.

Oil Flow

The flow of oil at the bearing, as seen through the sight-flow glass, must be uniform. Frequent inspections should be made during each watch, especially at high speeds. If the oil supply is interrupted at any time, the main shaft should be stopped and locked. If the oil temperature rises beyond allowable limits, reduce the shaft speed and notify the bridge.

Oil Temperatures

Bearing temperatures depend on the viscosity of the oil being used, design of the bearing, rpm, and clearances. The manufacturer's technical manual for a unit gives the correct temperatures of lube oil flowing from the bearings. The temperature rise of oil passing through the bearings should not exceed 50° F (difference between discharge of the lube oil cooler and the temperature leaving the bearing), even if the maximum allowable temperature (usually 180° F) is not exceeded. Investigate the cause of any rising temperature that fails to level off, no matter how slowly it is rising.

Since friction loss in a journal bearing is directly proportional to the oil viscosity and since the viscosity depends on the temperature, the oil leaving the cooler should be between 120° and 130° F. The efficiency of double reduction gears, for example, will be decreased appreciably at cruising speed if the oil is operated at temperatures lower than those prescribed.

The oil coolers should be put into operation when the temperature of the oil from the cooler reaches 120° F. The temperature of the oil from the cooler should be regulated between 120° and 130° F. When the system has more than one cooler, the coolers should be used alternately.

Oil Purity

Lubricating oils may be kept in service for long periods of time if the purity of the oil is maintained at the required standard. The simple fact is that lubricating oil does not wear out, although it can become unfit for use when it is robbed of its lubricating properties by the presence of water, sand, sludge, fine metallic particles, acid, and other contaminants.

Proper care of lubricating oil requires, then, that the oil be kept as free as possible from contamination and that, once contaminated, the oil must be purified before it can be used again.

Strainers are used in many lubricating systems to prevent the passage of grit, scale, dirt, and other foreign matter. Duplex strainers are used in lubricating systems in which an uninterrupted flow of lubricating oil must be maintained; the flow may be diverted from one strainer basket to the other while one is being cleaned. If pieces of metal are found, determine the character of the metal. Most ships have strainer magnets installed to remove ferrous (iron) particles from the oil. Bits of brass or babbitt metal indicate that there is a damaged, or wiped, bearing in the system or that the bearing metal is breaking up. If the metal has the appearance of rust, it indicates that corrosion is occurring in the system. Pieces of metal rust will scratch the bearing or mar a thrust shoe. A sudden rise in bearing temperature, followed by a return to normal, usually indicates that some foreign substance reached the bearing, scratched it, and was then washed out by the oil supply.

Strainers do not solve the problem of water contamination of lubricating oil. Even a very small amount of water in lubricating oil can be extremely damaging to machinery, piping, valves, and other equipment. Water in lubricating oil can cause widespread pitting and corrosion; also, by increasing the frictional resistance, water can cause the oil film to break down prematurely. Every effort must be made to prevent the entry of water into any lubricating system.

Water may actually cause corrosion in the entire system, particularly in those parts that are not covered with oil at all times. Condensation of moisture, which promotes rust on exposed surfaces, such as gear casings, upper portions of drain tanks, etc, should be prevented by eliminating factors which tend to reduce the temperature of the surfaces. All unprotected escape hatches in the vicinity of gear casings must be kept secured at all times when the temperature of the outside air is less than 70° F, except when engines are secured. Air from ventilation ducts should never blow directly or indirectly on the gear casing. When coming to anchor, or securing main propulsion machinery, circulate oil through the system for at least an hour to minimize the effects of an unavoidable amount of freshwater condensation.

Water enters the lubrication system at the following principal points:

1. Leaky tubes or joints in the oil coolers
2. Steam-sealed glands of turbines (sometimes because of clogged drain)
3. Vents on tanks and gear casings (as atmospheric moisture, subsequently condensed)
4. Leaks in drain or sump tanks located in bilges

Lube oil may lose its lubricating qualities if it is contaminated. But, if the impurities and water are removed as soon as their presence is noted, the oil can be used over and over indefinitely. To ensure that the oil is kept free of all foreign matter, samples of all lube oils are taken periodically and tested.

CENTRIFUGAL PURIFIERS.—Centrifugal purifiers (centrifuges) are used to purify the lube oils. Because of the importance of this purifier and its use in purifying lube oil used in other than forced-feed systems, we shall discuss it more fully later in this chapter. Generally, the oil must be heated to higher than operating temperature before being run through the centrifuge. This results in a greater degree of purification.

SELF-OILING SPRING BEARINGS

In most ships, main shaft spring bearings on the propulsion shaft are lubricated by a self-oiling system. Most of these bearings are ring-oiled, though some are chain-oiled. You must know how to ensure continuous, correct lubrication of these important units.

Ring-Oiled Spring Bearings

The lubrication system for the ring-oiled bearings consists of an OIL SUMP below the bearing journal and brass OILER RINGS which are hung loosely over the journal and lower half of the bearing. These rings are immersed in the oil and carry a continuous supply of oil over the journal as the rings are dragged around by the rotation of the shaft. The rings must be finished smoothly and must fit properly in the guides in the upper half of the bearing shell to prevent hanging and uneven rotation. The upper half of the bearing is cut away in the middle to accommodate the oiler rings. A hinged ACCESS COVER in the upper half of the bearing housing permits inspection of the journal and oiler rings. The OIL DEFLECTOR RINGS, secured to the shaft, keep the oil within the bearing space.

Care of Spring Bearing Oil

The frequency of changing the oil and cleaning the oil sumps depends on the service and the mechanism. If the oil doesn't become contaminated by impurities, it can be used for an extended period before the lubricating qualities are reduced. Regardless of condition, the oil should be drained once a quarter and run through the purifier. Whenever the oil is renewed, the sump should be thoroughly cleaned. Inspection covers must be kept closed

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when not in use. In addition, they must be kept accessible (do NOT run lines in front of them), and they must NOT be painted shut.

Samples of the oil in the sump should be examined after each extended run and after 10 days of periodic service. If the oil shows an increase in viscosity, discoloration, or formation of sludge deposits in the reservoir, immediate renewal is necessary. When underway, the oil level and bearing operations must be inspected and logged hourly.

GREASE LUBRICATION SYSTEMS

Grease lubrication is used in many locations where the retention of lube oil at the bearing surface would otherwise be difficult. The grease is applied either through grease cups or through pressure fittings, such as the Zerk type.

Grease Cup Lubrication

Whereas dirt in lube oil will generally settle out, dirt in grease remains mixed with the grease and becomes abrasive. For this reason, particular care must be taken to prevent contamination, especially where grease cups are used. Before opening the container, carefully remove all dirt from the exterior. Do NOT allow any dirt to enter either the opening or the grease cups. The cups should be frequently emptied, cleaned, and refilled with fresh grease.

Pressure Greasing

Pressure fittings form a convenient means of lubricating numerous low-speed, lightly loaded, or widely separated bearings. They are not, however, satisfactory for use on electric generators and motors because of the danger of forcing grease out of the bearing and onto windings. These fittings are similar to those on an automobile, where grease guns are used for lubrication.

Before applying the grease gun, wipe the pressure fittings and be sure they are clean. The gun tip, too, must be clean. Pressure should be applied to the fitting until grease comes out around the edges of the bearing. In bearings fitted with felt or other seal, you must be careful to avoid breaking the seals by overpressure. Excessive pressure in the lubrication of needle-type roller bearings may unseat the needles.

BALL AND ROLLER BEARING LUBRICATION

The oil or grease used to lubricate ball and roller bearings (known jointly as ROLLER CONTACT BEARINGS) provides a lubricating film among the balls, rollers, and retainers and between the ends of the rollers and the races; dissipates heat caused by friction; prevents corrosion of the highly polished parts; and aids in excluding dirt, water, and other foreign matter. The lubricant specified for each machine should be used, and excessive lubrication should be avoided.

LUBE OIL PURIFICATION

In the forced-feed lubrication systems in modern naval ships, if the purity of the oil remains intact, the oil may be kept in service for a long period of time. LUBE OIL DOES NOT WEAR OUT; it is merely robbed of its lubricating properties by foreign substances. In other words, improper performance of a correct oil is not due to internal change, but to contamination or to the formation of sludge. No one would ever willfully pour into the lubrication system of the ship's machinery a mixture of oil, water, sand, fine metallic particles, sludge, and acid. Yet lubricating systems do contain mixtures of this nature when preventive measures are not taken. The centrifugal oil purifier is used in all naval ships to remove the water and other foreign matter from the lube oil. Water is the greatest source of contamination.

Contamination must be removed or the oil will not meet lubrication requirements. Dirt, sludge, and other contaminants will act as abrasives to score and scratch the rubbing metal surfaces within engines, generators, pumps, and blowers. Contaminants interfere with the ability

of the oil to maintain a good lubricating film between metal surfaces.

Several different devices are used to keep the oil as clean as possible. Each device is designed to remove certain kinds of contamination, and several types of devices are required in a lubricating system to keep oil in a usable condition. Strainers, filters, settling tanks, and centrifugal purifiers are the devices used to free oil of contamination.

SETTLING TANKS

Shipboard lubricating systems include settling tanks which permit used oil to stand while water and other impurities settle out. Settling is due to force of gravity. A number of layers of contamination may form; the number of layers formed depends on the difference in specific gravity of the various substances. For example, there might be a layer of metal particles on the bottom, then a layer of sludge, then a layer of water, and then the clean oil.

Lubricating oil piping is generally arranged to permit two methods of purification: batch purification and continuous purification. In the batch process, usually done while the ship is in port, the lubricating oil is transferred from the sump to a settling tank by means of a purifier or a transfer pump. After the oil is heated and allowed to settle for several hours, water as well as other impurities are removed from the settling tanks. The oil is then centrifuged and returned to the sump or storage tank from which it was taken.

CENTRIFUGAL PURIFICATION

While a ship is at sea or when time does not permit batch purification in the settling tanks, the continuous purification process is used. Centrifugal purifiers are used in this process. The purifier takes the oil from the sump in a continuous cycle. Before entering the purifier, the oil is heated to facilitate easier removal of the impurities.

Detailed instructions on construction, operation, and maintenance of purifiers are furnished by manufacturers' technical manual, Preventive Maintenance System documentation and ship's instructions. These documents should be carefully studied and followed by the personnel who are responsible for operation and maintenance of purifiers. The following general information is provided to familiarize you with the methods of purification and the purposes and principles of purifier operation.

In the purification process, a purifier may be used to remove water and sediment from oil or to remove sediment only. When water is involved in the purification process, the purifier is called a SEPARATOR. When the principal item of contamination is sediment, the purifier is used as a CLARIFIER. When used to purify lubricating oil, a purifier may be used as either a separator or a clarifier. Aboard ship, a purifier is almost always operated as a separator.

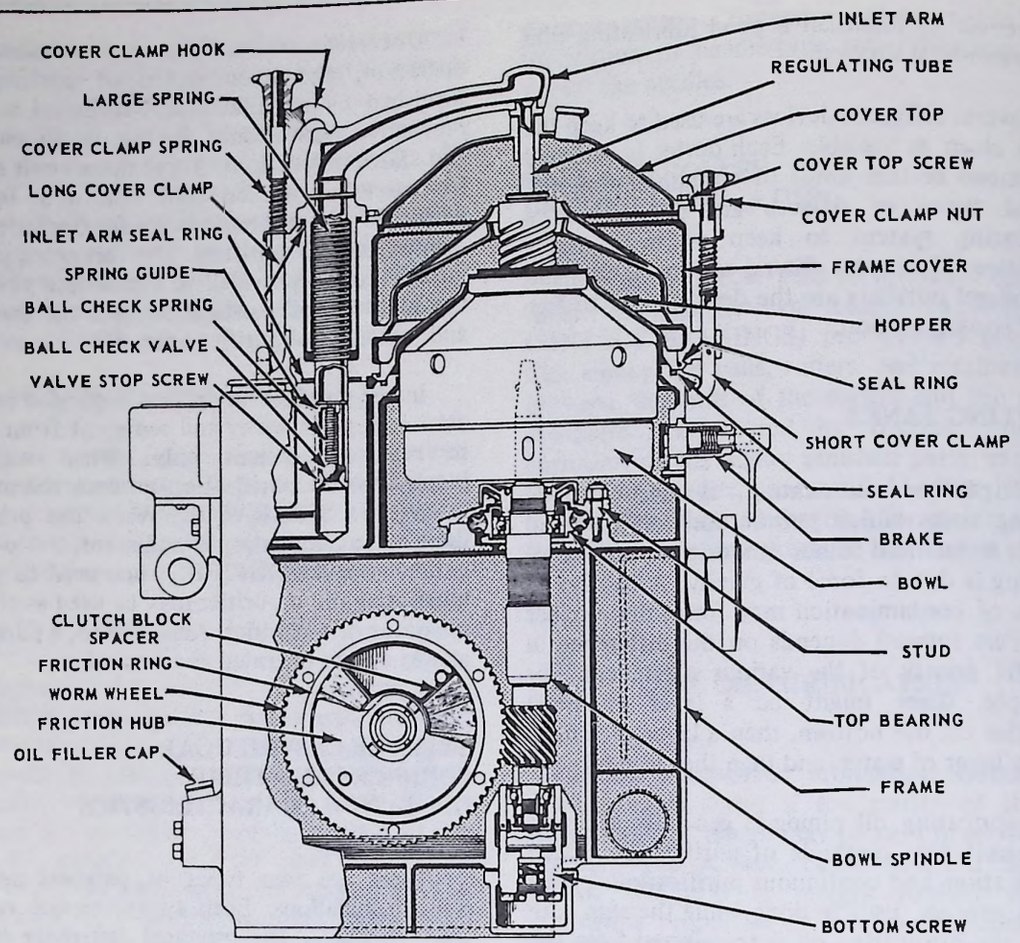
TYPES OF CENTRIFUGAL PURIFIERS AND THEIR OPERATING CHARACTERISTICS

There are two types of purifiers used in Navy installations. Both types operate on the same principle. The principal difference in the two types is in the design of the rotating units. In one type the rotating element is a bowl-like container which encases a stack of disks, and in the other type the rotating element is a hollow, tubular rotor; thus, they are known as the disk-type purifier and the tubular-type purifier.

Disk-Type Purifier

A sectional view of a disk-type centrifugal purifier is shown in figure 8-6. The bowl is mounted on the upper end of the vertical bowl spindle, which is driven by means of a worm wheel and friction clutch assembly. A radial thrust bearing at the lower end of the bowl spindle carries the weight of the bowl spindle and absorbs any thrust created by the driving action.

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Figure 8-6.—Disk-type centrifugal purifier.

The parts of a disk-type bowl are shown in figure 8-7. The flow of oil, through the bowl and additional parts, is shown in figure 8-8.

Contaminated oil enters the top of the revolving bowl through the regulating tube. The oil then passes down the inside of the tubular shaft and out at the bottom into the stack of disks. As the dirty oil flows up through the distribution holes in the disks, the high centrifugal force exerted by the revolving bowl causes the dirt, sludge, and water to move outward and the purified oil to move inward toward the tubular shaft. The oil passes through the discs, rises up underneath the top disc, and passes into the tubular shaft. The water forms a seal between the top disc and the bowl top. (The top disc is the "dividing line" between the water and the oil.) The disks divide the space within the bowl into many separate narrow passages or spaces. The liquid confined within each passage is restricted so that it can flow only along that passage. This arrangement prevents excess agitation of the liquid as it passes through the bowl and creates shallow settling distances between the disks.

Most of the dirt and sludge remains in the bowl and collects in a more or less uniform layer

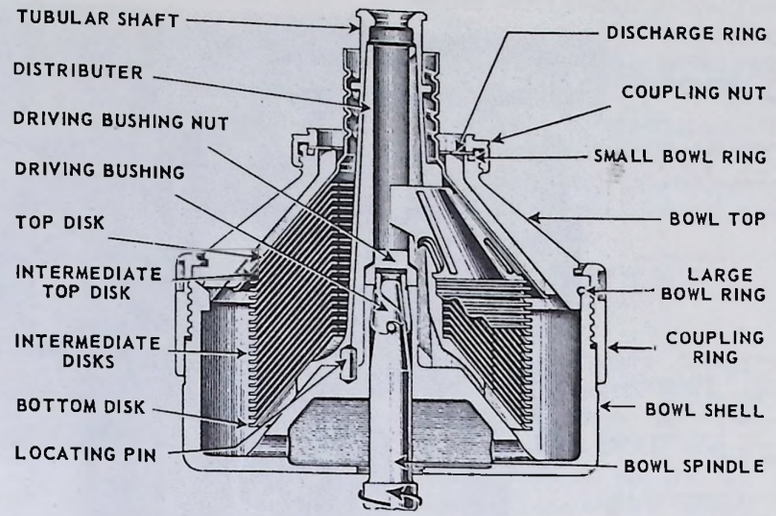
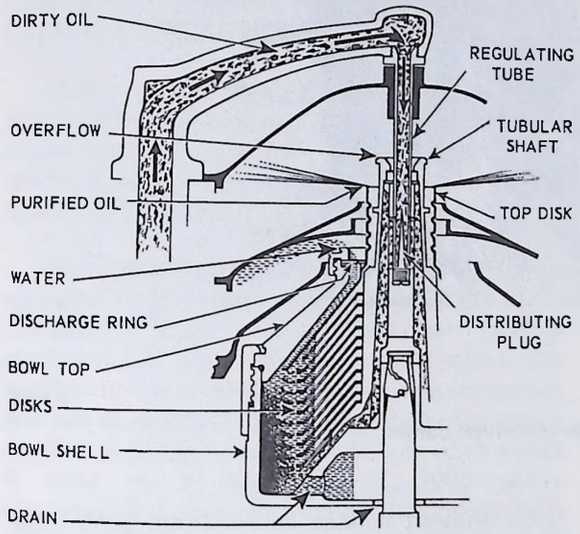


Figure 8-7.—Parts of a disk-type purifier bowl. 47.84



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Figure 8-8.—Path of contaminated oil through disk-type purifier bowl (DeLaval).

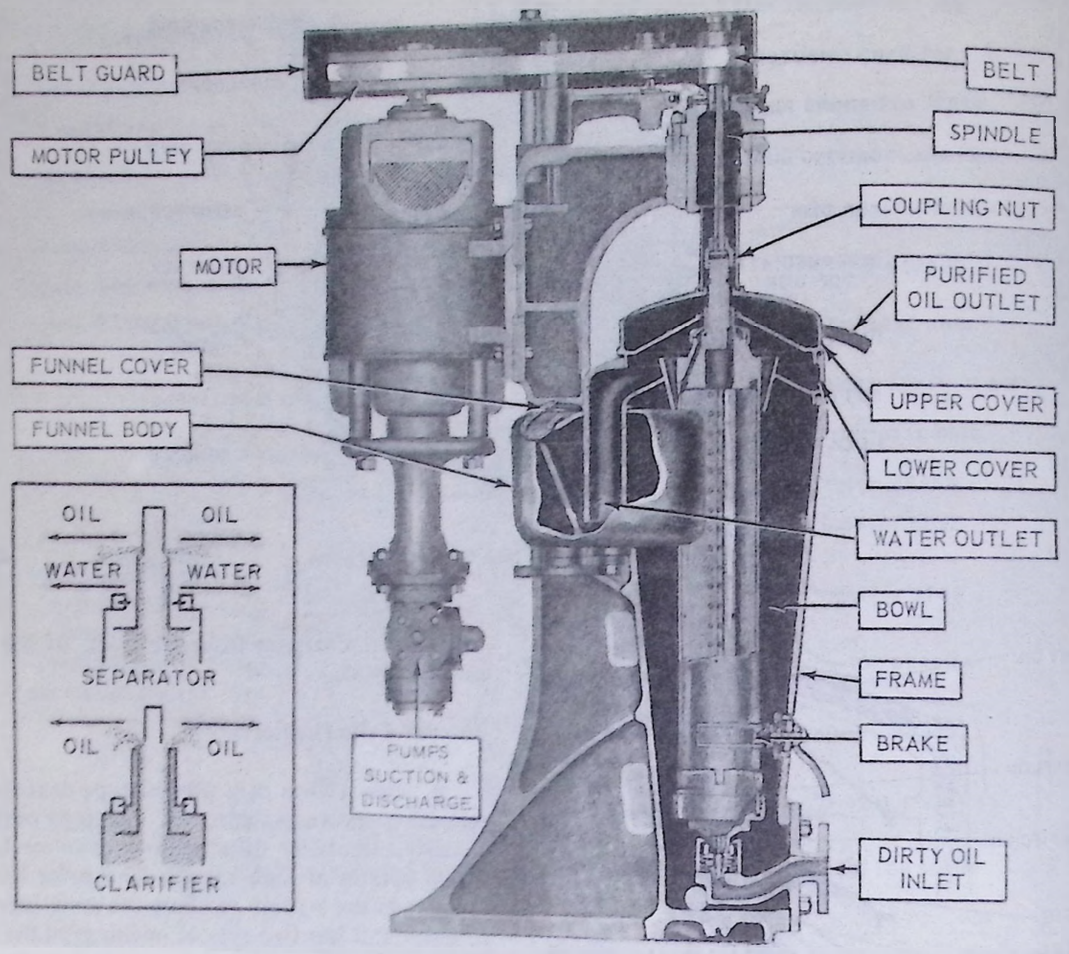
on the inside vertical surface of the bowl shell. Any water, along with some dirt and sludge, separated from the oil, is discharged through the discharge ring at the top of the bowl. The purified oil flows inward and upward through the disk, discharging from the neck of the top disk (fig. 8-8).

Tubular-Type Purifier

A cross section of a tubular-type centrifugal purifier is shown in figure 8-9. This type purifier consists essentially of a hollow rotor or bowl which rotates at high speeds. The rotor has an opening in the bottom to allow the dirty lube oil to enter and has two sets of openings at the top to allow the oil and water (separator) or the oil by itself (clarifier) to discharge (see insert, fig. 8-9). The bowl, or hollow rotor, of the purifier is connected by a coupling unit to a spindle which is suspended from a ball bearing assembly. The bowl is belt-driven by an electric motor mounted on the frame of the purifier.

The lower end of the bowl extends into a flexibly mounted guide bushing. The assembly, of which the bushing is a part, restrains movement of the bottom of the bowl but allows sufficient movement so that the bowl can center itself about its center of rotation when the purifier is in operation. Inside the bowl is a device consisting of three flat plates equally spaced radially. This device is commonly referred to as the three-wing device, or just the

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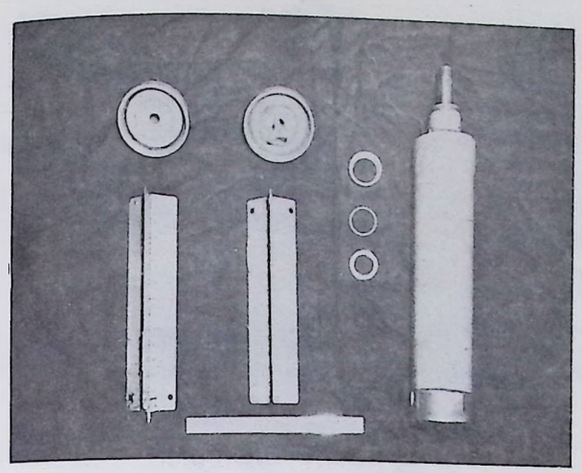
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Figure 8-9.—Tubular-type centrifugal purifier.

three-wing. The three-wing rotates with the bowl and forces the liquid in the bowl to rotate at the same speed as the bowl. The liquid to be centrifuged is fed, under pressure, into the bottom of the bowl through the feed nozzle so that the liquid jets into the bowl in a stream.

When the purifier is used as a lube oil clarifier, the three-wing has a cone on the bottom, against which the feed jet strikes in order to bring the liquid smoothly up to bowl speed without making an emulsion. Both types of three-wing devices are shown in figure 8-10.

The process of separation is basically the same in the tubular-type purifier as in the disk-type purifier. In both types, the separated oil assumes the innermost position, and the separated water moves outward. Both liquids are discharged separately from the bowls, and the solids separated from the liquid are retained in the bowl (fig. 8-11).



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Figure 8-10.—Parts of a tubular-type purifier bowl.

GENERAL NOTES ON PURIFIER OPERATIONS

The specific details for operating a given purifier should be obtained from the appropriate instructions provided with the unit. Information provided here is, in general, applicable to both types of purifiers.

For maximum efficiency, purifiers should be operated at maximum designed speed and rated capacity. Since turbine oils are always contaminated with water of condensation, the purifier bowls should be operated as separators and not as clarifiers. An exception to operating a purifier at designed rated capacity is when a unit is used as a separator of 9000 series (compounded- or additive-type heavy-duty lube oils) detergent oil. Some engine installations using oils of the 9000 series are exposed to large quantities of water. If the oil becomes contaminated with water, the oil has a tendency to emulsify. The tendency to emulsify is most pronounced when the oil is new and gradually decreases during the first 50 to 75 hours of engine operation. When an emulsion appears, the purifier should be reduced to approximately 80% of the rated capacity, and operation should be continued as long as an appreciable amount of free water discharges along with the emulsion.

When a purifier is operated as a separator, PRIMING OF THE BOWL with freshwater is essential before any oil is admitted to the purifier. The water serves to seal the bowl and to create an initial equilibrium of liquid layers. If the bowl is not primed, the oil will be lost through the water discharge ports.

Influencing Factors in Purifier Operation

There are several factors which influence purifier operation. The time required for purification and the output of a purifier depend on such factors as the viscosity of the oil, the pressure applied to the oil, the size of the sediment particles, the difference in the specific gravity of the oil and the substances that contaminate the oil, and the tendency of the oil to emulsify.

The viscosity of the oil determines to a great extent the length of time required to purify lube oil. The more viscous the oil, the longer the time required to purify it to a given degree of purity. Decreasing the viscosity of the oil by heating is one of the most effective methods of facilitating purification.

Even though certain oils may be satisfactorily purified at operating temperatures, a greater degree of purification will generally result by heating the oil to a higher temperature. To accomplish this, the oil is passed through a heater where the proper temperature is obtained before the oil enters the purifier bowl.

Oils used in naval installations may be heated to specified temperatures without adverse effects, but prolonged heating at higher temperatures is not recommended because of the tendency of such oils to oxidize. Oxidation results in rapid deterioration. In general, oil should be heated sufficiently to produce a viscosity of approximately 90 seconds, Saybolt Universal (90 SSU).

Pressure should not be increased above normal in order to force a high viscosity oil through the purifier. Instead, viscosity should be decreased by heating the oil. The use of pressure, in excess of that normally used, to force oil through the purifier will result merely

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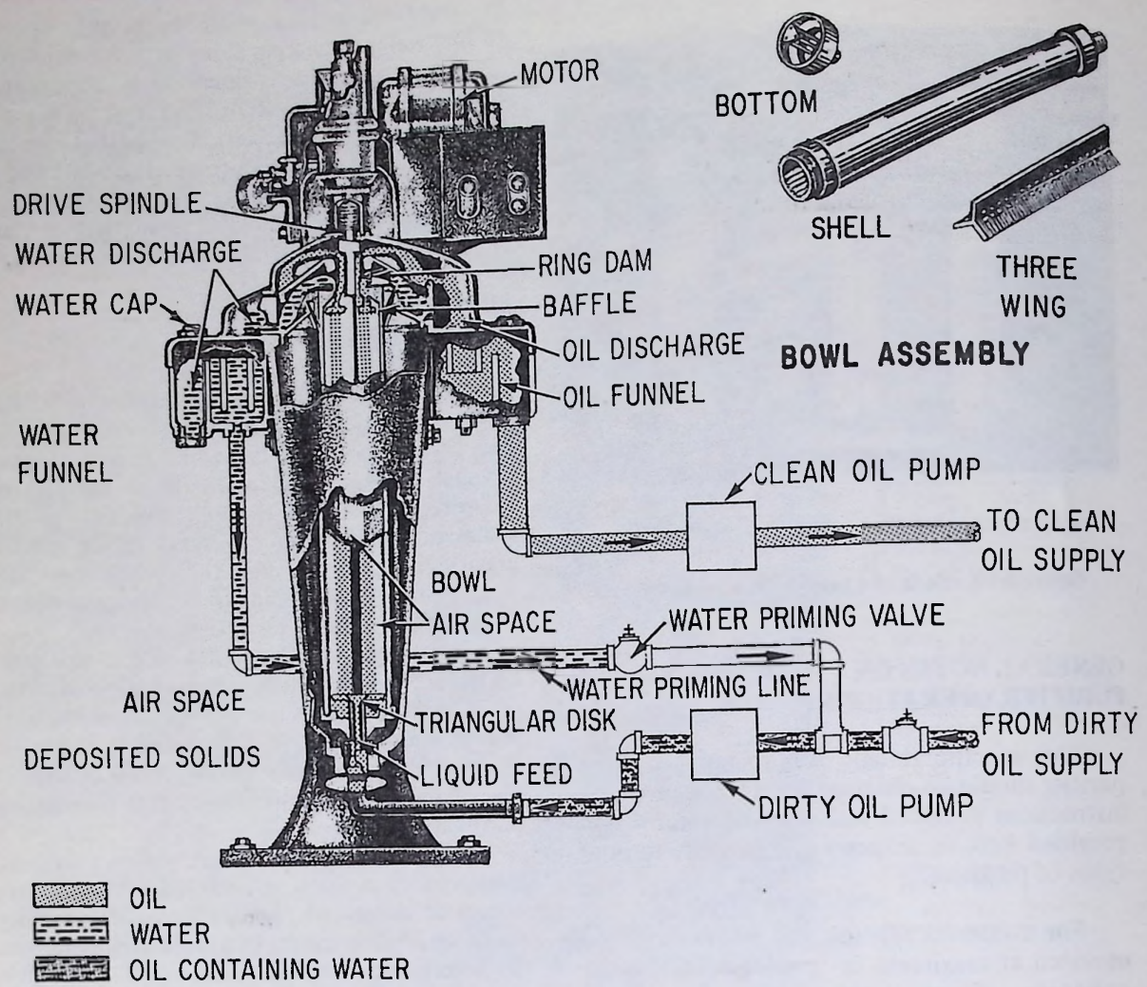


Figure 8-11.—Path of contaminated oil through a bowl-type purifier (Sharples).

in less efficient purification. On the other hand, a reduction in the pressure at which the oil is forced into the purifier will increase the length of time the oil is under the influence of centrifugal force and, therefore, will tend to improve results.

If the oil discharged from a purifier is to be free of water, dirt, and sludge, and if the water discharged from the bowl is not to be mixed with oil, the proper size discharge ring (RING DAM) must be used. The size of the discharge ring to be used depends on the specific gravity of the oil being purified. All discharge rings have the same outside diameter but have inside diameters of different sizes. Ring sizes are indicated by even numbers; the smaller the number, the smaller the ring size. The size, in millimeters, of the inside diameter is stamped on each ring. Sizes vary by 2-millimeter steps. Charts provided in manufacturer's technical manuals, specify the proper ring size to be used with an oil of a given specific gravity. Generally, the ring size indicated on a chart will produce satisfactory results. However, if the

recommended ring fails to produce satisfactory purification, it will be necessary to determine the correct size by trial and error. In general, the most satisfactory purification of the oil is obtained when the ring used is of the largest possible size that will prevent loss of oil with the discharged water.

MAINTENANCE OF PURIFIERS

Proper care of an oil purifier requires that the bowl be cleaned frequently and that all sediment be carefully removed. The frequency of cleaning depends on the amount of foreign matter in the oil to be purified. If the amount of foreign matter in an oil is not known, the machine should be shut down for examination and cleaning once during each watch, or more often if necessary. The amount of sediment found in the bowl at this time will give an indication as to how long the purifier may be operated between cleanings. The bowl should be thoroughly cleaned each time lube oil is run through for batch purification from the settling tank.

While the purifier is operating on a sump of an operating unit, frequent checks should be made to ensure that the purifier has not lost its seal. A loss of lube oil casualty can occur fairly rapidly if all the lube oil from a sump is dumped to the bilge or drain tank by an improperly operating purifier.

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CHAPTER 9

ENGINEROOM OPERATING PROCEDURES

The information in this chapter deals primarily with the Personnel Qualification Standards (PQS), Engineering Operational Sequencing System (EOSS), watchstanding, and operating notes on engineroom operation.

PERSONNEL QUALIFICATION STANDARDS

The PQS program is the result of an increasing need for greater technical know-how within the Navy. Proper qualification of personnel is a matter of great importance; the PQS documents are the guides to this qualification.

The Personnel Qualification Standards are the tools that: "Let every man know his job, his place in the ship, his responsibilities to his shipmates and his purpose in fighting." The system places the majority of the responsibility for learning on the learner and encourages self-achievement. The PQS describes the knowledge and skills that personnel must have to correctly perform their duties. By providing a convenient record of accomplishment, the system is a means whereby sailors and their superiors can check an individual's speed and manner of performance.

The Qualification Standard for a specific piece of equipment or an organized group of watchstanding requirements is in booklet form. Each PQS is designed to guide trainees toward qualification by telling them exactly what they must learn to achieve that goal.

The Personnel Qualification Standards are separated into four main subdivisions:

100 Series–THEORY
200 Series–SYSTEMS
300 Series–WATCHSTATIONS
400 Series–QUALIFICATION CARDS

THEORY

The theory section of the qualification standards lists the basic knowledge needed to understand the specific equipment or duties you will encounter in your duties as a Machinist's Mate. The 100 Series is a list of questions about all of the various engineering fundamentals, including safety. Figure 9-1 is a portion of a turbine theory section from a PQS guide.

Each portion of the theory section has a list of references which contain the "answers" to the individual items listed.

SYSTEMS

In the systems portion of the standards, the machinery is broken down into functional sections as the basic building blocks in the learning process. For a complete understanding of a system, you must study all the functional parts of that system.

In the 200 series there is a pattern to the numbers to the right of the decimal. A typical system qualification standard is shown in figure 9-2.

The system section will include:

.1 Explain SYSTEM FUNCTION.
.11 Draw a simplified version of the system from memory.
.2 SYSTEM COMPONENTS–GENERAL: Notice that a series of items

7103 TURBINE THEORY

This section identifies the terms, principles, and laws that will give you a foundation of understanding of Turbine Theory upon which a working knowledge can be built. The following references were used:
a. *Fireman* (NAVEDTRA 10520)
b. *Machinist's Mate 3 & 2* (NAVEDTRA 10524)
c. *Machinist's Mate 1 & C* (NAVPERS 10525)
d. *Principles of Naval Engineering* (NAVPERS 10788)
e. *NAVSHIPS Technical Manual*
f. Manufacturer's Instruction Books

7103.1 DRAWINGS, SYMBOLS, PUBLICATIONS

.11 Describe the following type of drawings:
a. Isometric
b. Exploded view
c. Perspective

.12 List the manuals and instructions books used most often by your unit.

7103.2 EQUIPMENT, DEVICES

.21 Explain the application and service use of the following:
a. Nozzles
b. Reversing chambers
c. Shrouding
d. Blading
e. Rotor
f. Diaphragm
g. Labyrinth shrouding
h. Carbon packing
i. Bearing
j. Casing
k. Foundations

.22 Explain the protective functions of the following:
a. Speed regulating governor
b. Overspeed trip
c. Relief valve
d. Back pressure trip
e. Emergency hand trip

7103.3 TERMS, DEFINITIONS

.31 Define the following terms as used in engineering:
a. Impulse and reaction
b. Nozzle
c. Staging
d. Pressure compounding
e. Velocity compounding
f. Rateau

Figure 9-1.–Personnel Qualification Standard–Theory Section.

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7232 MAIN FEED PUMP RECIRCULATION CONTROL SYSTEM

7232.1 Explain the function(s) of the MAIN FEED PUMP RECIRCULATION CONTROL SYSTEM as stated in Manufacturer's Instruction Manual.

.11 Draw a one line schematic diagram of this system from memory using appropriate symbols and showing all components listed in 7232.2.

.12 Refer to a standard print of this system during the rest of this discussion.

7232.2 SYSTEM COMPONENTS–GENERAL

Discuss the designated items for each component listed below:

A. Explain the function(s) of the component in terms of what it does for the system.
B. Describe the functional location of the component with respect to its position in the system and the reason(s) for its location in this position.
C. Show or describe the actual physical location of this component.
D. List or describe the source(s) of control signal(s).
E. Describe the modes of control.
F. Discuss the protection provided by this component.
G. List the positions and function(s) of each position of this component.
H. Describe the "fail" position of the component on loss of control signal and the reason(s) it fails in this position.
I. Describe the physical location of the sensing points for the component.
J. List the ratings of this component.

		A	B	C	D	E	F	G	H	I	J
.21	Metering orifice	X	X	X							
.22	Flow transmitter	X	X	X	X					X	
.23	Toggle relay	X	X	X	X			X			
.24	Transfer valve	X	X	X	X	X					
.25	Recirculation control valve	X	X	X	X	X	X	X	X		X
.26	Multiple orifice	X	X	X							

7232.3 COMPONENT PARTS

A. There are no component parts in this system to be discussed.

7232.4 PRINCIPLES OF OPERATION

Demonstrate an understanding of the internal operation of this system by describing:

.41 Feedwater from the discharge side of feed pump to deaerating feed tank during recirculation.
.42 How Recirculation Control System functions to maintain adequate flow of feed water through the main feed pump.

7232.5 MAJOR PARAMETERS

A. Show or describe the physical location of the sensing point.
B. Show or describe the physical location at which the parameter is displayed for monitoring.
C. State the setpoint(s).
D. State the reason(s) for the setpoint(s) in terms of the effect of operating above or below them.

		A	B	C	D
.51	Recirculation valve position	X	X	X	X
.52	Feed pump flow	X	X	X	X

7232.6 SYSTEM INTERRELATIONS

A. Describe the effect on this system due to the following:
1. Variation in boiler load
2. Loss of control air

B. Describe the effect(s) on the following system(s) due to the operation of this system:
1. Main Feed Pump System
2. Deaerating Feed Tank System

7232.7 SAFETY PRECAUTIONS

A. There are no safety precautions unique to this system.

Figure 9-2.–Personnel Qualification Standard–System Section.

about components is given, followed by a list of components with a matrix to identify the items that you are to apply to each component. For example: look at component .21 (metering orifice). In the matrix you notice X's below A, B, and C, indicating that items A, B, and C apply to the metering orifice.

.3 COMPONENT PARTS: This section breaks down the system components into their component parts, and indicates what you must learn about each part.

.4 PRINCIPLES OF OPERATION: Up to this point, you have considered the system from a purely "static" point of view (what the system is and does). In this section, you will analyze the system on a "dynamic" basis. (How the components and component parts work together to perform the function of the system.)

.5 MAJOR PARAMETERS: In this section you will learn the meanings of measurements such as temperatures, pressures, flow rates, etc and how these parameters or limits are monitored.

.6 SYSTEM INTERRELATIONS: Now you are required to fit the system into the "big picture." That is, how this system is affected by other systems in the engineering plant and how this system affects the operation of other systems.

.7 SAFETY PRECAUTIONS: Do NOT neglect safety precautions; they are written in bitter experience to protect you and your equipment. Here you will find the safety precautions that are unique to this system.

WATCHSTATIONS

The 300 series on watchstations includes the procedures that you must know to properly operate and maintain the machinery. Figure 9-3 is the first portion of a watchstation standard. You should not limit your thinking to the idea that you stand watch only if your name is on a watch bill. In the qualification standards usage, you are considered to be at your watchstation anytime you face the machinery and use your intelligence to cause it to perform correctly or try to analyze malfunctions. While all possible procedures may not be detailed in this section, the procedures that you can reasonably be expected to complete are covered by an OPERATOR and TECHNICIAN watchstation. These procedures are described in the following paragraphs.

Operation Watchstation

.1 OPERATING INSTRUCTIONS: As a result of your study of the 200 series of the qualification standard, you know what the systems do, how they do it, and many other aspects of their operation. You have spent a lot of time acquiring the necessary knowledge, all of which is of little value to you and the Navy unless you are able to use it to perform in an efficient manner. In this section, you will be directed to perform and discuss various aspects of procedures, demonstrating your ability to cope with the machinery at your watchstation.

.2 NORMAL OPERATIONS: In this section you are directed to describe existing conditions that indicate the system is functioning properly.

.3 ABNORMAL CONDITIONS that could lead to EMERGENCIES and/or CASUALTIES: An abnormal condition is the first stage of a sequence of events that will lead to an emergency and/or casualty. You must be able to recognize the symptoms of these abnormal conditions, and you must also know what immediate corrective action to take. In this section, you will be required to discuss the most pertinent of the abnormal conditions.

.4 EMERGENCIES and/or CASUALTIES: In this section, you will discuss and/or perform, when practicable, the procedures for limiting the damage from the emergencies and casualties most pertinent to the watchstation.

.5 INFREQUENT and/or ABNORMAL OPERATIONS: This section is devoted to the discussion and/or performance, when practicable, of those procedures that are too time-consuming or that occur too infrequently to be made mandatory performance items.

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7312 WATCHSTATION–DISTILLING PLANT WATCH

7312.1 OPERATING INSTRUCTIONS

For the operating instructions listed below:

A. Explain the reasons for each step of this procedure.
B. Discuss the control/coordination required while performing this procedure.
C. Discuss the communications that must be established and/or utilized.
D. Discuss the parameter indication(s) that must be monitored.
E. Discuss the safety precautions that must be observed.
F. Perform the steps of this procedure.
G. Perform the steps of this procedure when practicable.

		A	B	C	D	E	F	G
.11	Line up, warm up, operate and secure the distilling plant	X	X	X	X	X	X	
.12	Line up distilling plant distillate for distribution	X	X	X	X	X	X	X
.13	Perform chemical test on distillate	X	X			X	X	X
.14	Operate salinity indicating panel	X	X		X	X	X	X
.15	Observe and record temperatures, pressures and levels on distilling plant and associated machinery							X
.16	Turn all pumps by hand or power (PMS)						X	

Figure 9-3.—Personnel Qualification Standard—Watchstation Section.

Technician Watchstation

.1 MAINTENANCE INSTRUCTIONS: When studying to be a technician, your knowledge as an operator will be expanded to include the routine maintenance of the various equipment you have become qualified to operate. In this section, you are directed to discuss and perform the routine maintenance checks, tests, alignments, repairs, and replacements that keep the equipment and machinery assigned to you in a "Combat ready" condition.

.2 INFREQUENT and/or ABNORMAL MAINTENANCE OPERATIONS: As is true of the operator watchstation, there are infrequent and/or abnormal maintenance operations that are too time-consuming to make them mandatory performance items. In this section, you are asked to discuss and perform those procedures when practicable.

QUALIFICATION CARDS

The recommended steps to be performed by a ship's service turbogenerator operator at a designated watchstation are found in the 400 series (fig. 9-4).

The qualification standards have been written so that upon completion of all sections, you will be able to both operate and maintain the machinery at your watchstation(s). In practice, however, where you start in the standard will be determined by the need of your command. Therefore, depending upon the immediate need for your services, you will be given a qualification card that will tell you which section you must complete first.

2402 WATCHSTATION–SHIPS SERVICE TURBO GENERATOR WATCH

Complete the following system qualifications: 2202, 2205, 2208, 2231, 2235, 2236, 2237, 2238 and 2239.

2402.1 Perform the following practical factors: (in accordance with the requirements set forth in 2302.1)

		SIGNATURE	DATE	POINTS
.11	Light-off, bring up to speed and secure a turbo generator			4
.12	Line-up, and secure Auxiliary Condensate System			2
.13	Line-up and secure Auxiliary Condenser Circulating Water System			2
.14	Line-up and secure the auxiliary air ejector			3
.15	Prepare the turbo generator for loading			2
.16	Observe and record temperature, pressure and levels on a turbo generator			2
.17	Shift, clean and inspect lube oil strainers			3

2402.2 Discuss with a qualified operator the conditions or evolutions listed below: (in accordance with the requirements set forth in 2302.2)

.21	Maintaining auxiliary condenser hot well level			2
.22	Maintain proper lube oil			

2402.5 Discuss with or perform under the supervision of a qualified operator the following infrequent and/or abnormal operations: (in accordance with the requirements set forth in 2302.5)

.51	Operating with low or no vacuum			3
.52	Operating with auxiliary exhaust cut out of generator			2

2402.6 Stand a minimum of one satisfactory watch under qualified supervision.

SIGNATURE	REMARKS	DATE	POINTS
			8

Total Points This Page: 35
Total Points This Watchstation: 67

Figure 9-4.—Ship's service turbogenerator watch qualification card.

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The qualification cards list the items you must complete in the 100, 200, and 300 series of the standard. These cards are your guide, reference, and record of achievement. The qualification cards are packaged separately from the standard and should be carried by you at all times to permit you to take advantage of every opportunity to complete the requirements.

ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS)

The main propulsion plants in ships of the modern Navy are becoming more technically complex as each class is built and joins the fleet. The increased complexity requires increased engineering skills for proper operation. Ships that lack the required number of trained personnel may suffer material casualties which could seriously affect the ship's operational readiness. In addition, the rapid turnover of the engineering personnel who operate the ships further compounds the problem of training and maintaining a high level of operator and operating efficiency.

The Engineering Operational Sequencing System (EOSS) is designed to eliminate problems due to operator error when setting up and aligning piping systems and starting and stopping machinery. EOSS involves the participation of all personnel from the department head to the fireman on watch. EOSS consists of a set of detailed written procedures, using charts, instructions, and diagrams developed for safe operation and casualty control of a specific ship's engineering plant and configuration. EOSS improves the operational readiness of the ship's engineering plant by providing positive control of the plant, which reduces operational casualties and extends machinery life.

EOSS is divided into two subsystems: (1) Engineering Operational Procedures (EOP) and (2) Engineering Operational Casualty Control (EOCC).

ENGINEERING OPERATIONAL PROCEDURES (EOP)

Engineering operational procedures are prepared specifically for each level of operation: Plant Supervision (Stage 1), Space Supervision (Stage 2), and Component/System Operator (Stage 3). The materials for each level or stage of operation contain only the information necessary at that level. All materials are interrelated and must be used together to maintain the proper relationship and to ensure positive control and sequencing of operational events within the plant.

ENGINEERING OPERATIONAL CASUALTY CONTROL (EOCC)

This subsystem of EOSS is designed to provide plant and space supervisors with information necessary to enable them to recognize the symptoms of a possible casualty, to control the casualty to prevent possible damage to machinery, and to restore plant operation to normal for the most frequently occurring engineering plant casualties. The documents of the EOCC subsystem contain procedures and information that describe symptoms, causes, and effects of the most common engineering plant casualties.

WATCHSTANDING

Aboard ship, Machinist's Mates spend much of their working time as a watchstander. How you stand your watch is very important to the reliability of the engineering plant and the entire ship. To properly stand an engineroom watch, you must be skilled in detecting unusual noises, vibrations, or odors which may indicate faulty machinery operation. You must also be skilled in taking appropriate and prompt corrective measures. You must be ready, in emergencies, to act quickly and independently; you must know the ship's piping systems and HOW, WHERE, and WHY they are controlled. You must know each piece of machinery: how it is constructed, how it operates, how it fits into the engineering plant, and where related equipment is controlled. You must be skilled in reading and interpreting measuring instruments. You must understand how and why protective devices function (relief valves, speed-limiting governors, overspeed trips, cut-in and cutout devices). You must be able to recognize and remove fire hazards, stow gear that is adrift, and keep deck

plates clean and dry. You must NEVER attempt to operate a piece of equipment that is defective. You must report all unsafe conditions to the space and/or plant supervisor.

Whatever your watch, you are responsible for knowing the status of every piece of machinery at your station, for promptly handling any necessary change in speed or setup, for recording correctly all data concerning the operation and maintenance of the machinery. You must be sure that the log is up-to-date, that the status boards are correct, that you know what machinery is operating, and that you know what the night orders and standing orders are before you relieve the watch. Above all, if you don't know—ASK. If a noise, odor, or condition seems abnormal to you, but you are not certain whether it could be a problem, call your immediate watch supervisor, who is responsible for backing you up.

One of the best ways to gain the respect and confidence of your supervisors and shipmates is to stand a good watch. Relieve the watch on time or even a little early if possible, but, DON'T TRY TO RELIEVE THE WATCH FIRST AND FIGURE OUT THE SCORE LATER. The same applies when you are being relieved; don't be in a big hurry to take off. Be sure your relief understands the situation completely. Before being relieved, make sure your station is clean and squared away. These little considerations will not only get you a good reputation, but will also improve the overall quality of watchstanding within the department.

Under the PQS watchstation qualification procedures you will gain the technical know-how to stand a particular watch in your ship through the qualification process. You will be examined and certified as qualified to stand the watch.

THROTTLE WATCH

As an MM3 or MM2, you must be able to stand the main engine throttle watch. This duty requires a thorough knowledge of: throttle valve operating procedures and their use in conjunction with steam pressure and temperature, and ship's speed; correct readings for control board gages, to instantly detect any abnormality; safety precautions pertaining to the main engines and associated auxiliaries and the steps to be taken in cases of material casualty. You will need a general knowledge of acceleration and deceleration tables or rates and of boiler operations insofar as they concern the engineroom operation.

Orders from the bridge relative to the speed and direction of rotation of the propellers must be complied with immediately (within limits). To make correct adjustments to attain the ordered speed, you must keep a close watch on the rpm indicator on the control board.

Engineer's Bell Book

In addition to handling the throttles, you must accurately maintain the *Engineer's Bell Book* and visually check all parameters (pressure, temperature, vacuum, etc) installed on the control board.

The *Engineer's Bell Book,* NAVSEA 3120/1, shown in figure 9-5, is a record of all bells, signals, and other orders received by the throttleman regarding movement of the propeller that is being turned by the main engine the throttle controls. Entries are made in the *Bell Book* by the throttleman (or an assistant) as soon as an order is received. An assistant to the throttleman may be provided when a large number of bell changes are expected, such as entering or leaving port.

The *Bell Book* is maintained in accordance with the instructions shown in figure 9-6.

ENGINEROOM OPERATIONS

Although there are many basic similarities in steam-turbine propulsion plants, the many differences in specific detail make it impossible to present an all-encompassing operating procedure in this manual. Each individual ship must establish its own operating procedures based on the machinery installed.

This information will help you to better understand engineroom operating procedures and will give you a foundation of knowledge which you can use to help evaluate abnormal operating conditions in your engineroom.

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ENGINEER'S BELL BOOK - ALL VESSELS
NAVSHIPS 3120/1 (Rev. 10-69) (Formerly NAVSHIPS116)
S/N 0105-601-9462

ENGINEER'S BELL BOOK

SHIP TYPE	HULL NUMBER	SHEET SERIAL	YEAR	MONTH	ZONE	DAY	Ship Name	SHAFT NUMBER(S)	CLASS	HANDL
DA	CAG 132	Ø16	Ø4	Z	17		SAMPLE (CAG-132)	1 2 3 4	U	
1 2	3-4 5-7	10-11	12	13-14	15	16-17	J 22	74 - 77	78	79

Record of all "BELLS," SIGNALS, and ORDERS received regarding movement of propellers this data. Clocks set back or ahead 1 hrs. 0 min., at 1800

En route from SAN DIEGO, CA. to SUBIC BAY, R.P.

(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
18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38	18 - 21	24 - 28	29 - 32	33 - 38
01	COUNTER		212479	18	COUNTER		362775				
02	COUNTER		220939	~~19~~	~~COUNTER~~		~~371253~~ WOW				
03	COUNTER		229399	19	COUNTER		372235				
04	COUNTER		237859	20	COUNTER		379695				
05	COUNTER		246319	21	COUNTER		388155				
J. Smith MMFN				22	COUNTER		396615				
W. Walters Lt. USN				23	COUNTER		405075				
06	COUNTER		254779	J. Smith MMFN							
0616	2/3	95	256209	W. Walters Lt. USN							
0630	I	141	258109	24	COUNTER		413535				
0635	Z	0	258814	R. Doyle MM3, USN							
0640	2/3	95	258898	B. Johnson MMCM							
0650	I	141	259848								
07	COUNTER		261258								
08	COUNTER		269718								
09	COUNTER		278178								
10	COUNTER		286638								
11	COUNTER		295098								
R. Doyle, MM3, USN											
B. Johnson MMCM											
12	COUNTER		303558								
13	COUNTER		312018								
14	COUNTER		320478								
15	COUNTER		328935								
16	COUNTER		337395								
17	COUNTER		345855								
C. Bolden MM3											
K. Warren CWO, USN											
18	COUNTER		354315								

77.230

Figure 9-5.—Engineer's Bell Book.

INSTRUCTIONS FOR KEEPING THE ENGINEER'S BELL BOOK

NAVSEA 3120/1 (12-75) (formerly NAVSHIPS 3120/1)

1. A separate sheet shall be used for each shaft each date, except on small ships and craft where the keeping of separate sheets for separate shafts is not practicable. All sheets for the same date should be filed together as a single record. (Entries in the Bell Book shall be made at the time of receipt of each order.)

2. In column 1, times shall be entered according to the system used in the Engineering Log.

3. In column 2 enter the signal received.

(a) If the signal is transmitted by the engine (motor) order telegraph, use the following symbols:

Z - stop
1/3 - ahead one third speed
2/3 - ahead two thirds speed
I - ahead standard speed
II - ahead full speed
III - ahead flank speed

Backing signals for 1/3 and 2/3 speed shall be entered as "B 1/3" and "B 2/3," respectively. Signals for full back and emergency back shall be entered as "BF" and "BEM" respectively. On small ships and craft, using a single sheet for two or more shafts, the above symbols shall be used with an additional preceding symbol "P," "S," "C" (starting in box 74 for port, starboard, or center shaft respectively) if the signal is directed to other than all shafts.

(b) If the signal is transmitted by the engine revolution telegraph without change in the engine (motor) order telegraph, the number of propeller revolutions signaled shall be entered in column 2. In this case, entries shall not be made in column 3.

4. An entry in column 3 shall be made for all signals received on the engine order telegraph and shall be the Propeller R.P.M. corresponding to the engine order telegraph signal. When a signal is received simultaneously on the engine order telegraph and the engine revolution telegraph, appropriate entries shall be made in both column 2 and column 3.

5. It should be noted that the R.P.M. entered in either column 2 or column 3 is, in each case, the Propeller R.P.M. ordered and not the Propeller R.P.M. which result from the order, except, for submarines, when plant condition order is given, record resulting propeller R.P.M.

6. In column 4 enter the engine counter reading at the time the change is made. Also, enter the counter reading each hour on the hour.

7. Ships and craft equipped with controllable reversible pitch propellers shall record in column 4 the propeller pitch in feet and ffactions of feet set in response to a signaled speed change, rather than the shaft counter readings. The entries for astern pitch shall be preceded by the letter "B." Each hour on the hour entries shall be made for 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.

8. Before going off duty, the engineer officer of the watch shall sign the Bell Book in the line following the last entry for his watch and the next officer of the watch shall continue the record immediately thereafter. In machinery spaces where an engineer officer of the watch is not stationed, this record shall be signed by the senior petty officer of the watch.

9. The Bell Book shall be maintained at the station from which the engines are being controlled. When control is shifted, from one station to another station, the last entry in the Bell Book at the station from which control is being shifted shall indicate the time that control was shifted and the first entry in the Bell Book at the station to which control is shifted shall indicate the time when control was taken. The person in charge of the watch station at which the Bell Book is maintained shall sign the Bell Book in the same manner as prescribed for the engineer officer of the watch. On those ships equipped with automated propulsion systems, when the engine orders given at the bridge are transmitted directly to the engines from the bridge through electro/electronic/mechanical means, engine order information need not be recorded in the Engineer' Bell Book. In these circumstances, such information shall be recorded only in the Ship's Deck Log in accordance with the instructions contained in OPNAVINST 3100.7. However, the Ship's Deck Log and the Engineer's Bell Book shall each contain a notation of the time interval during which engine control was exercised directly from the bridge.

10. Alterations or erasures are not permitted. An entry which is incorrect shall be corrected by drawing a single line through it and making the correct entry on the following line. Such deleted entries shall be initialed by the engineer officer of the watch, senior petty officer, or O.O.D. (in the case of ships and craft equipped with controllable reversible pitch propellers), as appropriate.

11. For ships with automated bell loggers, the automatic bell logger sheets shall be included in the Engineer's Bell Book. Manual recording of data shall be limited to data not recorded by the automatic bell logger. The engineer officer of the watch shall sign the automatic bell logger sheets before going off duty. When the automatic bell logger is out of commission, the normal procedure for recording bells in the Engineer's Bell Book shall be followed.

12. Disposal of this record shall be in accordance with SECNAVINST 5212.5B, Sup 1, dated 25 May 1962.
Retention Period: Three years after date of last entry.

13. Fill in the top section of the Bell Book as follows:

(a) In spaces 3 and 4, enter the first two letters of ship type and enter remaining letters as appropriate in the next two shaded unnumbered spaces. In spaces 5-7, enter three-digit ship hull number; if hull number consists of four digits, enter the first digit in the shaded unnumbered space. For example:

DD	848	CVA	Ø32	DDGM	1058

(b) In boxes 10-11 consecutively number sheets at each recording station beginning with Ø1 for the first sheet for each day starting with ØØØØ local time (time zone used in the Engineering Log).

(c) In box 12, enter last digit of current year. In box 13-14, enter two digits to indicate current month, e.g., Ø2 = February. In box 15, enter the letter designation for time zone used to record time entries. In boxes 16-17, enter two digits for the day of the month. Start a new sheet when the day changes.

(d) In boxes 74-77, enter all shafts for which this sheet applies, i.e., 1, 2, 3, 4, P = Port, S = Starboard, C = Center, and M = Secondary propulsion motor.

(e) In box 78, enter the appropriate code for highest security classification of data entered on this form. T = TOP SECRET; S = SECRET; C = CONFIDENTIAL; U = Unclassified.

(f) An entry in box 79 indicates special security handling; leave blank unless special instructions are received.

14. When directed to make duplicates of this form, use Duplicate Engineer's Bell Book (NAVSEA 3120/1D, formerly NAVSHIPS 3120/1D) and follow the additional instructions on the back of that form. Check forms for completeness and accuracy prior to submission.

Records of ships being inactivated, placed in special status, or decommissioned are to be handled in accordance with special instructions contained in paragraphs 4500 and 5441 of Part III, Sup 1, to SECNAVINST 5212.5B dated 25 May 1962.

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Figure 9-6.—Instructions for keeping the Engineer's Bell Book.

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PREPARATION FOR GETTING UNDERWAY

Normally, the first step in lighting off a turbine unit is to check the cold rotor positions of the turbines. These readings are then logged, indicating they are cold readings. Next, the main lube oil system must be checked for the following: (1) proper sump level; (2) system integrity (i.e., strainers cleaned, inspected, and closed; drains shut; proper valve lineup; etc): and (3) proper temperature. This check normally entails starting a lube oil pump to establish normal system pressure. If the lube oil is too cold, it will be necessary to energize electrical immersion heaters, or line up steam to the heater for the lube oil purifier and direct the flow through this heat exchanger. Check oil delivery to all turbine and gear bearings by observing flow through the bearing oil sight-flow glasses.

Low lube oil pressure alarm, standby and emergency pump pickup setpoints, and alternate pump power supplies are to be checked during or before oil warmup.

Some installations require a lube oil temperature of 70° F (21° C) before the main engine is rotated with the turning gear and 90° F (32° C) prior to turning with steam. Others require a lube oil temperature of 90° F (32° C) before the engine is turned by any method. A NOTE OF CAUTION: You must have permission from the OOD prior to turning the main shaft. Divers or other obstructions may be in the vicinity of the screw. In ships with a main shaft clutch, the main engines may be turned with the clutch disengaged without OOD permission, in most cases.

Ensure that the main shaft bearings have sufficient oil level or that the shaft forced feed lube oil system is in operation.

All turbine and associated main steam drains should be properly lined up for warmup of the main engines. Engage the turning gear and start the drive motor.

The next step is to establish a vacuum in the associated condenser(s). To provide adequate circulating cooling water, start the main circulating pump or main seawater pump(s), depending on the plant. Start the gland exhauster fan (if provided) and the second stage of the air ejector simultaneously with or just prior to cutting in gland sealing steam to the turbines. Any time steam is being supplied to the turbine (including gland sealing steam), the turbine must be rotating. Stationary periods of more than a few minutes (usually 3 minutes are allowed by the manufacturer) will cause uneven heating (temperature gradients) along the length of the rotor and will result in rotor bowing.

During the turbine warmup period, a reduced condenser vacuum is normally maintained (10 to 15 inches Hg) to provide for maximum heating of the turbine rotors.

After the turbine rotors have been turned with the turning gear motor for the specified period, the turbines are ready to be turned with steam. First, stop the drive motor and disengage the turning gear from the turbines. Next, admit steam to the throttle valves and, then, spin the turbines astern and ahead (with OOD's permission). Remember that only 3 minutes are normally allowed from the time the turning gear is disengaged to the time the turbines roll with steam. Steam passing through the turbine with the rotors stationary will come in contact with only a small portion of the blading and cause uneven heating. Therefore, the throttle opening should be wide enough to cause the turbine rotors to begin rotating quickly. The turbines are to be spun alternately astern and ahead to facilitate even heating of the rotor to prevent putting way on the ship. Maximum shaft rpm limits may also be specified while spinning to aid in reducing ship movement. Some ships may specify spinning ahead first, then astern, then ahead; other ships use the reverse order. Unless the equipment technical manual is specific as to which throttle valve to open first, the Engineer Officer will decide.

When the main engines have been warmed and tested, the first stage of the air ejector may be cut-in and the main engine is ready to get underway. While standing by "ready to answer all bells," the main engines must be spun alternately astern and ahead every 3 to 5 minutes. The "hot rotor positions" are to be taken and logged. When underway, re-align turbine and associated main steam drains.

PROCEDURES FOR STANDING BY

A turbine in standby should be in such a condition that it is ready to answer all bells. The turbine is warmed up and being spun alternately astern and ahead at very low speed every few minutes.

Standing by for long periods of time may entail placing the turbines on the turning gear and possibly cross-connecting plants and securing unnecessary boilers and auxiliary equipment. NOTE: To change from ahead operation to stop, it is necessary to start the main circulating pump to maintain an adequate flow of cooling water through the main condenser to prevent loss of vacuum.

UNDERWAY OPERATION

Underway procedures must be carried out in a manner that enables the ship to accomplish its mission with the greatest operating economy possible. Economical and efficient operation of a propulsion plant, under varying conditions and speeds necessitates the maintenance of a high vacuum and the proper use of cruising and maneuvering combinations.

IMPORTANCE OF HIGH VACUUM

To attain the greatest operating economy, the vacuum for which the turbines was designed must be maintained. Therefore, you should realize the necessity for the prevention and detection of air leaks in the vacuum system.

When the steam pressure within the turbine is allowed to become greater than atmospheric pressure, steam tends to leak from the turbine to the surrounding atmosphere. On the other hand, when the pressure in the turbine is less than that of the atmosphere, air tends to leak into the turbine and impair the vacuum. To prevent air leakage into the turbine and steam leakage from the turbine, steam is led to the glands, and the pressure on the glands is maintained slightly greater than that of the atmosphere, generally 1/2 to 2 psi.

To ensure that the optimum vacuum will be maintained, care must be taken that the astern throttles do not leak; any leakage of steam past a closed throttle tends to raise the temperature and to increase the pressure within the turbine.

The following precautions must be observed to maintain the prescribed vacuum:

1. Gland packing must be kept in good condition.
2. A steam pressure between 1/2 and 2 psi must be maintained on the glands when the turbines are in operation.
3. There must be no air leaks in the condenser, exhaust trunks, throttles, lines to air ejectors, gage lines, idle condensate pump packing and valves, makeup feed lines, etc.
4. Adequate water must be maintained in the drain collecting or reserve feed tank on which the vacuum drag is being taken.
5. Adequate cooling water must be supplied to the main condenser and air ejector condenser.

TURBINE VIBRATION

If a turbine begins to vibrate as its speed is increased, the turbine should be slowed down immediately. If the vibration ceases at a lower speed, maintain that speed for several minutes; then attempt to build up the speed again. If no further vibration is noted, it may be assumed that the trouble was probably due to uneven heating of the rotor or to an accumulation of water in the turbine. (If the turbine drains were lined up correctly, water accumulation in the turbine should not occur.) If the vibration does not cease at a lower speed, the turbine must not be used, except in an emergency, and steps must be taken immediately to locate and remedy the trouble. If, after the turbine has been running at a reduced speed for some time, the vibration again occurs at the higher speed, a speed limit lower than that at which vibration occurs must be set. This reduced speed must not be exceeded until the trouble has been eliminated.

USE OF NOZZLES

In all modern installations, the flow of steam to the high-pressure turbines is controlled by the nozzle control valve arrangement. These valves are a lifting-beam mechanism. The lifting-beam mechanism consists of a steel beam drilled with

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holes which fit over the nozzle valve stems. The valve stems are of varying lengths and are fitted with shoulders at the upper ends. When the beam is lowered, all valves rest upon their seat. When the beam is raised, the valves open in succession, depending on their stem length—the shorter ones open first.

It is essential that the pressure in the steam chest be kept as high as practicable. High pressure here allows for greater steam expansion and a resulting increase in the useful work obtained from the steam. The fewer the nozzles in use, the higher will be the chest pressure.

TURBINE BLADE CLEARANCE

In an impulse turbine, the axial distance of the moving blades from the casing or the stationary blades is known as the axial (fore-and-aft) blade clearance. This clearance may be determined by means of a finger piece, a rotor-position indicator, or a clearance indicator.

Finger Piece

A ready visual check on the fore-and-aft position of the turbine rotor can be obtained from the finger piece. Most finger pieces consist of an indicator which extends almost to the shaft, fastened to a plate which is secured to the turbine case. Usually, three lines are scribed on the shaft to show the normal position and the maximum forward and aft positions. In some finger pieces, the indicator extends into a groove in the shaft, and the distance from the indicator to the shaft shoulder can be measured with feelers to determine fore-and-aft clearance.

Rotor-Position Indicator

The axial position of a turbine rotor may be determined with a rotor-position indicator. This instrument can be used when the rotor is either revolving or at rest. The indicator is mounted at the forward end of the turbine shaft with the spindle in line with the centerline of the shaft. When the indicator is being used, the spindle contacts the end of the shaft at the center. The reading obtained is compared with established limits to determine whether the position of the shaft is satisfactory. Care must be taken to prevent the end of the indicator spindle from becoming worn by long or hard contact with the rotating shaft.

Clearance Indicator

In some installations, the axial blade position of a turbine rotor is determined with a clearance indicator. The indicator may be used when the turbine is in operation. The instrument consists of a scale plate and an indicator, mounted within a bracket which is bolted to the turbine casing. The scale plate has scribed lines showing the normal position (midposition) and the maximum forward and aft positions. One end of the indicator is a pointer, and a roller or contact surface is mounted on the other end. The indicator operates on a pivot. To take a reading, you need only to press the arm of the indicator so that contact is made between the shaft and the roller, and then note the position of the pointer on the scale.

ROUTINE UNDERWAY INSPECTIONS

Periodic inspections of the propulsion plant must be made if the plant is to be kept operating efficiently. When a ship is underway, the following items should be checked or inspected at very short intervals during each watch:

1. Check all main engine and reduction gear bearing thermometers to detect signs of overheating.
2. Check oil sight-flow indicators for proper oil flow.
3. Check clearance indicators for proper rotor position.
4. Check all thermometers, pressure gages, and vacuum gages for a normal reading.
5. Check the oil level in the main sump for a normal indication.
6. Keep a constant check on salinity indicators.
7. Check the lube oil temperature from the lube oil cooler; maintain oil temperature at 120° to 130° F by throttling the cooling water as required.
8. Check the auxiliary machinery cooling water for proper pressure.

9. Be constantly on the alert for unusual sounds and vibrations.
10. Clean lube oil and bilge strainers at prescribed intervals.

A sight-flow indicator is fitted on most units in the lube oil line of each main engine bearing and each reduction gear bearing (fig. 9-7). When a lube oil service pump is in operation, each indicator should show a steady flow of lube oil. Frequent inspections of the sight-flow indicators should be made to detect any interruption to the flow of lube oil.

At a specified frequency, the rotor-position indicator for each turbine is checked and the rotor position is logged to determine the position of the rotor in respect to casing. Any abnormal reading must be thoroughly investigated. If the axial movement of the rotor is allowed to exceed the safe limit in either direction, the moving blades will strike the stationary blades or nozzles and great internal damage to the turbine will result.

One of the first indications of engineroom trouble is an abnormal reading on a thermometer or gage. All thermometers and gages must be checked frequently to detect and prevent casualties. NEVER take for granted that an abnormal reading is due to the fault of the gage or thermometer. NOTE: Many severe machinery casualties to machinery in an engineering plant can be traced directly to uncalibrated, inoperative or missing instruments.

Each hour, the oil level in the main engine sump is to be checked and logged. However, more frequent checks should be made. An

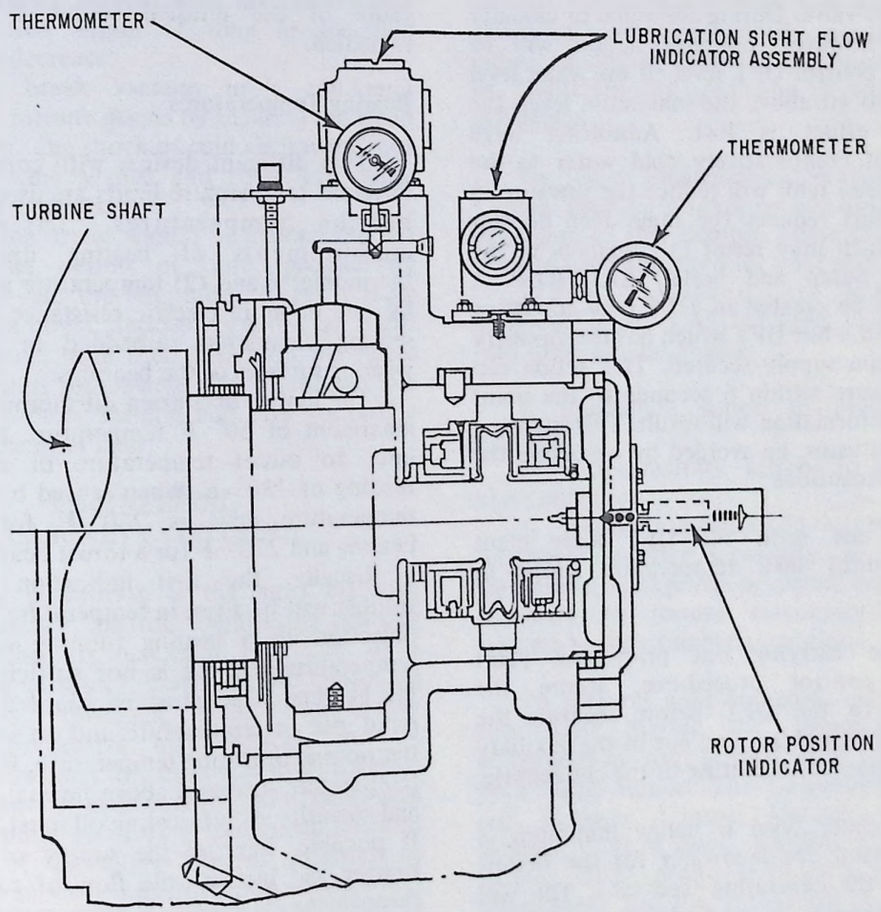


Figure 9-7.—Bearing housing assembly showing sight-flow indicator assemblies.

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increase in the oil level may mean that water is entering the lube oil system or that the system is gaining oil in some improper manner. The lube oil transfer and purification system may be lined up improperly. A decrease in the oil level of the main engine sump usually indicates that there is a leak in the lube oil system or that the lube oil purifier is discharging oil to the contaminated drain system. An increase or a decrease in the main sump oil level should NEVER be neglected. It could result in a temporary loss of a main engine or even costly repairs to main engine bearings and reduction gears.

For safe efficient operation, the water level in a steaming deaerating feed tank should be kept within the normal operating range. This is controlled automatically on most ships through the use of an automatic excess feed valve and makeup feed valve. During abnormal or casualty situations, however, operator action will be required to control DFT level. If the water level is allowed to go above the maximum level, the deaerating effect is lost. Admitting large quantities of comparatively cold water to the deaerating feed tank will reduce the pressure in the tank. This reduces the main feed booster pressure, which may result in casualties to the main feed pump and boiler. CAUTION: A vacuum can be created in a DFT by admitting cold water to a hot DFT which has the auxiliary exhaust steam supply secured. This action can reduce pressure within 6 seconds to the point that DFT deformation will result. This situation can, in most cases, be avoided by observing the following precautions:

1. Do not refill the DFT after plant shutdown until shell temperature drops to ambient.

2. When carrying out propulsion plant casualty control procedures, secure the condensate to the DFT before securing the auxiliary exhaust steam and cut in the auxiliary exhaust steam before cutting in the condensate.

If the water level is below minimum, a sudden demand for feedwater for the boilers may empty the deaerating feed tank. This will result in casualties to the boiler, the main feed booster pump, and the main feed pump.

A salinity indicator meter and alarm panel is located on most ships near the throttle board in each engineroom to detect the entrance of chemical contamination into the condensate system. The meter must be checked constantly because a small amount of salt in the condensate system will contaminate a steaming boiler beyond allowable limits. An abnormal reading must be checked and the source of contamination must be eliminated. You will find more information about salinity indicators in chapter 10 of this manual and in the appropriate manufacturer's technical manuals.

A properly operating main engine and reduction gear installation has a definite sound which trained personnel can recognize. Any abnormal sound should be investigated and the unit should be operated with caution until the cause of the unusual sound is found and remedied.

Bearing Temperatures

Two different devices with correspondingly different temperature limits are used to measure bearing temperatures. These are: (1) measurements of bearing drain oil by thermometer and (2) temperature measurement by one or more electric resistance type (RTE) sensing element(s) imbedded in the babbitt wearing surfaces of the bearings.

The limits for a drain oil thermometer are a maximum of 50° F temperature rise between inlet to outlet temperature or a maximum reading of 180° F. When sensed by RTE's, the temperature limit is 250° F for a journal bearing and 270° F for a thrust bearing.

Usually, the first indication of bearing trouble will be a rise in temperature. There is no objection to a bearing running warm if the temperature reached is not sufficient to harm the bearing. What must be guarded against is a rapid rise in temperature and an increase over the normal operating temperature. If the bearing temperature increases above normal, the quality and quantity of lubricating oil must be checked. If possible, increase the supply of oil to the bearing and increase the flow of cooling water through the oil cooler. If these measures do not reduce the bearing temperature, the unit must be slowed or stopped.

SHUTTING DOWN THE PLANT

Prior to entering port and shutting down a plant, certain preparations are necessary to ensure a smooth and orderly shutdown. Certain auxiliary machinery to be used in port must be placed in standby operation, system lineups must be altered, and many other tasks must be accomplished; these procedures are outlined in the EOSS.

A very definite cool-down procedure will be specified for the main engines of each ship type. Normally, main lube oil must be circulated until the oil cools to near-ambient (room) temperature.

Seawater must be circulated through the main condenser until the exhaust trunk temperature cools to near ambient. The main turbines must be rotated with the turning gear for a specified length of time or specified temperature decrease.

NEVER break vacuum in a condenser through the turbine glands by securing the gland sealing steam. The shock of cold air flowing over the hot turbine glands and rotor can cause damage to the glands.

All turbine drains should be opened and left open for the period of time specified by procedure. Avoid the temptation to get in a big hurry to shut down. Serious casualties can result when personnel have their hands on the valves and their minds somewhere else. Shutdown in a controlled, orderly fashion and save yourself a lot of possible grief later.

ENGINEERING CASUALTY CONTROL

Casualty prevention is the most effective form of casualty control. Engineering casualty control reaches its maximum efficiency by a combination of sound design, careful continued inspections, thorough plant maintenance (including preventive maintenance), and by effective personnel organization and training. Casualty control effectiveness may determine the ship's ability to fulfill its prescribed mission. Regardless of the ship's inherent resistance to damage, its survival depends upon prompt and correct control action when casualties occur. It is of vital importance, therefore, that you are fully aware of and trained for whatever action you may be called upon to perform in any possible casualty situation. Casualty control training must be a continuous step-by-step procedure with frequent refresher drills.

CONTROL OF CASUALTIES

Engineering casualty control is concerned with preventing, minimizing, and correcting the effects of operational and battle casualties to engineering space machinery, related machinery outside of engineering spaces, and the piping installations relative to the various pieces of machinery. The mission of engineering department personnel is the maintenance of all engineering services in a state of maximum reliability under all conditions. Failure to provide all normal services will affect a ship's ability to function effectively as a fighting unit, either directly by reducing its military function, or indirectly by reducing habitability and efficiency.

The use of Engineering Operational Casualty Control (EOCC) procedures was discussed at the beginning of this chapter. These procedures are prepared and approved for your ship.

Steps involved in HANDLING ENGINEERING CASUALTIES can be divided into three general phases:

1. Immediate action to prevent further damage.
2. Supplementary actions to stabilize the plant condition.
3. Restoration actions to restore equipment to operation after a casualty. In cases where equipment damage has occurred, repairs may be necessary to restore machinery, plants, or systems to their original condition.

To perform your casualty control job well, you must master the operation of the equipment at your normal duty station and at your battle station. The *Engineering Operation and Casualty Control Manual,* your ship's *Damage Control Book,* the *Ship's Organization Book,* the manufacturer's emergency instructions for the equipment or systems at your GENERAL QUARTERS STATION, and

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the ship's Damage Control Bills are your primary sources of instruction for handling any engineering casualty, in addition to maintaining the overall damage resistance of your ship. These publications may vary in different ships, but in all instances they present the organization and procedures to be followed in event of engineering casualties, damage to the ship, or other emergency conditions.

PREVENTIVE MAINTENANCE

One of the principal factors which influence the effectiveness of casualty control is preventive maintenance. Preventive inspections, tests, and maintenance are vital to successful casualty control. These actions minimize the occurrence of casualties caused by MATERIAL failures. Continuous detailed inspection procedures are necessary to discover worn or partly damaged parts, which may fail at a critical time, and to eliminate conditions, such as maladjustment, improper lubrication, corrosion, erosion, and other enemies of machinery reliability which could lead to early failure of a vital piece of machinery.

The inspections, tests, and maintenance called for in the 3-M System must be conscientiously performed since they are based on the known requirements of preventive maintenance.

SYMPTOMS OF OPERATIONAL CASUALTIES

You must be on the alert at all times to detect even the most minor sign of faulty operation of machinery. Particular and continuous attention must be paid to the following symptoms of malfunctioning in machinery:

1. Unusual noises
2. Vibrations
3. Abnormal temperatures
4. Abnormal pressures
5. Abnormal operating speeds
6. Leakage from systems or associated equipment

You should become thoroughly familiar with the normal operating temperatures, pressures, and speeds of equipment specified for each condition of operation; departures from normal will then be readily apparent. NEVER assume that an abnormal reading on a gage or other indicating instrument is due to a problem with the instrument. Each case should be investigated to establish fully the cause of the abnormal reading. Either the substitution of a spare instrument or a calibration test will quickly show whether an instrument error exists. Abnormal readings that are not caused by faulty instruments must be traced to their source if preventive maintenance is to be effective. Some specific examples of advance warning of ultimate failure are outlined in the following paragraphs.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence of trouble is readily apparent. In pressure governor-controlled equipment, changes in operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal in chest pressures, lubricating oil temperatures, and system pressures indicate either improper operation or poor condition of the machinery. When a material failure occurs in any unit, a prompt inspection should be made of all similar units to determine whether they are subject to the same type of failure. Prompt inspection may eliminate a wave of similar casualties.

Abnormal wear, fatigue, erosion, or corrosion of a part may indicate that the equipment is not being operated within its designed limits of loading, velocity, and lubrication, or it may indicate a design or material deficiency. If any of these symptoms have appeared, special inspections to detect damage should be undertaken as a routine matter, unless action can be taken which will ensure that such a condition will not recur.

Strict attention must be paid to the proper lubrication of all equipment; this will include frequent inspection and sampling to determine that the correct quantity of the proper lubricant is in each unit. It is good practice to take daily samples of lubricating oil from 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 sample should be drained from the lowest part of the oil sump. All settled water must be drained from the sump and the oil level must be brought back to normal by adding fresh oil. An unusual quantity of freshwater in the oil is normally indicative of either poorly fitted or worn carbon packing on the turbine-driven pumps.

Saltwater may enter the lube oil system from a leak in a saltwater-cooled oil cooler or from saltwater dripping or spraying on the unit. The presence of water in the oil can be detected by drawing off a sample of oil and allowing it to settle. To determine whether the water is freshwater or saltwater, a chemical chloride test is performed on a sample (or diluted sample) of the water. Because of its corrosive effects, saltwater in the lubricating oil is far more dangerous to a unit than an equal quantity of freshwater. Saltwater is particularly harmful to units with oil-lubricated ball bearings. When units with oil-lubricated ball bearings are found to be subject to saltwater contamination of the lubricating oil, it is essential that the oil be drained as soon as possible, that the bearings and sump be flushed thoroughly, and that the unit be refilled with fresh oil.

The importance of engineering casualty control cannot be taken lightly. Failure of any of the ship's normal services immediately reduces the ship's resistance to damage and impairs its ability to function effectively as either a fighting or auxiliary unit. The effects of engineering casualties are both direct and indirect. Directly, the casualties reduce the ship's mobility, offensive power, defensive power, and its ability to control fire, flooding, hull, and armament damage. Indirectly, the casualties reduce the ship's habitability and, thereby, lower the morale and efficiency of personnel.

It is quite easy for a single damaged unit in a machinery plant to disable the entire plant. A leaking condenser, for example, may disable both the boilers and the turbines. A damaged lube oil line or pump with the resulting loss of oil pressure can also quickly damage the turbine bearings and reduction gear bearings. Prompt remedial action must always be taken whenever the casualty occurs.

The speed with which corrective action is undertaken in an engineering casualty is frequently of paramount importance. This is particularly true when such casualties affect propulsion power, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to become cumulative, they may lead to serious damage to the engineering installation—damage which often cannot be repaired without loss of the ship's operating ability. When the risk of developing permanent damage exists, the commanding officer has the responsibility of deciding whether to continue operation of the equipment under casualty conditions; such action can be justified only when the risk of greater damage, or even loss of the ship, might be incurred as a result of immediately securing the affected unit. For example, an entire plant might be operated with abnormal salinity present if such operation were necessary to enable the ship to steam clear of an area of possible enemy attack. However, all possible steps must be taken to shorten such a period of hazardous operation. We reemphasize that 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 result.

Although speed in controlling a casualty is essential, action should NEVER be taken without accurate information; otherwise the casualty may be mishandled, and further damage to the machinery may result. Cross-connecting an intact plant with a partly damaged one must be delayed until it is certain that such action will not jeopardize the intact one.

Communication is an important phase in the control of casualties in the engineering plant of a ship. Prompt action to notify central engineering control and all other associated activities of the engineering plant can prevent additional damage which could be more serious than the original casualty. The sound-powered telephone system is considered to be the least vulnerable means of

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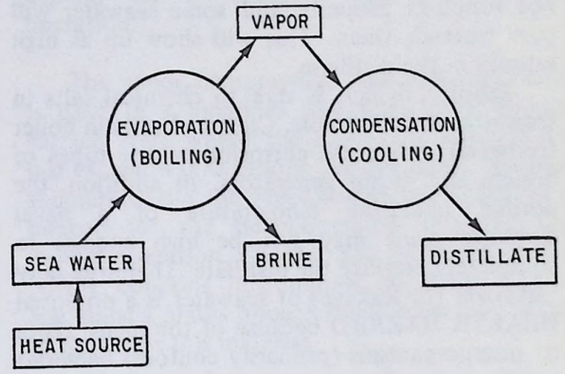
communication; it is essential that personnel be properly trained in its use and that the system be maintained in the best condition. An alternate system, such as announcing systems or messengers should be manned and ready for service if called upon. Rapid transmission of correct information regarding the casualty is essential to effective casualty control communication.

General engineering casualty control procedures are outlined in Chapter 079, Vol. 3 (9880-III) *Naval Ships' Technical Manual.*

CHAPTER 10

STEAM OPERATED DISTILLING PLANTS

A naval ship must be self-sufficient in producing freshwater. Freshwater demands include water for boiler/steam generator feed, drinking, cooking, bathing, washing, and cleaning. Space limitations permit only enough storage tanks for a couple of days' supply. The ship, therefore, depends on distilling plants to produce large quantities of freshwater of high purity from seawater.



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Figure 10-1.—Simplified diagram of shipboard distillation process.

PRINCIPLES OF DISTILLATION

The principle by which these machines (distilling plants) produce freshwater from seawater is quite simple. Even though there are several different types of distilling plants, each of which may appear very complicated at first sight, they all work on the same basic principles. When water is boiled, it gives off steam vapor, which is relatively free of salt and minerals. The distillation process consists of heating seawater to the boiling point and condensing the vapor (steam) into freshwater, leaving behind the impurities of the seawater. The distillation process for a shipboard plant is illustrated very simply in figure 10-1. Notice that the seawater after boiling is identified as a brine.

Seawater is a solution of water and various minerals and salts. In addition to these dissolved solids, seawater contains suspended matter such as vegetable and animal growths and bacteria and other microorganisms. When properly operated, naval distilling plants are capable of producing freshwater that contains only slight traces of chemical salts and no biological contaminants.

Distilling plants are not effective, however, in removing volatile gases or liquids which have a lower boiling point than water. These dissolved gases and liquids will simply boil into the vapor and be combined with the freshwater (distillate). In addition, distilling plants are not effective in killing ALL microorganisms. Naval distilling plants operate at low pressures and, consequently, the boiling temperatures are also low; the distillate, then, is not sterilized by the boiling process. For these reasons, very definite restrictions are placed on the operation of distilling plants in contaminated waters.

At this point, we need to mention the problem of distilling plant "carryover." Practically all cases of high salinity (salt content) in the distillate (freshwater) output of a distilling unit will be caused either by internal

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seawater leakage (from a tube or basket, etc) or by carryover. Carryover actually consists of molecules of seawater which are not filtered out of the vapor produced in a distilling plant before the vapor is condensed into distillate. All types of distilling plants have some type of device to prevent carryover, usually called moisture separators or vapor separators. If the plant is operated improperly, such as attempts to increase the output of the plant beyond rated capacity, the moisture or vapor separators will not function properly and some seawater will pass through them. This will show up as high salinity in the distillate.

Salinity, which is due to chemical salts in seawater, is undesirable. Chemical salts in boiler feedwater will cause corrosion of the tubes of boilers and steam generators. In addition, the normal operating temperature of a naval distilling plant may not be high enough to completely sterilize the distillate. Therefore, any carryover (or leakage) of seawater is a potential HEALTH HAZARD because of the many types of microorganisms (primarily coliform bacteria) which may be present. For these reasons restrictions are placed on the operation of distilling plants aboard ships while operating in either contaminated water or freshwater. Freshwater carryover may not have sufficient salinity to cause either the operator or the salinity indicating system to detect it. Restrictions for operation under these conditions are found in chapter 531 (9580) of the *Naval Ships' Technical Manual.*

There are two reasons that naval distilling plants are designed to operate at low pressures and low boiling temperatures. One reason is that low temperatures help to prevent the formation of harmful scale. Scale is formed when certain sea salts crystallize out of solution at high temperatures. The other reason is that a low pressure plant is more efficient because less heat is required to raise the temperature of the feedwater (seawater) to make it boil; therefore, less heat is wasted by the plant.

COMMON TERMS

Before getting into the discussion on the process of distillation, you should familiarize yourself with the terms defined in the following paragraphs. These terms apply basically to all types of distilling plants now in naval service.

DISTILLATION: The process of boiling seawater and then cooling and condensing the resulting vapor to produce freshwater.

EVAPORATION: The process of boiling seawater to separate it into freshwater vapor and brine. Note that evaporation is the first half of the process of distillation.

CONDENSATION: The process of cooling the freshwater vapor produced by evaporation to produce usable freshwater. Note that condensation is the second half of the process of distillation.

FEED: The seawater, which is the raw material of the distilling unit; also called SEAWATER FEED or EVAPORATOR FEED. Be careful how you use these terms. Do not confuse the "feed" (water) for the distilling units with the "feed" (water) for the boilers. Feed for the distilling units is nothing but raw seawater. Feed for the boilers or steam generators is distilled water of very high purity.

VAPOR: The product of the evaporation of seawater feed.

DISTILLATE: The product resulting from the condensation of the steam (vapor) produced by the evaporation of seawater. Distillate may also be referred to by different names such as FRESHWATER, FRESHWATER DISTILLATE, or CONDENSATE. Try to avoid using the term CONDENSATE to prevent confusion between the condensate of the distilling plant and the condensate in the main and auxiliary condensers. DISTILLATE is the preferred term when you refer to the product of a distilling plant.

BRINE: As seawater feed is evaporated in the distilling plant, the concentration of chemical salts in the remaining seawater feed becomes greater. Any water in which the concentration of chemical salts is higher than it is in seawater is called brine.

SALINITY: The concentration of chemical salts in water is called salinity and is measured by electrical devices, called salinity cells, in units of either epm (equivalents per million) or ppm (parts per million).

EFFECT: In a distilling plant, an effect is that part of a unit where a distillation process occurs. For example, the first place where boiling (or evaporation) of feed into vapor occurs is in the first effect. Most distilling plants are multiple effect types (two, three, four, or five effects). This means that the feed is boiled more than once within the plant. An effect may also be referred to as a STAGE.

SATURATED STEAM: The properties of saturated steam are defined in Table 10-1 according to pressure and temperature.

SUPERHEATED STEAM: Vapor which is not adjacent or next to its liquid source and has been heated to a temperature above its saturation temperature.

DEGREE OF SUPERHEAT: The temperature difference of a superheated vapor between its saturation temperature and its existing temperature.

Let's take an example where the steam pressure past an orifice is 16 in. Hg and auxiliary exhaust steam temperature is 240° F (116° C). Table 10-1 gives the properties of saturated steam. Look in the column labeled Vacuum Inches of Hg Gage and find 16.69 and 15.67. By interpolation (estimation), we find the saturation temperature (at the right) to be 176° F (80° C). However, the auxiliary exhaust steam is approximately 240° F (116° C). In this case, then, there is about 64° F (36° C) of superheat in the incoming steam (240° F - 176° F = 64° F).

TYPES OF DISTILLING PLANTS

Distilling plants installed in naval ships are of two general types: the vapor compression type and the low-pressure steam distilling unit. The major differences between the two types of plants 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 a compressor); steam distilling units use low pressure steam from either the auxiliary exhaust steam systems or the auxiliary steam system. In addition, vapor compression units boil the feedwater at a pressure slightly above atmospheric while the low-pressure steam units depend on a relatively high vacuum for operation.

The vapor compression type distilling plant is used in submarines and small diesel-driven surface craft where the daily requirements do not exceed 4,000 gallons per day (gpd). Nuclear submarines use the vapor compression plant as a backup for the steam-operated unit and for in-port operation. Chapter 531 (9580-II) of the NSTM contains information on these plants. Machinist's Mates aboard submarines may want to look over this material.

The low-pressure steam distilling unit is used in all steam-driven and gas turbine-driven surface ships and nuclear submarines. Machinist's Mates usually have prime responsibility for the maintenance and operation of the low-pressure steam distilling plants.

Low-pressure steam distilling units are "low pressure" from two points of view: First, they use low-pressure steam as the source of energy; and second, their operating shell pressure is less than atmospheric pressure.

There are three major types of low-pressure steam distilling units: (1) submerged tube, (2) flash-type, and (3) vertical basket.

SUBMERGED TUBE DISTILLING PLANTS

There are three classifications, or arrangements of submerged tube distilling plants: (1) Two-shell double-effect, (2) Soloshell double-effect, and (3) triple-effect. The principal difference between the double-effect type and the triple-effect type is the number of stages of evaporation.

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Table 10-1.—Properties of Saturated Steam

Absolute Pressure		Vacuum Inches of Hg Gage	Temperature	
Lb. per Sq. In.	Inches of Hg		°C	°F
0.20	0.41	29.51	11.74	53.14
0.25	0.51	29.41	15.17	59.30
0.30	0.61	29.31	18.04	64.47
0.35	0.71	29.21	20.52	68.93
0.40	0.81	29.11	22.70	72.86
0.45	0.92	29.00	24.66	76.38
0.50	1.02	28.90	26.43	79.58
0.60	1.22	28.70	29.56	85.21
0.70	1.43	28.49	32.27	90.08
0.80	1.63	28.29	34.66	94.38
0.90	1.83	28.09	36.80	98.24
1.0	2.04	27.88	38.74	101.74
1.2	2.44	27.48	42.18	107.92
1.4	2.85	27.06	45.14	113.26
1.6	3.26	26.66	47.77	117.99
1.8	3.66	26.26	50.13	122.23
2.0	4.07	25.85	52.27	126.08
2.2	4.48	25.44	54.23	129.62
2.4	4.89	25.03	56.05	132.89
2.6	5.29	24.63	57.74	135.94
2.8	5.70	24.22	59.33	138.79
3.0	6.11	23.81	60.82	141.48
3.5	7.13	22.79	64.21	147.57
4.0	8.14	21.78	67.21	152.97
4.5	9.16	20.76	69.91	157.83
5.0	10.18	19.74	72.36	162.24
5.5	11.20	18.72	74.61	166.30
6.0	12.22	17.70	76.70	170.06
6.5	13.23	16.69	78.64	173.56
7.0	14.25	15.67	80.47	176.85
7.5	15.27	14.65	80.52	176.94
8.0	16.29	13.63	83.81	182.86
8.5	17.31	12.61	85.36	185.64
9.0	18.32	11.60	86.82	188.28
9.5	19.34	10.58	88.22	190.80
10.0	20.36	9.56	89.57	193.21
11.0	22.40	7.52	92.08	197.75
12.0	24.43	5.49	94.42	201.96
13.0	26.47	3.45	96.60	205.88
14.0	28.50	1.42	98.64	209.56

In a submerged tube distilling plant feed floods into the bottom of the unit and surrounds the tubes which contain circulating low-pressure steam. The steam in the tubes causes the surrounding feed to boil and produce steam (vapor). The vapor passes up into the moisture separators where any entrained seawater droplets are removed. The clean vapor then passes on and is condensed into distillate. Submerged tube type distilling plants are found on older ships. To explain the principle of distillation in a submerged tube plant, we shall use the Soloshell double-effect plant as an example.

As the name implies, the Soloshell double-effect plant (fig. 10-2) is a double-effect distilling unit contained in a single shell. A division plate separates the two effects. Each effect has a set or "nest" of steam tubes in the bottom of its shell and a vapor separator unit in the upper part of its shell.

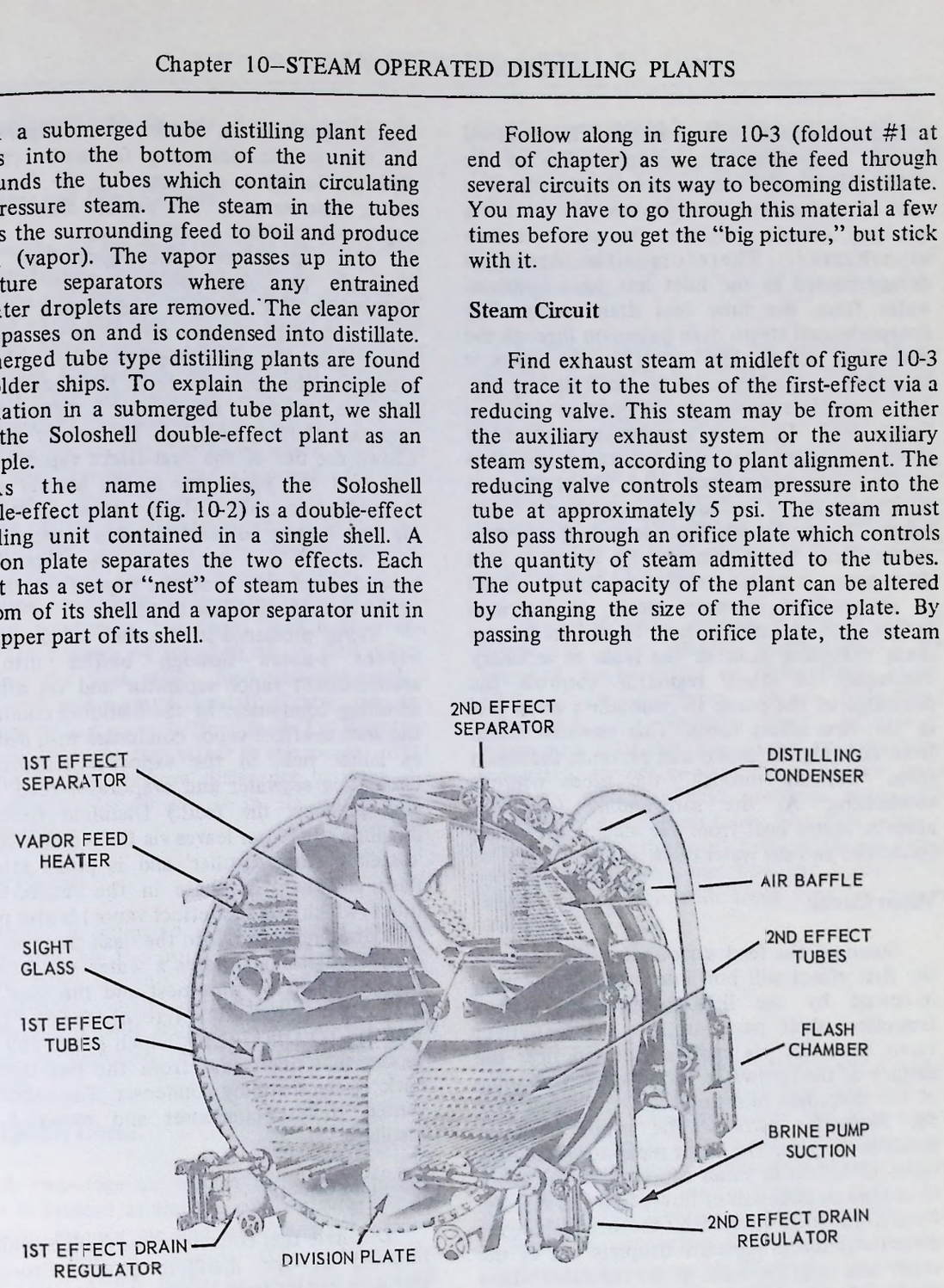


Figure 10-2.—Internal construction of a Soloshell double-effect distilling plant.

Follow along in figure 10-3 (foldout #1 at end of chapter) as we trace the feed through several circuits on its way to becoming distillate. You may have to go through this material a few times before you get the "big picture," but stick with it.

Steam Circuit

Find exhaust steam at midleft of figure 10-3 and trace it to the tubes of the first-effect via a reducing valve. This steam may be from either the auxiliary exhaust system or the auxiliary steam system, according to plant alignment. The reducing valve controls steam pressure into the tube at approximately 5 psi. The steam must also pass through an orifice plate which controls the quantity of steam admitted to the tubes. The output capacity of the plant can be altered by changing the size of the orifice plate. By passing through the orifice plate, the steam

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pressure is decreased to a vacuum. This is caused by the throttling (expanding) action of the orifice. Since the temperature of the steam is still at saturation temperature for existing auxiliary exhaust pressure, the steam is now superheated. Therefore, the steam is desuperheated in the inlet line by a spray of water from the tube nest drain pump. The desuperheated steam then passes on through the first-effect tubes. The steam in the tubes is indicated on the figure by the black dashed line. The first-effect tubes can be seen in detail in figure 10-2. The area surrounding the steam tubes is flooded with feed (seawater) indicated by the white area in figure 10-3. The steam gives up its heat to the feed and then condenses in the tubes. The condensate that forms in the tubes is continuously being removed by the tube nest drain pump. A portion of this condensate is used to desuperheat incoming steam as described earlier, and the rest is sent to the freshwater drain collecting tank or the main or auxiliary condenser. A drain regulator controls the discharge of the pump to maintain a water seal in the first effect tubes. This prevents steam from entering the pump and prevents the steam from "blowing through" the tubes without condensing. As the surrounding feedwater absorbs latent heat from the steam, the steam condenses and the water boils.

Vapor Circuit

Some of the feed surrounding the tubes in the first effect will boil into vapor. The vapor, indicated by the light green area in the first-effect shell, passes up into the first-effect vapor separator via baffles. Located near the surface of the feedwater, these baffles trap some of the entrained moisture from the vapor near the feedwater surface. The vapor separator removes the rest. The vapor separator contains a series of baffles or vanes which cause the vapor to change its direction of flow often and rapidly. Centrifugal force (caused by the steam changing directions) forces moisture droplets out of the vapor and onto the sides of the separator where the moisture collects and drains back down into the feed section of the first effect.

The clean moisture-free vapor passes into the vapor feed heater. The vapor feed heater and vapor separator can also be seen in figure 10-2. In this section, incoming feedwater (flowing through tubes) is preheated by the first-effect vapor (surrounding the tubes). Some of the vapor will condense in this process.

The vapor leaves the vapor feed heater through the line labeled 2ND EFFECT EVAPORATOR STEAM and passes into the tube nest of the second effect. As you can see, vapor from the first effect is used as heating steam for the second effect. The shell pressure of the second effect is a vacuum of approximately 26 in. Hg. This lower pressure allows the use of the first-effect vapor to heat and boil the feedwater in the second effect. According to table 10-1, at a pressure of 26 in. Hg, the boiling point of water is approximately 125° F (52° C). As it passes through the second-effect tube nest, the vapor from the first effect is condensed into distillate.

Vapor produced in the shell of the second effect passes through baffles into the second-effect vapor separator and on into the distilling condenser. In the distilling condenser, the second-effect vapor condenses into distillate as latent heat in the vapor is removed by circulating seawater and evaporator feed. (This also preheats the feed.) Distillate from the distilling condenser leaves via the red line labeled 'distillate from distiller' and is piped into the flash chamber. Distillate in the second-effect tubes (which was first-effect vapor) is also piped, via a drain regulator, into the flash chamber. The drain regulator maintains a water seal between the second-effect tube nest and the shell. The flash chamber has a line (green) labeled FLASH VAPOR TO DISTILLER which passes any flash vapors that may form from the hot distillate back to the distilling condenser. The vapors are vented to the condenser and recooled into distillate.

Distillate Circuit

Distillate that collects in the flash chamber is pumped by the distillate pump through a distillate cooler (red line) and to the test tank. From the test tank, the distillate is directed by a valve manifold (not shown) to either the potable water system or reserve feedwater tanks by the freshwater pump. If the water in the test tanks is

contaminated with chloride, it can be sent to the bilge.

Seawater and Feed Circuits

Locate the sea chest (blue) at the lower right of the figure. Seawater is brought in by the distilling condenser circulating water pump from the sea chest and strainer. The water is pumped through the distillate cooler into the distilling condenser (blue line) and overboard through a spring-loaded backpressure regulating valve. A backpressure regulating valve provides a 5 psi backpressure on the circulating water. This valve sets the pressure head required for the evaporator feed (blue-striped line) which is tapped off the circulating water line as it leaves the distilling condenser. The evaporator feed passes through the feed heater section of the distilling condenser, through the tubes of the air ejector condenser, the vapor feed heater, and into the bottom of the shell of the first effect. Leaving the first effect, feed passes through a loop seal and manual regulating valve, into the bottom of the second-effect shell. The direction of flow from the first effect to the second effect is due to the pressure difference between the two effects. (1st effect - 16 in. Hg, 2nd effect - 26 in. Hg).

Brine Circuit

Brine is removed (orange line) from the evaporator by the brine overboard pump. The pump takes suction from the bottom of the second-effect shell and discharges the brine overboard. Gland sealing water for the brine pump is provided by the circulating water system.

Air Ejector Circuit

A two-stage air ejector unit (black-striped line) is located at the top of the plant. The air ejectors remove air and noncondensable gases such as carbon dioxide (CO_2) from the evaporator which helps to maintain the high vacuum in the shell of the second effect. The vacuum in the first-effect shell is established and maintained by the condensation of steam in the vapor feed heater. Steam discharged from the air ejector is condensed by the evaporator feed. The resulting condensate is returned (yellow line) to the ship's feed system through the freshwater drain collecting system.

Salinity Monitoring and Indicating

Electrical salinity cells are provided in the evaporator system to electrically monitor the purity of the water at various points. Salinity cells are strategically located at: (1) discharge of the tube nest drain pump; (2) air ejector drains; (3) distillate out of the distilling condenser; (4) second-effect steam drains; and (5) the distillate pump discharge. The salinity cells are valved into the pipelines at these points to be in contact with the flow of water.

This distillation process is similar for all submerged tube plants, whether they are two-shell double-effect or triple-effect. Figure 10-4 is an illustration of a triple-effect submerged tube distilling plant. As a rule, submerged tube distilling plants are very large compared to other plant types of the same capacity and they have problems with scale formation on the steam tubes. For these reasons, primarily, the submerged tube plants are being phased out for naval use. You may, however, be assigned to a ship with these types of plants aboard.

FLASH-TYPE DISTILLING PLANTS

The flash-type distilling plant is widely used throughout the Navy. Flash-type plants have some distinct advantages over the submerged tube type plant. One is that the flash-type "flashes" the feed into vapor (steam) rather than boiling it inside the evaporator shell. The flashing process involves heating the feed before it enters the evaporator shell. The shell is under a relatively high vacuum. The feed is heated to a temperature at which it will flash into vapor when it enters the vacuum. With this design, there are no submerged heat transfer surfaces within the evaporator shell, such as the steam

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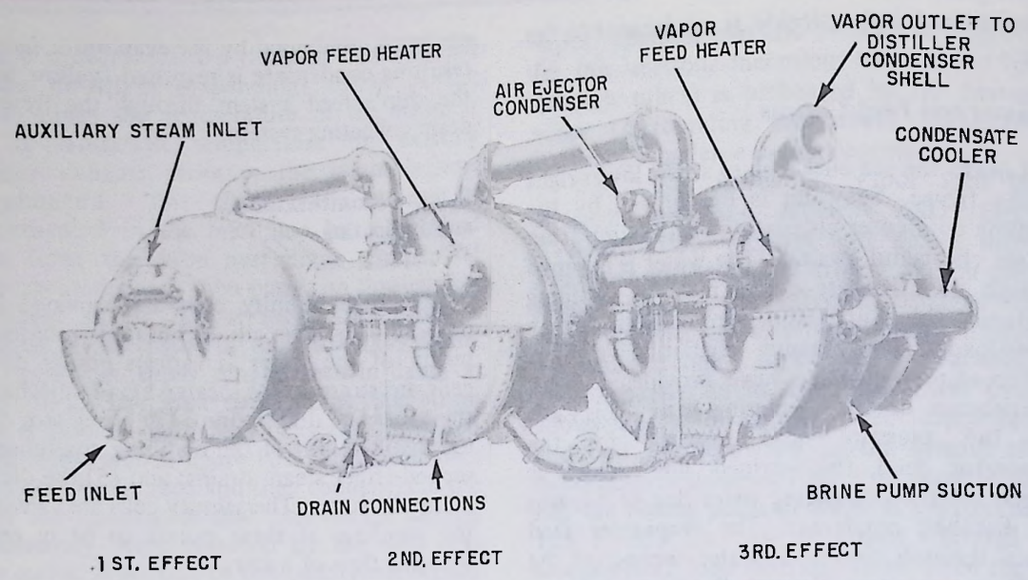


Figure 10-4.—Low-pressure, triple-effect, submerged tube distilling plant.

tubes in the submerged tube unit. The elimination of these surfaces greatly reduces the scale formation problem of evaporators and allows prolonged operation at maximum efficiency. Any scale that may form on heat transfer surfaces of a flash-type plant is composed mainly of soft calcium carbonate compounds that are relatively easy to remove.

Two-Stage Flash

Figure 10-5 is an illustration, showing the major components, of the two-stage flash distilling plant that we are going to discuss. Figure 10-6 (foldout #2 at end of chapter) shows the major flowpaths through the two-stage, 12,000 gpd flash distilling plant. Follow along on the diagram during the explanation of the plant which follows.

SEAWATER FEED CIRCUIT.—The seawater feed pump (upper left of fig. 10-6) takes a suction through a sea chest and strainer and discharges seawater into the tubes of the condensing section of the second stage of the evaporator. The seawater feed then flows over into the tubes of the first-stage condensing section. The condensing section of the evaporator is a shell and tube heat exchanger which extends the full length of the evaporator shell, i.e., through both the first stage and the second stage.

In the condensing sections, the seawater feed condenses the surrounding vapor and, as a result of the heat exchanger process, the feed increases in temperature. When the incoming seawater feed has a temperature of 85° F (29° C), the feed leaving the first-stage condensing section of the evaporator should be approximately 138° F (59° C).

Upon leaving the first-stage condensing section, the feed enters the air ejector condenser/seawater heater assembly. In this double-flow, shell and tube heat exchanger, the feed picks up heat by condensing exhaust steam from the air ejectors and from steam admitted to the seawater heater from the auxiliary exhaust steam system.

The feedwater leaves the air ejector condenser/seawater heater assembly at a

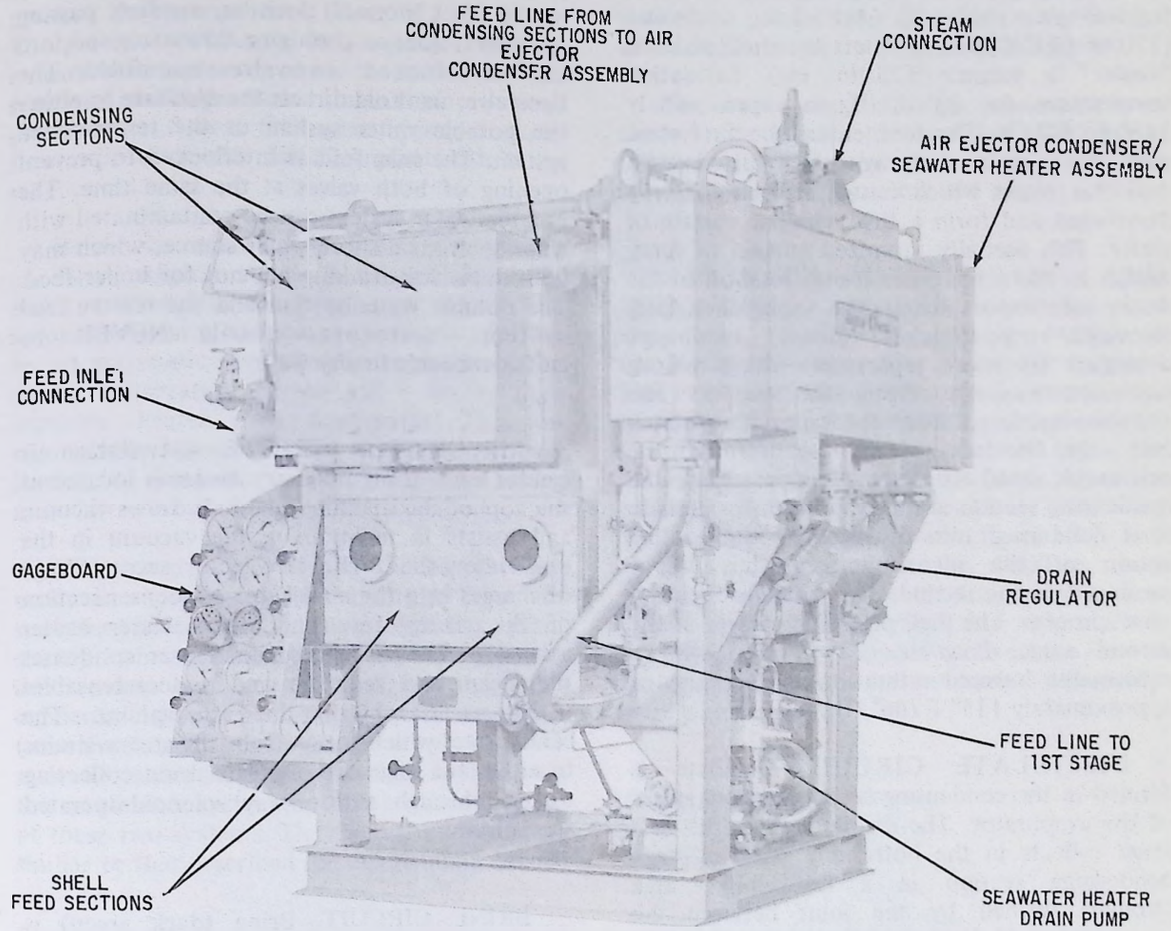


Figure 10-5.—2-stage, 12,000 gpd flash-type evaporator.

temperature of approximately 170° F (77° C) and is fed to the first stage of the evaporator shell. The feed enters the bottom of the shell through two spray pipes, which partially atomize the water, and aids in "flashing" the feed into vapor. Feed that does not flash in the first stage is directed to the second stage through an internal loop seal located at the bottom of the shell. Flow control of the feedwater is accomplished by manual operation of the feed valve in the line just before the first stage.

The feedwater enters the second stage in a manner similar to the way it entered the first-stage shell. The force that moves the feed from the first to the second stage is the pressure differential between the two stages. The first stage shell pressure is maintained at approximately 23 in. Hg while the second-stage shell pressure is approximately 27 in. Hg. Also assisting is the head due to the higher water level in the first stage which overflows into the second stage. This loop seal arrangement prevents the pressure from equalizing between the stages. Feedwater that does not flash into vapor in the second stage becomes brine which is pumped overboard.

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VAPOR CIRCUIT.–Vapor is formed in the first-stage shell by the hot feedwater (170° F [77° C]) as it enters the shell which is "under" a vacuum (23 in. Hg). Saturation temperature for 23 in. Hg is approximately 148° F (64° C). The feed enters the first stage shell through two spray pipes fitted with deflector plates which cause the feed to spray downward and form a thin, circular curtain of water. This partially atomized curtain of spray results in more complete transformation of the water into vapor steam. The vapor then rises through copper-nickel (Monel) mesh-type demisters (moisture separators) which remove entrained moisture from the vapor. (The moisture removed from the vapor drains back into the bottom [feed] section of the evaporator shell). The vapor then passes into the condensing section of the evaporator shell where it is condensed into distillate by the cooling action of the incoming feedwater. Vapor produced in the second stage goes through the same process. The shell pressure is lower in the second stage, however (27 in. Hg) with a subsequent lowered saturation temperature of approximately 115° F (46° C).

DISTILLATE CIRCUIT.–Distillate is formed in the condensing section of both stages of the evaporator. The distillate from the first stage collects in the bottom of the first-stage condensing section in a hotwell-like area (trough) formed by the joint between the evaporator shell division plate and the first-stage collection tray. The distillate passes through a loop seal into a higher trough (or tray) in the second stage. The piping between the two stages contains an orifice plate with a 5/8-inch diameter orifice which controls the flow rate and prevents equalization of pressure between the stages and, also, prevents premature "flashing" of the distillate as it enters the lower pressure area of the second stage.

The distillate is then pumped out of the second-stage distillate trough by the distillate pump. The distillate pump discharges the water through a three-way solenoid-operated trip valve, which, when tripped, will automatically divert the flow of distillate to the bilge if the salinity content reaches a predetermined setpoint (usually 0.065 epm). When the valve is in the reset (normal) position, distillate passing through it goes on through a flowmeter and into an interlocked two-valve manifold. The two-valve manifold directs the distillate to either the potable water system or the reserve feed system. The manifold is interlocked to prevent opening of both valves at the same time. The potable water system can be contaminated with chloride from a shore water source, which may be suitable for drinking but not for boiler feed. The potable water system and the reserve feed system, therefore, should NEVER be cross-connected in any way.

AIR EJECTOR CIRCUIT.–A two-stage air ejector unit, using auxiliary steam is located at the top of the distilling plant. It draws vacuum and assists in maintaining the vacuum in the evaporator shell. The air ejector second stage discharges into the air ejector condenser section of the air ejector condenser/seawater heater assembly. The air ejector condenser condenses the steam and vents air and noncondensables (such as CO_2) to the atmosphere. The condensate, which forms from the steam, drains to either the bilge or the steam drain collecting system through a three-way solenoid-operated trip valve.

BRINE CIRCUIT.–Brine (dark green) is pumped out from the bottom of the second-stage shell. A centrifugal pump is used for this purpose.

HEATING STEAM CIRCUIT.–Auxiliary exhaust steam is used in the seawater heater to provide the heat required to raise the temperature of the seawater feed to approximately 170° (77° C). The auxiliary exhaust steam entering the seawater heater passes through an orifice which controls the quantity of the steam admitted to the heater. The steam pressure upstream of the orifice is approximately 3 psig.

The seawater heater is vented to the first-stage evaporator through a line with a

1/4-inch orifice to bring the seawater heater pressure to approximately 9 in. Hg (10 psia). The pressure differential between the auxiliary exhaust steam pressure above the orifice and the seawater heater pressure is critical in providing proper steam flow to the heater. Improper steam flow will cause the distilling plant output to vary.

Before it enters the seawater heater, the auxiliary exhaust steam is desuperheated by water sprayed into the steam inlet piping. The amount of water for desuperheating is adjusted by an automatic control valve to maintain the steam temperature 5° to 10° F higher than seawater heater shell temperature. In this manner the temperature of the seawater feed leaving the air ejector condenser/seawater heater assembly is maintained relatively constant.

The water supply for the desuperheating water is a portion of the discharge from the seawater heater drain pump. During plant startup, when water from the seawater heater drain pump may not be available, the ship's condensate system furnishes the water supply. A two-valve interlock between the supply from the seawater heater drain pump and the supply from the condensate system prevents cross-connecting of these two systems. The two-valve interlock is similar to that described for the distillate circuit.

SEAWATER HEATER DRAIN CIRCUIT.–Condensed auxiliary exhaust steam is pumped from the shell of the seawater heater by the seawater heater drain pump. A drain regulator serves as a hotwell and assures a constant suction head for the pump. The drain regulator is a ball float-operated valve attached below the condensate drain connection of the seawater heater. The ball float in the drain regulator operates the valve to maintain a relatively constant water level in the housing, which is indicated by a gage glass. A decrease in water level will tend to close the valve in the drain regulator. Therefore, the amount of condensate discharged by the drain pump will be throttled until the water level in the float housing rises again. The water level in the regulator maintains a suction head for the seawater heater drain pump and prevents loss of vacuum in the seawater heater by maintaining a water seal between the heater and the pump.

The drain pump discharges condensate from the seawater heater to the condensate system (startup only) to the steam drain collecting system (normal lineup) or to the bilge.

SALINITY MONITORING AND INDICATING.–Four salinity cells in the plant shown in figure 10-6 provide continuous monitoring of water purity: (1) at the loop seal line between the first- and second-stage distillate; (2) at the distillate pump discharge; (3) at the air ejector drain line; and (4) at the seawater heater drain pump discharge. All of the salinity cells are read on a salinity indicating panel such as the one shown in figure 10-7. Two of the cells, located at the distillate pump discharge and the air ejector drains, also control three-way solenoid-operated trip valves which are automatically "tripped" to divert the flow of water to the bilge to prevent contamination of a pure water system.

Other Applications of the Flash-Type Distilling Unit

Flash-type distilling plants may have any number of stages and output capacities. For example, the Navy uses one type of three-stage, 30,000 gpd plant as well as a five-stage, 50,000 gpd unit. All flash-type plants operate on the same basic principles as those described for the two-stage plant.

FIVE-STAGE FLASH.–The five-stage flash unit consists of five evaporator-condenser stages in a single shell. Passages and loop seals, between the stages, permit the flow of feedwater and distillate while preserving a different vacuum in each stage.

In most instances, the feedwater heater, drain regulators, air ejectors, air ejector

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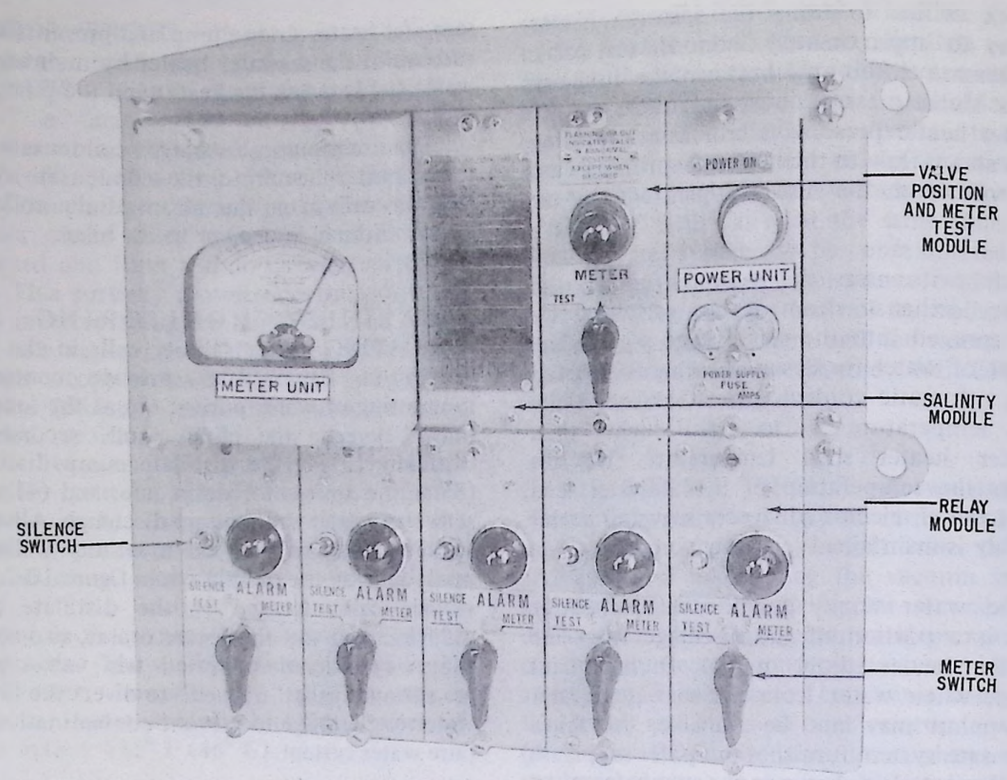


Figure 10-7.—Salinity indicator panel.

condensers, condensate coolers, interstage distillate drain regulators, feed and distillate flow regulators, and three-way solenoid dump valves are mounted directly on the shell. Follow the flow of the various fluids through the plant, shown in figure 10-8, as we discuss the plant in the following paragraphs.

In the flashing process, the feedwater gives up heat to the vapor produced in each stage; however, the lower pressure in each succeeding stage enables the flashing to continue with as much vapor produced in the final stage as in the first.

The concentrated feedwater (brine) overflows through the vacuum-preserving feedwater loop seals from stage to stage, becoming increasingly more concentrated in each stage until it is pumped out by the brine pump from the fifth stage.

Incoming feedwater is heated as it passes through the tubes of the following heat exchangers in this order: the distillate cooler, the condensers in each of the five stages (in reverse order), the pre-heater and the feedwater heater. The amount of feedwater flowing through the heater must be regulated manually so that the temperature rise in the feed can be controlled.

Operating Notes for Flash-Type Units

The rate of feed to the first-stage inlet box should be maintained constant at all times,

provided the plant is producing its normal capacity or less. Distilling plants are designed to operate at a definite number of gallons of feed per minute, which is indicated by rotameters in the feed line between the distilling condenser circulating water pump and the distillate cooler. All other valves in the feed line should be opened wide to prevent their interfering with the proper flow of feed through the plant.

With proper feed flow and with a clean plant, the temperature of the feed entering the first-stage feed inlet box will be 175° F (79° C) or less, depending on the temperature of the seawater. Plants are designed to operate with a feed temperature of 175° F (79° C) maximum when the temperature of the seawater is 85° F (29° C); when the seawater temperature is lower, the feed temperature will be correspondingly lower.

No attempt should be made to control the feedwater temperature after it leaves the feedwater heater and enters the first-stage flash box. The temperature should adjust itself to the varying plant conditions. Full capacity will be realized with proper feed flow, proper vacuums throughout the plant, and proper steam pressure above the orifice.

The feed temperature should never be allowed to exceed 175° F (79° C). Higher operating temperature will greatly increase the amount of scale formation.

Although the capacity of the flash-type distilling plant depends on (1) the quantity of evaporator feedwater entering the first-stage feed box and (2) the difference in temperature between the feedwater entering the first stage and the vapor in succeeding stages, the capacity can be changed only by increasing or decreasing the amount of heat added to the seawater by the feedwater heater.

With a constant steam pressure of 5 psig above the orifice, an increase in the feed flow will decrease the temperature in the first-stage flash chamber, which will also decrease the temperature of the vapor in the succeeding stages, and the capacity will remain constant. Therefore, the capacity of the plant can be changed by changing the steam pressure above the orifice.

VERTICAL BASKET DISTILLING PLANT

Single-stage, vertical basket-type distilling plants are used extensively in our nuclear submarines. These plants have a capacity of approximately 8,000 gallons per day and are sometimes referred to as the "8K evaporators."

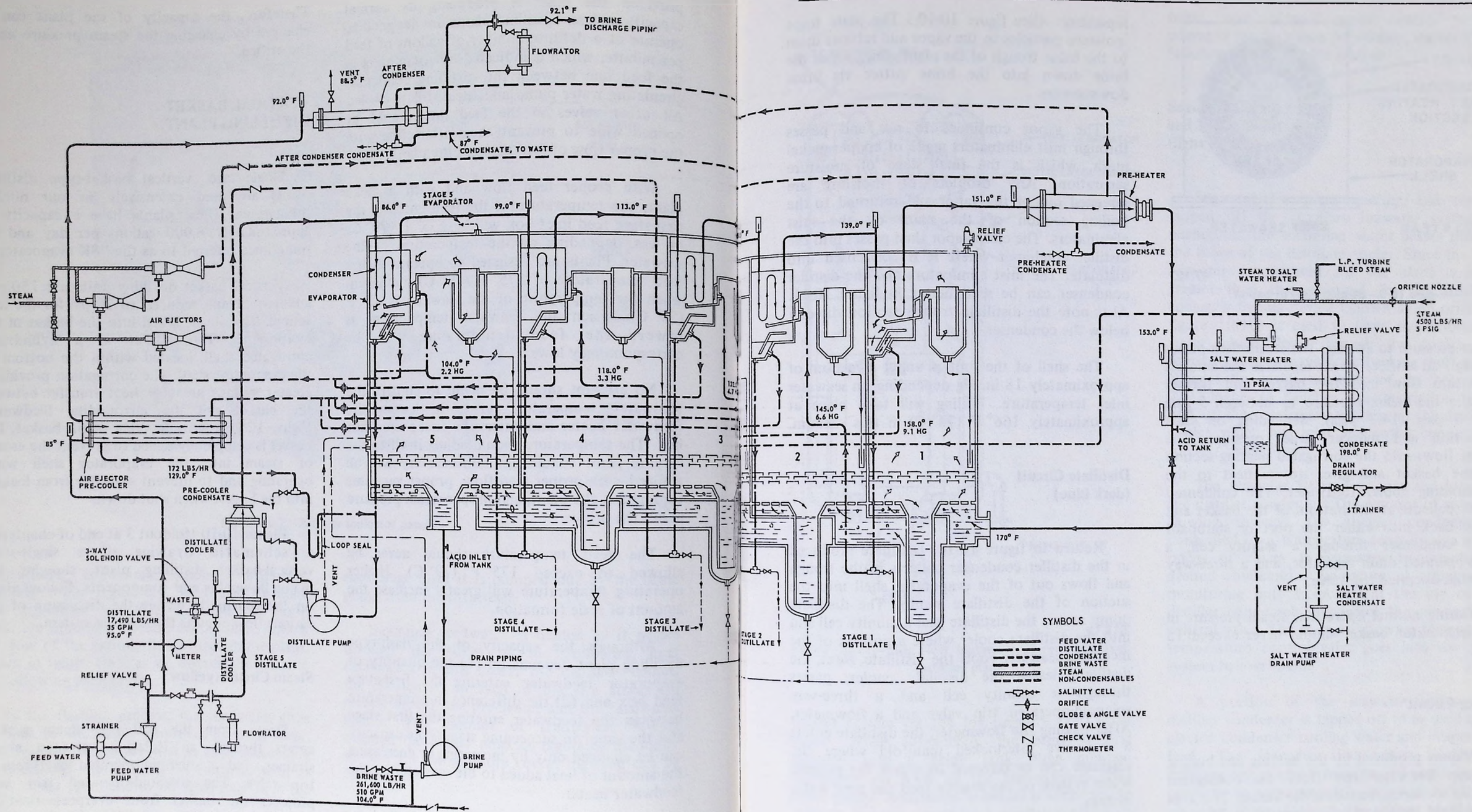
Vertical basket distilling units use 150 psig auxiliary steam, reduced to 20 psi for the heat source. The steam is fed into the basket of the evaporator. The basket is a cylindrical, corrugated shell, located within the bottom of the evaporator shell. The corrugation provides a greater surface area for heat transfer between the basket and the surrounding feedwater. Figure 10-9 shows a top view of the basket. The basket is completely sealed to prevent the escape of steam into the evaporator shell while operating and to prevent seawater from leaking into the basket when shut down.

Figure 10-10 (foldout 3 at end of chapter) is a schematic drawing of a single-stage vertical-basket distilling plant, showing the major flowpaths and components. Follow along on the schematic during the discussion of the various flow circuits through the system.

Steam Circuit (yellow)

Steam from the 150 psig steam system enters through an isolation valve, a steam strainer, and a solenoid-operated overpressure trip valve. The solenoid-operated trip valve protects the basket from overpressurization. With a steam supply of 150 psig, the basket could be ruptured if pressure downstream of the reducing valve rose unaccountably. The overpressure trip valve is actuated by a pressure switch located downstream of the reducing valve. The reducing valve reduces the 150 psig

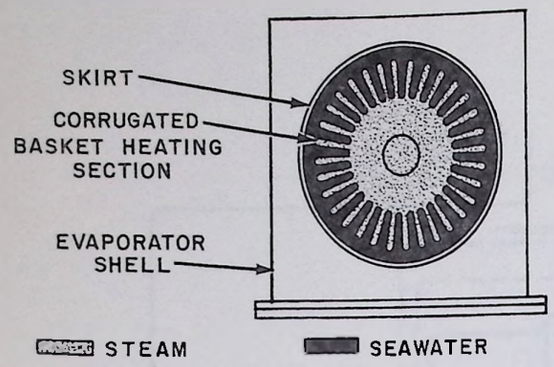
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Figure 10-8.—Flow diagram for a five-stage flash-type distilling unit.

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47.127

Figure 10-9.—Section view of basket.

steam pressure to 20 psig. The steam then passes through an orifice, which regulates the amount of steam flow into the basket and further reduces the steam pressure to between 5 psig and 0 psig (14.7 psia), depending on scale formation and reducer outlet pressure. The steam flows into the corrugated heating section of the basket and gives up its heat to the surrounding cooler feedwater. The condensed steam collects at the bottom of the basket and flows back into either the port or starboard main condenser through a salinity cell, a float-operated drain regulator, and a three-way solenoid-operated trip valve.

During normal operation, steam pressure in the evaporator basket should never exceed 15 psig.

Vapor Circuit

Vapors produced by the heating and boiling of the feedwater rise from the corrugated heating section surrounding the basket. This area is enclosed by a skirt (see figure 10-9). The area between the skirt and the basket is the actual boiling section. Hot water and vapors travel upwards between the skirt and the basket as the feed is heated. The vapor rises above the basket and passes through a corrugated, perforated plate which acts as the first stage of moisture separation. (See figure 10-10.) The plate traps moisture particles in the vapor and returns them to the brine trough of the plant which sends the brine down into the brine gutter via brine downcomers.

The vapor continues to rise and passes through mist eliminators made of copper-nickel mesh, which is the final stage of moisture separation. Any droplets of moisture are screened out of the vapor and returned to the boiling section of the plant by the mist eliminators. The clean vapor then passes into the distiller condenser where it is condensed into distillate. The mist eliminators and the distiller condenser can be seen better in figure 10-11. Also note the distillate trough section directly below the condenser.

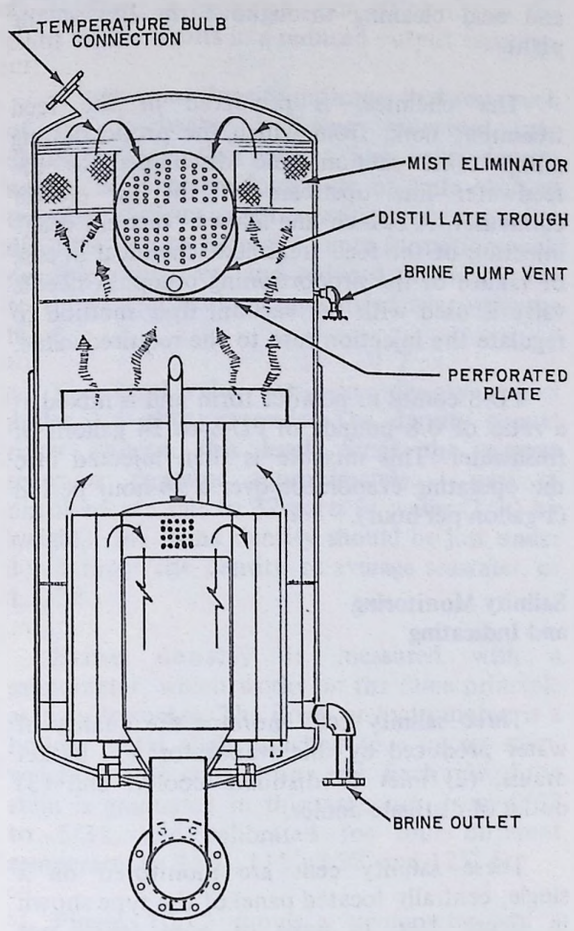
The shell of the unit is under a vacuum of approximately 18 in. Hg depending on seawater inlet temperature. Boiling will take place at approximately 166° F (74° C) in this vacuum.

Distillate Circuit (dark blue)

Return to figure 10-10. Distillate produced in the distiller condenser collects in the trough and flows out of the evaporator shell into the suction of the distillate pump. The distillate pump moves the distillate past a salinity cell and into the distillate cooler where a portion of the incoming seawater cools the distillate. Next, the distillate leaves the distillate cooler, passes through a salinity cell and a three-way solenoid-operated trip valve and a flowmeter. After passing the flowmeter, the distillate enters a two-valve interlocked manifold where the distillate can be directed to either the potable water system or the reserve feed and pure water system.

Brine Circuit (dark green)

When the submarine is on the surface, brine is pumped overboard via the auxiliary seawater



47.213

Figure 10-11.—Side view (cutaway) of vertical-basket distilling plant.

(ASW) system by the low-pressure (LP) brine pump. When submerged, the brine is first pumped into a brine tank, then pumped overboard via ASW by the high-pressure (HP) brine pump. Additional seawater is added to the brine in the brine tank on a continuous basis to prevent clogging or scaling in downstream piping. This is called brine dilution water. The HP brine pump has a variable speed motor with an automatic level control system. The control system will automatically vary the motor speed as necessary to maintain a constant level in the brine tank. Manual speed control is also provided for the pump for startup, shutdown, or failure of the automatic feature.

Seawater Circulating and Feed Circuit (light green)

Seawater for plant cooling and feed is tapped off the auxiliary seawater system. A portion of the incoming water passes through the tubes of the distillate cooler. Since the total seawater requirement for the plant is much greater than that required for the distillate cooler, a bypass device (shown as an orifice in figure 10-10) is used to limit the amount of water which flows through the cooler. The bypass device is actually a "backing ring" which changes the inside diameter of the pipe from 2 1/2 inches to 2 inches. This restriction diverts part of the total seawater flow to the distillate cooler which has inlet and outlet connections for 1 1/2-inch pipe.

The seawater flows next into the tubes of the distiller condenser. The amount of seawater flowing through the distiller condenser is controlled by a temperature control valve which opens or closes as necessary to maintain a desired condenser temperature. A temperature monitoring bulb is located at the top of the distiller condenser to control the temperature control valve. The seawater flowing through the temperature control valve goes into the ASW system to overboard.

A portion of the seawater leaving the distiller condenser is tapped off to be used as air ejector condenser cooling water and evaporator feed. The seawater first passes through a reducing valve which reduces and regulates the pressure to approximately 20 psig. Next, the seawater flows through the tubes of the air ejector condenser where it picks up heat by cooling and condensing air ejector discharge steam. The seawater is now ready for use as evaporator feed. The feed flows out of the air ejector condenser, past a manual feed control valve and a feed control orifice, and into the

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bottom of the evaporator feed section. The feed control orifice provides an indication of flow rate. A differential pressure gage is connected across the orifice. This two-element gage (contains two Bourdon tubes but has only one pointer) is connected to sense the pressure difference across the orifice plate, i.e., the difference between inlet pressure (7-9 psig) and outlet pressure (a vacuum of 18 in. Hg during normal operation of the unit). The gage is calibrated to give a pressure indication that is equivalent to the flow rate of seawater passing through the orifice. The operator can check the differential pressure on the gage against a flow chart and determine the flow rate of the feed in gallons per minute. In this way, the operator can properly adjust the feed rate into the evaporator.

A bypass is provided in the feed line to bypass some of the feed directly into the brine outlet of the evaporator. This bypass can be used during startup or shutdown and cool down of the evaporator to maintain level in the feed section while still providing adequate cooling water flow through the air ejector condenser.

Air Ejector Circuit

A single-stage air ejector establishes and assists in maintaining a vacuum in the evaporator shell. The air ejector is supplied with 150 psig steam from just upstream of the evaporator basket's steam supply first isolation valve. The air ejector takes a suction from the top of the distiller condenser and discharges into the air ejector condenser. Steam is condensed in the air ejector condenser into condensate and air, and noncondensables are vented to atmosphere. The condensate produced in the air ejector condenser is directed to a drain pan located on top of the brine tank or to the bilge. This condensate is not returned to the feed system.

Feed Treatment Circuit

A scale inhibiting additive (PD-8) is fed continuously into the evaporator feed during operation. The continuous use of feed treatment practically eliminates the need for chill shocking and acid cleaning throughout the life of the plant.

The chemical is premixed in the feed treatment tank, from which the proportioning pump takes suction, and discharged to the feedwater line upstream of the air ejector condenser. A branch line allows "vacuum drag" injection of the feed treatment chemical in case of failure of the proportioning pump. A needle valve is used with the vacuum drag method to regulate the injection rate to the required value.

PD-8 comes in powder form and is mixed at a ratio of 0.8 pounds of PD-8 to 24 gallons of freshwater. This mixture is then injected into the operating evaporator over a 24-hour period (1 gallon per hour).

Salinity Monitoring and Indicating

Three salinity cells monitor the quality of water produced by this evaporator: (1) basket drains, (2) inlet to distillate cooler, and (3) outlet of distillate cooler.

These salinity cells are monitored on a single, centrally located panel of the type shown in figure 10-6 in units of ppm (parts per million). These cells also generate the signals that control the 3 three-way solenoid-operated trip valves.

DISTILLING PLANT OPERATION AND MAINTENANCE

You have seen that not all of the seawater feed, which is fed into an evaporator, is changed into distillate. That portion of the feed which does not become distillate is called brine. The concentration of sea salts in this water is called brine density, which has a direct bearing on the quality of the distillate produced by the evaporator. A low brine density indicates that

not enough of the feedwater is being converted to distillate; it indicates poor efficiency in the plant which results in a reduced output capacity.

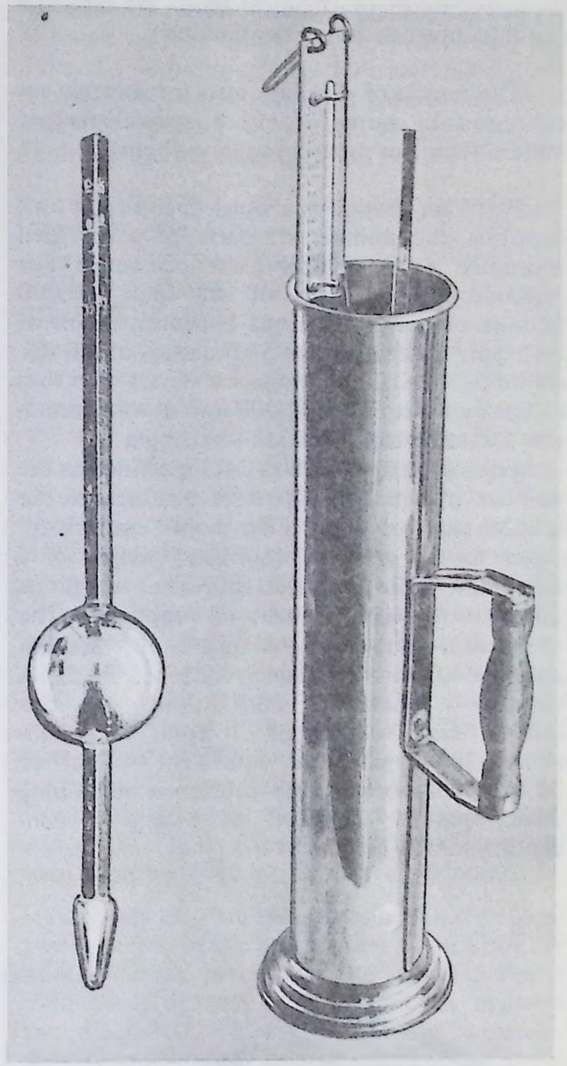
A high brine density indicates that too much of the feedwater is being converted into distillate. Operation with a high brine density results in excessive formation of scale on heat transfer surfaces with resulting poor quality distillate due to excessive vapor formation, with possible carryover, and reduced efficiency due to the loss of heat energy carried over with the brine.

The ideal value for brine density is just under 1.5 thirty-seconds. The density should never exceed this level. Since the average seawater contains approximately 1 part of dissolved sea salt to 32 parts of water (1/32 by weight), the brine density should be just under 1 1/2 times the density of average seawater, or 1.5/32.

Brine density is measured with a salinometer, which works on the same principle as a hydrometer. The float, or hydrometer, is a hollow metal shell attached to a square stem, weighted with shot at one end. Each side of the stem is graduated in thirty-seconds, from 0/32 to 5/32, and calibrated for four different temperatures: 110°, 115°, 120° and 125° F.

Figure 10-12 shows a salinometer and a brine sampling pot. A brine sample is drained into the pot from a test valve and the temperature is measured. The temperature must be adjusted to correspond with one of the temperature scales on the salinometer to accurately measure the density. The salinometer is then placed in the pot, weighted end down, and allowed to float in the brine. The brine density is read where the brine water level crosses the scale on the side of the graduated stem which corresponds to the brine temperature.

Salinometers should be checked monthly by measuring the density of distilled water. A sample at the proper temperature can be obtained by bypassing the distillate cooler, or a sample of the distillate may be heated. The reading of the pure water should always be zero.



47.136X

Figure 10-12.—Salinometer and sampling pot.

Different evaporator types will have different methods for adjusting the brine density. Follow the instructions and procedures in the EOSS for your plant and ship.

DISTILLATE PURITY AND TESTING

Distillate must meet specific standards of chloride content and salinity. To ensure that

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those standards or chemical limits are met, the distillate must be tested continuously.

The results of distillate tests for chloride are expressed in terms of either equivalents per million (epm) or parts per million (ppm).

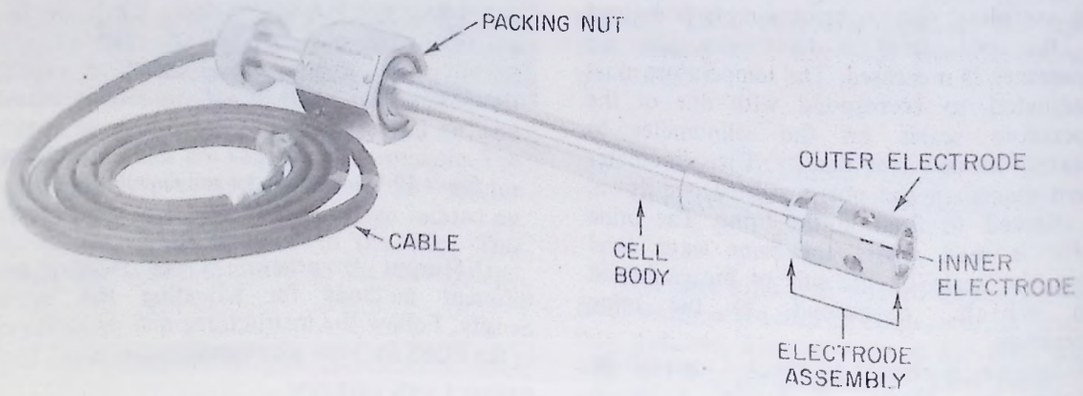
Parts per million is a weight-per-weight unit denoting the number of parts of a specified substance in a million parts of water. For example, 58.5 pounds of salt in 1,000,000 pounds of water represent a concentration of 58.5 ppm. Note also that 58.5 ounces of salt dissolved in 1,000,000 ounces of water or 58.5 tons of salt dissolved in 1,000,000 tons of water represent the same concentration—58.5 ppm.

Equivalents per million can be defined as the number of equivalent parts of a substance per million parts of water. (The word "equivalent" refers to the chemical equivalent weight of a substance.) The chemical equivalent weight is different for each element or compound. The chemical equivalent weight of sodium chloride (common table salt) is 58.5. A solution containing 58.5 ppm of this salt is said to contain 1 epm. If a substance has a chemical equivalent weight of 35.5, a solution of that substance containing 35.5 ppm is described as having a concentration of 1 epm.

Salinity Monitoring

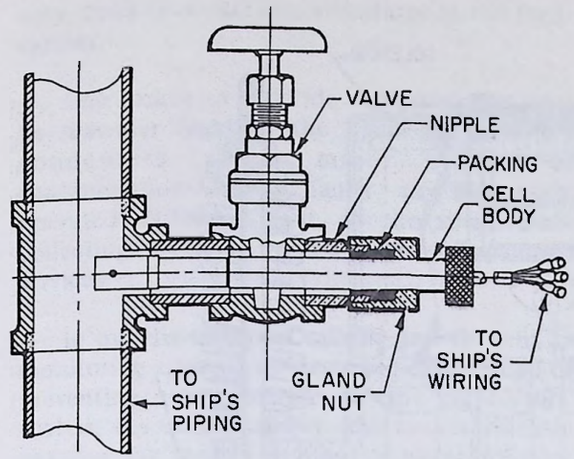
The salinity of distillate is monitored continuously by an electrical salinity monitoring system. A salinity cell (figure 10-13) is placed in the distillate line in constant contact with the distillate flowing out of the evaporator. The details of salinity cell installation into the line are shown in figure 10-14.

A salinity cell actually measures the ability of water to conduct electrical current (conductivity). The higher the concentration of chemical impurities in the water, the higher the conductivity of the water will be. This measurement is read out on a salinity monitoring panel which may be of the type shown in figure 10-6 or 10-15. The indicator shown in figure 10-15 is used when it is desired to continuously monitor one particular cell. The electrical reading from the cell is converted to either epm or ppm chloride on the meter face. The chloride reading is based on the assumption that all of the impurities in the distillate are from seawater; however, a salinity cell cannot differentiate between seawater or any other impurity. For this reason, the salinity cell readings are checked frequently by a chemical test for chloride. You must always believe a high



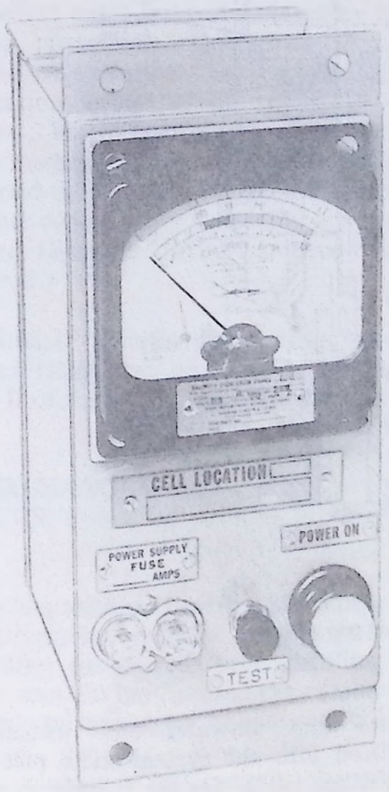
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Figure 10-13.—Salinity indicator cell.



27.382

Figure 10-14.—Salinity cell installation.



27.383

Figure 10-15.—Salinity indicator panel.

salinity cell reading (such as an alarm or tripped valve situation) until it is proven absolutely false. Some older salinity indicator panels have scales calibrated in grains per gallon (gpg) of sea salt. To convert a reading of gpg to epm, multiply the gpg reading by 0.261.

In practically all cases, the measurement made by the distillate salinity cell will also operate the trip function of a three-way solenoid-operated trip valve, shown in figure 10-16. If the salinity of the distillate reaches a preset value (0.5 ppm for some ships, 0.065 epm for others), the solenoid in the valve will deenergize, allowing spring pressure to disengage the latching linkage from the engaging lever, and the valve stem assembly will drop due to main spring pressure. When the stem assembly drops, the valve seat shuts off the water path of distillate to the freshwater tanks or reserve feed system and opens a path to the bilge or suitable dirty drain system. This type three-way valve is also used on the air ejector condenser drains of many distilling plants. These valves have locking pins which can be used to lock the main valve engaging lever in the reset position. The locking pins should NEVER be used without the specific permission of the engineer officer. Contaminated water can be put into clean tanks and systems at an excessive rate if these pins are used to prevent the trip valves from tripping.

Salinity cells are sometimes installed in other places in the evaporator system to monitor the salinity levels; such as in the seawater heater drain pump discharge and the loop seal between the first and second stages of the two-stage, flash-type distilling plant described earlier in the chapter. Cells installed in these places have a meter readout and an alarm, but do not actuate trip valves.

The temperature of the water affects the reading of the salinity cell. The higher the temperature of the water, the higher its conductivity will be. Salinity cells are designed to automatically compensate for changes in water temperature.

Chemical Test for Chlorides

The importance of keeping chloride contamination out of the reserve feed tanks

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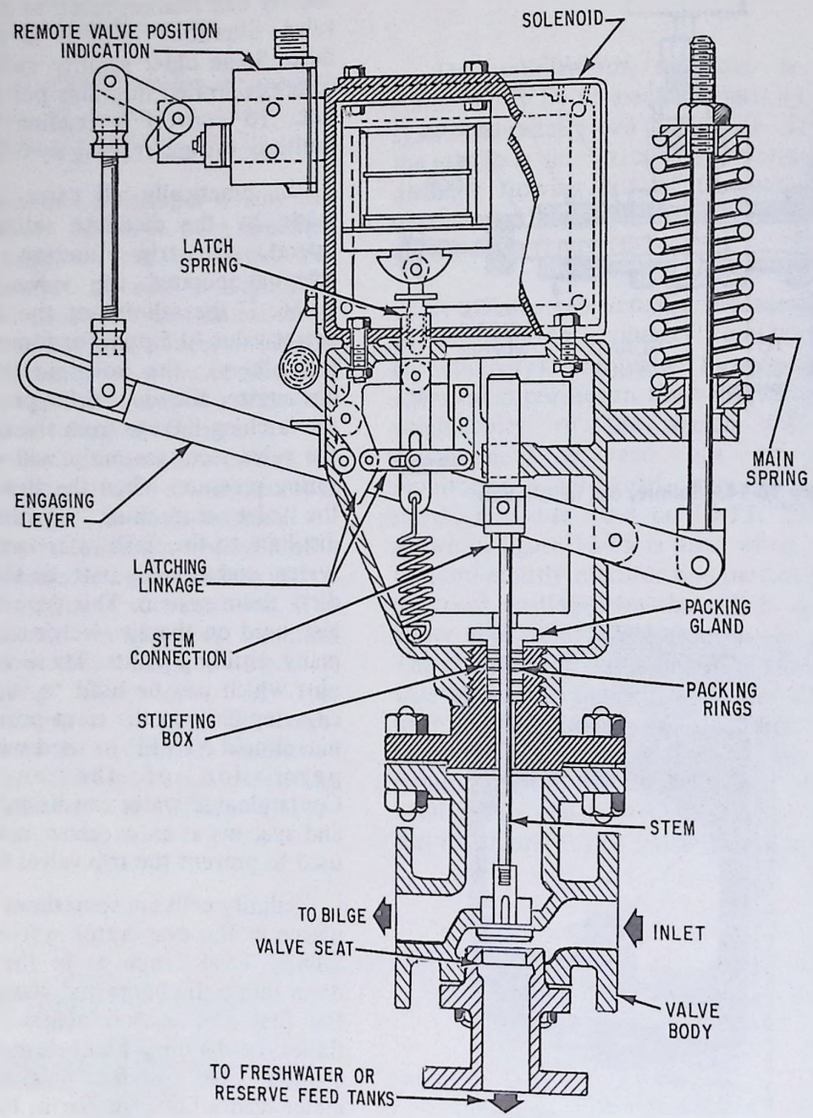


Figure 10-16.—Three-way solenoid trip valve. 47.214

cannot be overemphasized. As mentioned earlier in the chapter, serious damage can occur to boilers and steam generators if chlorides are not kept to an absolute minimum in the feed and condensate systems. High chloride concentration in boiler feedwater or condensate usually indicates that seawater has probably been introduced into the system some place, which means other impurities are present as well. The process of boiling in boilers and steam generators causes large buildups of chlorides, as well as other impurities, even with

very small (normal) concentrations in the feed system.

One source of chloride contamination may be seawater leaks in the main and auxiliary condensers. Other major sources of contamination are a faulty or improperly operated distilling plant, or the steam drain collecting system, particularly from hotel services.

In our discussion of salinity and the salinity monitoring system, we described one method of preventing contamination by the evaporators; that is, the use of salinity cells to continuously monitor the salinity content of water in piping systems connected to the evaporator and to set alarms and tripping valves if the salinity concentration rises above a setpoint. Another method is to chemically test water for chloride concentration. The chemical tests may be performed at some interval dictated by specific operating procedures. One chemical analysis used to determine the actual chloride concentration in a sample of water is by titration. When performed properly, the titration method is extremely accurate. This test can be used on distillate, air ejector drains, main condensate or any other water that is not greatly discolored. (Even discolored water can be used if it is filtered.)

Additional specific information on water and water testing can be found in chapter 220, Volume II of the *Naval Ships' Technical Manual.*

HEAT EXCHANGER SURFACES

Scale deposits on heat transfer surfaces will not appreciably reduce the output of a low-pressure submerged tube distilling plant until the deposits have caused the vacuum in the first-effect tube-nest to be reduced to 1 or 2 inches of mercury. When the first-effect tube-nest vacuum is lost entirely, the reduction in plant output becomes very great. Assuming the reduction in vacuum is due to scale, and is not the result of improper operating conditions, the evaporator tubes must be cleaned when the tube-nest vacuum approaches zero.

When the plant is properly operated and the evaporation feed is treated, the interval between cleanings should be 6 months or more.

Saltwater flows inside the tubes of the distilling condenser, air ejector condenser, and vapor feed heaters. Under some operating conditions, scale deposits may accumulate inside these tubes, particularly in the air ejector condenser and the first-effect feed heater. Every 6 months, or whenever the plant is secured to descale the evaporator tubes, the inside surfaces of the heat exchanger tubes should be inspected and cleaned if necessary. Neglect can lead to thick scale deposits which will be difficult to remove.

Scale Formation

Very little hard scale should form in a distilling plant that uses seawater as feed if (1) feedwater distribution is proper, (2) steam pressure above the orifice is not more than 5 psi, (3) a high vacuum is maintained, and (4) the brine density is not over 1.5 thirty-seconds.

During normal operating conditions, scale deposits will form at a certain rate on the distilling plant evaporator tubes. The rate of scaling depends on the concentration of suspended matter and carbonates present in the water used to feed the distilling plant. However, excessive scaling of the evaporator can be caused by improper operation of the plant.

Scale deposits increase as the density of the brine in the last-effect shell increases. The brine concentration is dependent mainly on the quantity of brine pumped overboard and on the amount of distillate produced. If the brine concentration is too high, there will be an increase in the rate of scaling of the evaporator tubes, and the quality of the distillate may be impaired.

To retard the formation of scale on evaporator tubes and to minimize priming, solutions are continuously injected into the evaporator.

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A chemical compound, either Ameroyal or PD-8, is used in all Navy evaporators that are feed-treated. Ameroyal or PD-8 increases the production of distilled water by decreasing downtime of plants for scale removal.

PD-8 is composed of polyphosphates, lignins, and antifoam agents. The polyphosphates combine with the scale-forming particles in seawater while the lignins keep the resulting solids dispersed and suspended. The antifoaming agents prevent foaming and help prevent scale.

NOTE: Ameroyal is NOT approved for use aboard ships with nuclear power propulsion plants.

CAUTION: Ameroyal is an alkaline chemical. (A more familiar form of an alkaline chemical is lye.) Use extreme care when handling and mixing Ameroyal to prevent splashing the liquid into the eyes or on the skin. Rubber gloves and a face shield MUST be worn when handling this chemical.

A proportioning pump and tank assembly are used to mix the chemical (either PD-8 or Ameroyal) and inject it into the evaporator feed at a controlled rate. The tank has a gage glass or an internal, fixed measuring plate which is marked off in gallons. The tank usually holds 24 gallons of mixture with room left for expansion.

To prepare the PD-8, dissolve the required amount by stirring it in a bucket of warm water at a temperature not to exceed 100° F (38° C). Ameroyal comes in concentrated liquid form. Dump the concentrated solution of PD-8 or Ameroyal into the mixing tank and add enough cold water to dilute the solution to a total of 24 gallons; then, stir the mixture thoroughly to ensure a uniform solution. This mixing and dilution can be carried out while the pump continues to deliver the chemical to the operating evaporator.

The proportioning pump is a small, motor-operated reciprocating pump unit and may be either simplex (one pump) or duplex (two pumps) in design. The maximum capacity of the proportioning pump is 2.5 gallons per hour per pump.

The simplex pump consists of one pump and one motor. The duplex pump consists of two pumps, driven by one motor, served by the same mixing tank. Duplex pumps may serve two distilling plants ONLY when the two plants have the same design distillate capacity and when these two distilling plants are located in the same compartment. In all other cases, simplex pumps must be installed.

With either the simplex or duplex pump, the length of the stroke determines the pump capacity. The stroke can be adjusted, but is never set at less than 20%, to assure accuracy of the injection rate and lubrication of the pump plunger. If possible, the pump stroke (or strokes on a duplex pump) should be set to empty the mixing tank, from the top to the bottom of the gage glass, in exactly 24 hours. If this rate of injection should require a pump stroke of less than 20%, the stroke should be set to empty the tank in less than 24 hours, preferably 12 or 8 hours to enable easy establishment of a routine for refilling. However, if the time is 12 hours, the solution will contain only half the amount of PD-8 required for a 24-hour period, and the tank must be filled twice a day. If the period of time for emptying the mixing tank is 8 hours, the solution will contain only 1/3 the required daily amount, and the tank must be filled three times each day.

If the pump stroke must be changed, the setting can be made from the indicator scale, mounted on the connecting rod, and verified by checking the amount of time required to empty the mixing tank. The indicator scale is calibrated from 0 to 10. If the pump has a maximum capacity of 7 gph, set the indicator pointer at 5 to deliver 3 1/2 gph. To change the stroke, stop the pump and loosen the connecting rod locknut. Watch the pointer on the indicator scale and turn the adjusting screw the required amount. Tighten the connecting rod locknut and restart the pump. Check the time required to empty the tank and reset the pump stroke if necessary.

A vacuum drag injection line, used when the proportioner pump fails, runs from the mixing tank to a point downstream (vacuum side) of the feed control valve. A needle valve, installed in the line, allows the operator to make relatively fine adjustments in the amount of solution that flows into the evaporator.

For submerged tube and basket-type distilling plants, PD-8 should be injected into the evaporator feed system at a rate not to exceed 1 pound per 10,000 gallons per day output. This rate of injection is required during the entire time the plant is in operation. A 4,000-gpd plant requires 0.4 of a pound for a 24-hour period. Two 12,000 gpd plants require the same quantity as a 24,000-gpd plant, or 2.4 pounds per day.

The injection rate of 1 pound per 10,000 gallons per day is a maximum figure; the most effective figure will probably be closer to 0.75 pound. To find the best figure, reduce the amount of PD-8 for each batch. Try each mixture for a week. If no scale is found on the evaporator tubes, the amount of PD-8 can be reduced further. If scale forms during this trial, it will gradually crack off when the proper injection rate is established. The brine overboard density should remain at 1.5 thirty-seconds as the density will influence the effectiveness of the PD-8.

The injection rate for Ameroyal is 1 pint per 4,000 gallons per day output.

In accordance with the Planned Maintenance System, the mixing tank should be drained to the bilges and flushed out with freshwater weekly, or more often if necessary, to prevent accumulation of sludge in the tank.

Scale Removal

As previously stated, the evaporator tubes of a submerged tube type unit MUST be cleaned when the first-effect tube-nest vacuum approaches zero. The vertical basket unit should be cleaned when it becomes necessary to use a basket steam pressure of 8 psig to produce rated capacity. The flash-type unit will require cleaning when it becomes necessary to use a steam pressure of 4 psig in the evaporator feedwater heater. Assuming these reductions in capacity are due to scale and not the result of improper operation, an approved cleaning method should be used to remove the scale.

CHILL SHOCKING.—The first-effect tube nest, in which the temperature of the tube nest is near that of the steam supply, tends to scale up more quickly than other parts of the plant. Chill shocking (cold shocking) the tubes is generally used to combat this scale. Drain the brine from all shells, then reflood them by means of a hose line connected to a flushing pipe or flooding connection on the shell. This reflooding chills the tube-nest bundles. Next, quickly admit steam into the tubes, causing differential expansion and contraction to take place, which breaks the scale loose from the tubes.

If a feed treatment is not used, the distilling plant should be chill shocked daily. If the Navy standard feed treatment is used, daily chill shocking may be desirable; however, longer intervals are satisfactory.

MECHANICAL CLEANING.—Mechanical cleaning should be used only as a last resort—chemical clean first. The evaporator tube nest must be withdrawn from the shell for mechanical cleaning. Lifting gear suitable to the type of installation is usually provided to facilitate removing the tube nest.

Submerged Tube Type.—Some evaporators or distilling plants are provided with an overhead trolley from which the tube nest can be suspended for cleaning. Another type is provided with tracks and roller brackets which bolt to the front head of the tube nest. In small installations, chain falls can be used to handle the tube nest.

When you withdraw the tube nest beyond the support plate, bolt the tube-nest stop in

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place to prevent accidental dropping of the rear head. Clean the tubes with a light scaling tool operated by a light air hammer. Hold the tool against the tube with moderate pressure and move it over the entire length of the tube. Clean every tube in the nest; missing one will impair the output of the plant and also make cleaning more difficult in the future.

NEVER use a torch to descale a tube nest made up of straight tubes. The expansion and contraction caused by the heat may cause the tubes to loosen at their joints.

After cleaning the tubes, apply a hydrostatic test of 50 psi to the bundle before replacing it within the shell.

When you pull the evaporator tubes for cleaning, inspect and clean the DISTILLATE CONDENSER, AIR EJECTOR CONDENSER, and the VAPOR FEED HEATERS, if necessary. Under some operating conditions, scale deposits may accumulate in these tubes, particularly in the air ejector condenser and the first-effect feed heater.

The distillate condenser on Soloshell plants must be removed for inspection and cleaning. On other types of plants you can inspect and clean the distillate condenser by removing the heads at both ends. You can clean the air ejector condensers on all plants by removing both heads. You must remove the vapor feed heater tubes on practically all designs for cleaning.

Clean these tube nests by using an extended shank drill, driven by a reversible motor at 250 or 300 rpm, or by using standard tube-cleaning equipment adapted for use with 5/8-inch outside diameter condenser tubes.

Flash-Type.—In the flash-type distilling plant, scale formation is reduced to a minimum because the feed is heated under pressure, which prevents boiling, and vapor is formed by free flashing under vacuum. The heat exchanger tubes require periodic cleaning. Remove the front and rear water boxes to gain access to the tube sheet outer surfaces and tube interiors of the distilling condensers, air ejector condensers, evaporator feedwater heater, and distillate cooler. Then, push an electric or air-driven cleaning tool through the tubes to remove scale deposits.

CHEMICAL CLEANING.—Chemical cleaning has proven to be faster, more economical, more effective, and less detrimental to evaporator parts than mechanical cleaning. In chemical cleaning, a heated, diluted acid solution circulates through the saltwater circuits of the system. The two acids used are hydrochloric and sulfamic. CAUTION: In using these acids which may be harmful to personnel, OBSERVE THE SAFETY PRECAUTIONS AND FOLLOW THE PROCEDURES LISTED IN CHAPTER 531 (9580-I) of *Naval Ships' Technical Manual.*

Hydrochloric acid comes in liquid form and presents hazards in both handling and storing. The use of hydrochloric acid is authorized ONLY when properly supervised by qualified naval shipyard personnel, NEVER by ship's force alone.

Sulfamic acid comes in powdered form and is safe for storage aboard ship, when stored in the original containers. The use of sulfamic acid is authorized under the supervision of qualified tender or naval shipyard personnel. At the discretion of type commanders, individual ships may be authorized to carry sulfamic acid and cleaning may be performed by qualified personnel in the ship's crew.

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, which are provided in the allowance of repair parts, should be used.

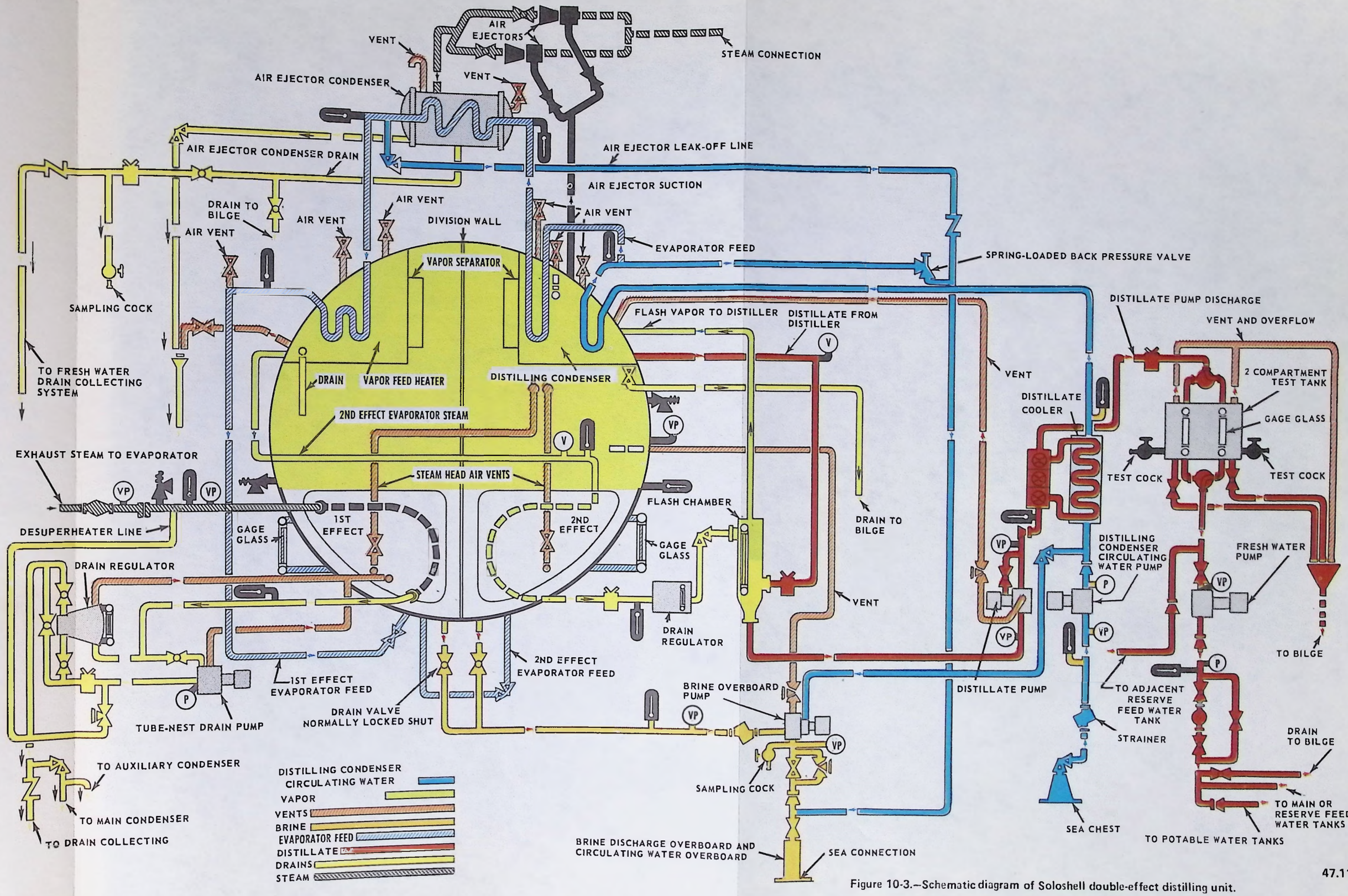
Since plugging the tubes reduces the amount of heating surface, the heat exchanger will fail to give satisfactory performance after a number of tubes have been plugged. It will then become necessary to retube the heat exchanger. Under normal conditions, this work should be accomplished by a naval shipyard or tender. However, repair parts and a number of special tools are included in the Ship's Allowance so that emergency repairs can be made to the heat exchangers and to other parts of the distilling plant.

To find which of the tubes within a REMOVABLE TUBE BUNDLE is leaking, it is necessary to test the individual bundles hydrostatically. If the leak is in a removable bundle (vapor feed heaters when within an evaporator shell, evaporator tube nests, distillate condensers on Soloshell end-pull plants), the bundle must be withdrawn and a hydrostatic test at full pressure (50 psi) must be applied on the tube side.

If a leak occurs in a NONREMOVABLE TUBE BUNDLE (distillate cooler, air ejector 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.

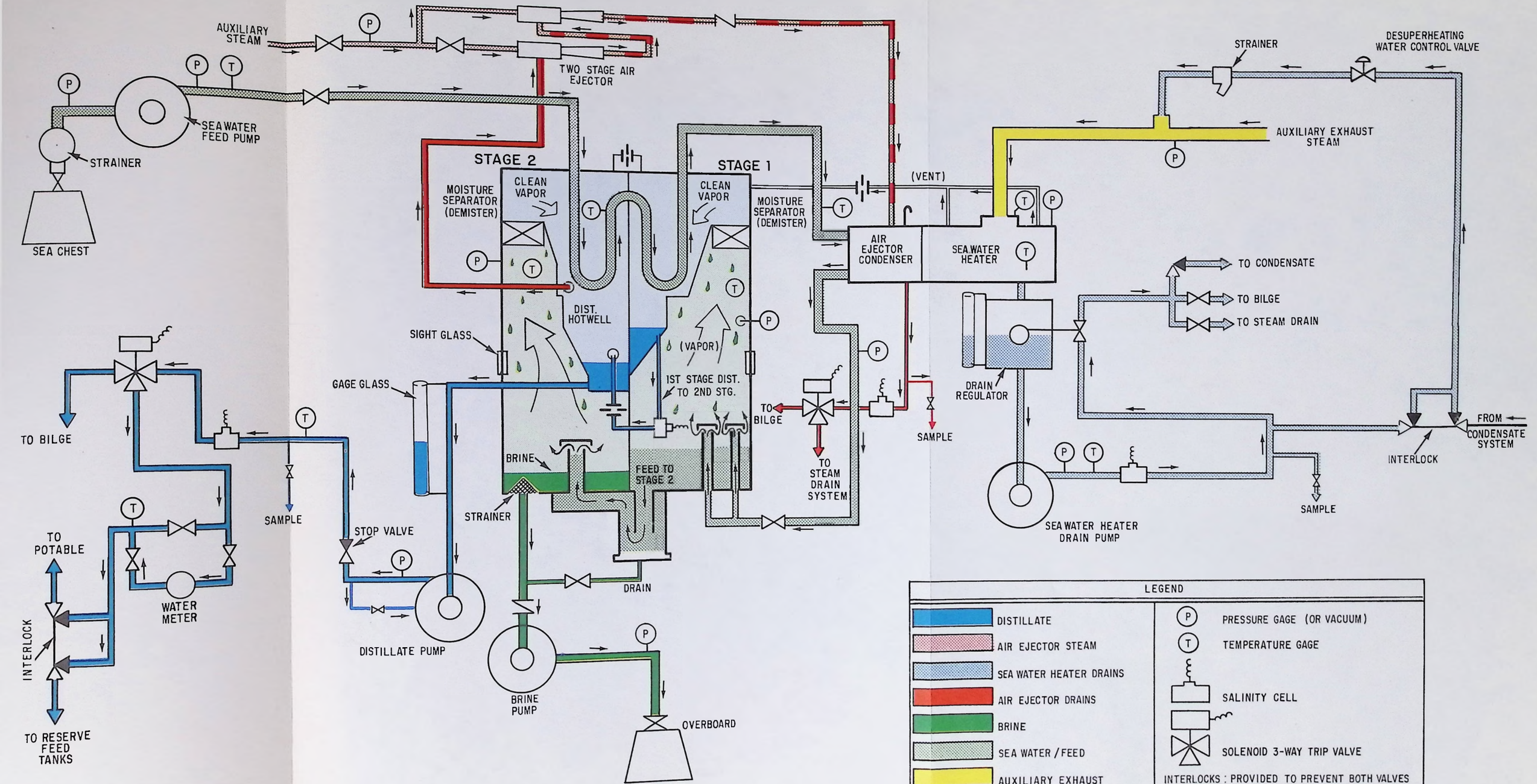
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Figure 10-3.—Schematic diagram of Soloshell double-effect distilling unit.

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Figure 10-6.—2-stage flash-type distilling plant 12,000 gpd capacity.

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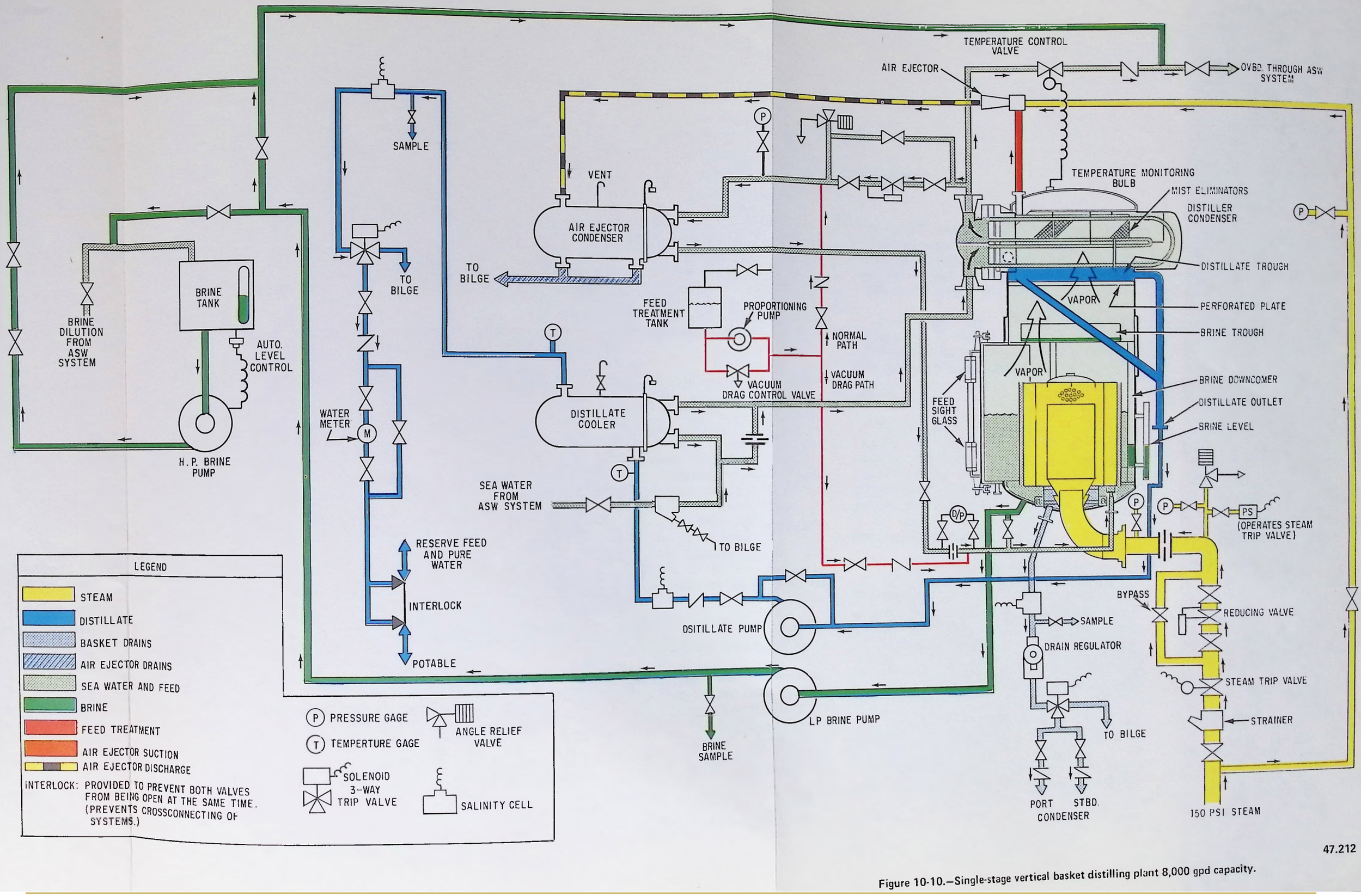


Figure 10-10.—Single-stage vertical basket distilling plant 8,000 gpd capacity.

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CHAPTER 11

REFRIGERATION

As a Machinist's Mate, you must have a knowledge of refrigeration and air conditioning systems. From practical experience, you will learn how to start, operate, stand watch on, and secure these systems. To do your job properly, you must have a thorough understanding of the operating principles of refrigeration systems. You can attain this understanding through study.

The refrigeration systems most commonly used by the Navy use R-12 as a refrigerant. Chemically, R-12 is dichlorodifluoromethane (CCl_2F_2). R-12 has such a low boiling point that it cannot exist as a liquid unless it is confined in a container designed for pressure. R-12 also has several advantages; it is practically nontoxic, nonflammable, nonexplosive, and noncorrosive and does not poison or contaminate foods. The information in this chapter is primarily concerned with R-12 systems. However, the cycle of operation and the main components of R-12 systems are basically the same for other refrigeration and air conditioning plants.

FUNDAMENTALS OF REFRIGERATION

Refrigeration is a general term that describes the process of removing heat from spaces, objects, or materials and maintaining them at temperatures below the temperature of the surrounding atmosphere. To produce a refrigeration effect, the material to be cooled needs only to be exposed to a colder object or environment; the heat will flow in its NATURAL direction—that is, from the warmer material to the colder material. Refrigeration, then, usually means an artifical way of lowering the temperature. Mechanical refrigeration is a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another.

You will more readily understand refrigeration if you know the relationships among temperature, pressure, and volume, and how pressure affects liquids and gases.

HEAT

The purpose of refrigeration is to maintain spaces at low temperatures. Remember, however, that you cannot cool anything by adding coolness to it; you have to REMOVE HEAT from it. Refrigeration, therefore, is a process of cooling by removing heat.

Heat and Temperature

It is important to distinguish between heat and temperature. HEAT is a form of energy. TEMPERATURE is the intensity of heat. The quantity or amount of heat energy in a substance is measured in BRITISH THERMAL UNITS (Btu). The Btu is the amount of heat required to raise the temperature of 1 pound of pure water 1° F. Temperature, as you know, is measured in degrees, which indicate the intensity of the heat in a given substance; it does not indicate the number of Btu's in the substance. For example, let's consider a spoonful of very hot water and a bucketful of warm water. Which has the higher temperature? Which has more heat? The heat in the spoonful of hot water is more intense; therefore, its temperature is higher. The bucketful of warm

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water has more Btu (more heat energy), but its heat is less intense.

Sensible Heat and Latent Heat

In the study of refrigeration, you must distinguish between sensible heat and latent heat. Sensible heat is the heat absorbed or given off by a substance that is NOT in the process of changing its physical state. When a substance is not in the process of changing its state, the addition or removal of heat always causes a change in the temperature of the substance. Sensible heat can be sensed, or measured with a thermometer.

Latent heat is the heat absorbed or given off by a substance while it is changing its physical state. When a substance is in process of changing its physical state, the heat absorbed or given off does NOT cause a temperature change in the substance—the heat is latent or hidden. In other words, sensible heat is the heat that affects the temperature of things; latent heat is the heat that affects the physical state of things. You will find more information on sensible heat and latent heat in chapter 3 of *Fireman*, NAVEDTRA 10520.

Specific Heat

Substances vary with respect to their ability to absorb or lose heat. The ability of a substance to absorb heat or to lose it is known as the specific heat of the substance. The specific heat of water is 1.0 (1 Btu/1b/°F), and the specific heat of each other substance is measured by comparison with this standard. Thus, if it takes only 1/2 Btu to raise the temperature of 1 pound of a substance 1° F, the specific heat of that substance is 0.5, or one-half the specific heat of water. If you look up the specific heat of ice in a table, you will find it to be approximately 0.5.

Heat Flow

Heat flows only from objects of higher temperature to objects of lower temperature. When two objects at different temperatures are placed near each other, heat will flow from the warmer object to the cooler one until both objects are at the same temperature. Heat flow takes place at a greater rate when there is a large temperature difference than when there is only a slight temperature difference. As the temperature difference approaches zero, the rate of heat flow also approaches zero. Heat flow may take place by radiation, by conduction, by convection, or by some combination of these methods.

Refrigeration Ton

The unit of measure for the amount of heat removed is known as the refrigeration ton. The capacity of a refrigeration unit is usually stated in refrigeration tons. The refrigeration ton is based on the cooling effect of 1 ton (2,000 pounds) of ice at 32° F melting in 24 hours. The latent heat of fusion of ice (or water) is 144 Btu. Therefore, the number of Btu required to melt 1 ton of ice is 144 X 2,000 = 288,000. The standard refrigeration ton is defined as the transfer of 288,000 Btu in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btu per hour (288,000 is divided by 24).

The refrigeration ton is the standard unit of measure used to designate the heat-removal capacity of a refrigeration unit. It is not a measure of the ice-making capacity of a machine, since the amount of ice that can be made depends on the initial temperature of the water and other factors.

PRESSURE, TEMPERATURE, AND VOLUME

As stated earlier, it is important that you understand some of the ways pressure affects liquids and gases, and some of the relationships between pressure, temperature, and volume in gases.

The boiling point of any liquid varies according to the pressure on the liquid—the higher the pressure, the higher the boiling point. It is well to remember that condensing a gas to a liquid is just the reverse process of boiling a liquid until it vaporizes and that the same pressure and temperature relationship is required to produce either change of state.

Water boils at 80° F under a vacuum of 29 inches of mercury and at 489° F at a pressure of 600 psig. Refrigerants used in vapor compressor cycle equipment usually have much lower boiling points than water, under any given pressure, but these boiling points also vary according to pressure. R-12, for example, boils at -21° F at atmospheric pressure; at 0° F at 9.17 psig; at 50° F at 46.69 psig; and at 100° F at 116.9 psig. From these figures, you can see that R-12 cannot exist as a liquid at ordinary temperatures unless it is confined in a container to maintain its own pressure.

If the temperature of a liquid is raised to the boiling point corresponding to its pressure and if application of heat is continued, the liquid begins to boil and vaporize. The vapor that is formed remains at the same temperature as the boiling liquid, as long as it is in contact with the liquid. A vapor CANNOT be superheated as long as it is in contact with the liquid from which it is being generated.

The pressure-temperature-volume relationships of gases are expressed by Boyle's law, Charles' law, and the general gas law or equation.

BOYLE'S LAW states that the volume of any dry gas varies inversely with its absolute pressure, provided the temperature remains constant. This law may also be expressed as

$$V_1 P_1 = V_2 P_2$$

where V_1 is the original volume of the gas, P_1 its original absolute pressure, V_2 its new volume, P_2 its new absolute pressure.

CHARLES' LAW states that the volume of a gas is directly proportional to its absolute temperature, provided the pressure is kept constant. The equation for this law is

$$V_1 T_2 = V_2 T_1$$

THE GENERAL GAS EQUATION combines Boyle's law and Charles' law, and expresses the interrelationship of the volume, the absolute pressure, and the absolute temperature of gases. The general gas law is expressed by

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

These equations indicate the nature of the interrelationship of the pressure, the volume, and the temperature of any gas. You probably will not find it necessary to use the equations themselves, but you should have a thorough understanding of the principles which they express. Let's summarize them:

1. When temperature is held constant, increasing the pressure on a gas causes a proportional decrease in volume; decreasing the pressure causes a proportional increase in volume.
2. When pressure is held constant, increasing the temperature of a gas causes a proportional increase in volume; decreasing the temperature causes a proportional decrease in volume.
3. When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure; decreasing the temperature causes a proportional decrease in pressure.

In this discussion of the effects of pressure on a gas, we have pointed out that the volume and the temperature of gas are different AFTER the pressure has been changed. It is important to note, however, that a temperature change normally occurs in a gas WHILE the pressure is being changed. Compressing a gas raises its temperature; allowing a gas to expand lowers its temperature. As you will see, this fact is of importance in the refrigeration cycle.

MECHANICAL REFRIGERATION SYSTEMS

Various types of refrigerating systems are used for naval shipboard refrigeration and air

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conditioning. The one most generally employed for refrigeration purposes is the vapor compression cycle with reciprocating compressors. Vapor compression cycle refrigerating systems with centrifugal compressors (described in chapter 12) are oftentimes used for air conditioning. Centrifugal units are generally used to cool a secondary refrigerant such as brine for cargo refrigeration and freshwater for air conditioning application.

The vapor compression cycle with reciprocating compressors using R-12 is used for most naval refrigerating plants. Figure 11-1 gives a general idea of this type refrigeration cycle. As you study this system, try to understand what happens to the refrigerant as it passes through each part of the cycle. In particular, be sure that you understand why the refrigerant changes from liquid to vapor and from vapor to liquid, and what happens in terms of heat because of these changes of state. It will be helpful to trace the refrigerant through its entire cycle, beginning with the thermostatic expansion valve.

Liquid refrigerant enters the expansion valve from the high-pressure side of the system and passes through an orifice, which reduces the pressure of the refrigerant. Due to the reduction in pressure, the liquid refrigerant begins to boil and to flash into vapor.

From the thermostatic expansion valve, the refrigerant passes into the cooling coil (or evaporator). The boiling point of the refrigerant under the low pressure in the evaporator is about 20° F lower than the temperature of the space in which the cooling coil is installed. As the liquid boils and vaporizes, it picks up its latent heat of vaporization from the surroundings, thereby removing heat from the space. The refrigerant continues to absorb latent heat of vaporization until all the liquid has been vaporized. By the time the refrigerant is ready to leave the cooling coil, it has not only absorbed this latent heat of vaporization, but has also picked up some additional heat—that is, the vapor has become superheated. As a rule, the amount of superheat is 4° to 12° F.

The refrigerant leaves the evaporator as low-pressure superheated vapor, having absorbed heat and thus cooled the space to the desired temperature. The remainder of the cycle is concerned with disposing of this heat and converting the refrigerant back into a liquid state so that it can again vaporize in the evaporator and thus again absorb the heat.

The low-pressure superheated vapor is drawn out of the evaporator by the compressor, which also keeps the refrigerant circulating through the system. In the compressor cylinders, the refrigerant is compressed from a low-pressure, low-temperature vapor to a high-pressure vapor, and its temperature rises accordingly.

The high-pressure R-12 vapor is discharged from the compressor into the condenser. Here the refrigerant condenses, giving up its superheat (sensible heat) and its latent heat of condensation to the ambient air in an air-cooled condenser or the cooling water in a water-cooled condenser. The refrigerant, still at high pressure, is now a liquid again.

From the condenser, the refrigerant flows into a receiver which serves as a storage place for the liquid refrigerant in the system. From the receiver, the refrigerant goes to the thermostatic expansion valve, and the cycle begins again.

This type of refrigeration system has two pressure sides. The LOW-PRESSURE SIDE extends from the orifice of the thermostatic expansion valve up to and including the intake side of the compressor cylinders. The HIGH-PRESSURE SIDE extends from the discharge valve of the compressor to the thermostatic expansion valve. Figure 11-2 shows most of the components on the high-pressure side of an R-12 system, as actually installed aboard ship.

MAIN PARTS OF THE R-12 SYSTEM

The main parts of an R-12 refrigeration system are shown diagrammatically in figure 11-3. 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

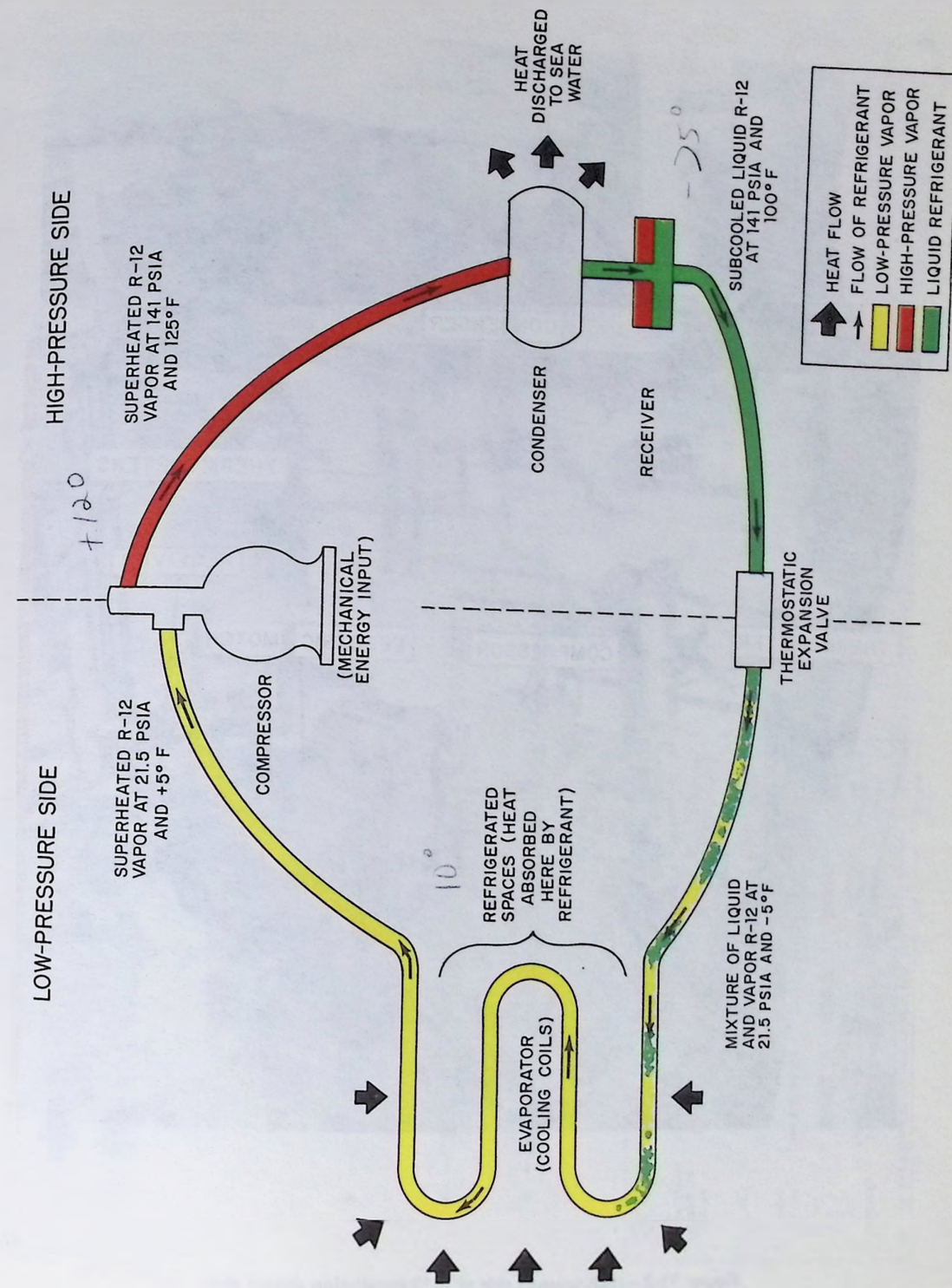
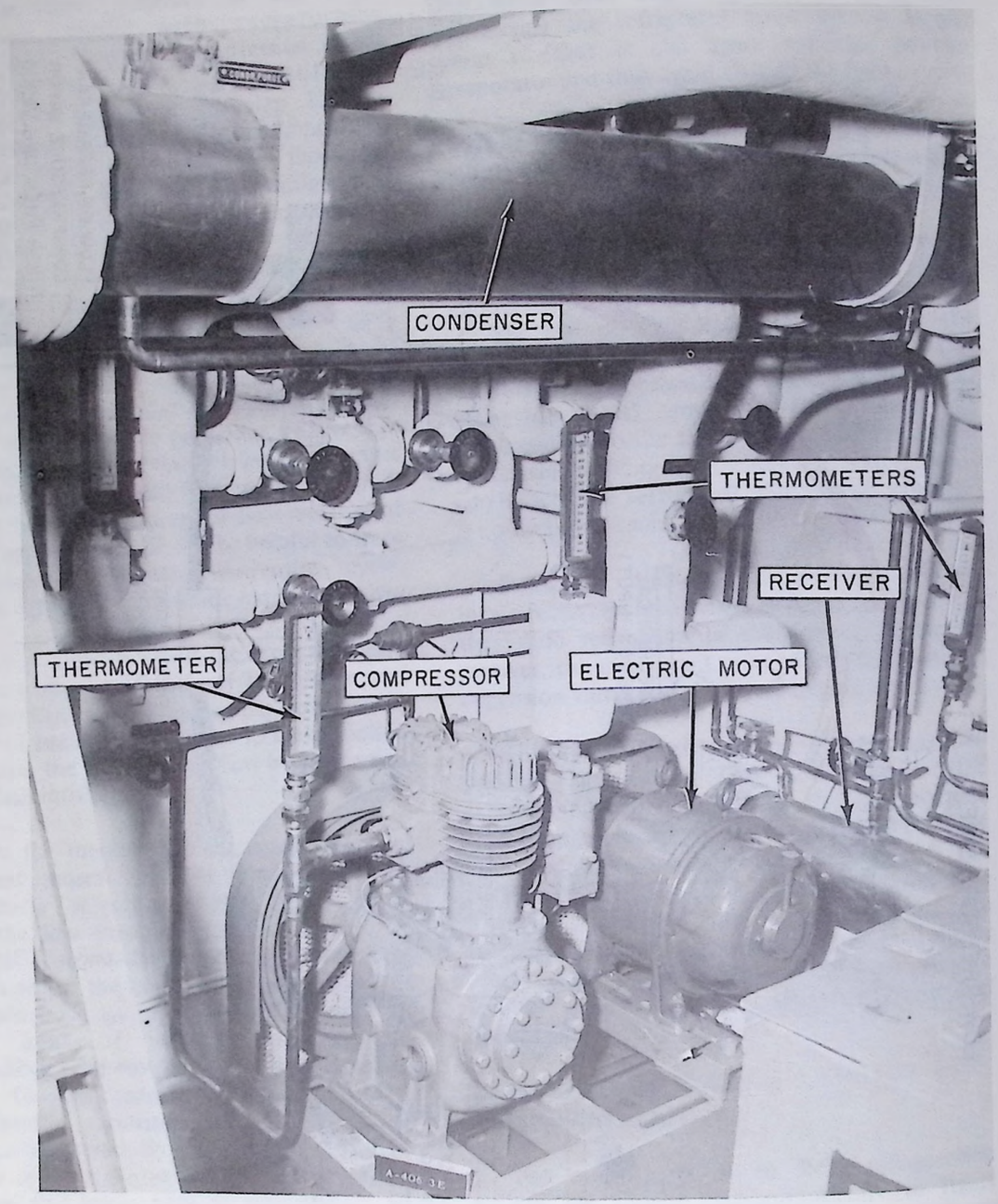


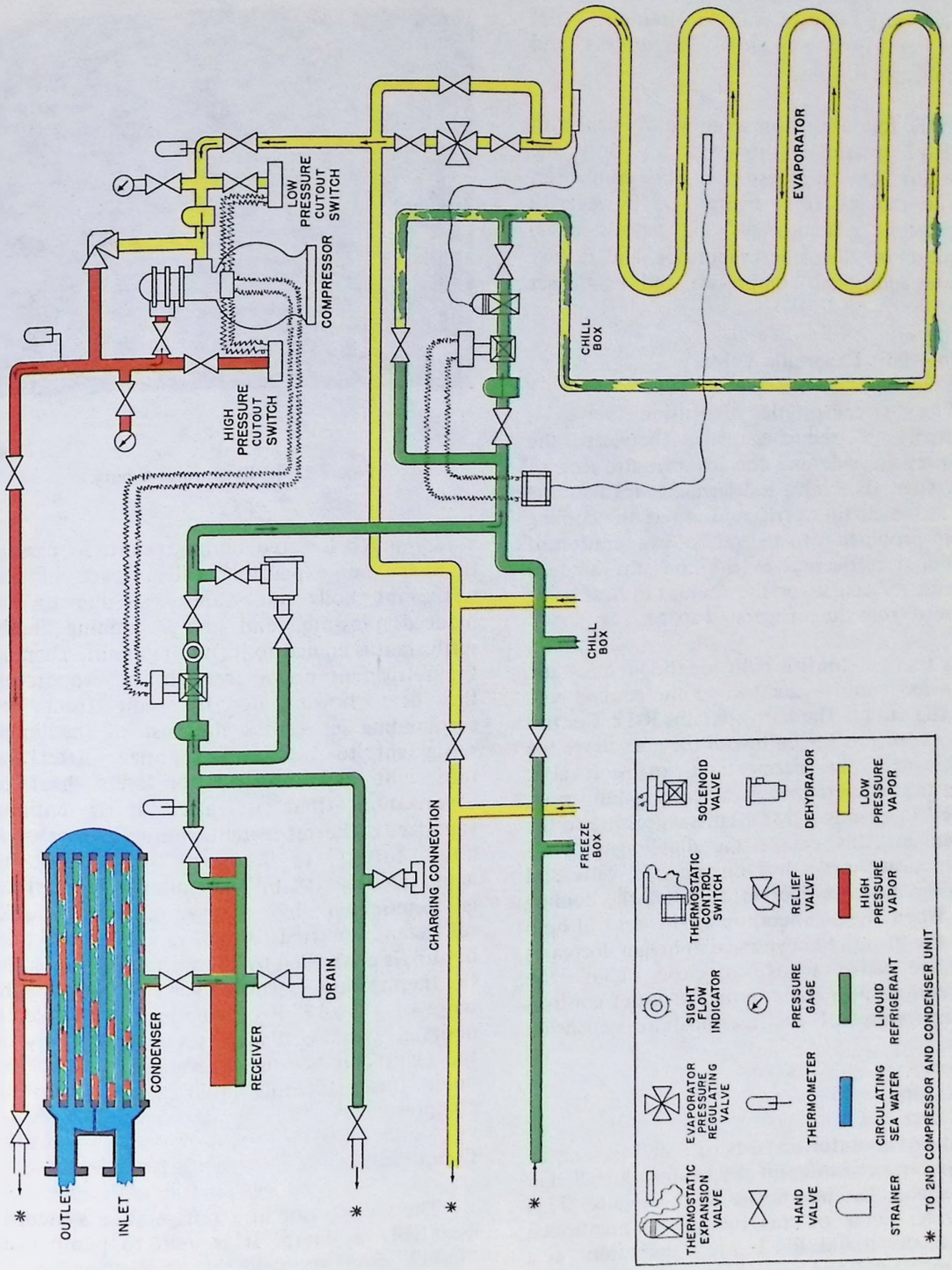
Figure 11-1.—Schematic representation of R-12 refrigeration cycle.

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Figure 11-2.—High-pressure side of R-12 installation aboard ship.



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Figure 11-3.—Diagram of an R-12 refrigeration system.

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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. As you can see from figure 11-3 however, a refrigeration system may (and usually does) include more than one evaporator, and it may include additional compressor and condenser units.

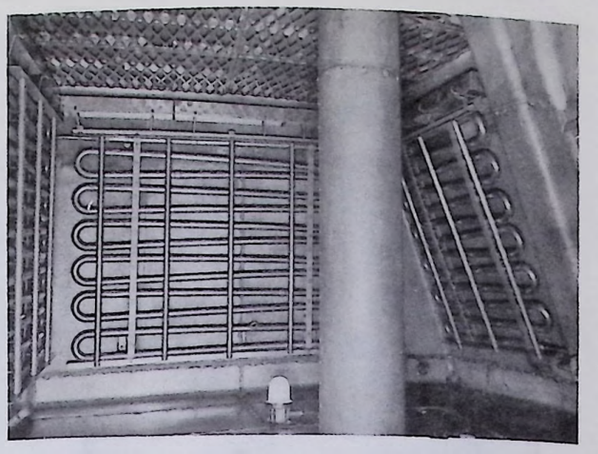
Thermostatic Expansion Valve

The thermostatic expansion valve is essentially a reducing valve between the high-pressure side and the low-pressure side of the system. The valve is designed to regulate the rate at which the refrigerant enters the cooling coil in proportion to the rate of evaporation of the liquid refrigerant in the coil; the amount depends, of course, on the amount of heat being removed from the refrigerated space.

A thermal control bulb for the thermostatic expansion valve is clamped to the cooling coil, near the outlet. The bulb contains R-12. Control tubing connects the bulb with the area above the diaphragm in the thermostatic expansion valve. When the temperature at the control bulb rises, the R-12 expands and transmits a pressure to the diaphragm; this causes the diaphragm to be moved downward, thus opening the valve and allowing more refrigerant to enter the cooling coil. When the temperature at the control bulb falls, the pressure above the diaphragm decreases and the valve tends to close. Thus, the temperature near the evaporator outlet controls the operation of the thermostatic expansion valve.

Evaporator

The evaporator consists of a coil of copper, aluminum, or aluminum alloy tubing installed in the space to be refrigerated. Figure 11-4 illustrates some of this tubing. As mentioned before, the liquid R-12 enters the tubing at a very much reduced pressure and, therefore, with



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Figure 11-4.--Evaporator tubing.

a very much lowered boiling point. In passing through the expansion valve, part of the refrigerant boils and vaporizes, due to the reduced pressure, and the remaining liquid refrigerant is cooled to its boiling point. Then, as the refrigerant passes through the evaporator, the heat flowing to the coil from the surrounding air causes the rest of the liquid refrigerant to boil and vaporize. After the refrigerant has absorbed its latent heat of vaporization (that is, after it is entirely vaporized), the refrigerant continues to absorb heat until it becomes superheated by approximately 10° F. The amount of superheat is determined by the amount of liquid refrigerant admitted to the evaporator; and this, in turn, is controlled by the spring adjustment of the thermostatic expansion valve. A temperature range of 4° to 12° F of superheat is considered desirable because it increases the efficiency of the plant and because it evaporates all of the liquid, thus preventing liquid carryover into the compressor.

Compressor

The compressor in a refrigeration system is essentially a pump. It is used to pump heat "uphill" from the cold side to the hot side of the system.

The heat absorbed by the refrigerant in the evaporator must be removed before the refrigerant can again absorb latent heat. The only way the vaporized refrigerant can be made to give up the latent heat of vaporization that it absorbed in the evaporator is by cooling and condensing it. Because of the relatively high temperature of the available cooling medium, the only way to make the vapor condense is by first compressing it.

The vapor drawn into the compressor is at very low pressure and very low temperature. In the compressor, both the pressure and the temperature are raised. Since an increase in pressure causes a proportional rise in temperature and since the condensation point of any vapor is dependent on the pressure, raising the pressure of the vaporized refrigerant provides a condensation temperature high enough to permit the use of seawater as the condensing and cooling medium. The compressor raises the pressure of the vaporized refrigerant sufficiently high to permit condensation to take place in the condenser.

In addition to this primary function, the compressor also keeps the refrigerant circulating and maintains the required pressure difference between the high-pressure side and the low-pressure side of the system.

Many different types of compressors are used in refrigeration systems. The designs of compressors vary depending on the application of the refrigerants used in the system. Figure 11-5 shows a motor-driven, single-acting, two-cylinder, reciprocating compressor such as is commonly used in naval refrigeration plants.

Compressors used in R-12 systems may be lubricated either by pressure lubrication or by splash lubrication. Splash lubrication, which depends on maintaining a fairly high oil level in the compressor crankcase, is usually satisfactory for smaller compressors. High speed or large capacity compressors use pressure lubrication systems.

SHAFT SEALS.–Where the crankshaft extends through the crankcase, a leakproof seal must be maintained to prevent the refrigerant 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 such as the rotary seal, the stationary bellows, the rotating bellows, and the diaphragm.

The rotary seal shown in figure 11-6 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 (a) between the crankshaft and the rotating carbon rings and sealed by a neoprene ring, (b) between the rotating carbon ring and the cover plate and sealed by lapped surfaces, and (c) 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 11-7. 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 (a) between the crankcase and the bellows and sealed by the cover plate gasket, (b) between the crankshaft and the shaft seal collar and sealed by a neoprene gasket, and (c) 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 11-8, 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 (a) between the crankshaft and bellows and sealed by a shaft seal clamping nut, (b) between the removable shaft seal shoulder and the crankcase and sealed by a neoprene gasket, and (c) between the bellows nose piece and the shaft seal collar and sealed by lapped surfaces. This type seal is also factory set.

The diaphragm seal, figure 11-9, consists of a diaphragm clamped to the crankcase at its outer

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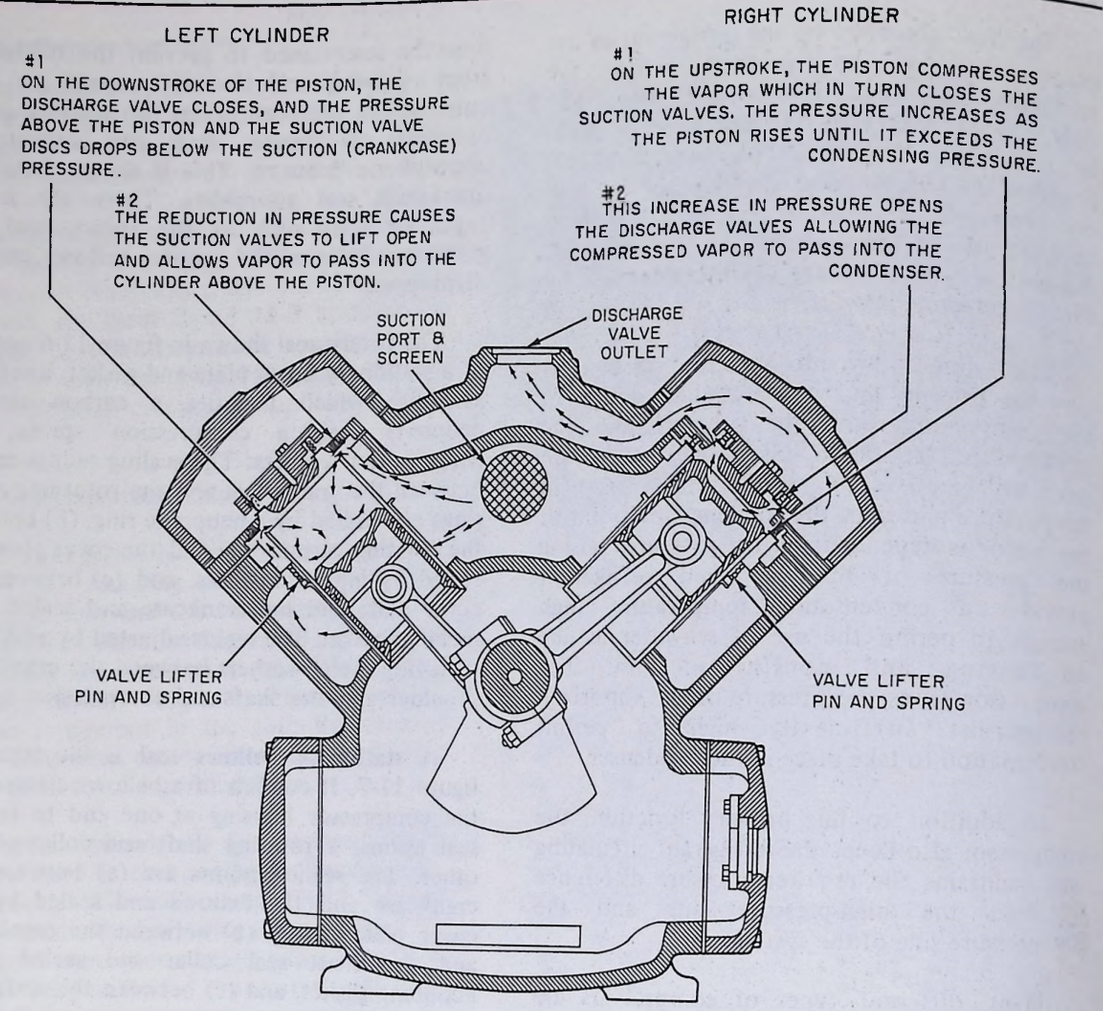


Figure 11-5.—Reciprocating compressor.

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 (a) between the outer circumference of the diaphragm and the crankcase and sealed by a copper ring gasket, (b) between the fulcrum ring and the diaphragm—sealed at the factory and not to be broken, (c) between the fulcrum ring and the rotating shaft seal collar and sealed by lapped surfaces, and (d) between the shaft seal collar and the crankshaft shoulder and 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 manufacturer's technical manual or the directions enclosed with the new seal.

CAPACITY CONTROL SYSTEM.—Most compressors are equipped with an oil-pressure operated automatic capacity control system which "unloads" or cuts cylinders out of

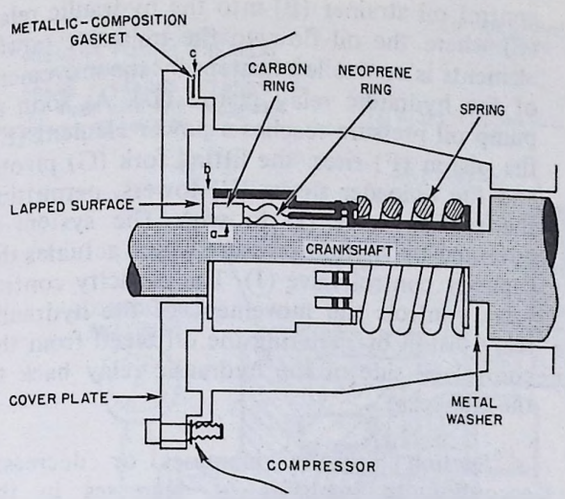


Figure 11-6.—Rotary seal.

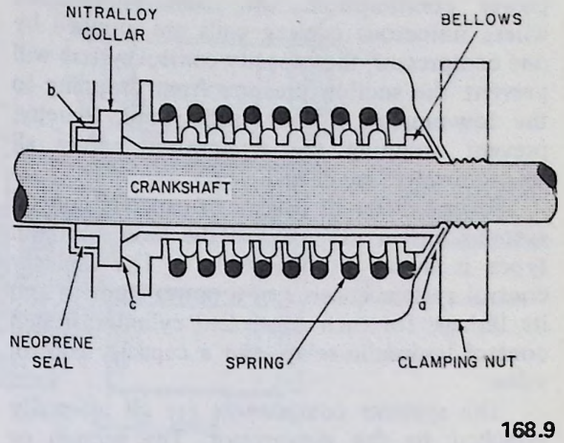


Figure 11-8.—Rotating bellows seal.

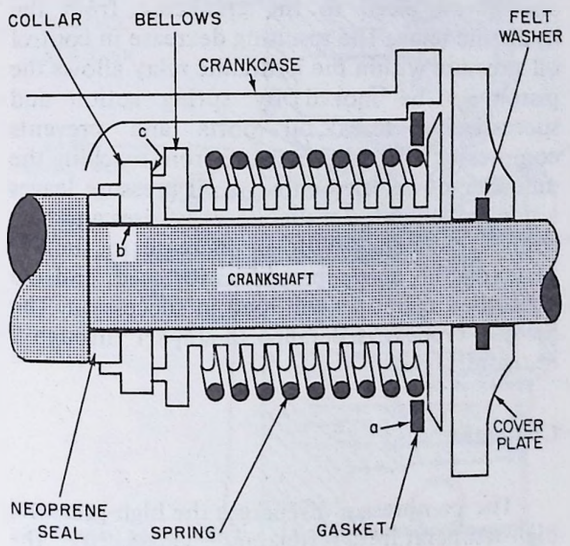


Figure 11-7.—Stationary bellows seal.

operation in accordance with decreases in the refrigeration load requirements of the plant. A cylinder is unloaded by a mechanism that holds the suction valve open so that no gas can be compressed.

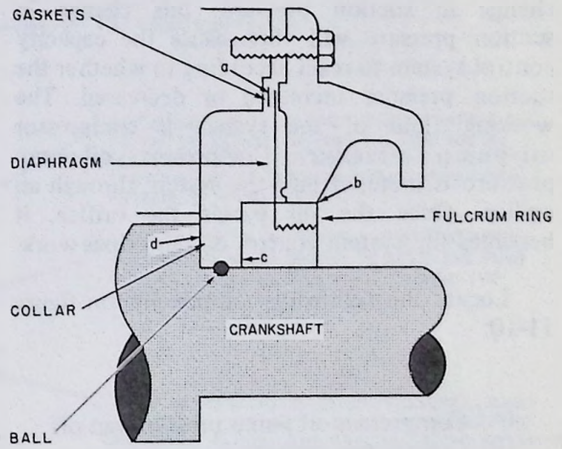


Figure 11-9.—Diaphragm type seal.

Since oil pressure is required to "load" or put cylinders into operation, the compressor will start with all controlled cylinders unloaded. But as soon as the compressor comes up to speed and full oil pressure is developed, all cylinders will become operative. After the temperature pulldown period, the refrigeration load imposed on the compressor will decrease and the capacity control system will unload cylinders accordingly. The unloading will result in reduced

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power consumption. On those applications where numerous cooling coils are supplied by one compressor, the capacity control system will prevent the suction pressure from dropping to the low-pressure cutout setting and, thereby, prevent stopping the compressor before all solenoid valves are closed.

Several different designs of capacity control systems are in use. One of the most common types is shown in figure 11-10. The capacity control system consists of a power element and its linkage for each controlled cylinder, a step control hydraulic relay, and a capacity control valve.

The systems components are all integrally attached to the compressor. The suction or crankcase pressure of the refrigeration plant is sensed by the capacity control valve to control the system. In other words, a change in the refrigeration load on the plant will cause a change in suction pressure; this change in suction pressure will then cause the capacity control system to react according to whether the suction pressure increased or decreased. The working fluid of the system is compressor oil-pump pressure. Compressor oil-pump pressure is metered into the system through an orifice. Once the oil passes the orifice, it becomes the system control oil, and does work.

Locate the following components on figure 11-10:

(A) Compressor oil pump pressure tap-off
(B) Control oil strainer
(C) Hydraulic relay
(D) Hydraulic relay piston
(E) Unloader power element
(F) Unloader power element piston
(G) Lifting fork
(H) Unloader sleeve
(I) Suction valve
(J) Capacity control valve
(K) Crankcase (suction) pressure sensing point

The following functions take place when the compressor is started with a warm load on the refrigeration system.

Compressor oil (A) is pumped through the control oil strainer (B) into the hydraulic relay (C) where the oil flow to the unloader power elements is controlled in steps by the movement of the hydraulic relay piston (D). As soon as pump oil pressure reaches a power element (E), the piston (F) rises, the lifting fork (G) pivots, and the unloader sleeve (H) lowers, permitting the suction valve (I) to seat. The system is governed by suction pressure which actuates the capacity control valve (J). The capacity control valve controls the movement of the hydraulic relay piston by metering the oil bleed from the control oil side of the hydraulic relay back to the crankcase.

Suction pressure increases or decreases according to increases or decreases in the refrigeration load requirements of the plant. After the temperature pulldown period with a subsequent decrease in suction pressure, the capacity control valve moves to increase the control oil bleed to the crankcase from the hydraulic relay. The resulting decrease in control oil pressure within the hydraulic relay allows the piston to be moved by spring action and successively closes oil ports and prevents compressor oil pump pressure from reaching the unloader power elements. As oil pressure leaves a power element, the suction valve rises and that cylinder unloads. With an increase in suction pressure, the above process is reversed, and the controlled cylinders will load in succession. The loading process is detailed in steps 1 through 7 in figure 11-10.

Condenser

The compressor discharges the high-pressure, high-temperature refrigerant vapor to the condenser, where it flows around the tubes through which seawater is being pumped. As the vapor gives up its superheat (sensible heat) to the seawater, the temperature of the vapor drops to the condensation point. As soon as the temperature of the vapor drops to its boiling, or condensing, temperature at the existing pressure, the vapor condenses, giving off its latent heat of vaporization in the process. The refrigerant, now in liquid form, is subcooled slightly below its

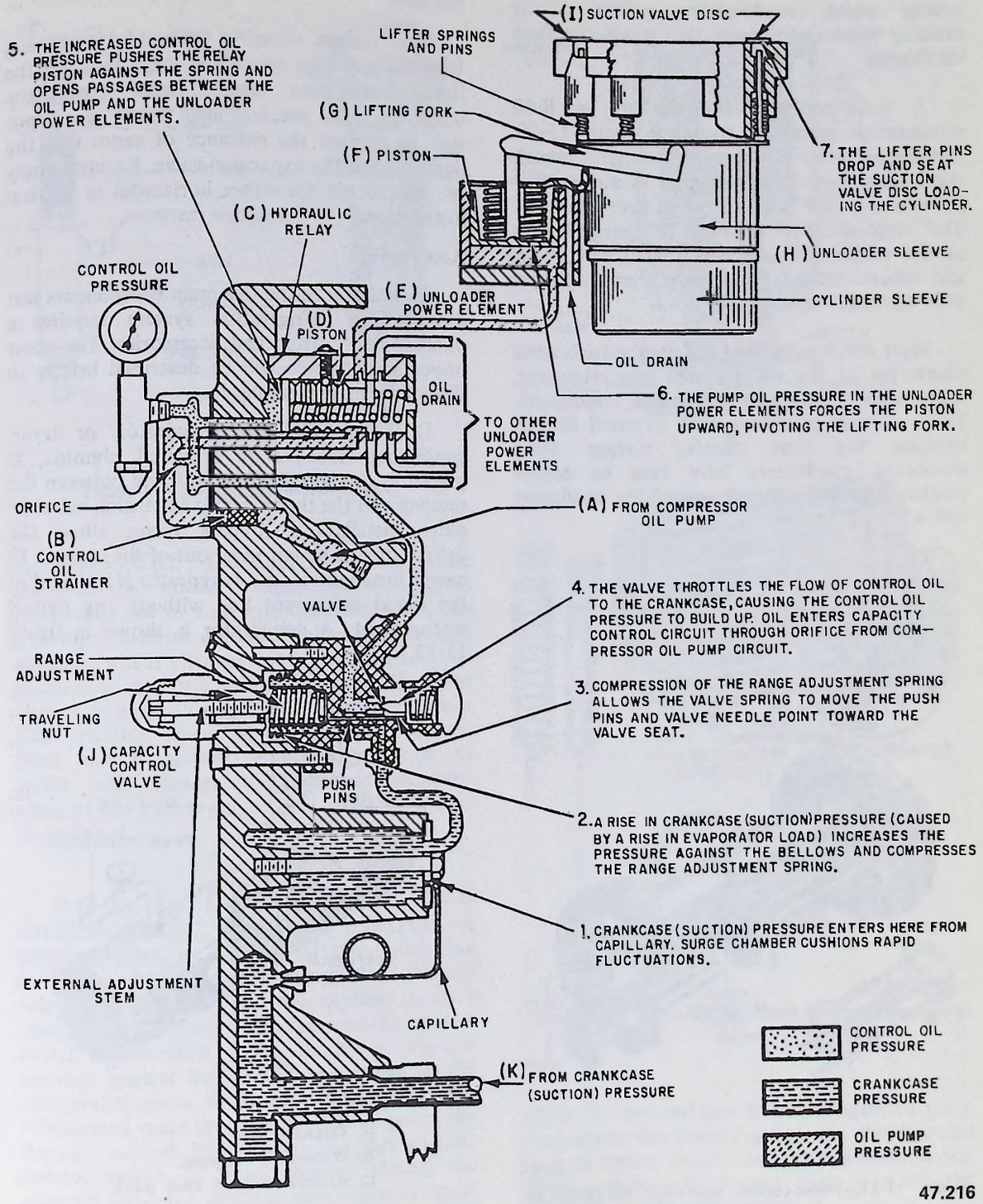


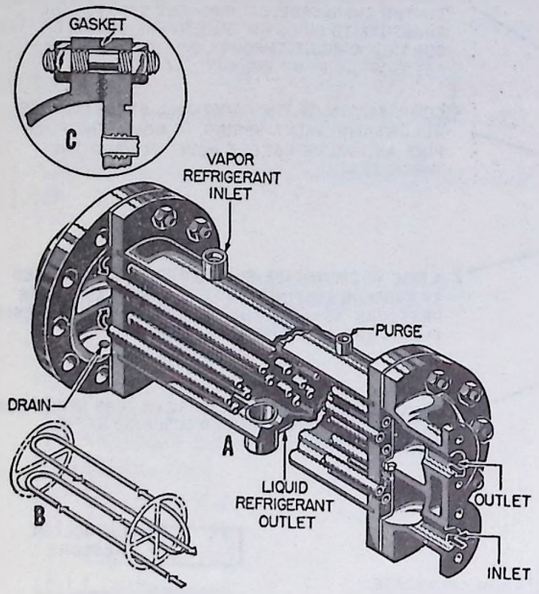
Figure 11-10.—Capacity control system.

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boiling point (condensation point) at the existing pressure to ensure that it will not flash into vapor.

A water-cooled condenser for an R-12 refrigeration system is shown in figure 11-11. Circulating water is obtained through a branch connection from the firemain or by means of an individual pump taking suction from the sea. The purge connection shown in figure 11-11 is on the refrigerant side; it is used to remove air and other noncondensable gases that are lighter than the R-12 vapor.

Most condensers used for naval refrigeration plants are of the water-cooled type. However, some small units have air-cooled condensers. These consist of tubing with external fins to increase the heat transfer surface. Most air-cooled condensers have fans to ensure positive circulation of air around the condenser tubes.



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Figure 11-11.—Water-cooled condenser for R-12 refrigeration system.

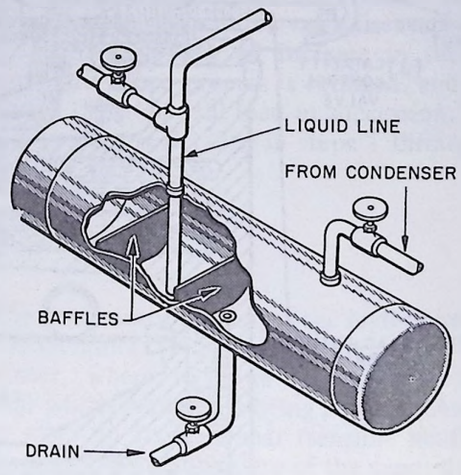
Receiver

The receiver, shown in figure 11-12, acts as a temporary storage space and surge tank for the liquid refrigerant which flows from the condenser. The receiver also serves as a vapor seal, to prevent the entrance of vapor into the liquid line to the expansion valve. Receivers may be constructed for either horizontal or vertical installation.

Accessories

In addition to the five main components just described, a refrigeration system requires a number of controls and accessories. The most important of these will be described briefly in the following paragraphs.

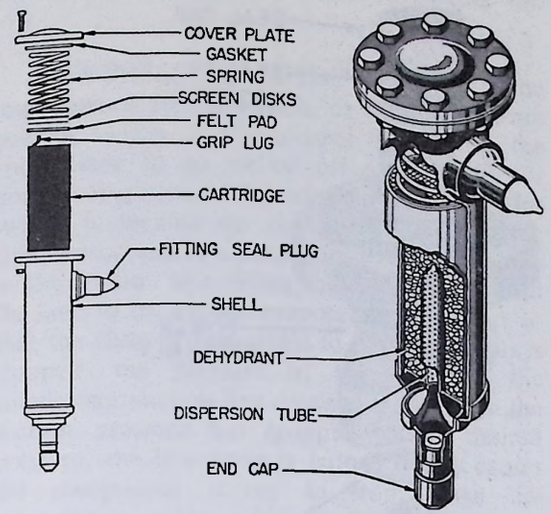
DEHYDRATOR.—A dehydrator, or dryer, containing silica-gel or activated alumina, is placed in the liquid refrigerant line between the receiver and the thermostatic expansion valve. In older installations, bypass valves allow the dehydrator to be cut in or out of the system. In newer installations, the dehydrator is installed in the liquid refrigerant line without any bypass arrangement. A dehydrator is shown in figure 11-13.



A. Cutaway view.
B. Water-flow diagram.
C. Arrangement of heat joint.

47.96

Figure 11-12.—Receiver.

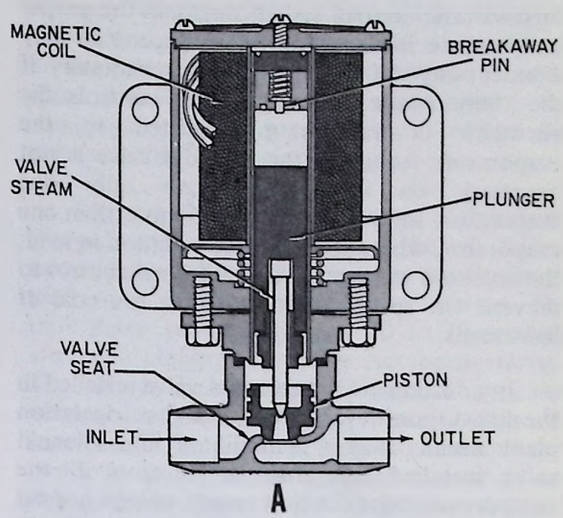


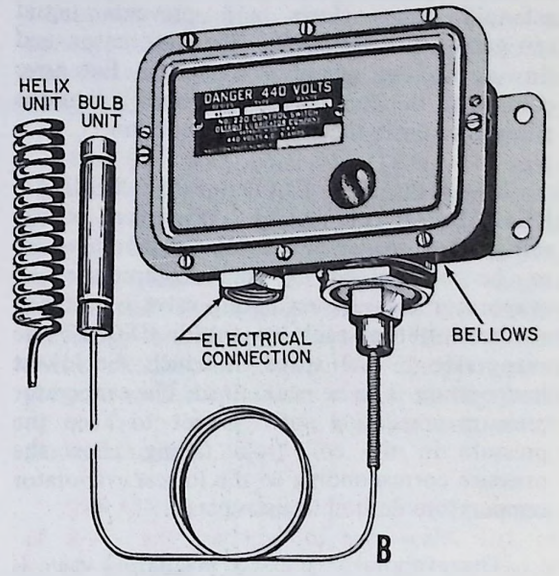
47.97

Figure 11-13.—Refrigerant dehydrator.

MOISTURE INDICATOR.—A moisture indicator is either located in the liquid refrigerant line or built into the dehydrator. The moisture indicator contains a chemically treated element which changes color when there is an increase of moisture in the refrigerant. The color change is reversible and will change back to a DRY reading when the moisture is removed from the refrigerant. Excessive moisture or water will damage the moisture indicator element and turn it gray, which indicates it must be replaced.

SOLENOID VALVE AND THERMOSTATIC CONTROL SWITCH.—A solenoid valve is installed in the liquid line leading to each evaporator. Figure 11-14 shows a solenoid valve and the thermostatic control switch that operates it. The thermostatic control switch is connected by long flexible tubing to a thermal control bulb which is located in the refrigerated space. When the temperature in the refrigerated space drops to the desired point, the thermal control bulb causes the thermostatic control switch to open, thereby closing the solenoid valve and shutting off all flow of liquid refrigerant to the thermostatic expansion valve.





47.93:77.120

Figure 11-14.—Solenoid valve and thermostatic control switch.

When the temperature in the refrigerated space rises above the desired point, the thermostatic control switch closes, the solenoid valve opens, and liquid refrigerant once again flows to the thermostatic expansion valve.

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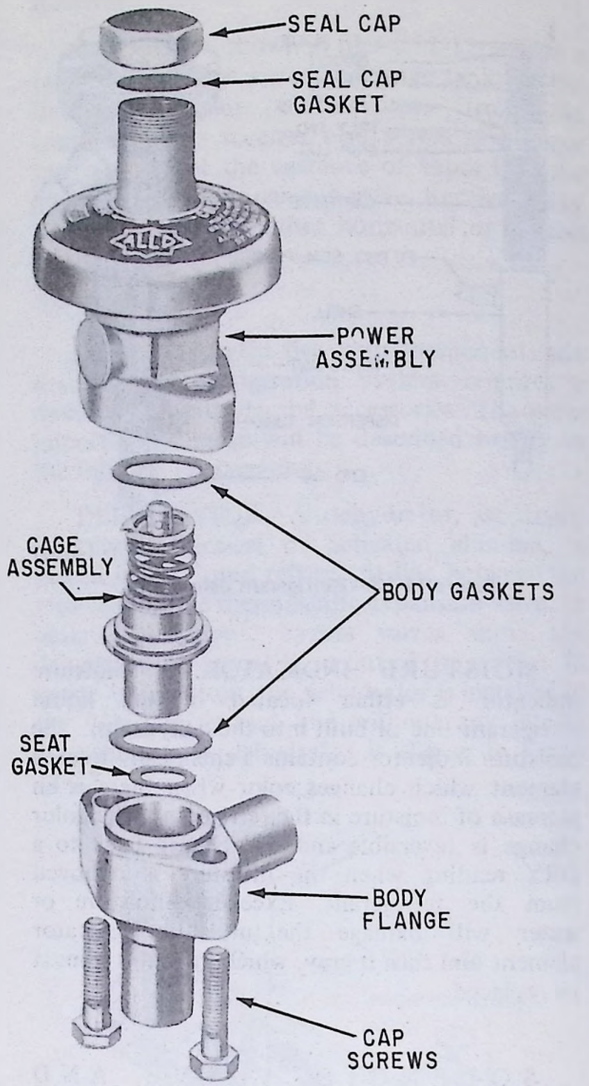
The solenoid valve and its related thermostatic control switch maintain the proper temperature in the refrigerated space. You may wonder why the solenoid valve is necessary if the thermostatic expansion valve controls the amount of refrigerant admitted to the evaporator. Actually, the solenoid valve is not necessary on units that have only one evaporator. In systems that have more than one evaporator, where there is wide variation in load, the solenoid valve provides additional control to prevent the spaces from becoming too cold at light loads.

In addition to the solenoid valve installed in the line to each evaporator, a large refrigeration plant usually has a main liquid line solenoid valve installed just after the receiver. If the compressor stops for any reason except normal suction pressure control, the main liquid solenoid valve closes and prevents liquid refrigerant from flooding the evaporator and flowing to the compressor suction. Extensive damage to the compressor can result if liquid is allowed to enter the compressor suction.

EVAPORATOR PRESSURE REGULATING VALVE.—Whenever several refrigerated spaces of varying temperatures are to be maintained by one compressor, an evaporator pressure regulating valve is installed at the outlet of each evaporator EXCEPT the evaporator in the space in which the lowest temperature is to be maintained. The evaporator pressure regulating valve is set to keep the pressure in the coil from falling below the pressure corresponding to the lowest evaporator temperature desired in that space.

The evaporator pressure regulating valve is used mostly on water coolers, on units where high humidity is required (such as fruit and vegetables stowage spaces) and in installations where two or more rooms are maintained at different temperatures by the use of the same refrigeration unit.

A cross section of a common evaporator pressure regulating valve (commonly called EPR valve) is shown in figure 11-15. The tension of the spring above the diaphragm is adjusted so



87.70

Figure 11-15.—Exploded view of typical evaporator pressure regulating valve (EPR).

that when the evaporator coil pressure drops below the desired minimum, the spring will shut the valve.

The EPR valve is not really a temperature control—that is, it does not regulate the temperature in the space. It is only a device to

prevent the temperature from becoming too low.

LOW-PRESSURE CUTOUT SWITCH.—The low-pressure cutout switch, or suction pressure control switch, is the control that causes the compressor to go on or off as required for normal operation of the refrigeration plant. This switch is located on the suction side of the compressor and is actuated by pressure changes in the suction line. When the solenoid valves in the lines to the various evaporators are closed, so that the flow of refrigerant to the evaporators is stopped, the pressure of the vapor in the compressor suction line drops quickly. When the suction pressure has dropped to the desired pressure, the low-pressure cutout switch causes the compressor motor to stop. When the temperature in the refrigerated spaces has risen enough to operate one or more of the solenoid valves, refrigerant is again admitted to the cooling coils, and the compressor suction pressure builds up again. At the desired pressure, the low-pressure cutout switch closes, starting the compressor again and repeating the cycle.

HIGH-PRESSURE CUTOUT SWITCH.—A high-pressure cutout switch is connected to the compressor discharge line to protect the high-pressure side of the system against excessive pressures. The design of this switch is essentially the same as that of the low-pressure cutout switch; however, the low-pressure cutout switch is made to CLOSE when the suction pressure reaches its upper normal limit, whereas the high-pressure cutout switch is made to OPEN when the discharge pressure is too high. As mentioned before, the low-pressure cutout switch is the compressor control for normal operation of the plant; the high-pressure cutout switch, on the other hand, is a safety device only and does not have control of compressor operation under normal conditions.

OIL FAILURE SWITCH.—An oil failure switch is provided with high-speed compressors. The switch is designed to prevent operation of the compressor in the event of low oil pressure. The switch is installed with one bellows connected to the oil pressure on the discharge of the compressor oil pump and the other connected to the compressor suction refrigerant pressure. The switch is set to open the electrical circuit and stop the compressor when the oil pressure drops to a low-pressure setpoint and to close the electrical circuit and start the compressor when the oil pressure reaches the reset setpoint.

To start the compressor after it has been stopped and the contacts of the oil failure switch have opened, a time delay mechanism is used with the compressor motor starter. The time delay switch will open 10 to 30 seconds after the compressor motor has been started. The oil pressure normally will be built up in this time interval so that the oil pressure switch will have made contact to keep the compressor motor electrical circuit energized after the time delay switch opens. If the oil pressure has not built up within about 30 seconds after the compressor is started, the contacts of the oil pressure differential switch will not have closed, and the compressor will stop because the time delay relay switch is open.

WATER FAILURE SWITCH.—A water failure switch is provided to stop the compressor in the event of failure of the circulating water supply. This is a pressure-actuated switch, generally similar to the low-pressure cutout switch and the high-pressure cutout switch previously described. If the water failure cutout switch should fail to function, the refrigerant pressure in the condenser would quickly build up to the point that the high pressure switch would function.

STRAINER.—Because of the solvent action of R-12, any particles of grit, scale, dirt, or metal that the system may contain are readily circulated through the refrigerant lines. To avoid damage to the compressor from such foreign matter, a strainer is installed in the compressor suction connection.

SPRING-LOADED RELIEF VALVE.—A spring-loaded relief valve is installed in the compressor discharge line as an additional precaution against excessive pressures. The relief valve is set to open at approximately 225 psi; therefore, it functions only in case of failure or

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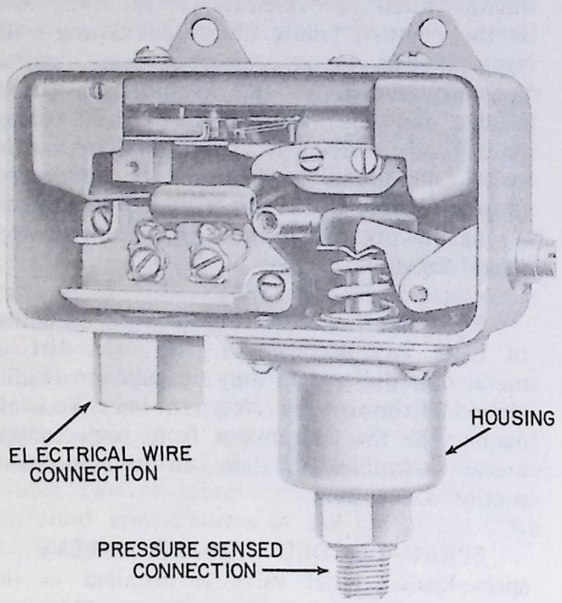
improper setting of the high-pressure cutout switch. If the relief valve opens, it discharges high-pressure vapor to the suction side of the compressor.

The type of pressure-actuated control switch used in all of the above installations is of the general type shown in figure 11-16 with its cover removed. (The oil pressure failure switch has two bellows instead of the one shown in the illustration.) These switches are designed to operate at various pressure ranges. Some switches have manual reset buttons to prevent the automatic restoration of power after a pressure failure, such as a high discharge pressure.

WATER REGULATING VALVE.—A water regulating valve controls the quantity of circulating water flowing through the refrigerant condenser. The water regulating valve is actuated by the refrigerant pressure in the compressor discharge line; this pressure acts upon a diaphragm (or, in some valves, a bellows arrangement) which transmits motion to the valve stem.

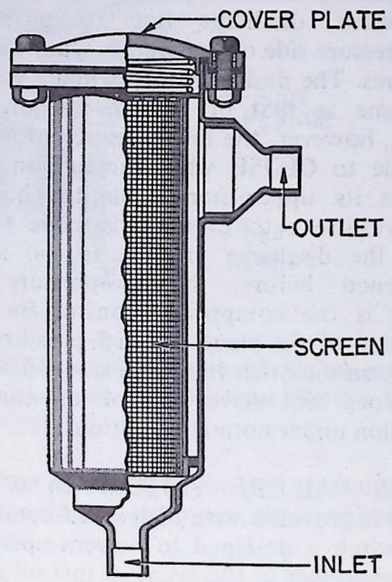
The primary function of the water regulating valve is to maintain a constant refrigerant condensing pressure. Basically, two variable conditions exist: (1) the amount of refrigerant to be condensed and (2) changing water temperatures. The valve maintains a constant refrigerant condensing pressure by controlling the water flow through the condenser. By sensing the refrigerant pressure, the valve permits only enough water through the condenser to condense the amount of refrigerant vapor coming from the compressor. The quantity of water required to condense a given amount of refrigerant varies with the water temperature. Thus, the flow of cooling water through the condenser is automatically maintained at the rate actually required to condense the refrigerant under varying conditions of load and temperature.

LIQUID STRAINER.—A liquid strainer of the type shown in figure 11-17 is also installed



77.119

Figure 11-16.—Pressure-actuated control switch.



47.101

Figure 11-17.—Strainer for liquid refrigerant.

in the liquid line leading to each evaporator; these strainers protect the solenoid valves and the thermostatic expansion valves.

PRESSURE GAGES AND THERMOMETERS.—A number of pressure gages and thermometers are used in refrigeration systems. Figure 11-18 shows a compound R-12 gage. The temperature markings on this gage show the boiling point (or condensing point) of the refrigerant at each pressure; the gage cannot measure temperature directly. The red pointer is a stationary marker that can be set manually to indicate the maximum working pressure.

A water pressure gage is installed in the circulating water line to the condenser to indicate failure of the circulating water supply.

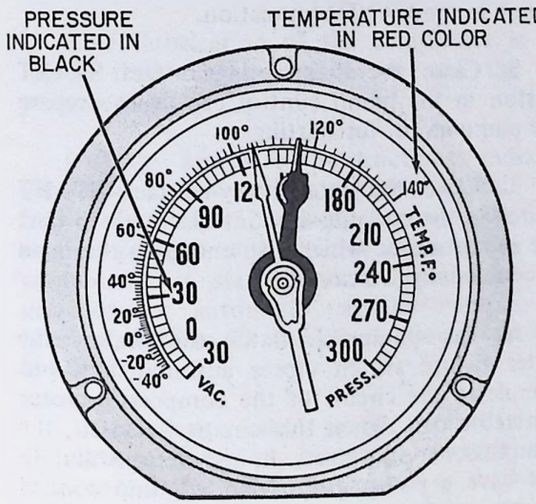
Standard thermometers of appropriate range are provided for the refrigerant system.

REFRIGERANT PIPING.—Refrigerant piping in modern naval installations is made of copper. Copper is good for this purpose because (1) it does not become corroded by refrigerants; (2) the internal surface of the tubing is smooth enough to minimize friction; and (3) copper tubing is easily shaped to meet installation requirements.

PACKLESS VALVES.—Nearly all hand-operated valves in large refrigeration systems are packless valves of the type shown in figure 11-19. In this type valve the upper part is sealed off from the lower part by a diaphragm. An upward-seating ball check in the lower valve stem makes it possible for the spring to lift the lower stem regardless of pressure differences developed while the valve was closed. Thus, the valve will operate properly regardless of direction of flow. By backseating the valve, the diaphragm can be changed without placing the system or unit out of operation.

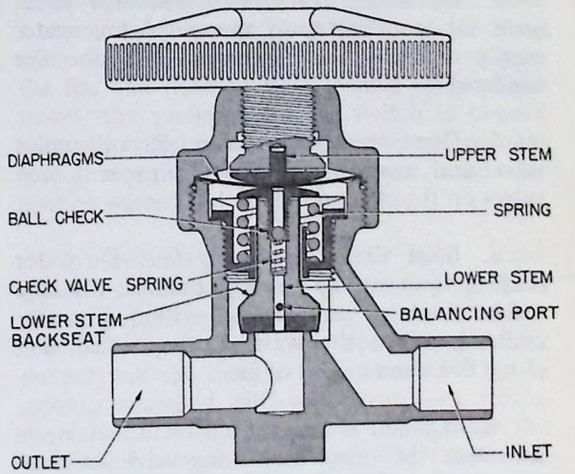
OPERATING PROCEDURES FOR AN R-12 SYSTEM

Learning to do all of the tasks related to refrigeration system operations will require (1) a good deal of practical experience and (2) attentive observation of the procedures followed by those qualified in refrigeration system operation and maintenance. As a Machinist's Mate, your first responsibility with an R-12



47.102

Figure 11-18.—Compound R-12 pressure gage.



47.103

Figure 11-19.—Packless valve for refrigeration system.

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system will probably include checking temperatures and pressures, maintaining the plant operating log, detecting symptoms of faulty operation, and checking conditions in the spaces or units being cooled.

The intervals of time between plant inspections will vary depending on the purpose for which the plant is used. The temperatures and pressures throughout the system and the oil level in the compressor crankcase are checked and the results are recorded every hour unless watchstanding instructions specify otherwise. The results of these checks are used to determine whether the plant is operating properly. One of the best methods for checking plant operation is to compare the existing temperatures and pressures with those recorded during a period when the plant was known to be operating properly, under conditions similar to the present conditions.

PRESTARTING CHECKS

The following information on operating procedures is of general nature intended only to familiarize you with plant operation, and should NOT be used for actual operation unless specifically approved for your plant.

1. Open the compressor discharge valve; open all stop valves in the circulating water supply and in the discharge lines for the condenser.

2. Open the condenser refrigerant outlet valve and open the thermal expansion stop valves on the chill and freeze boxes.

3. Start all air circulating fans. On water cooling applications (soda fountains, drinking water coolers, and air conditioning water chillers), admit the water to be cooled, and purge the water circuit of air.

4. If water is taken from the firemain, be sure that the pressure-reducing valve ahead of the water regulating valve is adjusted to provide a water pressure of 35 psi or less. When no pressure-reducing valve is installed, regulate the firemain connection stop valve manually so that the required water pressure ahead of the water regulating valve is maintained.

5. When an individual circulating pump is used to supply condenser circulating water, be sure that all valves, which permit transmission of pump discharge pressure to the water failure switch, are open.

6. If the compressor unit is equipped with an air-cooled condenser, be sure that the airflow passages to the condenser are unobstructed, and that the air circulating fans are clear.

7. Open the compressor discharge-line valve, the stop valve in the line connecting the condenser and the liquid receiver, and the main liquid-line valve.

STARTING THE COMPRESSOR

We must emphasize the need for thoroughness and care at the time the compressor is started. Bent crankshafts, distorted valves, and blown gaskets are a few of the casualties that can occur if proper procedures and applicable precautions are not followed. After accomplishing or checking the items listed under the posted prestarting instructions, proceed as follows:

1. Set the AUTOMATIC-MANUAL selector switch in the MANUAL position.

2. Close the maintaining-contact START button in the pump control circuit to prepare the pump motor for starting.

3. Close the momentary-contact START switch in the compressor control circuit to start the pump motor which also energizes the main line solenoid valve circuit.

As the pump circulates the water, the water failure switch closes automatically and completes the circuit of the compressor-motor contactor coil. When this circuit is closed, the compressor motor starts. In installations that do not have a pump motor and a pump control circuit installed, closing the momentary-contact START switch energizes the compressor control circuit and starts the compressor motor.

4. Start and stop the motor and compressor several times by manual control, to check their operating condition; then, stop the compressor and check the oil level.

5. After determining that the motor and the compressor are in operating condition, crack the suction stop valve and set the controls on AUTOMATIC. This arrangement prevents the pressure in the system from decreasing below that of the atmosphere and drawing air into the compressor.

With the compressor running, open the compressor suction valve slowly, to limit the quantity of suction gas handled by the compressor.

Watch the suction gage as you open the compressor suction valve to ensure that the suction pressure is within the limits of the automatic control low-pressure suction setting. Open the valve at a gradual rate so that there is neither a rapid fluctuation in suction pressure nor a rapid drop of pressure in the compressor crankcase. This will prevent the rapid boiling off of refrigerant from the oil and the carrying of oil into the system. Unusual noise or knocking in the compressor and frosting of crankcase or suction valve are indications that liquid refrigerant is being drawn into the compressor.

6. If lubrication of the compressor is by forced feed, check the pressure on the oil pressure gage.

Unless specific instructions indicate otherwise, the oil pressure should be between 15 and 30 psi above the compressor suction pressure within a few seconds after the compressor is started. If the compressor is designed for automatic capacity control, oil pressure of 50 to 60 psi above suction pressure is required.

7. Be sure the proper quantity of circulating water is flowing through the condenser before the compressor or discharge pressure reaches 125 psi.

8. Open the receiver outlet valve and the main solenoid outlet valve.

OPERATING AN R-12 PLANT IN AUTOMATIC

After the prescribed operating pressures and temperatures have been established with the compressor running in MANUAL, place the selector switch in the AUTOMATIC position. NOTE: A refrigeration compressor should NEVER be left unattended when in the MANUAL mode of operation. The suction-pressure control (low-pressure cutout switch) is connected electrically to start and stop the compressor automatically on the basis of load conditions. If the automatic control valves and switches are in proper adjustment, the operation of the plant, after proper starting, will be entirely automatic.

When the selector switch is set for automatic operation, the water failure switch, the high-pressure switch, or the low-pressure switch will close and energize their respective circuits. Other control devices require the intervention of an operator before the compressor can be restarted. Some high-pressure switches are provided with manual reset devices which must be reset by the operator after the switches have been opened by excessive pressure.

In some installations the supply of condenser cooling water is available either from a centrifugal pump or from the fire and flushing main directly. If cooling water is obtained from the fire and flushing main instead of from the pump, the pump controller switch is opened manually. The water failure switch remains closed regardless of the source of condenser cooling water.

In systems not equipped with water regulating valves, normal operating conditions generally produce condensing pressures of less than 125 psi, since the condensing water temperature is usually less than 85° F. In systems equipped with water regulating valves, the valves should be adjusted to maintain the condensing pressure at 125 psi. When the valves are so adjusted, the quantity of cooling water required decreases rapidly with decreasing circulating water temperatures. In systems equipped with air-cooled condensers, condensing

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pressures may exceed 125 psi when the temperature of the surrounding air is higher than normal.

SECURING THE COMPRESSOR

If a compressor is to be secured for only a short time, it is not necessary to pump down the system. The compressor, however, must be pumped down. To do this, first close the compressor suction valve slowly to prevent a too rapid reduction in crankcase pressure. Then, allow the compressor to run until it is stopped by the low-pressure control switch; push the STOP button on the motor-control panel. Next, close the compressor discharge shutoff valve; shut off the water supply to the condensers. Finally, close the main liquid valve downstream from the receiver.

If a refrigeration system is to be secured for an extended time, the system must be pumped down. The pumping-down procedure involves pumping most of the R-12 out of the coils of the evaporator and storing the refrigerant in the receiver. If the quantity of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid must be drawn off into refrigerant drums.

NOTES ON COMPRESSOR OPERATION

An R-12 compressor should not remain idle for an extended period of time. When two or more compressors are installed for a particular plant, the compressors should be operated alternately so that the total operating time on each of the compressors is approximately the same. An idle compressor should be operated at least once a week.

Only one compressor should serve a cooling coil circuit. When compressors are operated in parallel on a common cooling circuit, lubricating oil may be transferred from one compressor to another. Such transfer of oil may result in serious damage to all compressors on the circuit.

OPERATING LOG

The operating record of a refrigeration system must be maintained by the personnel on watch. The information recorded in the operating log serves as a guide to the condition of the plant.

MAINTENANCE OF R-12 SYSTEMS

As a Machinist's Mate, you will do some of the maintenance jobs required to keep a refrigeration plant operating efficiently. To perform your share of the required maintenance of a refrigeration system, you must be familiar with the proper procedures for the following jobs; defrosting the cooling coils, pumping down a system and checking for noncondensable gases, purging a system of noncondensable gases, using a halide torch to test for refrigerant leaks, checking compressor oil, taking care of V-belts, setting and adjusting refrigeration system controls and safety devices, testing and renewing compressor valves, and care of shaft seals. Most of these maintenance items are covered by the Planned Maintenance System and will be scheduled accordingly.

DEFROSTING OF COOLING COILS

The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Excessive accumulation of frost on the coils will result in reduced cooling capacity, low compressor-suction pressure, and a tendency for the compressor to short cycle. The maximum permissible time interval between defrosting operations depends on many factors, such as refrigerant evaporating temperature, free-moisture content of supplies placed in the refrigerated space, temperature of refrigerated spaces, frequency of opening of cold-storage compartment doors, and atmospheric humidity. In the average cold-storage refrigeration installation, it is good practice to defrost cooling coils before the average frost thickness reaches 3/16 inch. This is not a hard and fast rule, however; sometimes the frost layer may become appreciably thicker

without seriously interfering with plant operation. At other times it may be necessary to defrost more often to maintain satisfactory operation of the plant and proper compartment temperature.

The most COMMON METHOD OF DEFROSTING a cooling coil in the average refrigeration installation is (1) to shut off the supply of R-12 to the coil to be defrosted by closing the liquid-line stop valve ahead of the expansion valve and (2) to leave the entrance door open to permit the temperature in the compartment to rise above 32° F. The frost will melt off the coils or may be easily brushed off. Since the cooling coils are made of tinned copper or galvanized steel tubing, care should be taken not to damage the evaporator coil.

Most refrigeration systems now in use are provided with HOT-GAS DEFROSTING lines to facilitate defrosting where compartment temperatures are maintained at 32° F or less. The principal advantage of hot-gas defrosting is that the freeze room coils can be defrosting while the rest of the plant operates normally.

In the following paragraphs, defrosting procedures will refer only to freeze room coils.

A hot-gas defrosting line leads from the compressor discharge piping to the tail-coil of the freeze room cooling coil. The hot-gas line joins the suction line between the freeze room and the suction valve; therefore, hot gas admitted to the freeze room cooling coil flows "backwards" through the coil—that is, the hot gas flows in the direction opposite the flow of refrigerant under normal operating conditions.

To defrost the coils of the freeze room, close the normal refrigerant-liquid supply and the suction return-line valves of the freeze room cooling coil. Then, open the valve in the hot-gas supply line to admit compressed refrigerant-gas to the coil. As the frost melts on the exterior coil surfaces, the gas is condensed in the coils and becomes a liquid. The liquid is led, from the inlet end of the freeze room cooling coil to the main liquid supply line and is used in the other compartments.

When the defrosting has been completed, return the system to its normal operating condition by (1) closing the defrosting valves and (2) opening the valves in the refrigerant-liquid supply line to the freeze room coil and the suction return valve from the freeze room coil. Care must be taken that all liquid refrigerant has been discharged from the freeze room coil before the suction line valve from the compartment is opened. Proceed as previously outlined in step 5 for starting the compressor using the tail-coil suction valve, instead of the compressor suction valve, as the control valve. If all the liquid has not been discharged, liquid slugs may be returned to the compressor.

PUMPING DOWN A REFRIGERANT SYSTEM

The pumping-down procedure to be followed will depend on the maintenance to be done. In some cases, the necessary maintenance can be performed on the charged system after a part to be repaired or replaced has been isolated. Generally, it is possible to pump down any part of a charged system (except the condenser, the liquid receiver, and the compressor discharge line) by proper manipulation of cutout valves. When repairs are to be made to a major portion of the system, the refrigerant system must be pumped down to return all refrigerant to the receiver.

If repairs are to be made to the receiver, the condenser, or the compressor discharge line, the entire system must be drained into spare refrigerant drums. However, when a system has valves to isolate the compressor discharge line and condenser and when it is not objectionable to release refrigerant (which may still be trapped in the condenser after the system has been pumped down to the receiver) to the atmosphere, repairs to the compressor discharge line and condenser may be made with this section isolated.

Whenever it is necessary to open a charged system to make repairs or replacements or to clean strainers, the refrigerant pressure within the part of the system to be opened should be pumped down to a pressure slightly above

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atmospheric (1/2 to 2 psig) before any connections are broken. As a part of the system which contains liquid R-12 is pumped down, its temperature will decrease as a result of the evaporation of the liquid refrigerant. When the temperature of such a part of the system begins to rise to normal again, while the low pressure in the part is maintained, it is reasonably certain that all R-12 liquid within the part has evaporated.

If, in the final evacuation of a part of the system, a pressure of less than 0 psig is reached, sufficient refrigerant should be immediately bled into the evacuated part of the system to raise the pressure to between 1/2 and 2 psig. Connections may then be opened, and repairs, replacements of parts, or other necessary service operations may be accomplished.

When a refrigerant system is opened, the free ends of the refrigerant lines should be temporarily plugged to prevent the entrance of air and dirt. When the connections are remade, one connection is made tight while the other connection is left loose, temporarily, so that the air or other foreign gases in the section of the system which is serviced can be swept out through the free end as this section of the system is slowly purged with refrigerant-gas bled from the charge in the system. The other connection (or connections) is then quickly tightened. Refrigerant lines, oil-charging lines, gage lines, and control lines, although generally of small size and short length, should be purged with refrigerant-gas immediately before they are connected to the system. When connecting lines that have been removed are to be used again, the ends of the lines should be capped to protect the connecting fitting and to ensure that the tube will be clean when it is used again.

When MAJOR REPAIRS are to be made to a major portion of the system or when the system is to be secured for an extended period, the refrigerant system must be pumped down to return all refrigerant to the receiver. Sufficient refrigerant-gas should be retained within the system to create a positive pressure of approximately 2 psig throughout the circuit, except within the compressor-discharge line and the condenser, and between the receiver and the main liquid-line shutoff valve. To pump down the system, close the main liquid-line shutoff valve and the dehydrator-bypass valve (if installed), and open the cooling-coil solenoid valves. Allow the compressor to operate on manual control until the suction pressure reaches approximately 1/2 to 2 psig; then stop the compressor. Repeat the operation until the liquid refrigerant in the circuit has evaporated and the suction pressure remains relatively constant at 1/2 to 2 psig.

During the pump-down period, you can trace the evaporation of liquid refrigerant to the liquid line back to the main liquid-line shutoff valve by the formation of frost and its subsequent melting as the liquid refrigerant is evaporated and superheated. Open the power-supply switch to the compressor; close the compressor suction and discharge shutoff valves. Shut off the water supply to the condenser and drain the condenser water. When the amount of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid refrigerant must be drawn off into separate refrigerant drums.

To drain the refrigerant charge from the system when it is necessary to make repairs to the condenser, the liquid receiver, or the compressor discharge line, or for any other reason, proceed as follows:

1. Start the compressor and pump down the cooling coil and suction-line pressure, with the liquid-line valve at the receiver outlet closed, to the point at which the low-pressure control switch stops the unit.

2. When the compressor is stopped by the low-pressure cutout switch, restart the unit manually and continue the pumping-down procedure until the suction pressure reaches approximately 2 psig and stops the compressor. Repeat the operation in periodic cycles until the liquid refrigerant in the circuit has evaporated and the suction pressure remains relatively constant between 1/2 and 5 psig.

3. Close the compressor discharge line valve; close all liquid valves at the cooling coils.

4. Connect an empty R-12 service drum to the refrigerant drain valve. (Before connecting the drum to the R-12 system, cool the drum thoroughly so the refrigerant will drain rapidly into the drum.) Always use a clean R-12 service drum, containing no air or water, so that the drained R-12 is kept in suitable condition for future use.

5. Purge the air out of the line connecting the drain valve and the drum by leaving the connection at the drum valve open as you slowly flush refrigerant through the line and out at the connection; then close the connection. Drain the R-12 into the cooled drum by opening the drain valve and the service drum valve.

6. When the service drum is full, close the drain valve and permit the R-12 liquid in the drain line to evaporate; then, close the service drum valve and disconnect the drum from the system.

7. Weigh the drum while filling, to be certain that it is not overcharged. The net and gross weights are stamped on the drum. (These weights include that of the cast iron protector cap which fits over the cylinder valve.)

> CAUTION: NEVER fill a service drum beyond its rated capacity; drum rupture may result from hydraulic pressure upon rise in temperature.

8. Discharge the R-12 vapor that remains in the condenser and receiver to the atmosphere through the purge valve.

TESTING FOR REFRIGERANT LEAKS

Refrigerant leaks mean the loss of the refrigerating effect and loss of refrigerant. Various tests are used to determine the existence of leaks in refrigerant systems. Pressure tests are used after a system has been installed and after extensive repairs or replacement of parts has been made. Pressure tests are made BEFORE the system is charged with refrigerant. Charged systems are tested for leakage with either a halide leak detector, an electronic refrigerant gas detector, or with soapsuds; which of the three methods to be used will depend largely upon the size of the leak and upon the type of space in which the test is to be performed.

As an MM, you will be required to know how to use the detectors and how to use soapsuds to check for the refrigerant leakage.

In addition to tests for leaks that are made at periodic intervals, tests should be made before the compressors are started and at any other time that a shortage of refrigerant in the system is suspected. Unusual operating conditions which indicate a shortage of refrigerant in the system are:

1. High suction-line temperatures.

2. Relatively high crankcase and cylinder temperatures.

3. Excessively high refrigerant temperature in the liquid line.

4. Bubbles in the refrigerant sight-flow indicator.

5. Liquid refrigerant carrying partially through the coil, with considerable superheat at the thermal element.

6. Short cycle or compressor running continuously.

7. Excessive oil seepage at shaft seal connection.

8. Oil seepage at refrigerant-system piping and compressor connections.

A shortage of refrigerant in the system nearly always indicates the presence of leaks. When a shortage of refrigerant is found, the entire system should be tested for leaks by one of the following methods.

Halide Leak Dector

The most positive method of detecting leaks in a refrigerant system is with a halide leak

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detector which consists essentially of a torch burner, a copper reactor plate, and exploring hose. (See fig. 11-20.)

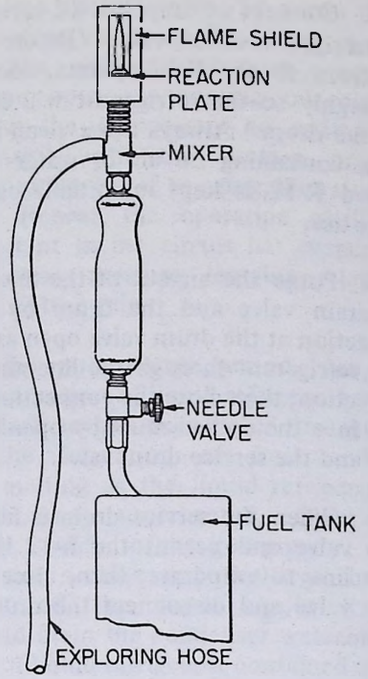
> CAUTION: Do NOT use a halide or electronic leak detector in any ammunition spaces. Soap-suds is the ONLY method of leak detection to be used in these spaces.

Most detectors use either acetylene gas or alcohol as a fuel. Pressure for detectors that use alcohol is supplied by a pump. If a pump-pressure type alcohol-burning detector is used, be sure that the air pumped into the fuel tank is pure.

Atmosphere suspected of containing R-12 vapor is drawn by injector action through the exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of R-12 present, the color of the torch flame will change from blue (neutral) to green as the R-12 comes in contact with the reactor plate. The shade of green will depend upon the relative amount of R-12 present; a pale green indicates small concentrations and a darker green shows heavier concentrations. Excessive quantities of R-12 will cause the flame to burn with a vivid purple color. Extreme concentrations of R-12 may extinguish the flame by crowding out the oxygen available from the air.

When a leak detector is used, best results are obtained if the following precautions are observed:

1. Be sure that the reactor plate is properly in place.
2. Adjust the flame so that it does not extend beyond the end of the burner. (A small flame is much more sensitive than a large flame. If you experience difficulty in lighting the torch when it is adjusted to produce the necessary small flame, block the end of the exploring hose until the fuel ignites; this will reduce the amount of oxygen drawn in. Then gradually open the hose.)
3. Clean out the exploring tube if the flame continues to have a white or yellow color. (A white or yellow flame indicates that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; you can make this check from time to time by holding the end of the tube to your ear.
5. Hold the end of the exploring tube close to the joint being tested to prevent dilution of the sample by stray air currents.
6. Move the end of the exploring hose tube slowly and completely around each joint being tested. (Leak testing cannot be hurried safely. There is a definite time lag between the moment when air enters the exploring tube and the moment it reaches the reactor plate; permit sufficient time for the sample to reach the reactor plate.)
7. If a greenish flame is noted at any time, repeat the test in the same vicinity until the source of the refrigerant is determined.



47.105

Figure 11-20.—Halide leak detector.

A halide torch or an electronic refrigerant gas detector is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of R-12. This is most likely to happen in a small or poorly ventilated compartment. If a compartment is contaminated by R-12 and cannot be ventilated, or if in an ammunition space, the soapsuds test must be used.

Soapsuds Test

In using the soapsuds test, prepare the soap-and-water solution so that it has the consistency of liquid hand soap and will work up a lather on a brush. (The lather will remain wet for a longer period if a few drops of glycerin are added to the solution.)

Apply the lather all the way around the joint; then look carefully for bubbles. If a joint is so located that a part of it is not visible, use a small mirror when inspecting that part.

Remember that it sometimes takes a minute or more for bubbles to appear if the leak is small. Doubtful spots should be lathered and examined a second time.

Always follow a definite procedure in testing for refrigerant leaks, so that you do not miss any joints. If available, use a ship's plan or authorized drawing of the system to "map out" your search. The extra time spent in testing all joints will be justified. Even the smallest leak is not to be considered negligible. However, insignificant the leak may seem, it eventually empties the system of its charge to the point of faulty plant operation. Because R-12 is practically odorless, the first indication that leakage exists is the loss of refrigerating effect. A refrigerant system should never be recharged until all leaks are discovered and definitely repaired.

NEVER use oil to test for R-12 leaks. Oil is not reliable because of the capacity of the oil to absorb R-12. If a small leak should exist where oil has been applied, the R-12 will be absorbed by the oil and will show no indication (bubbles) of the leak until the oil is saturated with R-12. Furthermore, if a halide torch is used to test a joint that has been tested previously with oil, the torch will give a false indication because of the R-12 released from the oil.

TESTING FOR AIR AND NONCONDENSABLE GASES

Every reasonable precaution MUST be taken to keep air and noncondensable gases out of a refrigerant system. When air enters the system the condenser must be purged, with a resultant loss of refrigerant. Atmospheric air always contains some moisture, which will enter the system when air does. A refrigerant system must be kept as moisture-free as possible to eliminate such troubles as the freezing of water at the expansion valves, internal oxidation or corrosion of parts, and emulsification or sludging of lubricating oils.

Air and noncondensable gases in a refrigerant system are pumped through the system and are discharged by the compressor into the condenser. These gases are trapped in the condenser by the liquid seal maintained over the receiver outlet. Generally, these gases are lighter than the relatively dense R-12 vapor; they tend to collect, therefore, in the upper part of the condenser when the compressor is stopped. The purge valve for discharging these gases to the atmosphere is located either in the upper part of the condenser shell or in the compressor discharge line above the condenser. While the compressor is in operation, any noncondensable gases in the system are thoroughly mixed with the R-12 vapor. This mixing is caused by the turbulence produced by the rapidly pulsating discharge of refrigerant into the condenser. Therefore, it is not advisable to attempt to purge noncondensable gases from the system while the compressor is in operation. Noncondensable gases in a condenser cause excessive condensing pressures with a resultant loss in plant efficiency.

The best time to check an R-12 system for noncondensable gases is immediately before the compressor starts after a shutdown period. When a condenser is to be checked for noncondensable gases, the gages and thermometers used must be in calibration and the system must have sufficient refrigerant charge so that the liquid refrigerant present in the receiver will seal the liquid line connection.

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The following procedure should be followed to check a refrigerant system for noncondensable gases:

1. Close the liquid-line valve.
2. Shut off the compressor and close the suction-line valves.
3. Determine the actual condensing temperature of the refrigerant. A service gage should be installed in the compressor discharge connection if a discharge-pressure gage is not already provided. An approximation of the actual condensing temperature of the refrigerant has been reached when no further decrease is noted in the discharge pressure. (On water-cooled condensers, you can speed up the reduction in pressure by circulating the condenser water until the discharge pressure is reduced.) In most ships the thermometer provided in the liquid line at the receiver indicates the actual condensing temperature. If a thermometer is not installed in an air-cooled condenser application, one should be placed near the condenser to record the ambient temperature at that location. When the temperature of an air-cooled condenser has dropped to the ambient temperature, the reading of the thermometer will approximate the actual condensing temperature.
4. On the compound-pressure gage, read the condensing temperature which corresponds to the condensing pressure registered by the high-pressure gage; the temperature indicated on the temperature scale is the condensing temperature of pure R-12 at the pressure indicated by the gage.
5. Subtract the existing condensing temperature from the condensing temperature of pure R-12 at the existing condenser pressure. If the difference between these two temperatures is more than 5° F, it will be necessary to purge the condenser of noncondensable gases.

If the above test indicates the need for purging, slowly release the noncondensable gases. When a purge valve is not provided, purge the gases by opening the discharge pressure gage connection.

The proportion of R-12 gas that will mix with the condensable gases and escape, while the condenser is being purged, will depend on the rate of purging and upon the concentration of the noncondensable gases in the condenser. No practical test is available aboard ship to determine definitely when an excessively high proportion of R-12 gas is being purged with the noncondensable gases. To keep the R-12 loss to a minimum when the condenser is being purged, purge slowly and frequently check the condenser for noncondensable gases. R-12 is odorless in concentrations of less than 20% by volume in air; in heavier concentrations, however, it resembles carbon tetrachloride in odor. If you can get close to the purge-valve discharge, you may be able to determine by the odor of the purged gases when purging should be discontinued and when the check for noncondensable gases should be repeated. PROTECT YOUR EYES WITH GOGGLES WHEN YOU ARE CHECKING THE ODOR OF PURGED GASES.

CHECKING COMPRESSOR OIL

If the apparent oil level observed immediately after a prolonged shutdown period is lower than normal, it is almost certain that the actual working oil level is far too low. After you have added a sufficient quantity of oil to raise the apparent oil level to the center of the bull's-eye sight glass, check the actual oil level as follows:

1. Operate the compressor on MANUAL control for at least 1 hour. If the compressor is operating on a water cooler or other coil that is apt to freeze, observe the temperature and interrupt compressor operation as necessary to prevent freezing. Repeat cycling until the total running time (1 hour) is obtained. Then slowly close the suction line stop valve.
2. Stop the compressor. If the compressor is force lubricated, immediately observe the oil level in the sight glass. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are immersed in the lubricating oil, then check the oil level.

To check the oil level when the compressor has been running on its normal cycle with no abnormal shutdown period, proceed as follows:

1. Wait until the end of a period of operation; if the operation is continuous, wait

until the compressor has been in operation at least 1/2 hour, then stop the compressor.
2. As soon as the compressor stops, observe the oil level in the sight glass on force-lubricated compressors. If the compressor is splash lubricated, turn the flywheel until the crankshaft and connecting rod ends are satisfactorily immersed in the lubricating oil; then check the oil level.

Do NOT remove oil from the crankcase because of an apparent high level unless too much oil has been previously added, or unless it is apparent that oil from the crankcase of one compressor of the plant has been inadvertently deposited in the crankcase of another.

However, if the oil level is lower than its recommended height on the glass, a sufficient quantity of oil should be added to obtain the desired level. Do NOT add more oil than is necessary; too much oil can result in excessive oil transfer to the cooling coils.

Adding Oil

There are two common methods of adding oil to a compressor. In one type of installation, a small oil-charging pump is used for adding oil to the compressor crankcase. In another type, a clean, well-dried funnel is used. In either installation, you must be careful to prevent air or foreign matter from entering the compressor.

When performing hourly checks of the compressors, you may observe either no oil in the crankcase or a very low oil level on the sight glass. This indicates that the oil has left the compressor and is circulating in the system; it will be necessary to add oil and operate the system. After the compressor has reclaimed the excessive oil in the system, the excess oil should be drained.

Removing Oil

To remove oil from the compressor crankcase, reduce the pressure in the crankcase to approximately 1 psi by gradually closing the suction line stop valve. Then stop the compressor and close the suction and discharge line valves. Loosen the lubricating oil drain plug near the bottom of the compressor crankcase and allow the required amount of oil to drain out. Since the compressor crankcase is under a slight pressure, do NOT fully remove the drain plug from the compressor; allow the oil to seep out around the threads of the loosened plug. When the desired amount of oil has been removed, tighten the drain plug, open the suction and discharge line valves, and start the compressor. If an oil drain valve is provided in lieu of a plug, you can drain the required amount of oil without pumping down the compressor.

Renewing the Lubricating Oil

When clean copper tubing is used for R-12 systems and when reasonable care has been taken to prevent the entrance of foreign matter and moisture during installation, the oil in the compressor crankcase will probably not become so contaminated that it requires renewal more than once a year. When iron or steel pipe and fittings are used in the R-12 system, a sample of oil from the compressor crankcase should be withdrawn into a clean glass container every 3 months. If the sample shows contamination, all the lubricating oil should be renewed. It is good practice to check the cleanliness of the lubricating oil after each cleaning of the compressor suction scale trap.

CARE OF V-BELTS

Excessive looseness will cause slippage, rapid wear, and deterioration of V-belts. On the other hand, a belt that is too tight will cause excessive wear of both the belt and the main bearing of the compressor. In extreme cases it may cause a bad seal leak. When properly tightened, a belt can be depressed 1/2 to 3/4 inch by the pressure of one finger at a point midway between the flywheel and the motor pulleys.

When replacement of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts should be installed. Belts stretch considerably during the first few hours of operation. Replacement of a single belt will upset the load balance between the new and old belts and will be a potential source of trouble. It is better practice to run the unit temporarily with a defective belt removed than to operate a

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new belt in conjunction with two or more seasoned belts.

V-belts, motor pulleys, and compressor flywheels should be kept dry and free of oil. Belt dressing should NEVER be used.

SETTING CONTROL AND SAFETY DEVICES

A refrigeration plant cannot operate efficiently and safely unless the control and safety devices are in good working order and set properly. When a new control or safety device is installed in a refrigeration system, it must be adjusted or set to function at pressures or temperatures in accordance with the plant design. Periodic tests and inspections may indicate faulty plant operation that is due to improperly adjusted control or safety devices. As a Machinist's Mate, you must know how these devices operate and how to adjust them.

This section contains information on some of the most common types of control and safety devices used by the Navy.

The methods of setting the low-pressure switch, the water failure switch, and the thermostatic switch are similar; however, these switches differ as to operating range, purpose, and setting. Also, the high-pressure switch and the water failure switch are safety devices while the low-pressure switch and the thermostatic switches are control devices. For detailed information, consult *Naval Ships' Technical Manual* and the manufacturer's technical manuals.

High-Pressure Switch

The high-pressure switch has an operating range of 60 to 350 psig and an adjustable differential (difference between the cut-in point and cutout point). Turning the range adjusting screw clockwise raises both the cut-in point and cutout point. Turning it counterclockwise lowers these points. The differential adjustment affects only the cutout point. Turning it clockwise raises the cutout point and turning it counterclockwise lowers the cutout point.

To set the switch, first remove the cover plate. Then the two adjusting screws; one labeled differential, the other labeled range, are easily accessible. Start the compressor and control the discharge pressure by throttling the circulating water through the condenser. Turn the differential screw to its limit counterclockwise and turn the range screw to its limit clockwise. Raise the compressor discharge to about 10 psig above the desired cut-in pressure. Turn the range screw counterclockwise until the contactor in the switch opens, thereby stopping the compressor. When the discharge pressure drops the desired cut-in pressure, turn the range screw clockwise until the contacts close, starting the compressor. The cut-in point is now set. With the compressor running, turn the differential screw to its limit clockwise, then raise the discharge pressure to the desired cutout pressure. Turn the differential screw counterclockwise until the contacts open, stopping the compressor. The cutout point is now set.

Low-Pressure Switch

The low-pressure switch has an operating range of 20 inches of vacuum to 80 psig and an operating differential of 9 psig to 30 psig.

To set the low pressure switch, start the compressor and control the suction pressure by throttling the compressor suction valve. Turn the range and differential adjustment screws counterclockwise. Lower the suction pressure to about 10 psig below the desired cut-in pressure and turn the range screw clockwise until the switch contacts open, stopping the compressor. Allow the suction pressure to rise to the desired cut-in pressure and turn the range screw counterclockwise until the switch contacts close, starting the compressor. The cut-in point is now set. Turn the differential screw to its limit clockwise, throttle the suction valve to lower the suction pressure to the desired cutout pressure. Turn the differential screw counterclockwise until the switch contacts open, stopping the compressor. The cutout point is now set.

Water Failure Switch

The water failure switch should be set to cut in at 15 psig and to cut out at 5 psig. To set the water failure switch, turn the differential screw to its limit counterclockwise for minimum

differential since the required differential (difference between cut-in and cutout points) is 10 psig. Throttle the water overboard valve until a pressure of 15 psig is maintained at the condenser inlet. Turn the range screw clockwise until the switch contacts open, then turn the screw counterclockwise slowly until the contacts close. Slowly shut off the water supply, decreasing the pressure. The contacts should open at 5 psig.

Thermostatic Expansion Valve

The thermostatic expansion valve is generally factory set and seldom needs adjustment. The design and construction of expansion valves vary greatly. Figure 11-21 shows a cross-sectional assembly view of a type that is generally used aboard ship. Other designs may have different arrangements for adjustment, sealing, and control.

When the thermostatic expansion valve is operating properly, the temperature at the outlet side of the valve is much lower than that at the inlet side. If this temperature difference does not exist when the system is in operation, the valve seat is probably dirty and clogged with foreign matter.

Once a valve is properly adjusted, further adjustment should not be necessary. The major trouble encountered can usually be traced to a collection of moisture or dirt at the valve seat and orifice. The symptoms of improper valve operation should be carefully analyzed before concluding that the valve is out of adjustment. Once a valve is properly adjusted, additional adjustment should not be necessary unless changes are made to the cooling coil arrangement or thermal element location.

By means of a gear and screw arrangement, the thermostatic expansion valve is adjusted to maintain a superheat ranging from approximately 4° to 12° F at the cooling coil outlet. The proper superheat adjustment varies with the design and service-operating conditions of the valve and the design of the particular plant. Increased spring pressure increases the degree of superheat at the coil outlet and decreased pressure has the opposite effect. Many thermostatic expansion valves are initially

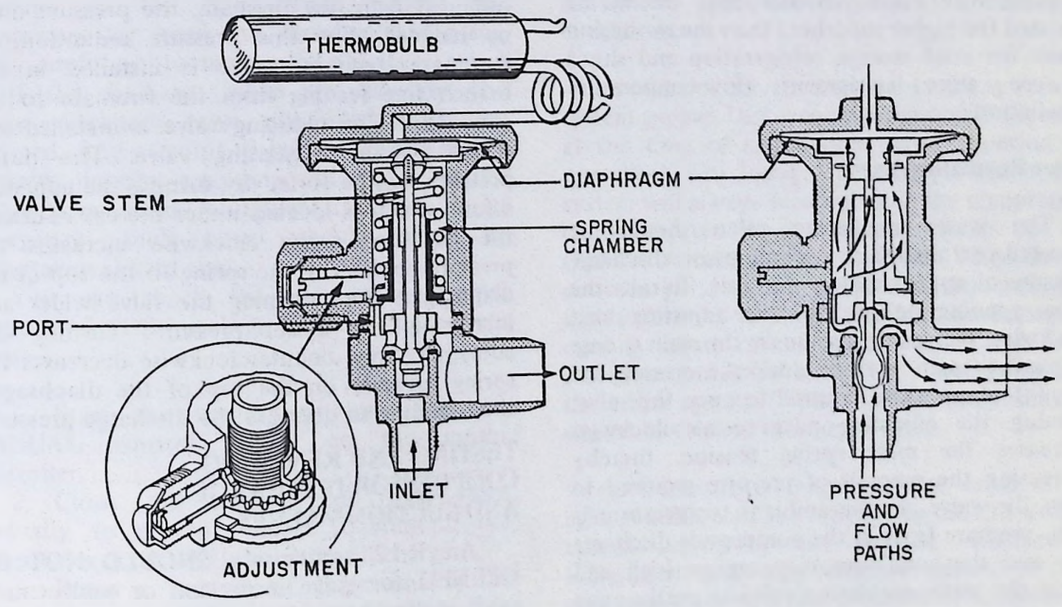


Figure 11-21.—Thermostatic expansion valve.

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adjusted by the manufacturer to maintain a predetermined degree of superheat, and no provision is made for further adjustments in service.

If expansion valves are adjusted to give a high degree of superheat at the coil outlet or if the valve is stuck shut, the amount of refrigerant admitted to the cooling coil will be reduced. With an insufficient amount of refrigerant, the coil will be "starved" and will operate at a reduced capacity. Compressor lubricating oil carried with the refrigerant may tend to collect at the bottom of the cooling coils, thus robbing the compressor crankcase and providing a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for a too low degree of superheat or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. If the liquid collects at a low point in the suction line or coil and is drawn back to the compressor intermittently in slugs, there is danger of injury to the moving parts of the compressor.

In general, the expansion valves for air conditioning and water cooling plants (high-temperature installations) must be adjusted for higher superheat than the expansion valves for cold storage refrigeration and ship's service store equipment (low-temperature installations).

Water Regulating Valve

The water regulating valve should be adjusted to maintain a compressor discharge pressure of approximately 125 psig. To raise the valve opening point, turn the adjusting nuts clockwise, increasing tension on the main spring. Increasing main spring tension increases the amount of pressure required to open the valve. Turning the adjusting nuts counterclockwise decreases the main spring tension, thereby decreasing the amount of pressure required to open the valve. If the ambient temperature is high, pressure (gas) in the compressor discharge line and the condenser may remain high and cause the water regulating valve to partly open when the compressor is idle. In such instances, the point of valve opening should be raised just enough to cause the valve to close during compressor shutdown.

The valve can be flushed by opening it with an outside force; a screwdriver or similar tool may be used to force the spring yoke.

Thermostatic Switch

The thermostatic switch which operates the solenoid valve is similar to the low-pressure switch. Tubing connects a bellows in the thermostatic switch to a thermobulb in the compartment being cooled. The thermobulb and tubing are charged with R-12 or some other volatile liquid. Temperature changes in the refrigerated compartment cause corresponding pressure changes of the actuating medium in the thermobulb. These pressure changes are transmitted to the thermostatic switch, through the connecting tubing. To set or adjust the cut-in and cutout points of the thermostatic switch, the same procedure is used as in setting and adjusting the low-pressure switch.

Automatic Reducing Valve

When condenser circulating water is obtained from the firemain, the pressure must be reduced. For this pressure reduction, an automatic reducing valve is installed in the branch line leading from the firemain to the condenser. The reducing valve is installed just ahead of the regulating valve. The outlet pressure can be varied by turning the adjusting screw, which is located under the cap. Turning the adjusting screw clockwise increases the pressure applied by the spring to the top of the diaphragm, thus opening the valve wider and increasing the outlet pressure. Turning the adjusting screw counterclockwise decreases the spring pressure on the top of the diaphragm, thus tending to decrease the discharge pressure.

TESTING AND RENEWING COMPRESSOR DISCHARGE AND SUCTION VALVES

An R-12 compressor SHOULD NOT BE OPENED for valve inspection or replacement until it has been determined that the faulty operation of the system is caused by improper functioning of the valves. Faulty compressor

valves may be indicated by either an increase in discharge temperature or decrease in the normal compressor capacity. Either the compressor will fail to pump at all or the suction pressure cannot be pumped down to the designed value, and the compressor will run for abnormally long intervals (or even continuously). If the compressor shuts down for short periods (short cycles), the compressor valves may be leaking.

If the refrigeration plant is not operating satisfactorily, it will be best to first shift the compressor and then check the operation of the plant. If the operation of the plant is satisfactory when the compressors have been shifted, this indicates that the trouble was with the compressor.

The compressor discharge valves may be tested by pumping down the compressor to 2 psig, then stopping the compressor, and quickly closing the suction and discharge line valves. If the discharge pressure drops at a rate in excess of 3 psi per minute and the crankcase suction pressure rises, there is evidence of compressor discharge valve leakage. If it is necessary to remove the discharge valves with the compressor pumped down, break the connection to the discharge pressure gage to release discharge pressure on the head. Then remove the compressor top head and discharge valve plate, being careful not to damage the gaskets.

If the discharge valves are defective, the entire discharge valve assembly should be replaced. Any attempt to repair the valve would probably involve relapping and would require highly specialized equipment. Except in an emergency, such repair should never be undertaken aboard ship.

You can check the compressor internal suction valves for leakage by performing these steps:

1. Start the compressor by using the MANUAL control switch on the motor controller.
2. Close the suction line stop valve gradually to prevent violent foaming of the compressor crankcase lubricating oil charge.
3. Pump a vacuum of approximately 20 inches of mercury. If this vacuum can be readily obtained, the compressor suction valves are satisfactory.

Do not expect the vacuum to be maintained after the compressor stops because R-12 being released from the crankcase oil will cause the pressure to rise. Do NOT attempt to check compressor suction valve efficiency of new R-12 units until after the compressor has been in operation for at least 3 days. It may be necessary for the valves to wear in.

However, if any of the compressor valves are defective, the compressor should be pumped down, opened, and the valves inspected. Defective valves or pistons should be replaced with spare assemblies.

SHAFT SEALS

The first indication of shaft seal failure is excessive oil leaking at the shaft. When the seal requires replacement or when signs of abnormal wear or damage to the running surfaces are present, a definite reason for the abnormal conditions exists and an inspection should be made. It is very important to locate and correct the trouble, or the failure will recur.

Seal failure is very often the result of faulty lubrication, usually due to the condition of the crankcase oil. Dirty or acidic oil is generally caused by one or both of the following conditions:

1. Dirt or foreign material in the system or system piping. Dirt frequently enters the system at the time of installation. After a period of operation, any foreign material present in the system will always accumulate in the compressor crankcase, tending to concentrate in the oil chamber surrounding the shaft seal. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal. At any time foreign material is found in the lubricating oil, the entire system (piping, valves, and strainers) should be cleaned thoroughly.

2. Moisture is frequently the cause of an acid condition of the lubricating oil. Oil in this condition will not provide satisfactory lubrication and will promote failure of the compressor parts. If the presence of moisture is suspected, a dryer should be used when the compressor is put into operation.

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Removing Shaft Seal

In the event a shaft seal must be repaired or renewed, the procedure is generally as follows:

If the seal is broken to the extent that it permits excessive oil leakage, do not attempt to pump the refrigerant out of the compressor because air (containing moisture) will be drawn into the system through the damaged seal. Moisture in the air may cause expansion valves to freeze. If oil is leaking excessively, close the compressor suction and discharge valves and relieve the pressure to the atmosphere by loosening a connection on the compressor discharge gage line. If the condition of the seal permits, pump down the compressor as explained earlier in this chapter.

Next, drain and measure the oil from the compressor crankcase so that an equal amount can be replaced. Since the oil contains refrigerant, it will foam while being drained. The oil drain valve or plug should be left open while you are working on the seal so that refrigerant escaping from the oil remaining in the crankcase will not build up pressure and unexpectedly blow out the seal while it is being removed.

Remove the compressor flywheel (or coupling) and carefully remove the shaft seal assembly. If the assembly cannot be readily removed, build up a slight pressure in the compressor crankcase by slightly opening the compressor suction valve, taking the necessary precautions to support the seal to prevent it from being blown from the compressor and damaged.

Installing Shaft Seal

When replacement is made, the entire seal assembly should be replaced. The parts should be cleaned and replaced in accordance with the manufacturer's instructions.

Wipe the shaft clean with a cloth. Do NOT use a dirty or lint-bearing cloth. Unwrap the seal, being careful not to touch the bearing surfaces with your hands. Rinse the seal in an approved solvent and allow it to air-dry. (Do NOT wipe the seal dry.) Dip the seal in clean refrigerant oil. Insert the assembly in accordance with the manufacturer's instructions and bolt the seal cover in place, tightening the bolts evenly. Replace the flywheel and belts and add the amount of oil removed; then test the unit for leaks by opening the suction and discharge valves and using a halide leak detector.

CHARACTERISTICS OF REFRIGERANTS

Pure R-12 (CCl_2F_2) is colorless. In concentrations of less than 20% by volume in air, R-12 is odorless; in higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of -21° F at atmospheric pressure. At ordinary temperatures R-12 is a liquid when under a pressure of approximately 70 to 75 psig.

Mixtures of R-12 vapor and air, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous; it will not support respiration, however, and it produces mild euphoria when it is inhaled in sufficient quantities. If R-12 concentration becomes excessive, unconciousness or even death may result due to lack of oxygen to the brain. In view of R-12's low boiling point at atmospheric pressure, you must always protect your eyes from contact with liquid R-12; the liquid will freeze the tissues of the eyes. Always wear goggles if you are to be exposed to R-12.

R-12 in either a liquid or vapor state is nonflammable and nonexplosive. R-12 will not corrode the metals commonly used in refrigerating systems.

One REMOTE health hazard could exist if leakage of a large amount of R-12 vapor came in direct contact with an open flame of high temperature (about 1,000° F) and decomposed. To be a health hazard, the leakage of R-12 must be within a confined and poorly ventilated space and the vapor must come in contact with a high-temperature flame. When these conditions exist, however, the products of decomposition are pungent and irritating, rendering them noticeable even when present only in minute quantities; ample warning is available before concentrations dangerous to health are reached.

R-12 is a stable compound capable of undergoing (without decomposition) the physical changes required of it in refrigeration service. It is an excellent solvent and has the ability to loosen and remove all particles of dirt, scale, and oil with which it comes in contact within a refrigerating system.

R-22 ($CHClF_2$) and R-11 (CCl_3F) are colorless, nonexplosive, nonpoisonous refrigerants with many properties similar to those of R-12.

SAFETY PRECAUTIONS

Refrigerants are furnished in cylinders for use in shipboard refrigeration systems. The following precautions MUST BE OBSERVED in the handling, use, and storage of these cylinders:

1. NEVER drop cylinders nor permit them to strike each other violently.
2. NEVER use a lifting magnet or a sling (rope or chain) when handling cylinders. A crane may be used if a safe cradle or platform is provided to hold the cylinders.
3. Caps provided for valve protection must be kept on cylinders except when the cylinders are being used.
4. Whenever refrigerant is discharged from a cylinder, the cylinder should be weighed immediately and the weight of the refrigerant remaining in the cylinder should be recorded.
5. NEVER attempt to mix gases in a cylinder.
6. NEVER put the wrong refrigerant into a refrigeration system! No refrigerant except the one for which a system was designed should ever be introduced into the system. Check the equipment nameplate or the manufacturer's technical manual to determine the proper refrigerant type and charge. Putting the wrong refrigerant into a system may cause a violent explosion.
7. When a cylinder has been emptied, close the cylinder valve immediately to prevent the entrance of air, moisture, or dirt. Also, be sure to replace the valve protection cap.
8. NEVER use cylinders for any purpose other than their intended purpose. Do NOT use them as rollers, supports, etc.
9. Do NOT tamper with the safety devices in the valves or cylinders.
10. Open cylinder valves slowly. NEVER use wrenches or other tools except those provided by the manufacturer.
11. Be sure that the threads on regulators or other connections are the same as those on the cylinder valve outlets. NEVER force connections that do not fit.
12. Regulators and pressure gages provided for use with a particular gas must NOT be used on cylinders containing other gases.
13. NEVER attempt to repair or alter cylinders or valves.
14. NEVER fill R-12 cylinders beyond 85% capacity.
15. Store cylinders in a cool, dry place, in an UPRIGHT position. If the cylinders are exposed to excessive heat, a dangerous increase in pressure will occur. If cylinders must be stored in the open, ensure that they are protected against extremes of weather. NEVER allow a cylinder to be subjected to a temperature above 125° F.
16. NEVER allow R-12 to come in contact with a flame or red-hot metal! When exposed to excessively high temperatures, R-12 breaks down into PHOSGENE gas, an extremely POISONOUS substance.

Because R-12 is such a powerful freezing agent that even a very small amount can freeze the delicate tissues of the eye, causing permanent damage, it is essential that goggles be worn by all personnel who may be exposed to a refrigerant, particularly in its liquid form. If refrigerant does get into the eyes, the person suffering the injury should receive IMMEDIATE medical treatment to avoid permanent damage to the eyes. In the meantime, put drops of clean olive oil, mineral oil, or other nonirritating oil in the eyes, and MAKE SURE that the person does NOT rub his eyes. CAUTION: Do NOT use anything except clean, nonirritating oil for this type of eye injury.

If R-12 comes in contact with the skin, it may cause frostbite. This injury should be treated as any other cause of frostbite. Immerse the affected part in a warm bath for about 10 minutes, then dry carefully. Do NOT rub or massage the affected area.

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Although R-12 is generally classed as nontoxic, it IS dangerous in high concentrations such as might occur from excessive R-12 leakage in a confined or poorly ventilated space due to lack of oxygen. If someone should be overcome by R-12, remove the person IMMEDIATELY to a well-ventilated place and get medical attention at the earliest opportunity. Watch for breathing. If the person is not breathing, begin artificial respiration.

CHAPTER 12

AIR CONDITIONING

Air conditioning is a field of engineering dealing with the design, construction, and operation of equipment used in establishing and maintaining desirable indoor air conditions. It is the science of maintaining the environment of an enclosure at any required temperature, humidity, and purity. As such, air conditioning involves the cooling, heating, dehumidifying, ventilating, and purifying of air.

This chapter covers the principal factors involved in the conditioning of air; the type of equipment used in ventilating, cooling, and heating the air; and general information concerning the maintenance of air conditioning equipment.

PURPOSES OF AIR CONDITIONING AND RELATED FACTORS

One of the chief purposes of air conditioning aboard ship is to keep the crew comfortable, alert, and physically fit. The human body cannot long maintain a high level of efficiency under adverse environmental conditions. A variety of compartments must be maintained at a prescribed temperature with proper circulation and must contain proper moisture content, correct proportion of oxygen and an acceptable level of air contamination (dust, airborne dirt, etc).

The health and comfort of the crew is only one purpose of air conditioning. Mechanical cooling or ventilation must also be provided in AMMUNITION SPACES to prevent deterioration of ammunition components; in GAS STORAGE SPACES to prevent excessive pressure buildup in containers and contamination in the space caused by gas leakage; and in ELECTRICAL/ELECTRONIC EQUIPMENT SPACES to maintain the ambient (encompassing) temperature and humidity as specified for the equipment.

Some of the principal factors to consider in achieving the objectives of air conditioning are humidity, heat of the air, temperature, body heat balance, the effect of air motion, and the sensation of comfort.

HUMIDITY

Humidity is the vapor content of the atmosphere, and it has a great influence on human comfort. The common expression, "It isn't the heat, it's the humidity," indicates an awareness of the discomfort produced by moisture-laden air in hot weather. Extremely low moisture content also has undesirable effects on the human body. The measurement and control of the moisture content of the air is an important phase of air conditioning engineering. To understand this phase of air conditioning you should become familiar with the meaning of saturated air, absolute and specific humidity, and relative humidity.

Saturated Air

Depending on its temperature (at a given atmospheric pressure) air can hold varying amounts of water vapor. As temperature rises, the amount of moisture that the air can hold increases (assuming no change in atmospheric

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pressure). But for every temperature there is a definite limit to the amount of moisture that the air is capable of holding. When air contains the maximum amount of moisture that it can hold at a specific temperature and pressure, it is said to be saturated.

The saturation point is usually called the DEWPOINT. If the temperature of saturated air falls below its dewpoint, some of the water vapor in the air must condense to water. The dew that appears on decks and bulkheads in the early morning, when there is a drop in temperature, is such a condensation. The "sweating" of cold water pipes is the result of water vapor from the relatively warm air condensing on the cold surface of the pipes.

Absolute and Specific Humidity

The amount of water vapor in the air is expressed in terms of the weight of the moisture. The weight is usually given in grains (7,000 grains = 1 pound). ABSOLUTE humidity is the weight in grains of water vapor per cubic foot of air. SPECIFIC humidity is the weight in grains of water vapor per pound of air. (The weight of water vapor refers only to moisture that may be present in the liquid state, such as rain or dew.)

Relative Humidity

Relative humidity is the ratio of the weight of water vapor in a sample of air to the weight of water vapor the same sample of air would contain if saturated at the existing temperature. This ratio is usually stated as a percentage. For example, when air is fully saturated, the relative humidity is 100%. When air contains no moisture at all, its relative humidity is 0%. If air is half-saturated, the relative humidity is 50%. The normal comfort range of relative humidity for humans is between 30% and 70%.

Insofar as humidity is concerned, the deciding factor in human comfort is the relative humidity, not the absolute or specific humidity.

Just as heat travels from regions of higher temperature to regions of lower temperature, moisture always travels from regions of greater wetness to regions of lesser wetness. If the air above a liquid is saturated, the two are in equilibrium (balance) and no moisture can travel from the liquid to the air; that is, the liquid cannot evaporate. If the air is only partially saturated, some moisture can travel to the air; that is, some evaporation can take place.

When the temperature of the air is 76° F and the relative humidity is nearly 90%, the air is nearly saturated. At such a relative humidity, the body may perspire freely but the perspiration does not evaporate rapidly; thus a general feeling of discomfort results.

However, when the temperature of the same air is 86° F, the relative humidity would then be only 64%. That is, although the absolute amount of moisture in the air is the same, the relative humidity is lower, because at 86° F the air is capable of holding more water vapor than it can hold at 76° F. The body is now able to evaporate its excess moisture and the general feeling is much more agreeable, even though the temperature of the air is 10° higher. (The cooling effect on the body is brought about by the absorption of latent heat during the evaporating process.)

In both examples, the specific humidity is the same, but the ability of the air to evaporate liquid is quite different at the two temperatures. The ability to evaporate moisture is directly indicated by the relative humidity. This is the reason that the control of relative humidity is of extreme importance in air conditioning.

HEAT OF AIR

The heat of air is considered from three standpoints—sensible, latent, and total heat.

SENSIBLE HEAT is the amount of heat which, when added to or removed from air, changes the temperature of the air. Sensible heat changes can be measured by the common, or dry-bulb, thermometer.

Air always contains some water vapor. Any water vapor in the air contains the LATENT HEAT OF VAPORIZATION. (Remember that

the amount of latent heat present has no effect on temperature, and it cannot be measured with a dry-bulb thermometer.)

Any mixture of dry air and water vapor contains both sensible and latent heat. The sum of the sensible heat and the latent heat in any sample of air is called the TOTAL HEAT of the air.

TEMPERATURES

To test the effectiveness of air conditioning equipment and to check the humidity of a space, two different temperatures are considered. These are the dry-bulb and wet-bulb temperatures.

Measurement of Temperatures

The DRY-BULB TEMPERATURE is the temperature of sensible heat of the air, as measured by an ordinary thermometer. Such a thermometer in air conditioning engineering is referred to as a dry-bulb thermometer because its sensing bulb is dry, in contrast with the wet-bulb type described next.

The WET-BULB TEMPERATURE is best explained by a description of a wet-bulb thermometer. It is an ordinary thermometer with a loosely woven cloth sleeve or wick placed around its bulb which is then wet with distilled water. The water in the sleeve or wick is caused to evaporate by a current of air (see next paragraph) at high velocity. This evaporation withdraws heat from the thermometer bulb, lowering the temperature by several degrees. The difference between the dry-bulb and the wet-bulb temperature is called the wet-bulb depression. When the wet-bulb temperature is the same as the dry-bulb, the air is saturated (that is, evaporation cannot take place). The condition of saturation is unusual, however, and a wet-bulb depression is normally expected.

The wet-bulb and dry-bulb thermometers are usually mounted side by side on a frame that has a handle or short chain attached so that the thermometers can be whirled in the air, thus providing a high-velocity air current to promote evaporation. Such a device is known as a SLING PSYCHROMETER (fig. 12-1). When using the sling psychrometer, whirl it rapidly, at least four times per second. Observe the wet-bulb

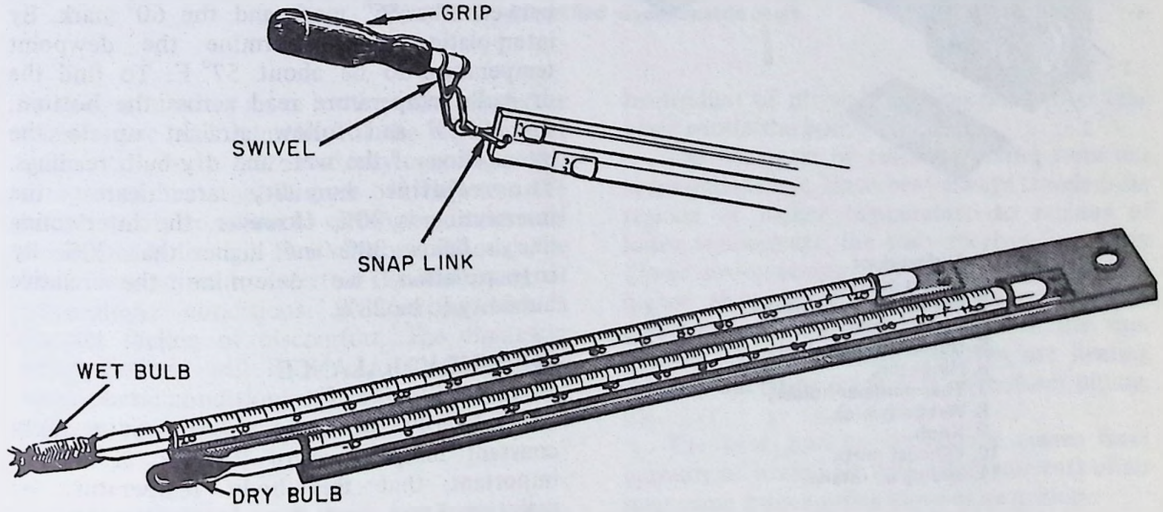


Figure 12-1.—A standard sling psychrometer.

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temperature at intervals. The point at which there is no further drop in temperature is the wet-bulb temperature for that space.

MOTORIZED PSYCHROMETERS (fig. 12-2) are provided with a small motor-driven fan and dry cell batteries. Motorized psychrometers are generally preferred and are gradually replacing sling psychrometers.

Relationships Between Temperatures

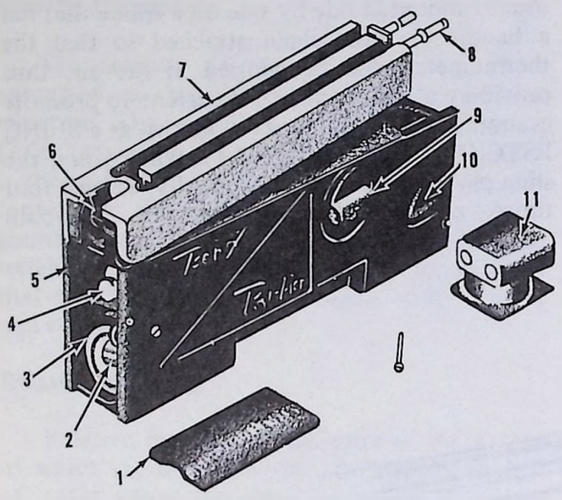
The definite relationships between three temperatures, dry-bulb, wet-bulb, and dewpoint should be clearly understood.

1. When air contains some moisture but is not saturated, the dewpoint temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.

2. As the amount of moisture in the air increases, the difference between the dry-bulb temperature and the wet-bulb temperature will become less.

3. When the air is saturated, all three temperatures will be the same.

4. By using both the wet-bulb and the dry-bulb temperature readings, the relative humidity and the dewpoint temperature can be found on a psychrometric chart. See figure 12-3. The wet-bulb temperature lines are angled across the chart. The dewpoint temperature lines are straight across the chart. This is indicated by the arrows for wet-bulb and dewpoint. Find where the wet-bulb line dry-bulb lines cross, interpolate the relative humidity from the nearest humidity lines to the temperature line crossing point. Then to find the dewpoint, follow the straight dewpoint line closest to the intersection across to the left of the chart and read the dewpoint temperature. For instance, find the wet-bulb temperature of 70° F and trace the line angling down to the right to the dry-bulb temperature of 95° F. Next, to find the dewpoint temperature, follow the dewpoint temperature lines nearest the intersection straight across to the left of the chart. The dewpoint line falls about one-third of the way between the 55° mark and the 60° mark. By interpolation, we determine the dewpoint temperature to be about 57° F. To find the dry-bulb temperature read across the bottom, find 95° F and follow straight up to the intersection of the wet- and dry-bulb readings. The relative humidity arc nearest the intersection is 30%. However, the intersecting line is below 30% and higher than 20%. By interpolation, we determine the relative humidity to be 28%.



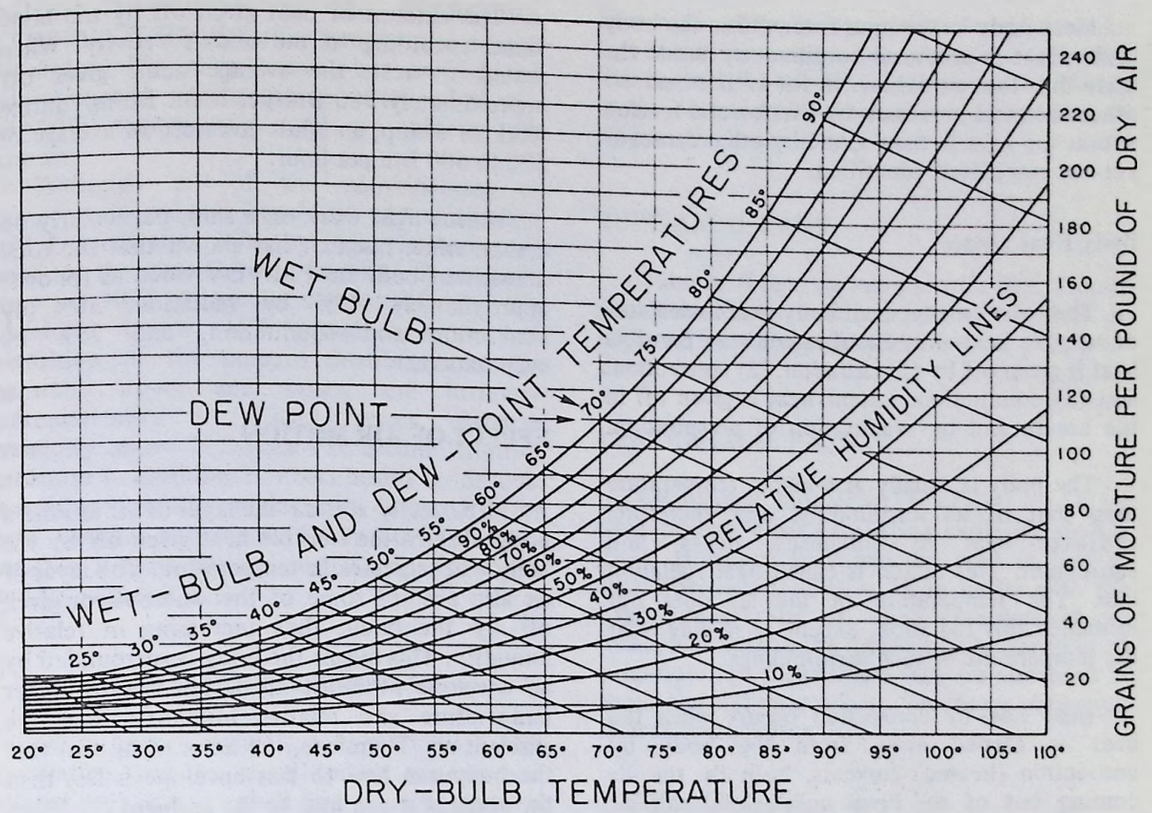
1. Sliding door.
2. Spring contact.
3. Battery compartment.
4. Water bottle.
5. Bottle compartment.
6. Hinge pin.
7. Thermometer holder.
8. Wet-bulb wick.
9. Knob.
10. Exhaust ports.
11. Sliding air intake.

168.23

Figure 12-2.—Exposed view of motorized (hand electric) psychrometer.

BODY HEAT BALANCE

Ordinarily the body remains at a fairly constant temperature of 98.6° F. It is very important that this body temperature be maintained and, since there is a continuous heat gain from internal body processes, there must also be a continuous outgo to maintain body heat in balance. Excess heat must be absorbed



54.176

Figure 12-3.—Simplified psychrometric chart.

by the surrounding air or lost by radiation. As the temperature and humidity of the environment vary, the body automatically regulates the amount of heat that it gives off. However, the body's ability to adjust to varying environmental conditions is limited. Furthermore, although the body may adjust to a certain (limited) range of atmospheric conditions, it does so with a distinct feeling of discomfort. The discussion which follows will help you understand how atmospheric conditions affect the body's ability to maintain a heat balance.

Body Heat Gains

The body gains heat (1) by radiation, (2) by convection, (3) by conduction, and (4) as a by-product of physiological processes that take place within the body.

The heat gain by radiation comes from our surroundings but, since heat always travels from regions of higher temperature to regions of lower temperature, the body receives heat from those surroundings that have a temperature higher than body surface temperature. The greatest source of heat radiation is the sun. Sources of indoor heat radiation are heating devices, operating machinery, hot steam piping, etc.

The heat gain by convection comes from currents of heated air only. Such currents of air may come from a galley stove or an engine.

The heat gain by conduction comes from objects with which the body, from time to time, is in contact.

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Most body heat comes from within the body itself. Heat is produced continuously inside the body by the oxidation of foodstuffs and by other chemical processes, by friction and tension within the muscle tissues, and by other causes as yet not completely identified.

Body Heat Losses

There are two types of body heat losses: loss of sensible heat and loss of latent heat. Sensible heat is given off by (1) radiation, (2) convection, and (3) conduction. Latent heat is given off in the breath and by evaporation of perspiration.

The body is usually at a higher temperature than that of its surroundings and, therefore, radiates heat to bulkheads, decks, and equipment. This action is called heat radiation loss. The temperature of the air does not influence this radiation, except as it may alter the temperature of such surroundings.

Heat loss by convection occurs when the heat is carried away from the body by convection (heated) currents, both by the air coming out of the lungs and by exterior air currents.

Heat loss by conduction is caused by bodily contact with cooler objects or substances. Since the body is usually at a higher temperature than that of its surroundings, it gives up heat by conduction through physical contact with its surroundings.

When the air temperature and relative humidity are not too high and when the body is not too active, the body gets rid of its excess heat by radiation, convection, conduction, and a slight amount of perspiration. When engaged in work or exercise, the body develops much more internal heat and perspiration increases. If the relative humidity is low, perspiration rapidly evaporates. As the perspiration evaporates, the body loses additional heat (latent heat of vaporization). However, if the relative humidity of the air is high, the moisture cannot evaporate, or it does so at a slow rate; hence, the excess heat cannot be removed fast enough by evaporation and discomfort follows.

The amount of heat given off by the body varies according to the body's activity. When seated at rest, the average adult gives off approximately 380 Btu per hour. Doing routine work in a ship, an adult gives off an average of 500 to 600 Btu per hour.

During light work on a ship, particularly on a submarine, research has shown that the total amount of body heat loss is divided as follows: approximately 45% by radiation, 30% by convection and conduction, and 25% by evaporation.

EFFECT OF AIR MOTION

In perfectly still air the layer of air around a body absorbs the sensible heat given off by the body and increases in temperature. The layer of air also absorbs some of the water vapor given off by the body, thus increasing in relative humidity. This means the body is surrounded by an envelope of moist air which is at a higher temperature and relative humidity than the ambient air. Therefore, the amount of heat that the body can lose to this envelope is less than the amount it can lose to the ambient air. When the air is set in motion past the body, the envelope is continually being removed and replaced by the ambient air, thereby increasing the rate of heat loss from the body. When the increased heat loss improves the heat balance, the sensation of a "breeze" is felt; when the increase is excessive, i.e., the rate of heat loss makes the body feel cool and the sensation of a "draft" is felt.

SENSATION OF COMFORT

From the foregoing discussion, it is evident that the three factors—temperature, humidity, and air motion—are closely interrelated in their effects upon comfort and health of personnel aboard ship. In fact, a given combination of temperature, humidity, and air motion will produce the same feeling of warmth or coolness as a higher or lower temperature in conjunction with a compensating humidity and air motion. The term given to the net effect of these three

factors is known as the EFFECTIVE TEMPERATURE. Effective temperature cannot be measured by an instrument, but can be found on a special psychrometric chart when the dry-bulb temperatures and air velocity are known.

Although all of the combinations of temperature, relative humidity, and air motion of a particular effective temperature may produce the same feeling of warmth or coolness, they are NOT all equally comfortable. Relative humidity below 15% produces a parched condition of the mucous membranes of the mouth, nose, and lungs, and increases susceptibility to disease germs. Relative humidity above 70% causes an accumulation of moisture in clothing. For best health conditions, a relative humidity ranging from 40% to 50% for cold weather and from 50% to 60% for warm weather is desirable. An overall range from 30% to 70% is acceptable.

VENTILATION EQUIPMENT

Since proper circulation is the basis for all ventilating and air conditioning systems and related processes, we shall first consider methods used aboard ship to circulate air. In the following sections you will find information on shipboard equipment used to supply, circulate, and distribute fresh air, and to remove used, polluted, and overheated air.

Fans used in Navy ships in conjunction with supply and exhaust systems are divided into two general classes; axial flow and centrifugal. Most fans in duct systems are of the axial-flow type because they generally require less space for installation.

Centrifugal fans are generally preferred for exhaust systems that handle explosive or hot gases. The motors of these fans, being outside the air stream, cannot ignite the explosive gases. The drive motors for centrifugal fans are subject to overheating to a lesser degree than are motors of vane-axial fans.

VANE-AXIAL FANS

Van-axial fans (fig. 12-4) are high pressure fans, generally installed in duct systems. They have vanes at the discharge end to straighten out rotational air motion caused by the impeller. The motors for these fans are cooled by the air in the duct and will overheat if operated with all air over the fan shut off.

TUBE-AXIAL FANS

Tube-axial fans are low-pressure fans, usually installed without duct work. However, they do have sufficient pressure for a short length of duct.

CENTRIFUGAL FANS

Centrifugal fans (part A of fig. 12-5) are used primarily for exhausting explosive or hot gases. However, they may be used in lieu of axial-flow fans if they work in better with the arrangement or if their pressure-volume characteristics suit the installation better than an axial-flow fan. Centrifugal fans are also used in some fan-coil assemblies, which are discussed later in this chapter.

PORTABLE FANS

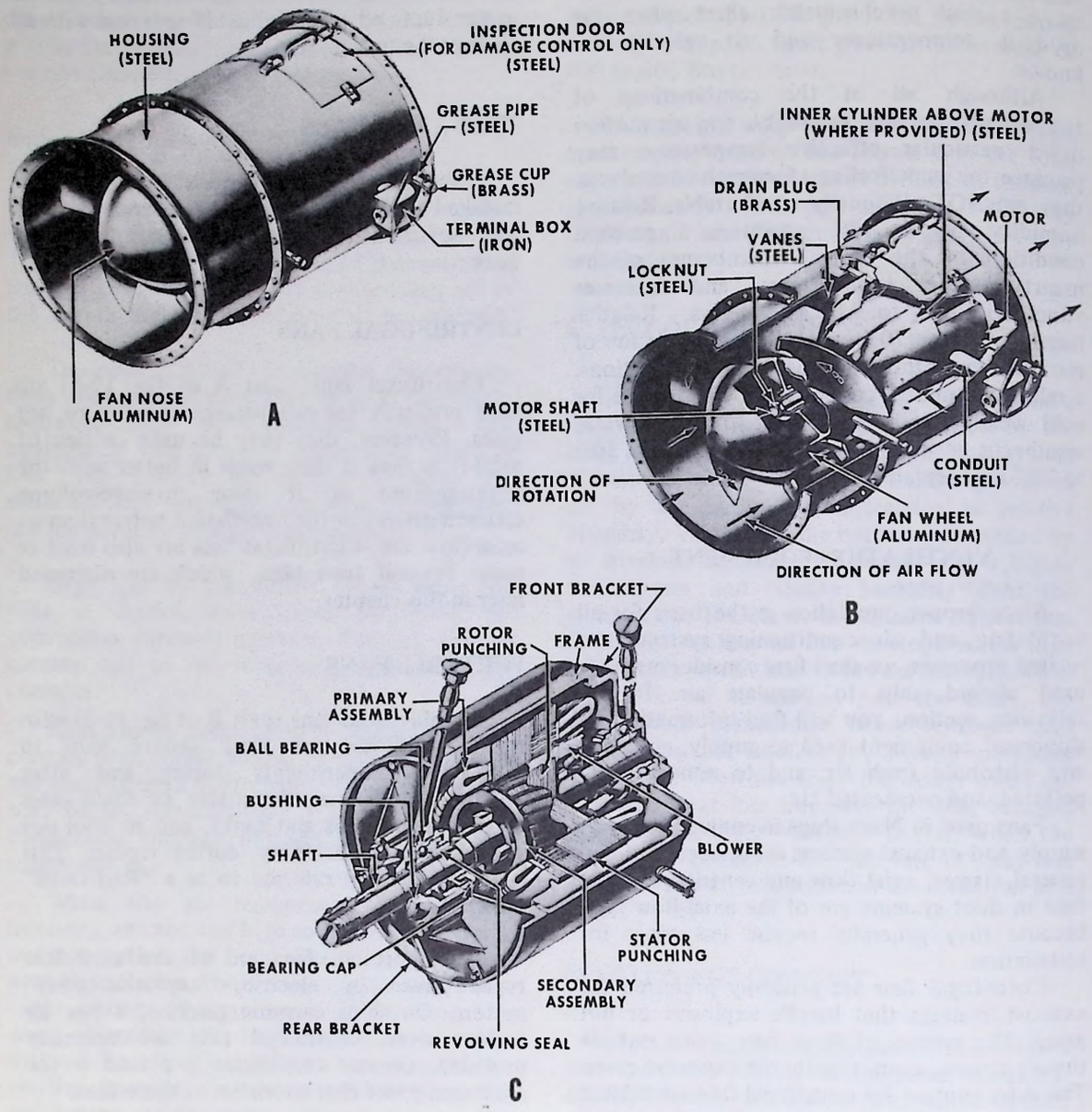
Portable axial fans (part B of fig. 12-5) with flexible airhoses are used aboard ship to ventilate compartments during and after painting, to exhaust flammable or toxic gases from closed spaces and tanks, and to cool hot spots around machinery during repairs. This type fan is often referred to as a "Red Devil" blower.

Most portable fans are of the axial-flow type, driven by electric, "explosion-proof" motors. On ships carrying gasoline, a few air turbine-driven centrifugal fans are normally provided. Greater confidence is placed in the explosion-proof characteristics of these fans.

WATERPROOF VENTILATOR

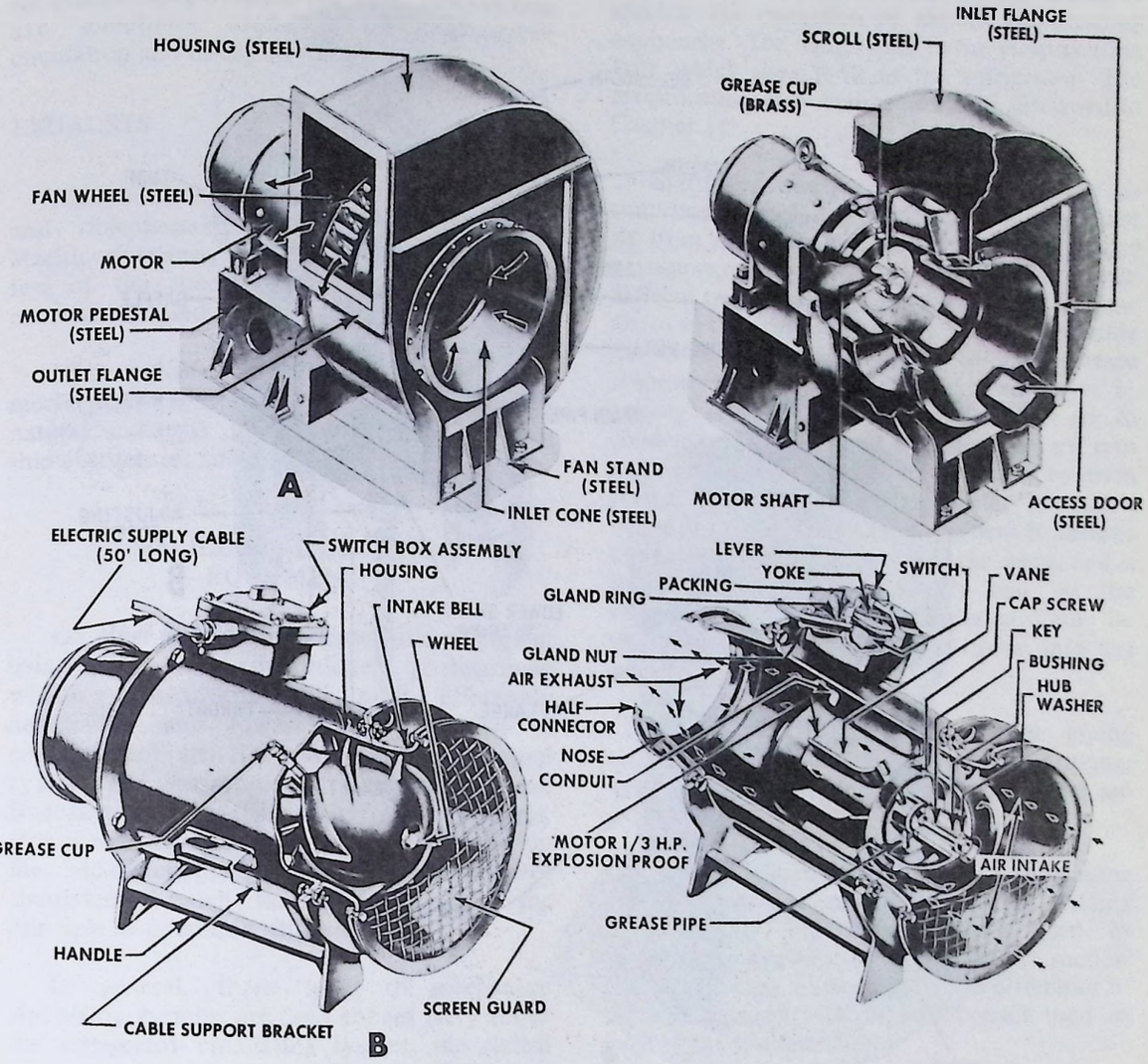
The waterproof ventilator, shown in figure 12-6, consists of an outer housing, an inner ventilator shaft extending up to the outer

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Figure 12-4.—Vane-axial ventilating fan: A. Exterior view. B. Cutaway view. C. Cutaway veiw of the fan motor.



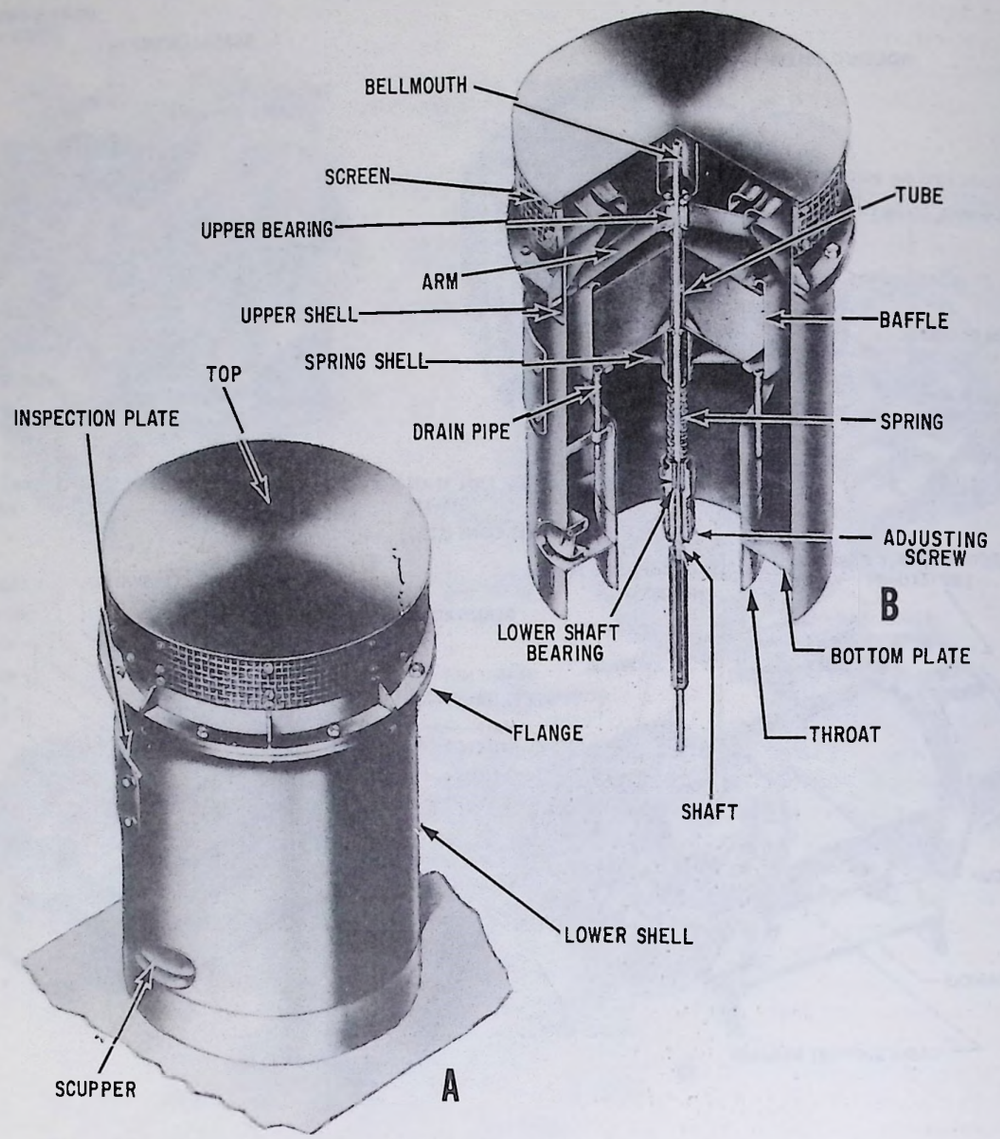
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Figure 12-5.—Miscellaneous ventilating fans: A. Centrifugal fan. B. Portable axial fan.

housing, and a bucket-type closure supported over the ventilator shaft by a compression spring. The bucket has drain tubes which extend into a sump between the ventilator shaft and the outer housing. The sump has scupper valves which drain onto the weather deck.

The ventilator operates automatically and is normally open. Small quantities of water, which enter the ventilator, fall into the bucket and drain out through the drain tubes and scuppers. In heavy seas, when water enters the bucket faster than it drains out, the weight of water forces the bucket down against the top of the ventilator shaft. Thus, a watertight seal is formed and maintained until sufficient water drains out to permit the force of the spring to

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Figure 12-6.—Waterproof ventilators: A. Exterior view. B. Cutaway view.

raise the bucket to the open position. Normally, some provision is made so that the ventilator can also be closed manually. With slight variations in construction, ventilation of this type may be used for both the supply and exhaust of air.

BRACKET FANS

Bracket fans are used in hot weather to provide local circulation. These fans are normally installed in living, hospital, office,

commissary, supply, and berthing spaces. Where air conditioning systems are used, bracket fans are sometimes used to facilitate proper circulation and direction of cold air.

EXHAUSTS

Many local exhausts are used to remove heat and objectionable odors at their source. Machinery spaces, laundries, and galley are but a few of the spaces aboard ship where local exhausts are used.

Most exhausts used on Navy ships are mechanical, (contain an exhaust fan) although natural exhausts are sometimes provided in ship's structures and on small craft.

MECHANICAL COOLING EQUIPMENT

On most newer ships, almost all working and living spaces are air conditioned. To determine which equipment will most effectively dehumidify and lower the temperature of compartment air, the Navy has tested several types of environmental control systems. Basically, these systems are refrigerant systems, their design and construction are dependent on the characteristics of the cooling element circulated through the system and on the principle of operation utilized.

In general, three types of mechanical air-cooling systems are used aboard Navy ships: the refrigerant circulating system, the chilled water circulating system, and the self-contained air conditioners.

REFRIGERANT CIRCULATING SYSTEMS

The refrigerant circulating system (fig. 12-7) is essentially a shipboard refrigerating plant, consisting of a compressor, condenser, cooling coils, fan, air filter, and the necessary controls. The cooling coils are installed in the ventilation ducts leading to the spaces to be air conditioned. Automatic and manual controls are added to regulate the operation of the air conditioning equipment. The compressor is the reciprocating type which uses R-12 as the refrigerant. The reciprocating type compressor was discussed in Chapter 11.

Starting at the space to be cooled, the air conditioning cycle is as follows: The hot, moist air from the space is drawn through a duct, or passageway, where it mixes with fresh air drawn in from the outside. The fan is located to blow air over the cooling coil; the refrigerant inside the coil cools the coil surface. The cold surface absorbs the heat from the air passing over it, causing some of the moisture in the air to condense. The condensed moisture drips off into a pan below the coil and is carried away by drain piping. The cooler, dryer air leaving the coil is blown into the compartment, where it absorbs the excess heat and moisture in the space, and is then returned to the cooling coil by the ventilation system. Air is exhausted from the space to allow fresh air to be drawn into the space.

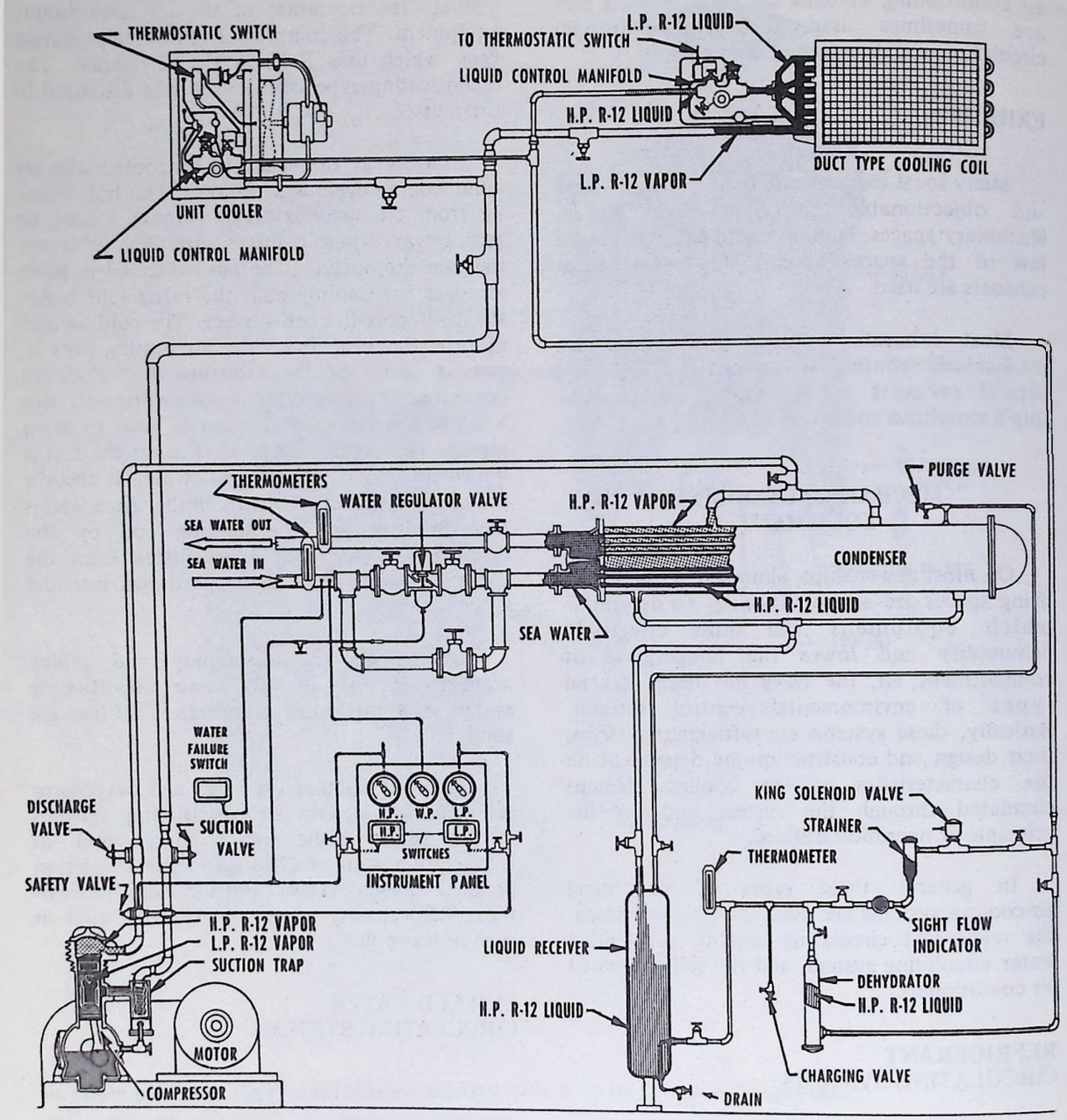
In general, the machinery and piping arrangements of the R-12 air conditioning system and the ship's refrigeration system are similar.

Operating suction pressures and evaporator temperatures used in air conditioning systems are normally higher than those used in refrigeration systems. The difference in suction pressure in each system results in a difference in the rated capacity of the compressor used in each of the systems.

CHILLED WATER CIRCULATING SYSTEMS

There are two basic types of chilled water air conditioning systems currently in use. The primary refrigerant cools the secondary refrigerant, or chilled water, that is used to cool the spaces. The first type uses the vapor compression cycle and R-11 or R-114 as the primary refrigerant. The type of primary refrigerant used depends on the size and type of

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Figure 12-7.—Basic diagram of a shipboard refrigerant circulating air conditioning system.

compressor used. The second type operates on the absorption cycle and uses water as the primary refrigerant. Lithium bromide is used as an absorbent. Vapor compression plants are used in most ships. Because they require no compression, which results in quieter operation, lithium bromide plants are installed in submarines.

Vapor Compression Units

The vapor compression chilled water circulating system differs from a refrigerant circulating (direct expansion) air conditioning system in that the air conditioning is accomplished by using a secondary refrigerant (chilled water) which is circulated to the various cooling coils. Heat from the air conditioned space is absorbed by the circulating chilled water and removed from the water by the primary refrigerant system in the water chiller. In most vapor compression air conditioning systems, the compressor is a centrifugal type that uses R-11 or R-114 as the primary refrigerant.

The operating cycle of the centrifugal refrigeration plant (fig. 12-8) is basically the same as other types of refrigeration plants except for the method of compression. The refrigerant gas is pressurized in the centrifugal turbocompressor and is discharged into the condenser where it is condensed by circulating seawater flowing through the condenser tubes. The condensed liquid refrigerant drains to the bottom of the condenser into a float chamber. When the refrigerant level is high enough, a float-operated valve opens, allowing the liquid high-pressure refrigerant to spray out into the water chiller (evaporator). Water to be chilled flows through the tubes of the water chiller. As the refrigerant from the condenser sprays out over the tubes, the water within the tubes is chilled or cooled due to the vaporization of the liquid refrigerant. The vaporized refrigerant then reenters the suction side of the compressor to start the cycle again.

The load on the air conditioning plant is determined by maintaining the desired chilled water temperature. The compressor capacity is changed due to either increased or decreased load, by the use of PREROTATION VANES, located at the inlet of the compressor. The prerotation vanes are adjustable and act as dampers to either increase or decrease the flow of refrigerant vapor into the suction of the compressor. This throttling action at the compressor suction allows an increase or decrease of the capacity of the compressor without changing the compressor speed.

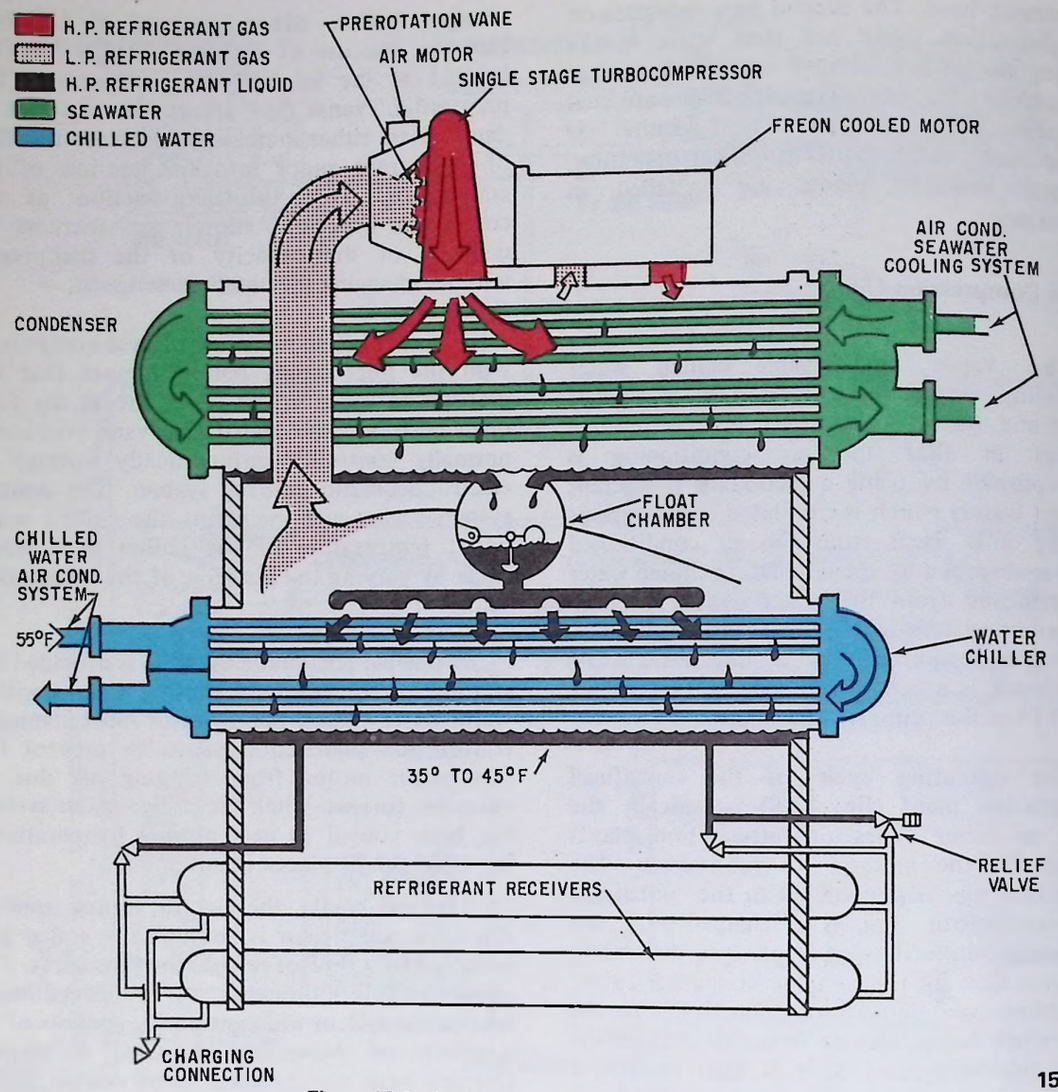
Figure 12-9 shows a centrifugal compressor with the inlet piping removed; note that the prerotation vanes in the figure are in the fully open position. The prerotation vane position is normally controlled automatically through an electropneumatic control system. The control system senses and maintains the chilled water outlet temperature of the chiller at a preset value by varying the position of the prerotation vanes.

A manual-pneumatic override is provided for starting a warm plant. In starting a plant with a warm water chiller, the operator must manually control the prerotation vanes to prevent the compressor motor from tripping off due to excessive current. When the chilled water system has been cooled to near normal temperatures, the plant can be placed in automatic.

In some plants, the electric motor used to drive the compressor is hermetically sealed and is cooled by a flow of refrigerant through it. The compressor is lubricated by a forced feed lubrication system which normally consists of an auxiliary oil pump, an attached oil pump (integral with compressor), an oil cooler, and a set of oil filters. The auxiliary oil pump is used for starting and securing the plant.

Several automatic controls are built into the centrifugal compressor control system. These devices increase the self-operating ability of the plant by automatically shutting down the compressor if a hazardous situation develops such as: (1) high condenser pressure; (2) low compressor lube oil pressure; (3) seawater loss to the condenser; (4) loss of chilled water; (5) low refrigerant temperature; (6) low chilled water temperature; and (7) high discharge temperature.

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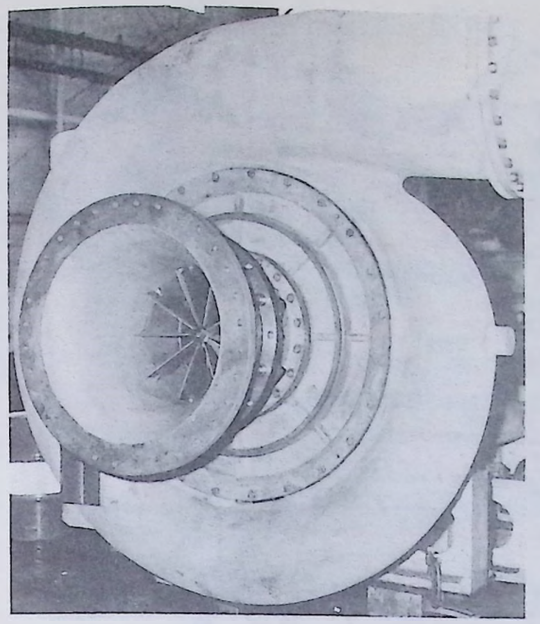
Figure 12-8.—Vapor compressor (centrifugal) unit.

An oil heater keeps the oil warm in the oil sump of the compressor during plant shutdown. If the compressor oil is not kept heated, it will absorb large amounts of refrigerant which will result in excessive oil foaming when the unit is started. The heaters in most plants are connected so that they are automatically turned on when the compressor is off and off when the compressor is on.

Figure 12-10 shows a centrifugal compressor air conditioning unit. This particular plant has a 150-ton capacity and uses R-114 as the refrigerant. The gages and controls for the plant are on the other side of the unit.

Lithium Bromide Absorption Unit

Another type of refrigeration plant used in conjunction with a circulating chilled water system is the lithium bromide absorption unit.



168.14X

Figure 12-9.—Suction end of a centrifugal compressor showing prerotation vanes.

Water is the refrigerant used in the absorption cycle. The absorption system differs from the compression type refrigeration machines in that the absorption cycle uses heat energy instead of mechanical energy to cause the change in conditions necessary for a complete refrigeration cycle. In other words, the compressor is replaced by steam heat.

These two basic principles are the basis for the lithium bromide absorption refrigeration cycle:

1. Lithium bromide has the ability to absorb large quantities of water vapor.

2. When under a high vacuum, water will boil (vaporize) at a low temperature and in doing so, absorb heat.

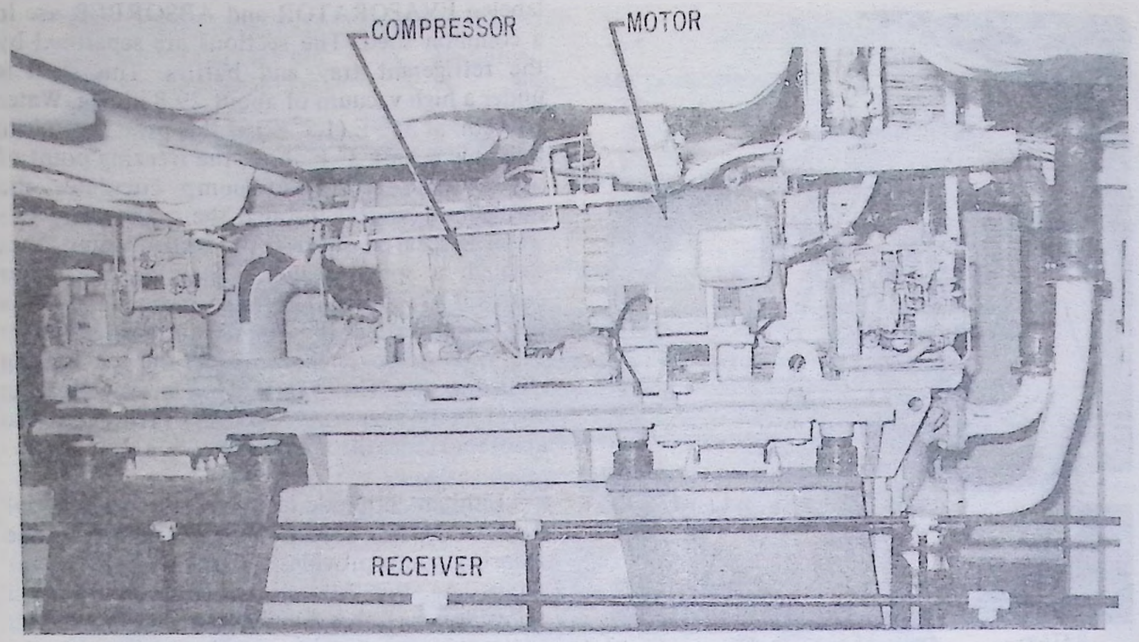
To understand the lithium bromide absorption cycle, follow along on figure 12-11 during the explanation. Notice that the sections labeled EVAPORATOR and ABSORBER are in a common shell. The sections are separated by the refrigerant tray and baffles. This shell is under a high vacuum of about 29.8 in. Hg. Water will boil at 35° F (1.7° C) at this pressure. (Note that this is only 3° F above the freezing point of water.) The refrigerant pump circulates the refrigerant (water) through the evaporator. The water is sprayed out over the chilled water tubes through a spray header. (Spraying the water causes it to vaporize [or flash] more readily.) As the water vaporizes around the chilled water tubes, it removes heat from the circulating chilled water. The water vapor is now floating about in the evaporator/absorber shell. Now, the absorber comes into play.

Lithium bromide solution is sprayed out from a spray header in the absorber. The absorber pump provides the driving head for the spray. As the lithium bromide solution is sprayed out, it absorbs the water vapor which is in the shell from the evaporation process. As the lithium bromide absorbs more and more water vapor, its ability to absorb decreases. This is referred to as a WEAK solution. The weak solution is rejuvenated for reuse as STRONG solution (solution containing little water vapor) in the generator section of the plant. The generator pump pumps the weak solution from the weak solution section of the absorber up to the generator.

In the generator the weak lithium bromide solution is sprayed out over steam tubes which heat the solution and drive the water vapor out of solution. The strong solution thus produced flows back into the absorber for reuse. The water vapor driven out of the solution flows from the generator into the condenser where it is condensed by circulating seawater for reuse as refrigerant. The condensed vapor flows into the evaporator and down to the refrigerant tray.

A regenerative heat exchanger is provided in the system for the lithium bromide solution. The weak solution must be heated to drive out the water vapor, and the strong solution must be cooled to absorb water vapor. The regenerative heat exchanger aids in this process by cooling

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47.217

Figure 12-10.—R-114 centrifugal air conditioning plant.

the strong solution and preheating the weak solution in the cycle.

Seawater (condensing) flow is provided through the absorber section to cool the strong solution returning from the generator and to remove the heat produced as the lithium bromide solution absorbs the water vapor. The outlet seawater from the absorber is the inlet water for the condenser.

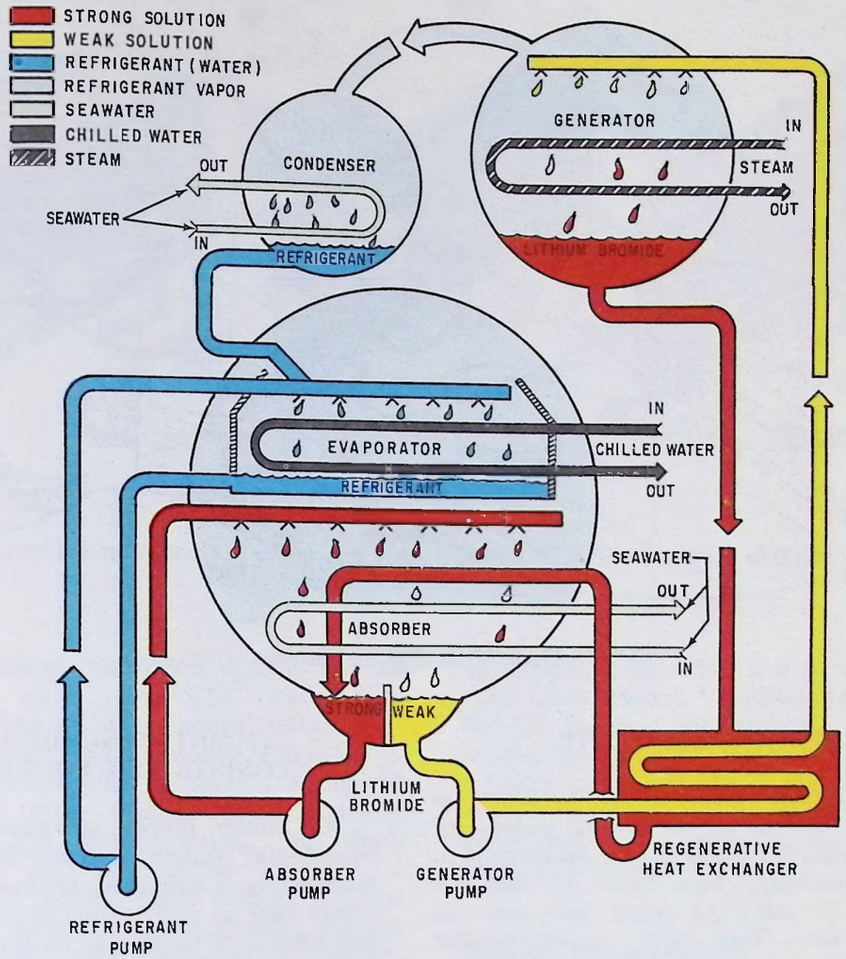
The absorber pump and the generator pump are driven by a common electric motor and, therefore, the two pumps are referred to cumulatively as the absorber/generator pump.

A purge system (not shown) consisting of a pump, eductor, and a purge tank is provided with the lithium bromide absorption system to keep air and noncondensables out of the evaporator/absorber shell. The maintenance of the high vacuum within the shell is of utmost importance to the proper operation of the plant.

Fan-Coil Assemblies

To utilize the cold chilled water for the air conditioning of spaces, fan-coil assemblies are used. These assemblies may be referred to as "spot coolers." The chilled water is piped through the cooling coils of the units and a fan forces air over the coils. One type of fan-coil assembly is shown in figure 12-12. Note the chilled water connections, the vent cock at the top and the condensate collection tray at the bottom of the unit.

The condensate collection tray collects the moisture condensed out of the air onto the cooling coils. The condensate is generally piped to the bilge or a waste water drain system. It is important that the drain for the collection tray be kept clear. If the condensate cannot drain out of the tray, it will collect and evaporate, leaving impurities which will rapidly lead to the corrosion of the tray.



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Figure 12-11.—Basic absorption cycle.

SELF-CONTAINED AIR CONDITIONERS

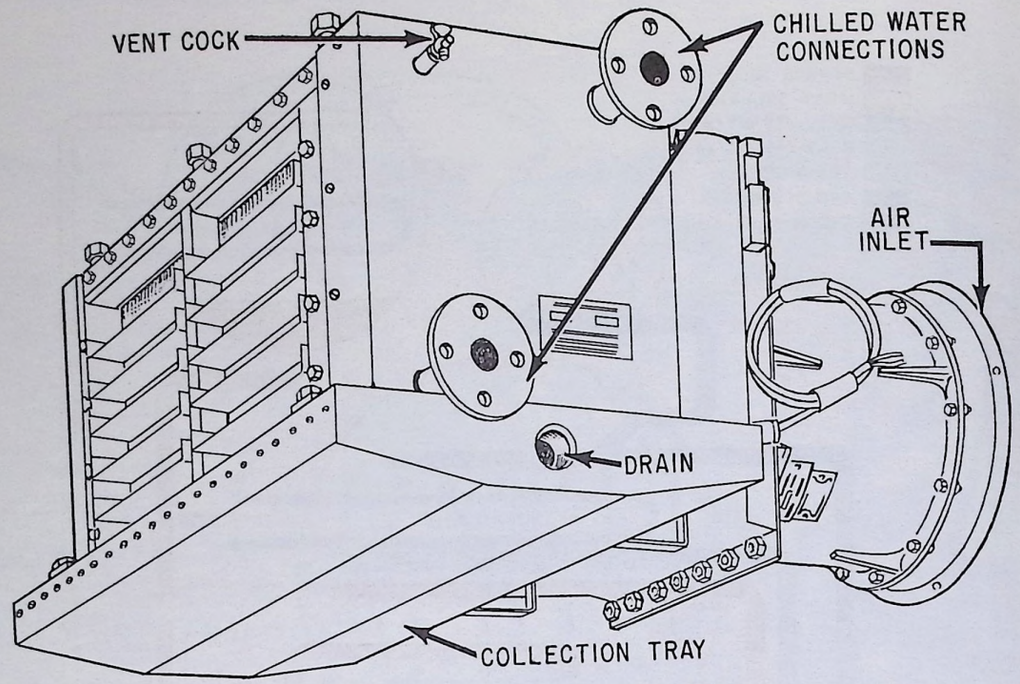
Ships without central-type air conditioning installed may use self-contained air conditioning units. Approval of NAVSEA is required for using these units aboard ship.

A self-contained air conditioning unit is simply the type of air conditioner you see installed in the windows of many homes. All that is required for installation is to mount the proper brackets for the unit case and provide electrical power for the unit.

These units use nonaccessible hermetically sealed compressors (motor and compressor are contained in a welded steel shell); therefore, shipboard maintenance of the motor-compressor unit is impractical. The thermal expansion valve used in these units is preset and nonadjustable.

A thermostat and fan speed control are normally provided for comfort adjustment.

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168.18

Figure 12-12.—Fan-coil assembly.

HEATING EQUIPMENT

Ventilation heaters are installed in ventilation ducting for the obvious purpose of providing heat for spaces in cold weather and to control humidity. Two types of heat are currently in use: (1) steam heat and (2) electrical heat. Two types of duct-installed steam ventilation heaters are shown in figure 12-13. The S-type heater is used in small installations; the T-type is used where larger heaters are required.

The heater shown in figure 12-14 is a convection-type heater, used in small spaces or in spaces where mechanical ventilation is not installed.

All three types of steam heaters described can be used with steam pressures up to 150 psi.

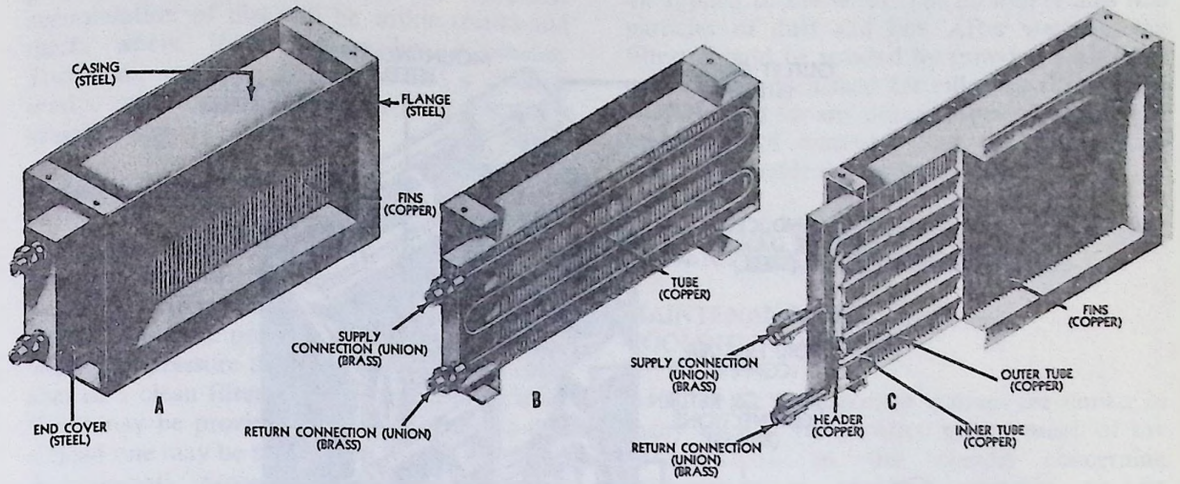
Electric heaters are simply banks of heating elements installed in the airflow of a ventilation system.

MAINTENANCE OF AIR CONDITIONING EQUIPMENT

To ensure proper operation of any air conditioning system, periodic inspection and maintenance is absolutely necessary. Each ship should have an organization responsible for the maintenance of ventilating, heating, and cooling equipment.

MAINTENANCE OF VENTILATION EQUIPMENT

Shipboard ventilation must serve not only to supply, circulate, and distribute fresh air, but also to remove the used, contaminated, and overheated air from the various spaces. If the ventilation equipment fails to perform its functions properly, conditions may be created which will jeopardize the health or life of crew members. Therefore, the individuals responsible for inspection and maintenance must be thoroughly familiar with the ventilation equipment.



47.111

Figure 12-13.—Ventilation heater: A. Exterior view of S-type heater. B. Tube arrangement of S-type heater. C. Tube arrangement of T-type heater.

A shipboard ventilation system and its constituent parts cannot be isolated and separated from other component systems in a complete air conditioning system. For example, the air duct distribution system of a ship may be utilized for other systems used in cooling, heating, and dehumidifying the ship's atmospheric air. In addition to ducts, a ventilation system may include weather openings, screens, filters, fans, gratings, closures, heaters, cooling coils, venturi tubes, dampers, and terminals. Obviously, if a ventilation system is to function effectively, it is essential that all of its various units be kept clean and in satisfactory operating condition. To maintain a ventilating system in the best condition requires the observance of applicable precautionary measures and the adherence to prescribed maintenance procedures.

Guarding Against Obstructions to Ventilation

Such items as swabs, deck gear, and trash stowed in fan rooms or ventilation trunks not only restrict airflow but also increase dirt and odors taken inboard. Ventilation terminals must NEVER be used for stowage. Wet clothing secured to ventilation terminals increases the moisture content of the compartment air and restricts the airflow. Stowage arrangements should be such that ventilation weather openings are NEVER restricted.

Keeping the System Clean

Dirt accumulation in a ventilation system not only restricts the flow of air but also creates a serious fire hazard. In a clean duct the cooling effect of the metal tends to act as a flame arrester, but an accumulation of foreign matter within a duct becomes a potential source of combustion. One method of reducing the amount of dirt and combustible matter, which may be carried into a ventilation system, is to wet down the areas in the vicinity of the air intakes before sweeping.

Since a great volume of air passes through or over the elements of a ventilation system, dirt

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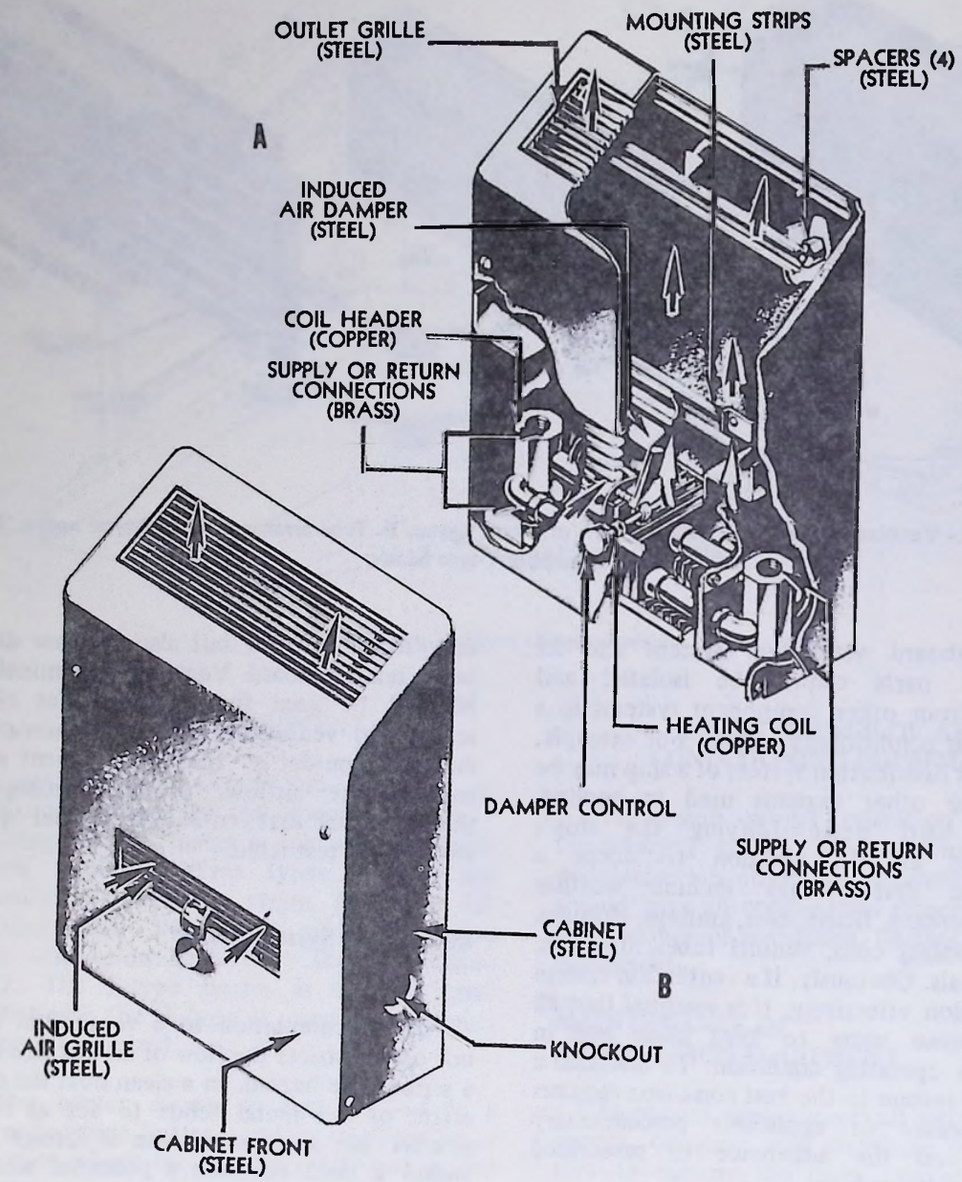


Figure 12-14.—Convector heater: A. Cutaway view. B. Exterior view. 47.112

will collect in the various units in spite of precautionary measures. The greatest accumulation of dirt will be within trunks and ducts where it is not readily noticeable. Therefore, periodic inspections and a definite service procedure are necessary to keep the system clean.

Cleaning Filters

Navy standard air filters have pressure taps on each side of the filter bank. By using a portable differential pressure gage, you can quickly read the pressure drop across the filter. When the pressure drop increases to three times that of a clean filter, the filter must be cleaned. Ships may be provided with spare filters so that a clean one may be substituted for the dirty one. A systematic procedure should be set up for cleaning all filters in the ship.

Special cleaning sinks are installed in ships having a sufficient number of filters to justify the space, expense, and weight. These sinks may be of the steam type, where steam is used to heat and agitate the water, or of the ultrasonic type, where cleaning is done by vibration due to sound waves passing through the cleaning fluid.

Navy standard air filters have a thin film of oil applied to the wires. The oil film retains fine particles of dust and lint. After washing, the filters should be re-oiled by spraying with filter oil. Sprayers furnished for oiling air filters must NOT be used for any other purpose, to avoid the possibility of contaminating the filters with toxic, flammable or smelly materials.

FLAME ARRESTERS AND GREASE FILTERS SHOULD NEVER BE OILED.

MAINTENANCE OF COOLING EQUIPMENT

Since air conditioning systems are similar in many ways to refrigeration plants, much of the information in this manual concerning refrigeration is equally applicable to air conditioning equipment.

To ensure proper maintenance of any air conditioning plant, the requirements of the 3-M systems must be strictly adhered to. A Maintenance Index Page for a centrifugal air conditioning plant (R-114) is shown in figure 12-15. It shows the requirements for that particular plant.

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SYSTEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
Centrifugal Air Conditioning Plant (R-114)		March 197-

CONFIGURATION

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN-HOURS	RELATED MAINTENANCE
C5 J33N N	1. Renew oil filter-dehydrator cartridge. NOTE: Accomplish quarterly or when an interrupted flow is observed in liquid indicator during oil return operation, whichever occurs first.	Q-1R	MM/EN3	0.6	R-1
12 R19M Q	1. Provide compressor lube oil sample for chemical analysis.	Q-6	MM/EN3	0.2	None
T 36 J73D N	1. Test operation of pressure switches and safety devices.	A-1	MM/EN1 MM/EN3 EM3	3.0 3.0 0.5	None
23 C44K A	1. Clean and inspect sea-water side of condenser.	A-5	MM/EN1 MM/EN2 FN	0.5 4.0 4.0	None
B5 J27U N	1. Inspect foundation bolts/fasteners.	A-9	MM/EN3	0.1	None
13 C44S C	1. Clean and inspect strut-type lube oil cooler	C-2	MM/EN3 FN	2.0 2.0	None
T 34 D91X N	1. Test refrigerant system for leaks. NOTE: Accomplish after repairs and when leaks are suspected.	R-1	MM/EN2 FN	1.0 1.0	None
C5 J33Q N	1. Renew compressor oil. NOTE: Accomplish as directed by results of chemical analysis.	R-2	MM/EN3 FN	2.0 2.0	R-3
C5 J33R N	1. Renew compressor active oil filter element. NOTE: Accomplish when oil pressure gauge indicates a 70 percent drop from original pressure and when compressor oil is renewed.	R-3	MM/EN2	0.3	None

MAINTENANCE INDEX PAGE (MIP) SYSCOM MIP CONTROL NUMBER
OPNAV 4700-3 (A) (REV. 3/69)

98.171

Figure 12-15.—MIP (Maintenance Index Page) for a centrifugal air conditioned plant.

CHAPTER 13

COMPRESSED AIR SYSTEMS

As an MM3 or MM2, you should have a thorough knowledge of air compressors, their construction, and care. You will find that compressed air serves many purposes aboard ship and that air outlets are installed in various suitable locations throughout the ship. The uses of compressed air include, but are not limited to, the operation of pneumatic tools and equipment, prairie-masker system, diesel engine starting and/or speed control, air deballasting, torpedo charging and ejecting, aircraft starting and cooling, and the operation of pneumatic boiler and propulsion control systems. Compressed air is supplied to the various systems by high-pressure, medium-pressure, or low-pressure air compressors, depending on the needs of the ship. Reducing valves may be used to reduce high-pressure air to a lower pressure for a specific use.

AIR COMPRESSORS

The air compressor is the heart of any compressed air system. The compressor takes in atmospheric air, compresses it to the pressure desired, and "pumps" the air into supply lines or into storage for later use.

There are a number of variations in the design, construction, and method of compression of air compressors. The construction and principles of operation of some of the most common types of air compressors, used in Navy ships, will be discussed in this chapter.

COMPRESSOR CLASSIFICATIONS

Air compressors are classified in various ways. A compressor may be duplex single-stage or multistage and horizontal, angle, or vertical, as shown in figure 13-1.

In a duplex compressor (fig. 13-1D) the two pistons travel together (parallel). In other words, both pistons (compression elements) are either discharging or taking a suction at the same time.

A compressor may be designed so that either ONLY one stage of compression takes place within one compressing element or so that MORE than one stage takes place within one compressing element. In a single-stage compressor the compression of the air, from suction pressure to final discharge pressure, is completed in a single compression element, i.e., a single cylinder. In a multistage compressor the air is compressed in two or more compression elements to reach final discharge pressure.

In addition, a compressor may be either single-acting (compression takes place on only one stroke per revolution) or double-acting (compression takes place on both strokes per revolution, meaning that compression is taking place on both sides of the piston and that each end of the cylinder is fitted with suction and discharge valves).

In general, compressors are classified according to capacity (high or low) type of compressing element, the source of driving

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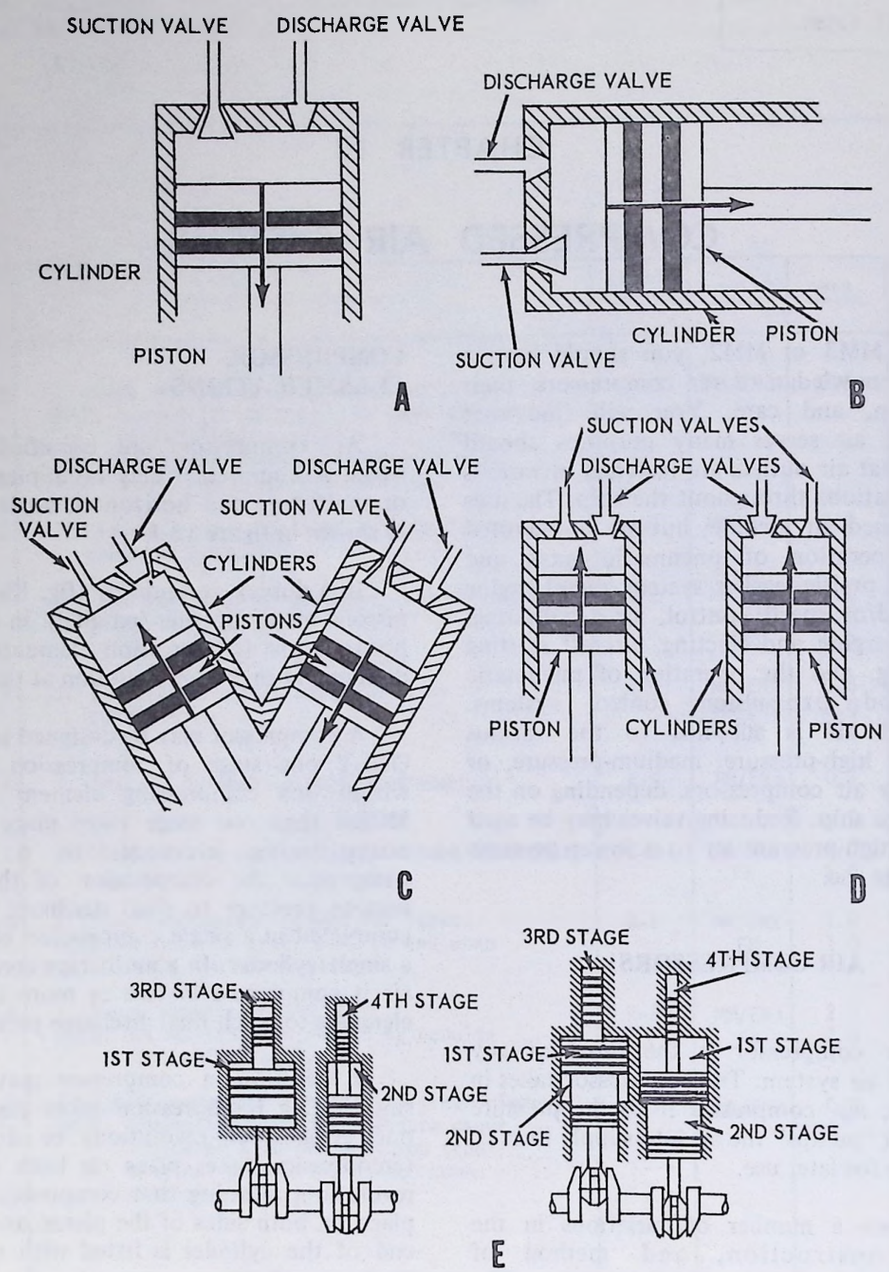


Figure 13-1.—Types of air compressors: A. Vertical. B. Horizontal. C. Angle. D. Duplex. E. Multistage.

power, the method by which the driving unit is connected to the compressor (belt-driven, direct-connected, etc), the pressure developed, and whether the air delivered is oil free or nonoil free.

Types of Compressing Elements

Shipboard air compressors may be centrifugal, rotary, or reciprocating. The reciprocating type is generally selected for capacities from 200-800 cubic feet per minute (cfm) and for pressures of 100 to 5,000 psi; the rotary lobe type for capacities up to 8,800 cfm and for pressures no more than 20 psi; and the centrifugal type for 800 cfm or greater capacities (up to 2,100 cfm in a single unit) and for up to 125 psi.

Most general-service-use air compressors aboard ship are "reciprocators" (fig. 13-2). In this type compressor the air is compressed in one or more cylinders, very much like the

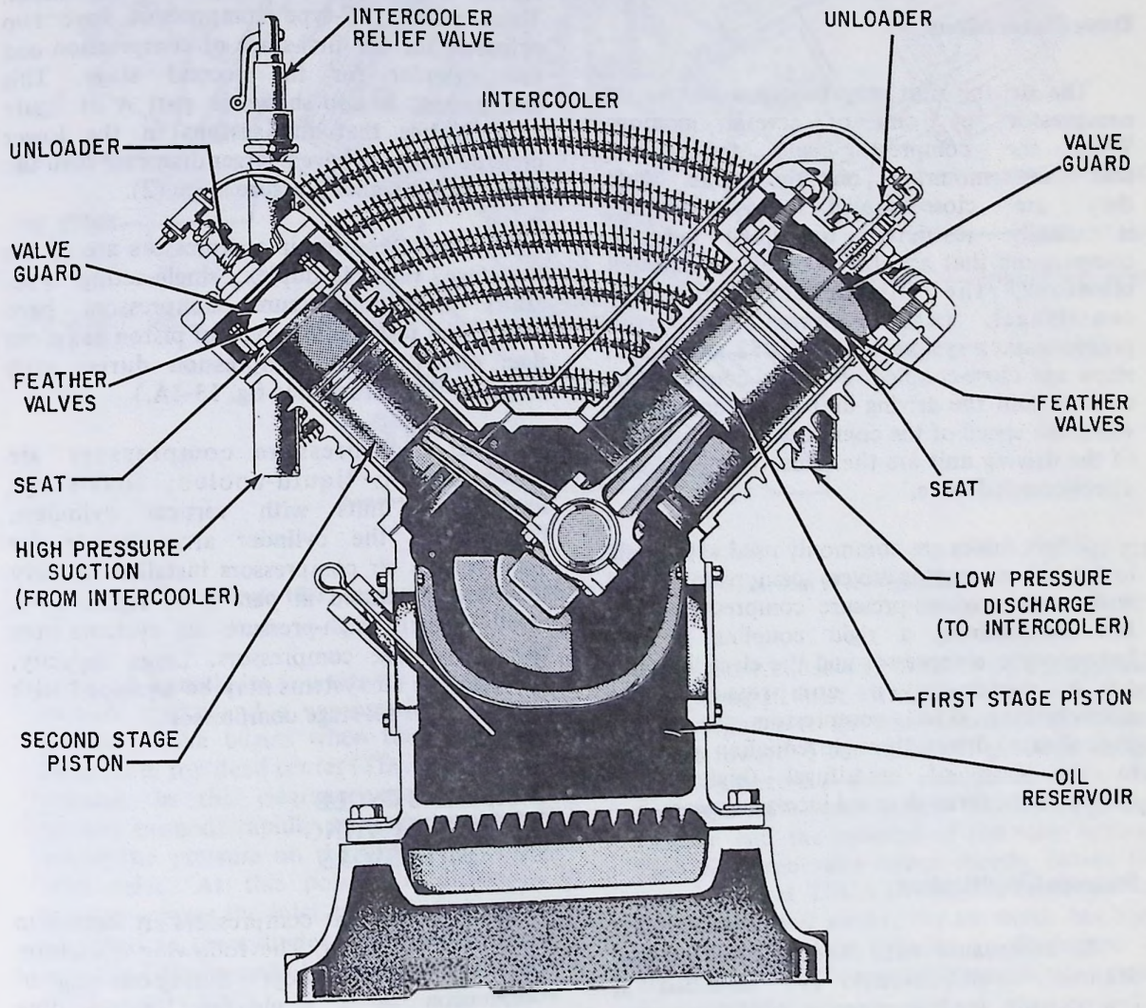


Figure 13-2.—A simple two-stage reciprocating low-pressure air compressor.

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compression that takes place in an internal-combustion engine.

Sources of Power

Compressors are driven by electric motors or steam-turbines. Aboard ship, most low-pressure and high-pressure air compressors are driven by electric motors.

Drive Connections

The driving unit may be connected to the compressor by one of several methods. When the compressor and the driving unit are mounted on the same shaft, they are close-coupled. Close coupling is usually restricted to small capacity compressors that are driven by electric motors. However, the high-speed, single-stage, centrifugal, turbine-driven units serving prairie-masker systems in FF 1052 and similar ships are close-coupled. Flexible couplings are used to join the driving unit to the compressor when the speed of the compressor and the speed of the driving unit are the same. This is called a direct-coupled drive.

V-belt drives are commonly used with small, low-pressure, motor-driven compressors, and with some medium-pressure compressors. In a few installations, a rigid coupling is used between the compressor and the electric motor of a motor-driven compressor. In a steam-turbine drive, compressors are usually (not always) driven through reduction gears, or, in the case of centrifugal (high speed) compressors, through speed increasing gears.

Pressure Classification

In accordance with *NAVSHIPS' Technical Manual*, compressors are classified as low-pressure, medium-pressure, or high-pressure. Low-pressure compressors have a discharge pressure of 150 psi or less. Medium-pressure compressors have a discharge pressure of 151 psi to 1,000 psi. Compressors that have a discharge pressure above 1,000 psi are classified as high-pressure.

Most low-pressure reciprocating air compressors are of the two-stage type with either a vertical "V" (fig. 13-2) or a vertical "W" (fig. 13-3) arrangement of cylinders. Two-stage, two-cylinder, V-type low-pressure compressors have one cylinder for the first (lower pressure) stage of compression and one cylinder for the second (higher pressure) stage of compression. Three-cylinder, W-type compressors have two cylinders for the first-stage of compression and one cylinder for the second stage. This arrangement is also shown in part A of figure 13-4. Notice that the pistons in the lower pressure stage (1) have a larger diameter than the piston in the higher pressure stage (2).

Medium-pressure air compressors are of the two-stage, vertical, duplex, single-acting type. Many medium-pressure compressors have differential pistons; this type of piston has more than one stage of compression during each stroke of the piston. (See fig. 13-4A.)

Most high-pressure compressors are motor-driven, liquid-cooled, four-stage, single-acting units with vertical cylinders. Example of the cylinder arrangements for high-pressure air compressors installed in Navy ships are illustrated in part B of figure 13-4. Small capacity high-pressure air systems may have three-stage compressors. Large capacity, high-pressure air systems may be equipped with four-, five-, or six-stage compressors.

OPERATING CYCLE OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors are similar in design and operation. The following discussion relates to the operating cycle during one stage of compression in a single-stage, single-acting compressor.

The cycle of operation, or compression cycle, within an air compressor cylinder (shown

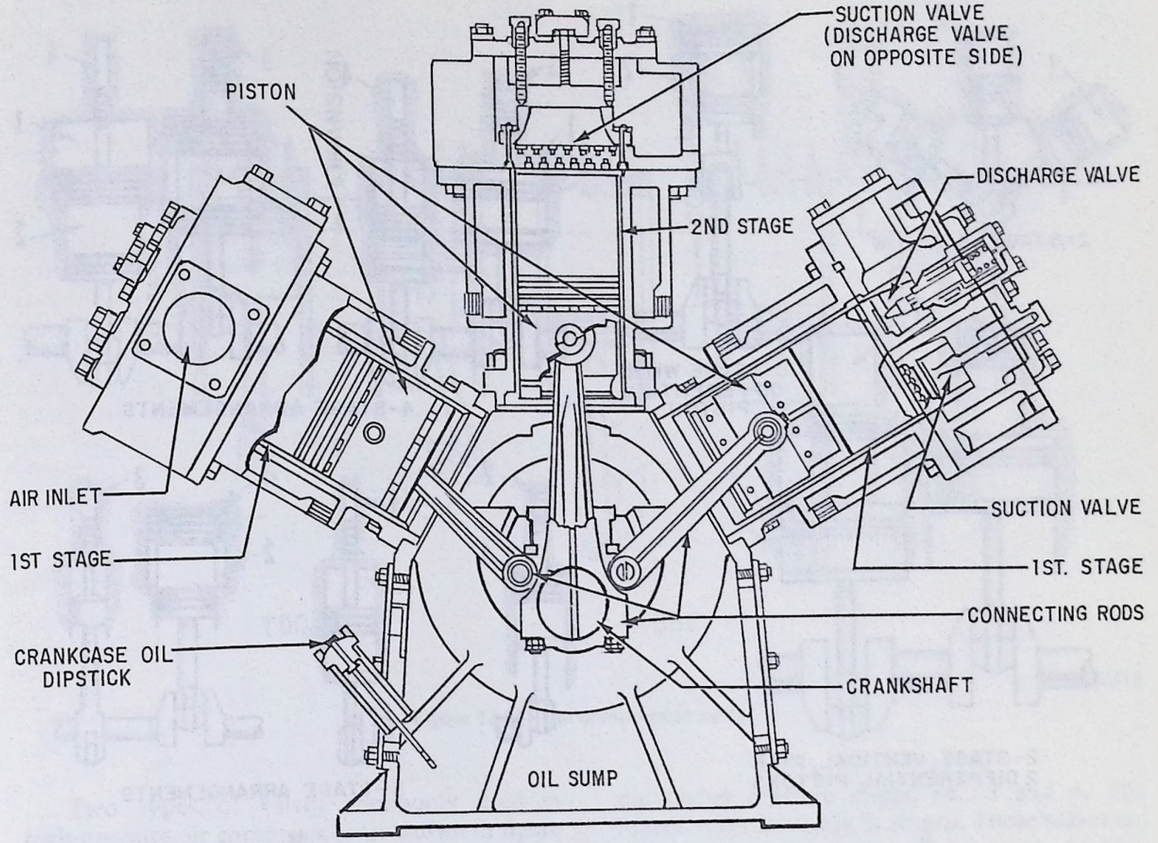


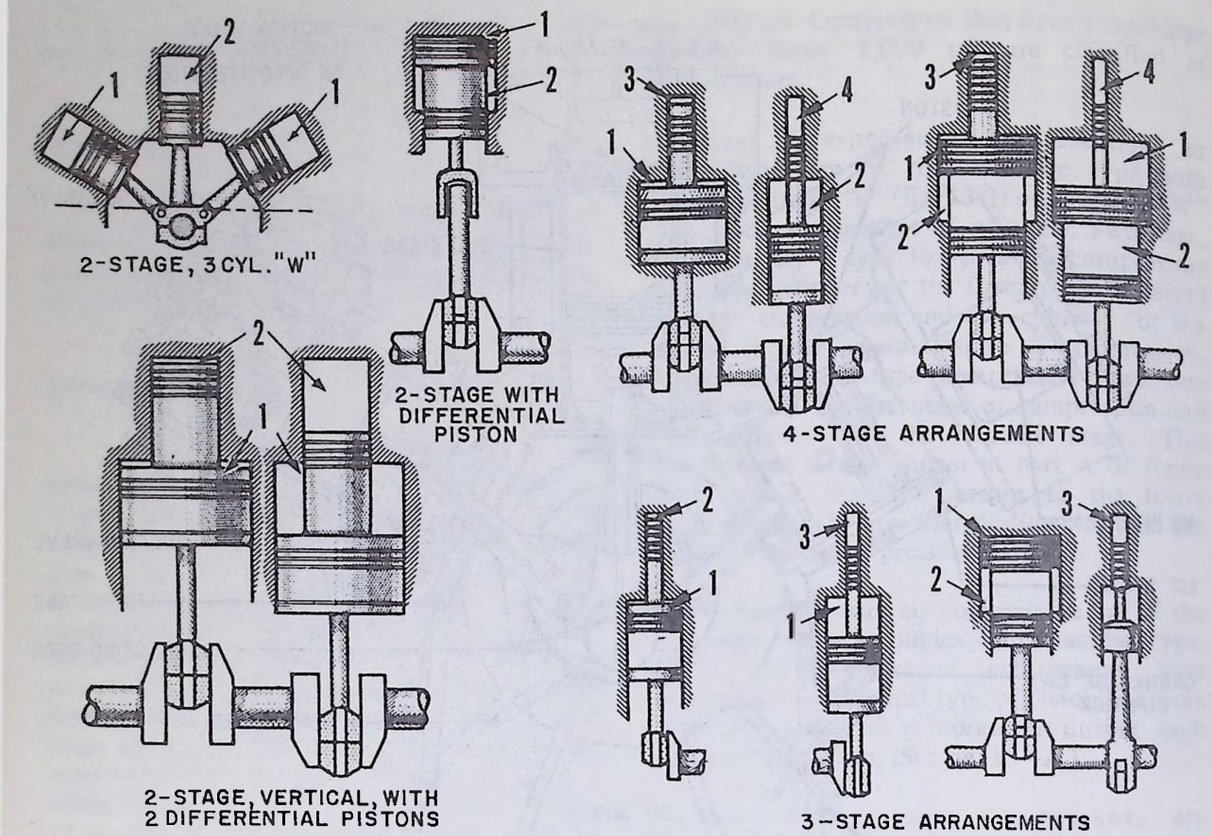
Figure 13-3.—Low-pressure reciprocating air compressor, vertical W configuration.

in fig. 13-5) includes two strokes of the piston: a suction stroke and a compression stroke. The suction stroke begins when the piston moves away from top dead center (TDC). The air under pressure in the clearance space (above the piston) expands rapidly until the pressure falls below the pressure on the opposite side of the inlet valve. At this point, the difference in pressure causes the inlet valve to open, and air is admitted to the cylinder. Air continues to flow into the cylinder until the piston reaches bottom dead center (BDC).

The compression stroke starts as the piston moves away from BDC and continues until the piston reaches TDC again. When the pressure in the cylinder equals the pressure on the opposite side of the air inlet valve, the inlet valve closes. Air continues to be compressed as the piston moves toward TDC, until the pressure in the cylinder becomes great enough to force the discharge valve open against the discharge line pressure and the pressure of the valve springs. (The discharge valve opens shortly before the piston reaches TDC.) During the remainder of the compression stroke, the air which has been compressed in the cylinder is discharged at almost constant pressure through the open discharge valve.

The basic operating cycle just described is completed twice per revolution of the

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Figure 13-4.—Air compressor cylinder arrangements: A. Low- and medium-pressure compressors. B. High-pressure compressors.

crankshaft in double-acting compressors, once on the down stroke and once on the up stroke.

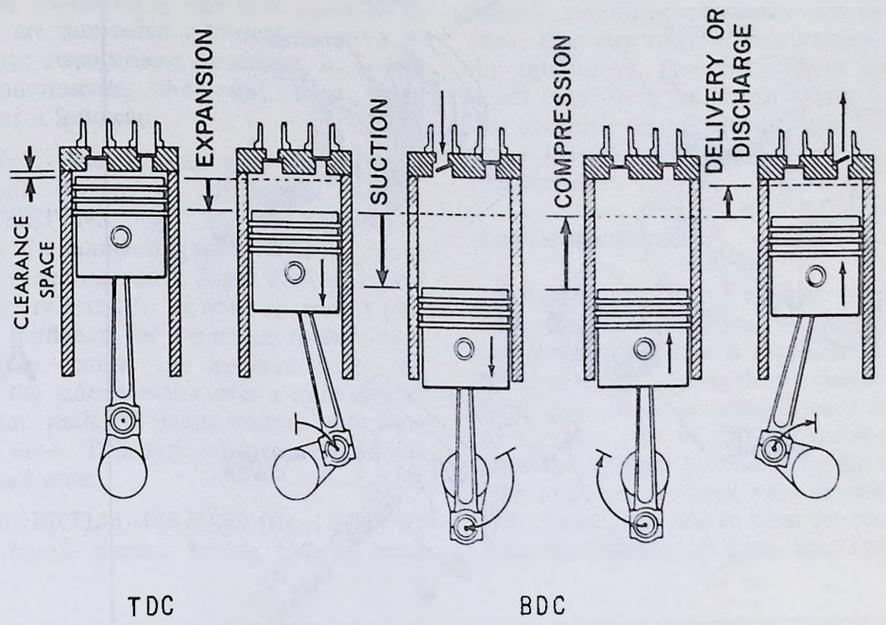
COMPONENT PARTS OF RECIPROCATING AIR COMPRESSORS

Reciprocating air compressors consist of a system of connecting rods, crankshaft, and flywheel, which are used to transmit power developed by the driving unit to the pistons, as well as lubrication systems, cooling systems, control systems, and unloading systems.

Compressing Element

A compressing element of a reciprocating compressor consists of the cylinder, the piston, and the air valves.

VALVES.—The valves are made of special steel and come in a number of different types. The opening and closing of the valves is caused by the difference between (1) the pressure of the air in the cylinder and (2) the pressure of the external air on the intake valve or the pressure of the discharged air on the discharge valve.



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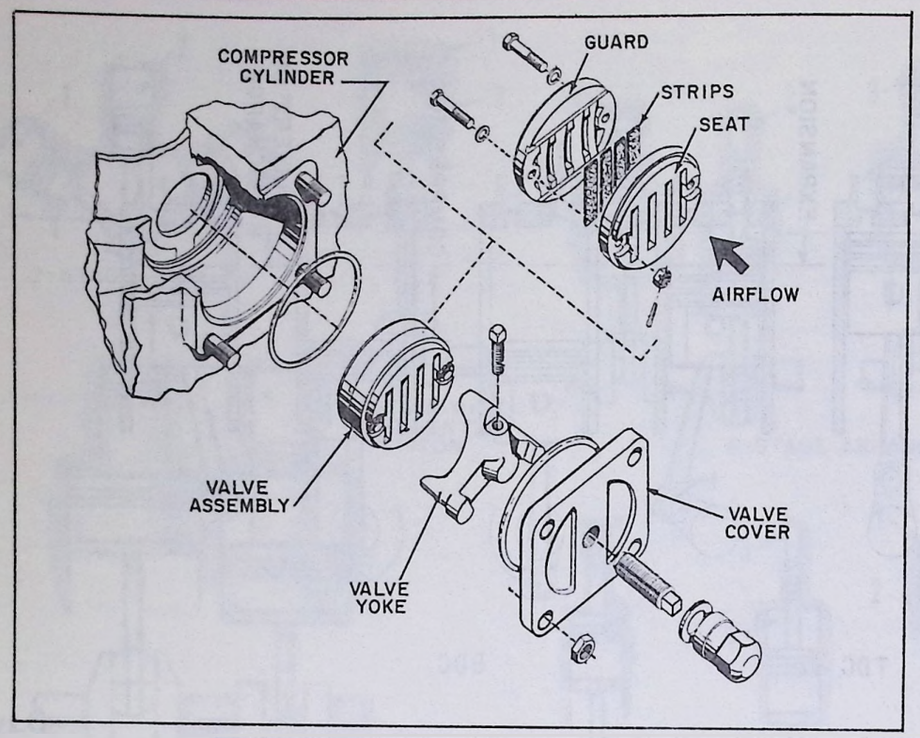
Figure 13-5.—The compression cycle.

Two types of valves commonly used in high-pressure air compressors are shown in figure 13-6. The strip, or feather, type valve shown in part A of the figure is used for the suction and discharge valves of the lower pressure stages, i.e., 1 and 2. The valve shown in the figure is a suction valve; the discharge valve assembly (not shown) is identical except that the positions of the valve seat and the guard are reversed. At rest, the thin strips lie flat against the seat, covering the slots and sealing any pressure applied to the guard side of the valve. In either a suction or discharge operation (depending on the valve service), as soon as pressure on the seat side of the valve exceeds the pressure on the guard side, the strips flex against the contoured recesses in the guard and permit air to pass around the edges of the strip and through the slots in the guard. As soon as the pressure equalizes or reverses, the strips unflex and return to their original position flat, against the seat.

The disk-type valve in part B of figure 13-6 is used for the suction and discharge valves of the higher pressure stages, i.e., 3 and 4. The fourth stage assembly is shown. These valves are of the spring-loaded, dished-disk type. At rest, the disk is held against the seat by the spring and is sealed by pressure applied to the keeper side of the valve. In either a suction or discharge operation (depending on the valve service), as soon as the pressure on the seat side of the valve exceeds the pressure on the keeper side, the disk lifts against the stop in the keeper, compressing the spring, and permitting air to pass through the seat, around the disk and through the openings in the sides of the keeper. As soon as the pressure equalizes or reverses, the spring returns the disk to the seat.

CYLINDERS.—Various designs of cylinders are used, depending primarily upon the number of stages of compression required to produce the maximum discharge pressure. Several common cylinder arrangements for low- and medium-pressure air compressors are shown in part A of figure 13-4. Several arrangements for

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Figure 13-6.—High-pressure air compressor valves. (A) Valve arrangement for lower pressure stages (suction shown). (B) Valve arrangement for higher pressure stages (both suction and discharge shown).

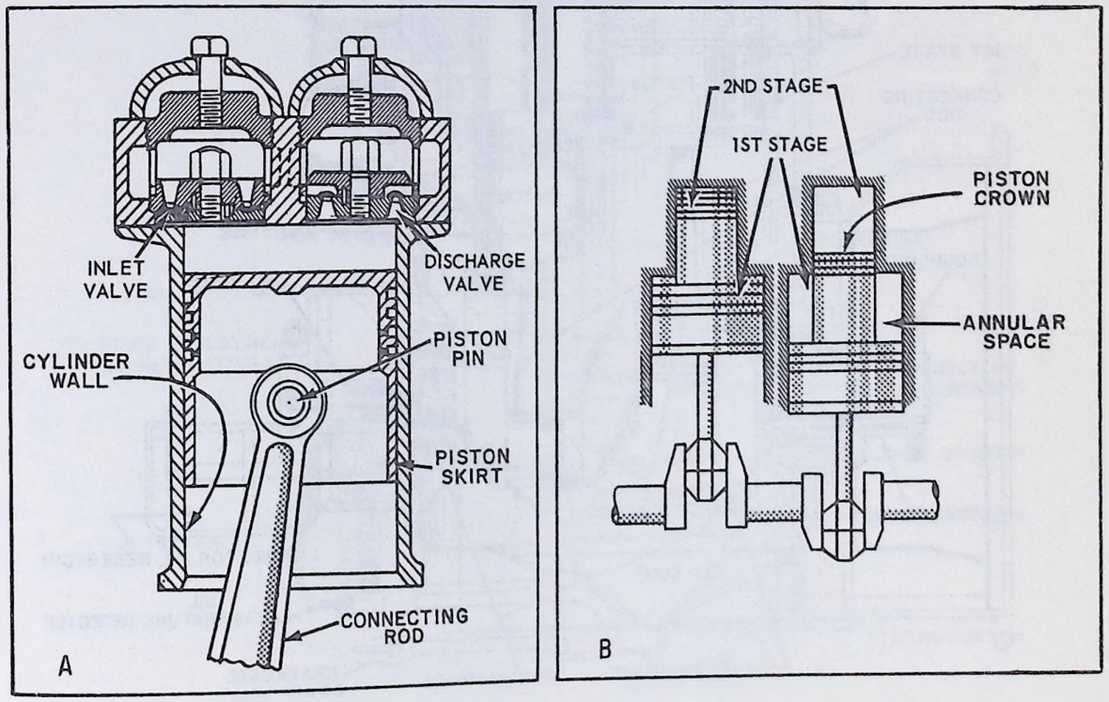
cylinders and pistons of high-pressure compressors are shown in part B of figure 13-4. The stages are numbered 1 through 4, and a 3- and a 4-stage arrangement are shown. In 5- and 6-stage compressors, the same basic stage arrangement is followed.

PISTONS.—The pistons may be of two types, trunk pistons or differential pistons. TRUNK PISTONS (fig. 13-7A) are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston (also referred to as wrist or trunk) pin, there is a tendency for the piston to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, pistons with long skirts are used. This type of piston minimizes cylinder wall wear.

DIFFERENTIAL PISTONS (fig. 13-7B) are modified trunk pistons having two or more different diameters. These pistons are fitted into special cylinders which are arranged so that more than one stage of compression is achieved by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Lubrication System

Except for the oil-free (nonlubricated) compressors, lubrication of high-pressure air compressor cylinders is generally accomplished by means of an adjustable mechanical force-feed lubricator, which is driven from a reciprocating or a rotary part of the compressor. Oil is fed from the cylinder lubricator by separate lines to each cylinder. A check valve is installed at the end of each feed line to keep the compressed air from forcing the oil back into the lubricator.



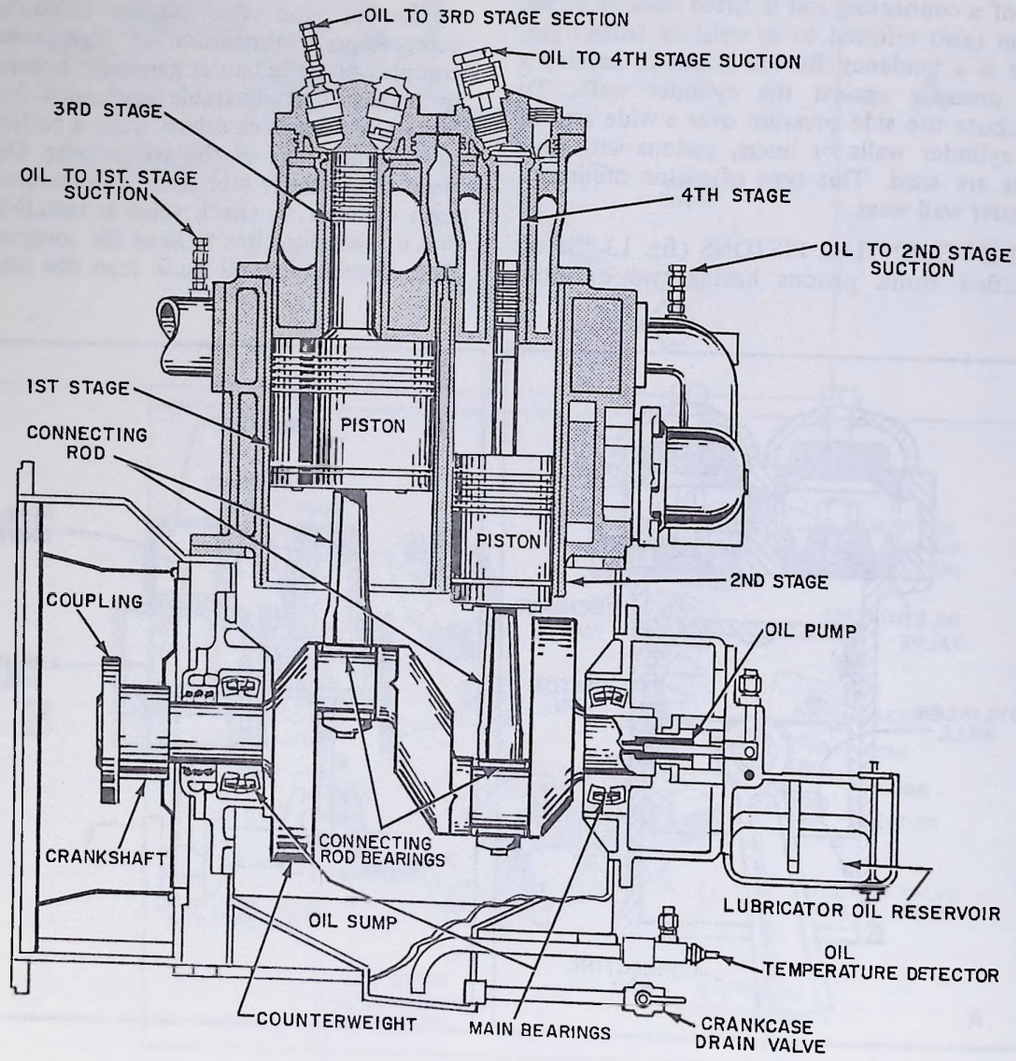
47.155

Figure 13-7.—Air compressor pistons. A. Trunk type. B. Differential type.

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Each feed line is equipped with a sight-glass oil flow indicator. Lubrication begins automatically as the compressor starts up. The amount of oil that must be fed to the cylinder depends on the cylinder diameter, the cylinder wall temperature, and the viscosity of the oil. Figure 13-8 shows the lubrication connections for the cylinders. The type and grade of oil used in compressors is specified in the equipment technical manual and is vital to the operation and reliability of the compressor.

The running gear is lubricated by an oil pump, which is attached to the compressor and is driven from the compressor shaft. This pump (usually of the gear type) draws oil from the reservoir (oil sump) shown in figure 13-8, in the compressor base and delivers it, through a filter, to an oil cooler (if installed). From the cooler,



47.221

Figure 13-8.—High-pressure air compressor.

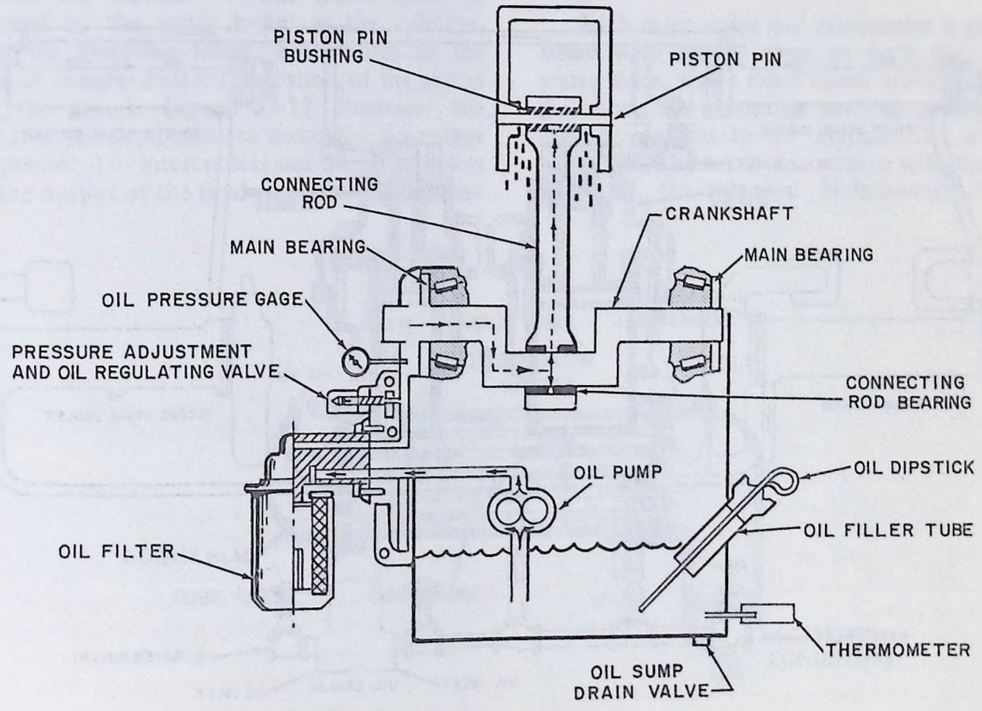
the oil is distributed to the top of each main bearing, to spray nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so that oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages which conduct lubricating oil from the crank bearings up to the piston pin bushings. As oil leaks out from the various bearings, it drips back into the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the sump by the drain lines.

Low-pressure air compressor lubrication is shown in figure 13-9. This system is similar to the running gear lubrication system for the high-pressure air compressor.

Nonlubricated reciprocating compressors have lubricated running gear (shaft and bearings) but no lubrication for the pistons and valves. This design produces oil free air.

Cooling Systems

Most high-pressure and medium-pressure compressors are cooled by the ship's auxiliary freshwater or by seawater supplied from the ship's fire main or machinery cooling water service mains. The cooling water is generally supplied to each unit from either of two sources. Compressors located outside the larger machinery spaces may be equipped with an attached circulating water pump as a standby source of cooling water. Small low-pressure compressors used to supply ship's service air and diesel engine starting air and some small capacity high-pressure air compressors are air-cooled by a fan driven by the compressors.



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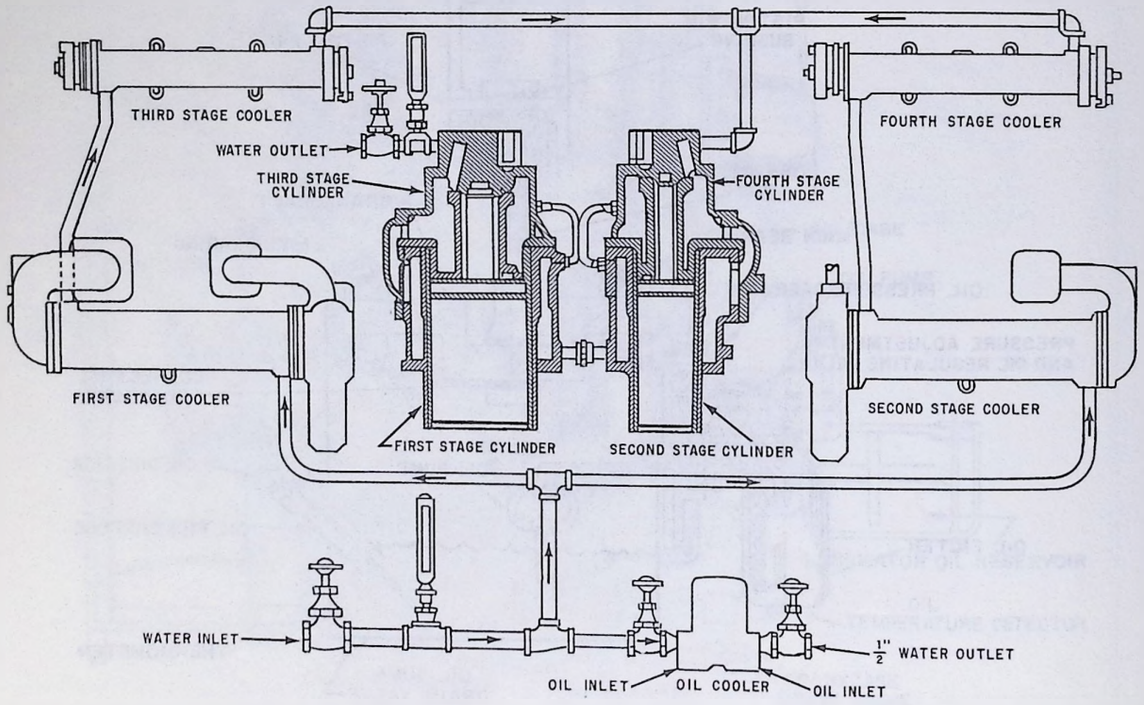
Figure 13-9.—Lubricating Oil System of a low-pressure air compressor.

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The path of water in the cooling water system of a typical four-stage compressor is illustrated in figure 13-10. Not all cooling water systems have identical path-of-water flow, but in systems equipped with oil coolers it is important that the coldest water be available for circulation through the cooler. Valves are usually provided to control the water to the cooler independently of the rest of the system. Thus, oil temperature can be controlled without harmful effects to other parts of the compressor. Cooling of the air in the intercoolers and aftercoolers is very important, as well as cooling the cylinder jackets and heads. The amount of cooling water required depends on the capacity (cfm) and pressure. High-pressure air compressors require more cooling water (for the same cfm) than the low-pressure units.

When seawater is used as the cooling agent, all parts of the circulating system must be of corrosion-resistant materials. The cylinders and heads are therefore composed of a bronze alloy with water jackets cast integral with the cylinders. Each cylinder is generally fitted with a liner of special cast iron or steel to withstand the wear of the piston. Wherever practicable, cylinder jackets are fitted with handholes and covers so that the water spaces can be inspected and cleaned. Jumpers are usually used to make water connections between the cylinders and heads because they prevent possible leakage into the compression spaces. In some compressors, however, the water passes directly through the joint between the cylinder and the head. With this latter type, the joint MUST be properly gasketed to prevent leakage which, if allowed to continue, will damage the compressor.

The INTERCOOLERS and AFTERCOOLERS remove heat generated during compression and promote condensation



47.157

Figure 13-10.—Cooling water system in a typical multistage air compressor.

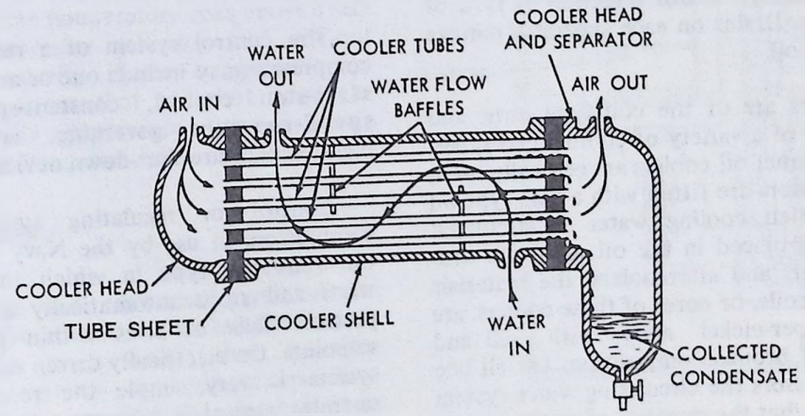
of any vapor that may be present. Figure 13-11 is a diagram of a basic cooler and separator unit showing the collected condensate in the separator section. The collected condensate must be drained at regular intervals to prevent carryover into the next stage. Accumulation at low points may cause water hammer, freezing and bursting of pipes in exposed locations, faulty operation of pneumatic tools, and possible damage to electrical apparatus when air is used for cleaning. The removal of heat is also required for economical compression. During compression the temperature of the air increases, thus causing the air to expand to a larger volume which, in turn, requires a corresponding increase of work to compress it. Multistaging, therefore, with interstage cooling of the air, reduces the power requirement for a given capacity.

The interstage cooling reduces the maximum temperature in each cylinder and thereby reduces the amount of heat which must be removed by the water jacket at the cylinder. Also, the resulting lower temperature in the cylinder ensures better lubrication of the piston and the valves. Figure 13-12 illustrates the pressures and temperatures through a four-stage compressor. The intercoolers and the aftercoolers (on the output of the final stage) are of the same general construction except that the aftercooler is designed to withstand a higher working pressure than the intercoolers.

Water-cooled intercoolers may be of the straight tube and shell type (fig. 13-11) or, if size dictates, of the coil type. In coolers with an air discharge pressure below 250 psi, the air may flow either through the tubes or over and around them. In coolers with an air discharge pressure above 250 psi, the air generally flows through the tubes. In tubular coolers, baffles deflect the air or water in its course through the cooler. In coil-type coolers the air passes through the coil and the water flows around the coils.

Air-cooled intercoolers and aftercoolers may be of the radiator type or may consist of a bank of finned copper tubes located in the path of cooling air supplied by the compressor cooling fan.

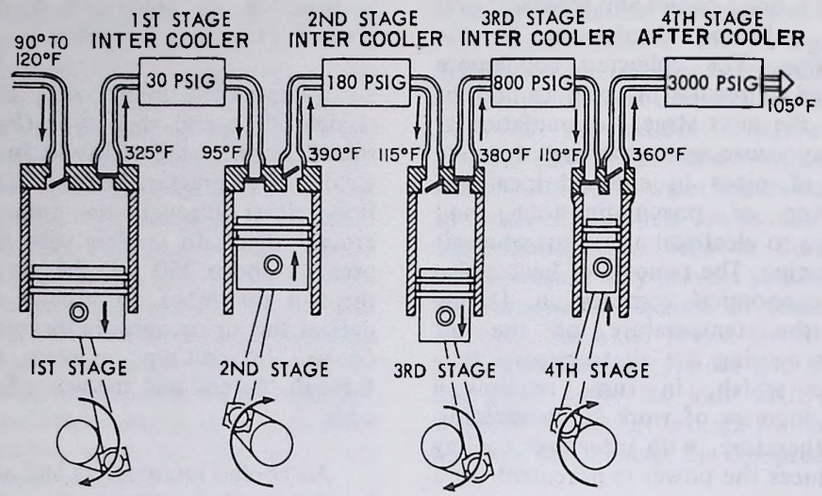
Each intercooler and aftercooler is generally fitted with relief valves on both the air and water sides. Water relief valves are usually set 5 psi above the maximum working pressure that may be applied to the system. The air relief valves must be set in accordance with directions given in the Planned Maintenance System,



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Figure 13-11.—Basic cooler and separator.

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Figure 13-12.—Pressures and temperatures resulting from multistaging and interstage cooling.

manufacturer's technical manual, or in the *Naval Ships' Technical Manual*, Chapter 551 (9590).

As seen earlier, intercoolers and aftercoolers are normally fitted with moisture separators on the discharge side to remove the condensed moisture and oil from the air stream. The separators are of a variety of designs. Liquid is removed by centrifugal force, impact, or sudden changes in velocity and/or direction of flow of the air stream. Drains on each separator remove the water and oil.

Oil coolers are of the coil type, tube and shell type, or of a variety of commercial types. Although external oil coolers are generally used, some compressors are fitted with a base type oil cooler in which cooling water is circulated through a coil placed in the oil sump. As with the intercoolers and aftercoolers, the materials of the tubes, coils, or cores of these coolers, are made of copper-nickel alloy with shell and tube sheets of bronze composition. On all late model compressors the circulating water system is arranged so that the quantity of cooling water passing through the oil cooler can be regulated without disturbing the quantity of water passing through the cylinder jackets, intercoolers, or aftercoolers. Thermometers or other temperature measuring devices are fitted to the circulating water inlet and outlet connections, to the intake and discharge of each stage of compression, to the final air discharge, and to the oil sump.

Control Systems

The control system of a reciprocating air compressor may include one or more devices for start-stop control, constant-speed control, speed-pressure governing, and automatic high-temperature shut-down devices.

Control or regulating systems for air compressors in use by the Navy are largely of the start-stop type in which the compressor starts and stops automatically as the receiver pressure falls or rises within predetermined setpoints. On electrically driven compressors the system is very simple—the receiver pressure operates against a pressure switch that opens when the pressure upon it reaches a given limit and closes when the pressure drops a predetermined amount. Centrifugal compressors do not have automatic start-stop controls mainly

because of their high horsepower. An automatic load/unload control system is used.

On electrically driven units required to start at either of two pressures, as in some of the medium-pressure systems, one of two pressure switches are selected with a three-way valve or cock that admits pressure from the air accumulator to the selected pressure switch. Another method is to direct the air from the receiver through a three-way valve to either of two control valves set for the respective range of pressures. A line is run from each control valve to a single pressure which may be set at any convenient pressure since the setting of the control valve selected will determine the operation of the switch.

The CONSTANT-SPEED CONTROL regulates the pressure in the air receiver by controlling the output of the compressor without stopping or changing the speed of the unit. This control prevents frequent starting and stopping of compressors when there is a fairly constant but low demand for air. Control is provided by directing air to unloading devices through a control valve set to operate at a predetermined pressure.

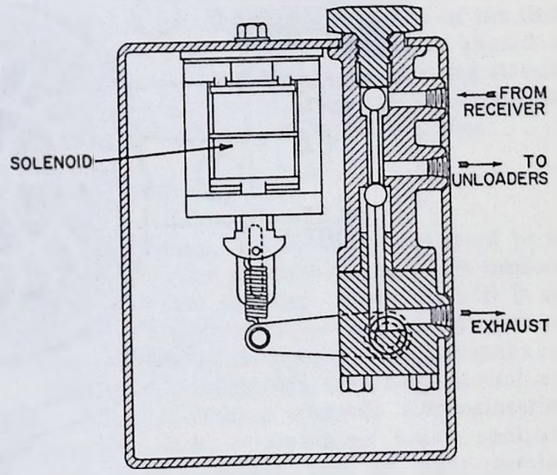
AUTOMATIC HIGH-TEMPERATURE SHUTDOWN DEVICES are fitted on all recent designs of high-pressure air compressors. Thus, if the cooling water temperature rises above a safe limit, the compressor will stop and will not restart automatically. Some compressors are fitted with a device that will shut down the compressor if the temperature of the air leaving any stage exceeds a preset value.

Unloading Systems

Air compressor unloading systems are installed for the removal of all but the friction loads on the compressors; that is, they automatically remove the compression load from the compressor while the unit is starting and automatically apply the load after the unit is up to operating speed. For units having start-stop control, the unloading system is separate from the control system. For compressors equipped with constant-speed control, the unloading and control systems are integral parts of each other.

We cannot give a detailed explanation for every type of unloading device used to unload air compressor cylinders, but you should know something about several of the unloading methods which you will probably encounter. These include closing or throttling the compressor intake, holding intake valves off their seats, relieving intercoolers to the atmosphere, relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake), opening up cylinder clearance pockets, using miscellaneous constant-speed unloading devices, and various combinations of these methods.

As an example of a typical compressor unloading device, consider the MAGNETIC TYPE UNLOADER. Figure 13-13 illustrates the unloader valve arrangement. This unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is deenergized, admitting air from the receiver to the unloading mechanism. When the compressor reaches



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Figure 13-13.—Magnetic type unloader.

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near-normal speed, the solenoid valve is energized, releasing the pressure from the unloading mechanism and loading the compressor again.

For detailed information on the various unloading devices, refer to the pertinent manufacturers' technical manuals for compressors installed in your ship.

ROTARY-CENTRIFUGAL AIR COMPRESSORS

A nonreciprocating type of air compressor that may be found aboard ship is variously referred to as a rotary compressor, a centrifugal compressor, or a "liquid piston" compressor. Actually, the unit is something of a mixture, operating partly on rotary principles and partly on centrifugal principles; most accurately, perhaps, it might be called a rotary-centrifugal compressor.

The rotary-centrifugal compressor is used to supply low-pressure compressed air. Because this compressor is capable of supply air that is completely free of oil, it is often used as the compressor for pneumatic control systems and for other applications where oil-free air is required.

The rotary-centrifugal compressor, shown in figure 13-14, consists of a round, multibladed rotor which revolves freely in an elliptical casing. The elliptical casing is partially filled with high-purity water. The curved rotor blades project radially from the hub. The blades, together with the side shrouds, form a series of pockets or buckets around the periphery. The

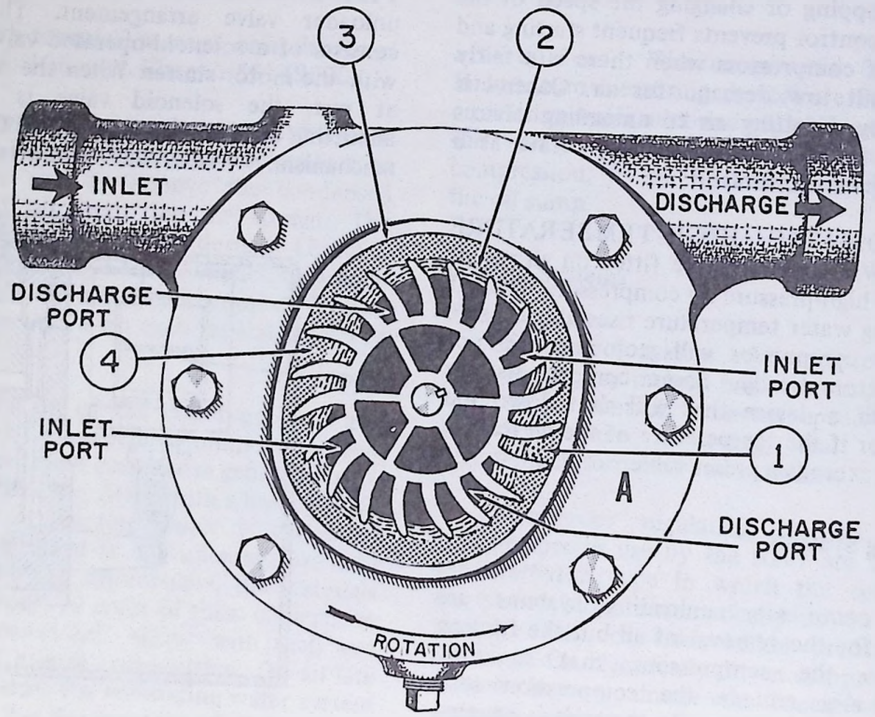


Figure 13-14.—Rotary-centrifugal compressor. 147.119

rotor, which is keyed to the shaft of an electric motor, revolves at a speed high enough to throw the liquid out from the center by centrifugal force, resulting in a solid ring of liquid revolving in the casing at the same speed as the rotor but following the elliptical shape of the casing. This action alternately forces the liquid to enter and recede from the buckets in the rotor at high velocity.

To follow through a complete cycle of operation, look at figure 13-14 and let us start at point A (located at right center). The chamber (1) is full of liquid. The liquid, because of centrifugal force, follows the casing, withdraws from the rotor, and pulls air in through the inlet port. At (2) the liquid has been thrown outward from the chamber in the rotor and has been replaced with atmospheric air. As the rotation continues, the converging wall (3) of the casing forces the liquid back into the rotor chamber, compressing the trapped air and forcing it out through the discharge port. The rotor chamber (4) is now full of liquid and ready to repeat the cycle which takes place twice in each revolution.

A small amount of water must be constantly supplied to the compressor to make up for that which is carried over with the compressed air. The water which is carried over with the compressed air is removed in a refrigeration-type dehydrator.

COMPRESSED AIR RECEIVERS

An air receiver is installed in each space that houses air compressors (except centrifugal and rotary lobe types). The receiver is an air storage tank. If demand is greater than the compressor capacity, some of the stored air is supplied to the system. If demand is less than the compressor capacity, the excess is stored in the receiver or accumulator until the pressure is raised to its maximum setting, at which time the compressor unloads or stops. Thus, in a compressed air system, the receiver functions to minimize pressure variations in the system and to supply air during peak demand. This will minimize start-stop cycling of air compressors. Air receivers may be horizontal or vertical. Vertically mounted receivers have convex bottoms to permit proper draining of accumulated moisture, oil, and foreign matter. All receivers have such fittings as inlet and outlet connections; drain connections and valves; connections for an operating line to compressor regulators, pressure gages, relief valves (set at approximately 12% above normal working pressure of the receiver); and handhole or manhole plates (depending on the size of the receiver). The discharge line between the compressors and the receiver is as short and straight as possible to eliminate vibration due to pulsations of air and to reduce pressure losses due to friction.

In high-pressure air systems, air receivers are called AIR FLASKS. Air flasks are usually cylindrical in shape, having belled ends and female-threaded necks. The flasks are also constructed in shapes to conform to the hull curvature for installation between hull frames.

One or more air flasks connected together constitute an air BANK.

COMPRESSED AIR SUPPLY SYSTEMS

The remainder of a compressed air system is the piping and valves which distribute the compressed air to the points of use.

HIGH-PRESSURE AIR

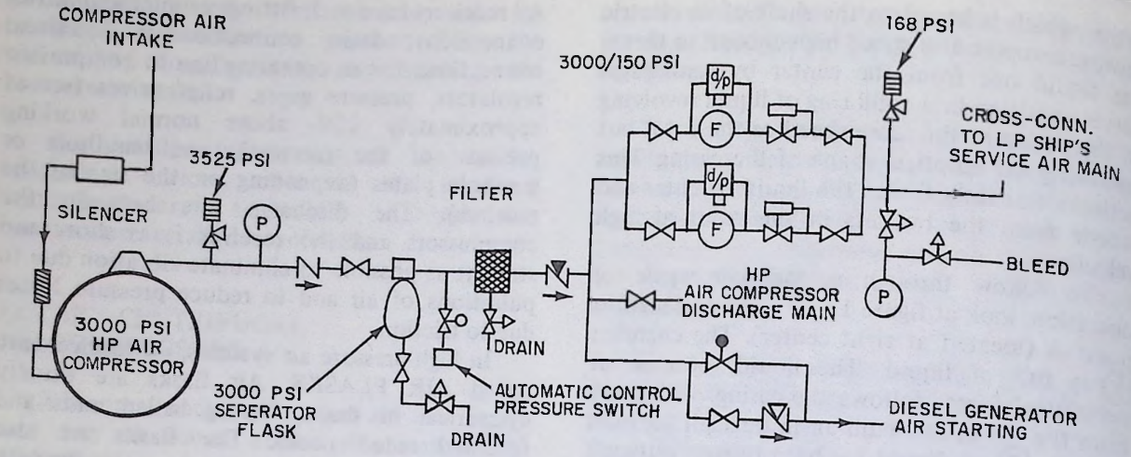
Figure 13-15A is an illustration of the first part of a high-pressure air system aboard a surface ship. The 3000/150 psi reducing station is used for emergencies or abnormal situations to provide air to the low-pressure air system.

LOW-PRESSURE AIR

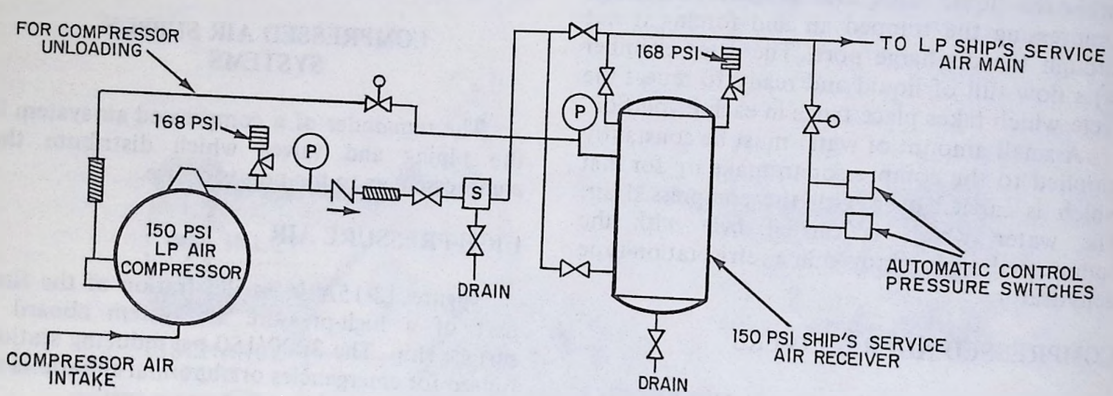
Low-pressure air (sometimes referred to as LP ship's service air) is the most widely used air system aboard the ship. Figure 13-15B is an illustration of the first part of a low-pressure air system. Many of the low-pressure air systems are divided into subsystems, vital and nonvital air.

Vital air is used primarily for engineering purposes such as automatic boiler controls, water level controls, and air pilot-operated control valves. Vital air is also supplied to electronics systems. Vital air systems are split between all main machinery groups with cross-connect capability.

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(A) HP AIR COMPRESSOR AND CROSS CONNECTION REDUCING STATION



(B) SHIP'S SERVICE LP AIR COMPRESSOR AND RECEIVER

LEGEND		
PRESSURE REDUCING VALVE	GLOBE VALVE	DIFFERENTIAL PRESSURE INDICATOR
PRESSURE SWITCH	NEEDLE VALVE	LP AIR PURIFIER
GLOBE VALVE LOCKED SHUT	CHECK VALVE SWING	FILTER
GLOBE VALVE LOCKED OPEN	CHECK VALVE LIFT	ANGLE RELIEF VALVE
PRESSURE GAGE	FLEXIBLE CONNECTOR	

Figure 13-15.—HP and LP air compressor piping arrangements. 47.225

Nonvital air is provided for many different purposes, such as laundry equipment, tank-level indicating systems, and airhose connections. Air for a nonvital air system is supplied through a PRIORITY VALVE, which will shut automatically to secure air to nonvital components when the pressure in the air system drops to a specified setpoint and to reopen to restore nonvital air when pressure in the system returns to normal. This system gives the vital air first priority on all the air in the low-pressure system.

PRAIRIE-MASKER AIR SYSTEMS

A special purpose air system installed in many surface ships is the prairie-masker air system. This system supplies "disguise" air to a system of emitter rings or belts surrounding the hull and to the propeller blades through the propulsion shafts.

The emitter rings contain small holes which release the masker air into the sea, coating the hull with air bubbles.

The prairie air passing through the propulsion shafts is emitted to sea by small holes in the propeller blades.

The air supply for the prairie-masker system is provided by a turbocompressor. The turbocompressor is composed of the following five major parts contained in one compact unit: turbine-driven compressor, lube water tanks, air inlet silencer, lube water system and control system.

The turbine-driven compressor consists of a single-stage centrifugal compressor driven by a single-stage impulse turbine. The compressor impeller and the turbine wheel are mounted at opposite ends of the same shaft. Two water-lubricated bearings support the rotor assembly. The compressor runs at speeds approaching 40,000 rpm. A control system for the unit provides constant steam admission, overspeed trip, overspeed alarm, low lube pressure trip and alarm, and a high lube water temperature alarm.

MOISTURE REMOVAL

The removal of moisture from compressed air is an important part of compressed air systems. If air at atmospheric pressure, with even a very low relative humidity, is compressed to 3,000 psi or 4,500 psi, it becomes saturated with water vapor. Some moisture is removed by the intercoolers and aftercoolers as seen earlier in the chapter. Also, air flasks, receivers and banks are provided with low point drains to periodically drain any collected moisture. However, many shipboard uses of air require air with an even smaller moisture content than is obtained through these methods. In addition, moisture in air lines can create other problems which are potentially hazardous, such as the freezing up of valves and controls. This can occur, for example, if very high-pressure air is throttled to a very low pressure at a high flow rate. The venturi effect of the throttled air produces very low temperatures which will cause any moisture in the air to freeze into ice, making the valve (especially an automatic valve) either very difficult or impossible to operate. Also, droplets of water in an air system with a high pressure and high flow rate can cause serious water hammer within the system. For these reasons, air dryers or dehydrators are used to dry the compressed air. Two basic types of air dehydrators are in use: the desiccant type and the refrigerated type.

Desiccant Type Dehydrators

A desiccant is a drying agent. More practically, a desiccant is a substance with a high capacity to remove (absorb) water or moisture and also a high capacity to give off that moisture so that the desiccant can be reused.

In compressed air system dehydrators, a pair of desiccant towers (flasks full of desiccant) are used. One is on service dehydrating the compressed air while the other is being "reactivated." A desiccant tower is normally reactivated by passing dry, heated air through the tower being reactivated in the direction opposite to normal dehydration airflow. The hot air evaporates the collected moisture and carries it out of the tower to the atmosphere. The purge air is heated by electrical heaters. Once the tower that is reactivating has completed the

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reactivation cycle, it is placed on service to dehydrate air and the other tower is reactivated.

Another type of desiccant dehydrator in use is the Heat-Les Dryer. These units require no electrical heaters or external source of purge air to operate. Figure 13-16A shows the compressed air entering at the bottom of the left tower, passing upward through the desiccant where it is dried to a very low moisture content. The dry air passes through the check valve to the dry air outlet. Simultaneously, a small percentage of the dry air is passed through the orifice between the towers and flows down through the right tower, reactivating the desiccant and passing out through the purge exhaust. At the end of the cycle, the towers are automatically reversed, as shown in part B of figure 13-16.

Refrigerated Type Dehydrators

Another method of removing moisture from compressed air is through the use of refrigeration. If we pass the compressed air over a set of refrigerated cooling coils, oil and moisture vapors will condense from the air and can be collected and removed via a low point drain.

Some installations may use a combination of a refrigerated dehydrator and desiccant dehydrators to purify the compressed air.

COMPRESSED AIR PLANT OPERATION AND MAINTENANCE

The operation of any air compressor or air system must be done in strict compliance with approved operating procedures. Compressed air is potentially very dangerous. Cleanliness is of utmost importance in all maintenance that requires opening compressed air systems.

Figure 13-17 is a Maintenance Index Page (MIP) for one design and make of high-pressure air compressor. This will give you an idea of the planned maintenance required on an air compressor.

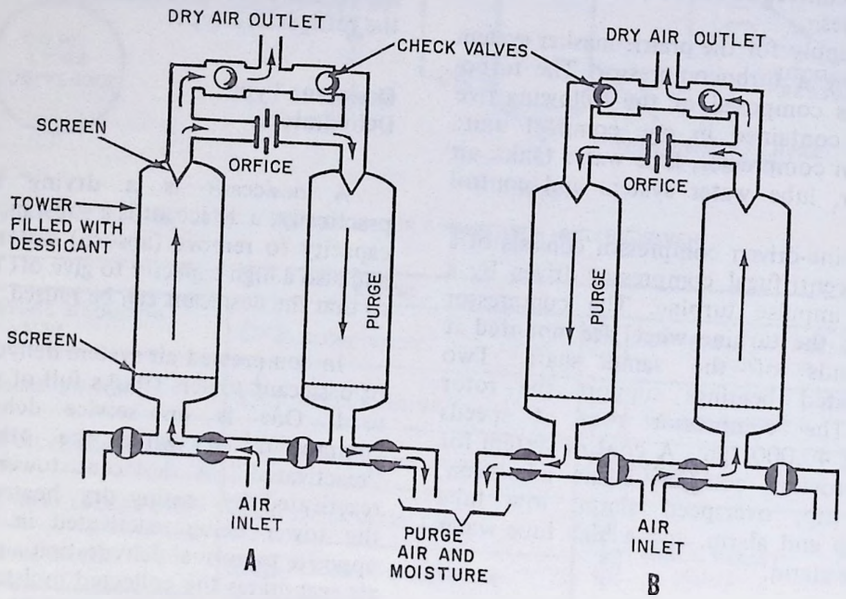


Figure 13-16.—Heat-Les dehydrator. 47.226

SAFETY PRECAUTIONS

There are many hazards associated with pressurized air, particularly high-pressure air. Serious explosions have occurred in high-pressure air systems because of diesel effect. If a portion of an unpressurized system or component is suddenly and rapidly pressurized with high-pressure air, a large amount of heat is produced. If the heat is excessive, the air may reach the ignition temperature of the impurities present in the air and piping (oil, dust, etc). When the ignition temperature is reached, a violent explosion will occur as these impurities ignite. In addition, ignition temperatures may result from rapid pressurization of a low-pressure dead end portion of the piping system, malfunctioning of compressor aftercoolers, leaky or dirty valves, and many other causes. Every precaution must be taken to have only clean, dry air at the compressor inlet.

Air compressor accidents have also been caused by improper maintenance procedures such as disconnecting parts while they are under pressure, replacing parts with units designed for lower pressures, and installing stop valves or check valves in improper locations. Improper operating procedures have also caused air compressor accidents with resulting serious injury to personnel and damage to equipment.

To minimize the hazards inherent in the process of compression and in the use of compressed air, all safety precautions outlined in the manufacturers' technical manuals and in *Naval Ships' Technical Manual*, Chapter 551 (9590) must be strictly observed. Some of these hazards and precautions are:

1. Explosions may be caused by dust laden air or by oil vapor in the compressor or receiver. The explosions are triggered by abnormally high temperatures, which may be caused by leaky or dirty valves, excessive pressurization rates, and faulty cooling systems.

2. NEVER use distillate fuel oil or gasoline as a degreaser to clean compressor intake filters, cylinders, or air passages. These oils vaporize easily and will form a highly explosive mixture with the air under compression.

3. Secure a compressor immediately if you observe that the temperature of the air discharged from any stage rises unduly or exceeds the maximum temperature recommended.

4. NEVER leave the compressor station after starting the compressor unless you are sure that the control, unloading, and governing devices are operating properly.

5. To prevent damage due to overheating, compressors must NOT run at excessive speeds. Proper cooling water circulation must be maintained.

6. If the compressor is to remain idle for any length of time and is in an exposed position in freezing weather, the compressor circulating water system should be thoroughly drained.

7. Before working on a compressor, be sure that the compressor is secured and cannot start automatically or accidentally. The compressor should be blown down completely, then, all valves (including control or unloading valves) between the compressor and the receiver should be secured. Appropriate tag-out procedures for the compressor control and the isolation valves must be followed. (Leave the pressure gage open at all times the gages are in place.)

8. When cutting air into the whistle, siren, or a piece of machinery, be sure the supply line to the equipment has been properly drained of moisture. When securing the supply of air to the affected equipment, be sure all drains are left open.

9. Prior to disconnecting any part of an air system, be sure that the part is not under pressure. Pressure gage cutout valves should always be left open to the sections to which they are attached.

10. Avoid rapid operation of manual valves. The heat of compression caused by sudden flow of high pressure into an empty line or vessel can cause an explosion if oil or other impurities are present. Valves should be slowly cracked open until flow is noted and should be kept in this position until pressures on both sides have equalized. The rate of pressure rise should be kept under 200 psi per second.

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SYSTEM, SUBSYSTEM, OR COMPONENT	REFERENCE PUBLICATIONS	DATE
High Pressure Air Compressor		

CONFIGURATION

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN-HOURS	RELATED MAINTENANCE
84 E44R N	1. Sample and inspect lube oil. 2. Turn compressor several revolutions by hand; if power is available, turn by power.	W-2	MM/EN3	0.3	W-3R
82 B74P W	1. Inspect crankcase oil level NOTE: Accomplish weekly or every 24 hours of compressor operation, whichever occurs first.	W-3R	MM/EN3	0.1	None
84 E44S N	1. Clean air intake filter.	S-2	FN	0.5	None
84 E45D N	1. Clean and inspect lubricator reservoir.	A-5	MM/EN3 FN	0.3 0.3	None
B7 C76X N	1. Inspect foundation fasteners for condition and tightness.	A-9	MM/EN3	0.2	None
84 E45E N	1. Test relief valves.	C-1	MM/EN3	1.0	None
84 E45F Y	1. Renew compressor oil. 2. Clean crankcase vent. NOTE: Accomplish after every 200 hours of compressor operation.	R-1	MM/EN2 FN	1.5 1.5	None
84 E45G Y	1. Clean and inspect third and fourth stage valve assemblies. NOTE: Accomplish after every 1000 hours of compressor operation.	R-2	MM/EN2 MMFN	2.0 2.0	None
84 E44X Y	1. Clean and inspect first and second stage valve assemblies. NOTE: Accomplish after every 1000 hours of operation.	R-3	MM/EN2 MMFN	2.0 2.0	None
84 E45H Y	1. Inspect internal parts. NOTE: Accomplish after every 2000 hours of compressor operation.	R-4	MM/EN1 MM/EN2 EM3 2FN	30.0 30.0 1.0 60.0	R-1 R-2 R-3 R-6 R-7 R-9
84 E45J Y	1. Clean and inspect automatic drain valve. NOTE: Accomplish after every 2000 hours of compressor operation.	R-5	MM/EN2 FN	2.0 2.0	None
84 E45K N	1. Clean and inspect cylinder lubricator check valves. NOTE: Accomplish after every 2000 hours of compressor operation.	R-6	MM/EN3 FN	1.6 1.6	None
84 E45L N	1. Clean and inspect final discharge check valve. NOTE: Accomplish after every 1000 hours of compressor operation.	R-7	MM/EN3 FN	0.5 0.5	None

MAINTENANCE INDEX PAGE (MIP) SYSCOM MIP CONTROL NUMBER (Page 1 of 2)

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Figure 13-17.—MIP for a high-pressure air compressor (front).

SYSCOM MRC CONTROL NO.	MAINTENANCE REQUIREMENT	PERIODICITY CODE	SKILL LEVEL	MAN-HOURS	RELATED MAINTENANCE
84 E45M N	1. Clean and inspect oil filter. NOTE: Accomplish after every 2000 hours of compressor operation.	R-9	MM/EN3 FN	2.0 2.0	None
84 E45B Y	1. Clean and inspect condensate accumulator. NOTE: Accomplish after every 1000 hours of compressor operation.	R-10	MM/EN3 FN	2.0 2.0	None
84 E45N Y	1. Inspect cooling water shutoff valve. NOTE: Accomplish after every 2000 hours of compressor operation.	R-11	MM/EN2 FN	2.5 2.5	None

MAINTENANCE INDEX PAGE (MIP) SYSCOM MIP CONTROL NUMBER (Page 2 of 2)

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Figure 13-17.—MIP for a high-pressure air compressor (back)—Continued.

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CHAPTER 14

ADDITIONAL AUXILIARY EQUIPMENT

The Machinist's Mate may be concerned with wide variety of auxiliary equipment not directly related to the propulsion plant of the ship. This equipment includes, but is not limited to steering gear, cargo, or weight-handling equipment, hydraulic systems of all types such as fin stabilizers, and laundry and galley equipment. Much of this machinery you will not be required to operate, but you will be expected to perform preventive maintenance (PMS) and repair the equipment. Some equipment, such as that installed in the laundry and galley, is maintained in operating condition through the joint efforts of operating personnel and maintenance personnel.

In general, the operator will keep the equipment clean, make minor adjustments related to the operation of the machine and, in some cases, perform routine preventive maintenance (PMS). The Machinist's Mate is responsible for making any necessary repairs, replacements, or adjustments. Any problems of an electrical nature will be taken care of by the Electrician's Mate. In some cases where the machine is primarily electrical in operation, the responsibility for the entire machine is assigned to the Electrician's Mates.

ELECTROHYDRAULIC DRIVE MACHINERY

Hydraulic units are used for driving or controlling steering gears, windlasses, winches, capstans, airplane cranes, ammunition hoists, and distant control valves. This chapter contains information on some hydraulic units with which Machinist's Mates are concerned.

The electrohydraulic type of drive very efficiently meets the operating requirements of several different kinds of machinery. Some advantages of electrohydraulic machinery are:

1. Tubing, which can readily transmit fluids around corners, is used to conduct the liquid which transmits the force.
2. Very little space is required for tubing.
3. It allows flexibility in location of components.
4. Operation at variable speeds is possible.
5. Close control of speeds from minimum to maximum limits is allowed.
6. It can be shifted from no load to full load rapidly without damage to machinery.
7. It accelerates quickly.
8. It has a high efficiency.
9. It has a favorable power to weight ratio.

ELECTROHYDRAULIC SPEED GEAR

The unit most frequently used in electrohydraulic applications is the electrohydraulic speed gear. Different variations of the basic design are used for specific applications but the principles remain the same. Basically, the unit consists of an electric motor-driven hydraulic pump (A-end) and a hydraulic motor (B-end). (See Chapter 5 of this manual for a discussion on axial piston variable-stroke pumps.)

The B-end (fig. 14-1) is already on stroke and will be made to rotate by the hydraulic

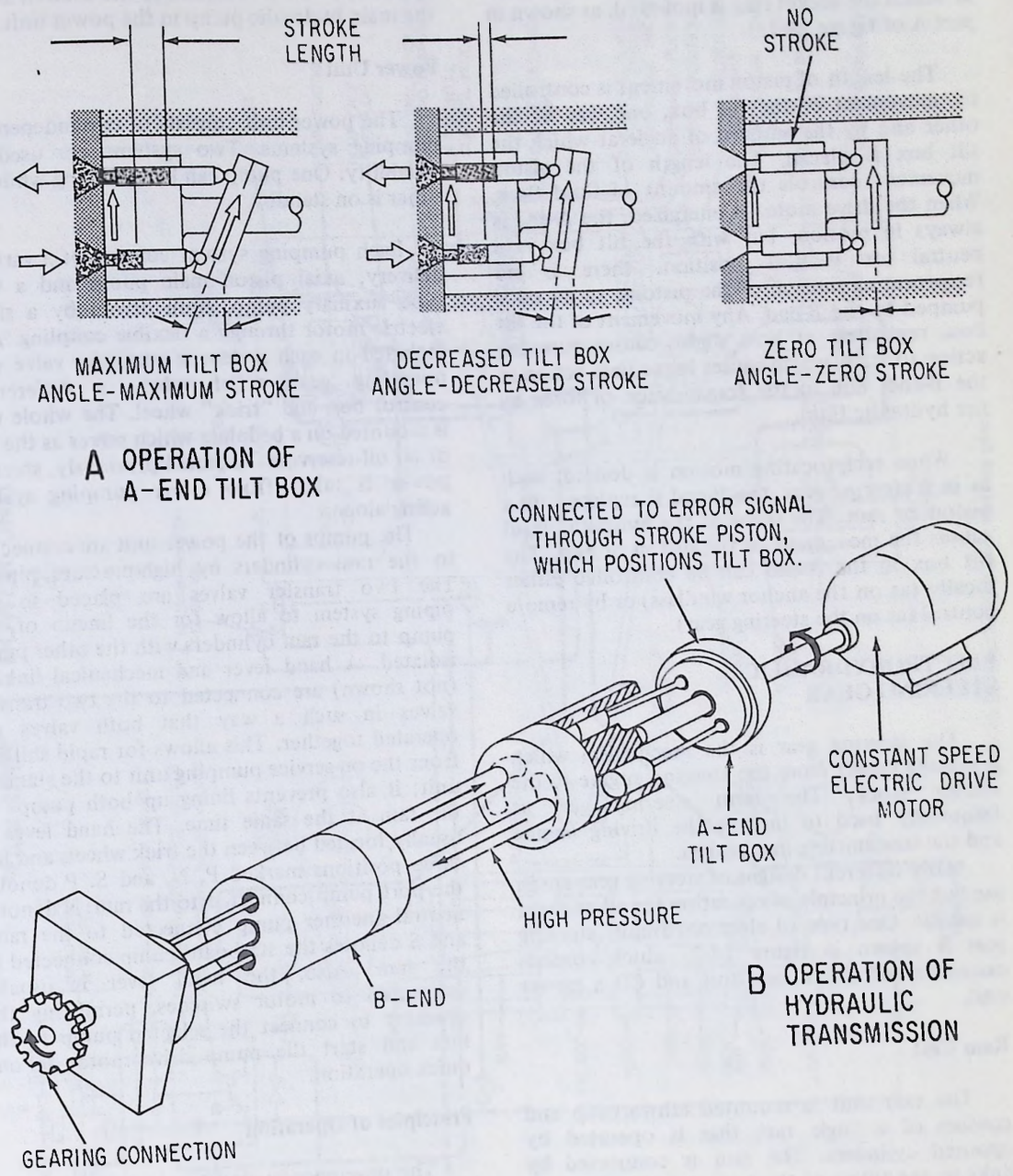


Figure 14-1.—Electrohydraulic Speed Gear.

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force of the oil acting on the pistons. Movement of the pistons' A-end is controlled by a tilt box in which the socket ring is mounted, as shown in part A of figure 14-1.

The length of piston movement is controlled by movement of the tilt box, one way or the other and by the amount of angle at which the tilt box is placed. The length of the piston movement controls the amount of fluid flow. When the drive motor is energized, the A-end is always in motion, but with the tilt box in a neutral or vertical position, there is no reciprocating motion of the pistons, so no oil is pumped to the B-end. Any movement of the tilt box, regardless of how slight, causes pumping action to start, which causes immediate action in the B-end, due to the transmission of force by the hydraulic fluid.

When reciprocating motion is desired, such as in a steering gear, the B-end is replaced by a piston or ram. The force of the hydraulic fluid causes the movement of the piston or ram. The tilt box in the A-end can be controlled either locally (as on the anchor windlass) or by remote control (as on the steering gear).

ELECTROHYDRAULIC STEERING GEAR

The steering gear is the mechanism which transmits power from the steering engine to the rudder stock. The term steering gear is frequently used to include the driving engine and the transmitting mechanism.

Many different designs of steering gear are in use but the principle of operation for all of them is similar. One type of electrohydraulic steering gear is shown in figure 14-2, which consists essentially of (1) a ram unit and (2) a power unit.

Ram Unit

The ram unit is mounted athwartship and consists of a single ram that is operated by opposed cylinders. The ram is connected by links to the tillers of the twin rudders. When oil pressure is applied to one end of the operating cylinder, the ram will move, causing each rudder to move along with it. Oil from the opposite end of the cylinder is returned to the suction side of the main hydraulic pump in the power unit.

Power Unit

The power unit consists of two independent pumping systems. Two systems are used for reliability. One pump can be operating while the other is on standby.

Each pumping system consists of a variable delivery, axial piston main pump and a vane type auxiliary pump, both driven by a single electric motor through a flexible coupling. Also included in each system is a transfer valve with operating gear, relief valves, a differential control box and "trick" wheel. The whole unit is mounted on a bedplate which serves as the top of an oil reservoir. As stated previously, steering power is taken from either pumping system acting alone.

The pumps of the power unit are connected to the ram cylinders by high-pressure piping. The two transfer valves are placed in the piping system to allow for the lineup of one pump to the ram cylinders with the other pump isolated. A hand lever and mechanical linkage (not shown) are connected to the two transfer valves in such a way that both valves are operated together. This allows for rapid shifting from the on-service pumping unit to the standby unit; it also prevents lining up both pumps to the ram at the same time. The hand lever is usually located between the trick wheels and has three positions marked P, N, and S. P denotes the port pump connected to the ram; N denotes neutral (neither pump connected to the ram) and S denotes the starboard pump connected to the ram. Also, the hand lever is usually connected to motor switches, permitting the operator to connect the selected pump to the ram and start the pump drive motor in one quick operation.

Principles of Operation

The on-service hydraulic pump is running at all times and is a constant-speed pump. Unless steering is actually taking place, the tilt box of the main hydraulic pump is at zero stroke, and

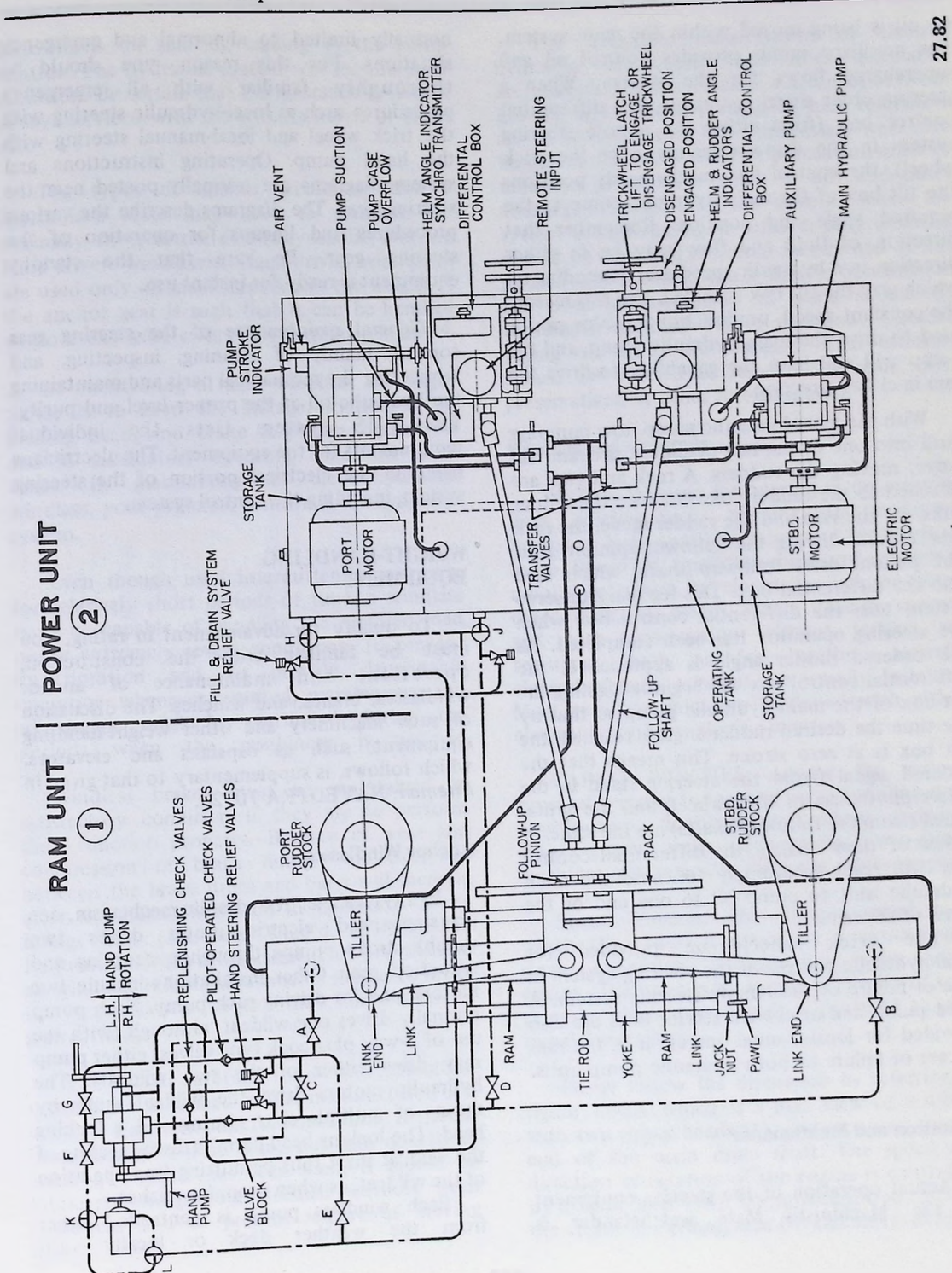


Figure 14-2.—Electrohydraulic steering gear.

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no oil is being moved within the main system. The auxiliary pump provides control oil and supercharge flows for the system. When a steering order signal comes into the differential control box (from either the remote steering system in the ship's wheelhouse or the trick wheel), the control box mechanically positions the tilt box of the main hydraulic pump to the required angle and position. Remember that direction of fluid and flow may be in either direction in a hydraulic speed gear depending on which way the tilt box is angled. For this reason, the constant speed, unidirectional motor can be used to drive the main hydraulic pump, and the pump will still have the capability to drive the ram in either direction.

With the main hydraulic pump now pumping fluid into one of the ram cylinders, the ram will move, moving the rudders. A rack and gear are attached to the rudder yoke between the rudder links. As the ram and the rudder move, the rack gear moves, driving the followup pinion gear. The pinions drive followup shafts which feed into the differential box. This feedback or servo system tells the differential control box when the steering operation has been completed. As the ordered rudder angle is approached, the differential control box will begin re-aligning the tilt box of the main hydraulic pump so that by the time the desired rudder angle is reached, the tilt box is at zero stroke. This means that the ordered signal (from the steering stand in the ship's pilothouse or trick wheel) and the actual signal (from the followup shafts) are the same. If either of these change, the differential control box will react accordingly to cause the main hydraulic unit to pump oil to one end or the other of the ram.

The trick wheels are provided for local-hydraulic control of the steering system in case of failure of the remote steering system. A hand pump and associated service lines are also provided for local-manual operation of the ram in case of failure of both hydraulic pump units.

Operation and Maintenance

Actual operation of the steering equipment by the Machinist's Mate watchstander is normally limited to abnormal and emergency situations. For this reason, you should be thoroughly familiar with all emergency procedures such as local-hydraulic steering with the trick wheel and local-manual steering with the hand pump. Operating instructions and system diagrams are normally posted near the steering gear. The diagrams describe the various procedures and lineups for operation of the steering gear. Be sure that the standby equipment is ready for instant use.

General maintenance of the steering gear consists mainly of cleaning, inspecting, and lubricating the mechanical parts and maintaining the hydraulic oil at the proper level and purity. The PMS system lists the individual requirements for the equipment. The electricians maintain the electrical portion of the steering system, including the control system.

WEIGHT-HANDLING EQUIPMENT

To qualify for advancement in rating, you must be familiar with the construction, operation, and maintenance of anchor windlasses, cranes, and winches. The discussion of such machinery and other weight-handling equipment, such as capstans and elevators, which follows, is supplementary to that given in *Fireman*, NAVEDTRA 10520.

Anchor Windlasses

In a typical electrohydraulic mechanism, one constant-speed electric motor drives two variable-stroke pumps through a coupling and reduction gear. Other installations include two motors, one for driving each pump. Each pump normally drives one wildcat, although (with the use of 3-way plug cock type valves) either pump may drive either of the two wildcats. The hydraulic motors drive the wildcat shafts by means of multiple spur gearing and a locking head. The locking head permits disconnecting of the wildcat shaft thus permitting free operation of the wildcat, as when dropping anchor.

Each windlass pump is controlled either from the weather deck or locally with

handwheels on shafting leading to the pump control. The hydraulic system will require your attention. Be certain that the hydraulic system is always serviced with the specified type of clean oil.

The types of anchor windlasses that a Machinist's Mate may have to maintain are normally the electric, electrohydraulic, and the hand-driven windlasses. Hand-driven windlasses are used only on small ships where the weight of the anchor gear is such that it can be handled without excessive effort by operating personnel.

In maintaining a hand windlass, the major factor is to keep the linkage, friction shoes, locking head, and brake in proper adjustment and in satisfactory operating condition at all times. In maintaining an electrohydraulic windlass, your principal concern is the hydraulic system.

Even though used intermittently and only for relatively short periods of time, a windlass must be capable of handling the required load under extremely severe conditions. To prevent deterioration and to provide dependable operation whenever required, maintenance and adjustment must be continued during the periods when the machinery is not in use.

Windlass brakes must be maintained in satisfactory condition if they are to perform their function properly. Because of wear and compression of brake linings, the clearance between the brake drum and band will increase after a windlass has been in operation. Brake linings and clearances should be inspected frequently. Means of adjustment are provided on all windlass brakes. Adjustments should be made in accordance with the manufacturer's instructions.

You should carefully follow the lubrication instructions furnished by the manufacturer. If a windlass has been idle for some time, it should be lubricated before being put into operation. After a windlass has been used, it should be lubricated to protect finished surfaces from corrosion, and to prevent seizure of moving parts.

The hydraulic transmissions of electro-hydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. If these tolerances are to be maintained and unnecessary wear is to be prevented, every possible precaution must be taken to prevent the entry of dirt and other abrasive material into the system. When the system is replenished or refilled, only clean oil should be used and it should be strained as it is poured into the tank. If a hydraulic transmission has been disassembled, all parts should be thoroughly cleaned before reassembly. Before piping or valves are installed, their interiors should be cleaned to remove any scale, dirt, preservatives, or other foreign matter.

Winches and Capstans

Winches are used for heaving in on mooring lines, hoisting boats, topping lifts on jumbo booms of large auxiliary ships, and for handling cargo. Power for operating shipboard winches is usually furnished by electricity and, on some older ships, by steam. Where delicate control and high acceleration without jerking are required, such as for handling aircraft, electrohydraulic winches are usually installed. Most auxiliary ships are equipped with either electrohydraulic or electric winches.

CARGO WINCHES.—Among the various types of winches for general cargo handling are : double-drum, double-gypsy, and single-drum, single-gypsy units. Four-drum, two-gypsy machines are generally used for minesweeping.

Steam Winches.—The steam-operated deck winch (fig. 14-3) is driven by a two-cylinder single expansion, double-acting reciprocating engine. The drive is by means of a train of spur gears in which a gear shaft is provided to give two-drive speeds.

Please follow the discussion by referring to figure 14-3A which is a plan view of a winch with two gypsy heads (1), one mounted at each end of the main drive shaft. The speed and direction of rotation of the engine is controlled by a hand lever (14). Steam is admitted through the steam line connection (8) and steam exhaust

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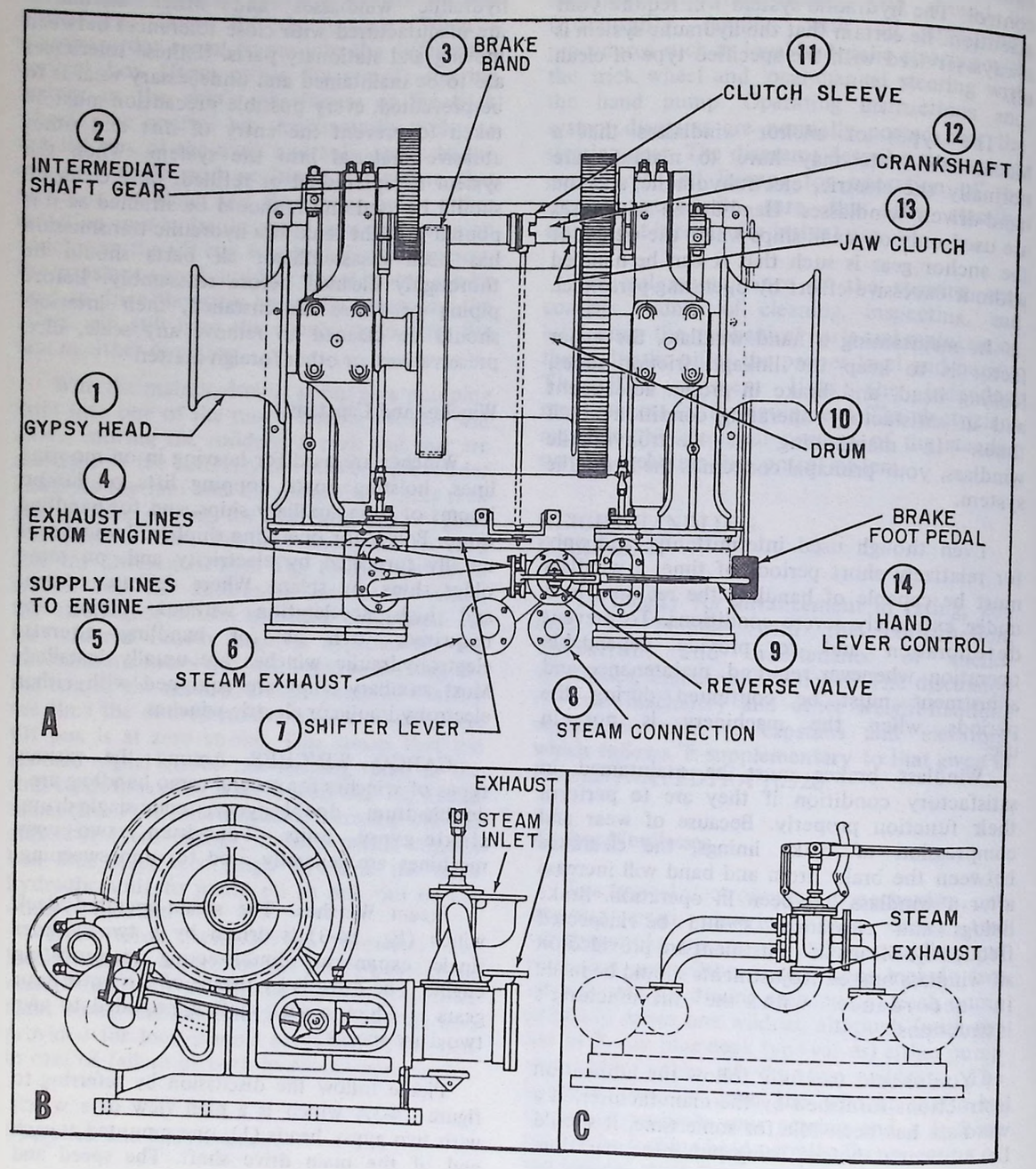


Figure 14-3.—Steam-operated winch. A. Plan view. B. Side view. C. Reversing throttle valve.

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passes out connection (6). With the winch in "compound gear," the drum turns to lift a load when the hand lever (14) is raised. With the lever in this position, a spool-type valve passes steam from the reverse valve (9) through the two top horizontal pipelines (5) to the cylinders where it drives the engine. (Also see parts B and C of fig. 14-3.) The two lower pipes (4) are exhaust lines. When the lever is lowered below the horizontal position, the direction of steam flow is reversed in these pipes and the engine turns in the opposite direction, thus lowering the load. Some levers have an automatic latch for holding them in the horizontal, or neutral positions. For all other positions, the controls must be in the hands of the winch operator who must hold the lever in position for the desired speed.

A spool-type steam valve slides back and forth, opening and closing the ports for the flow of steam to or from the cylinders. The reciprocating motion of the steam valve is imparted to it by a rod moving through a stuffing box and connected to the eccentric on the main shaft.

With the winch in "single gear" the direction of rotation is reversed and a load is raised by lowering the lever. The clutch mechanism consists of a sleeve (11) which is keyed to the crankshaft (12) and provided with a shifter yoke which is operated by a lever (7) located near the reverse valve (9). When this lever is thrown to the left (the position shown in part A of figure 14-3), the pinion, which is integral with it, is engaged with the gear (2) on the intermediate shaft. This is the "compound gear" position and gives a slower-drum speed with an increase in available line pull. When the shifter lever (7) is thrown to the right, the driving sleeve is shifted to the right. This disengages the pinion from the intermediate shaft gear (2) and engages the square jaw clutch (13) and pinion which is always in mesh with the main drive gear. This gives a direct drive from the crankshaft to the main shaft and is called the single gear position. The single gear position gives a higher drum speed for a given engine speed but with a decrease in the available line pull.

The "neutral" position is obtained by placing the shifter lever (7) in the vertical position, leaving no connection between the driving sleeve (11) and either pinion. The shifter lever can be latched in any of the three described positions. Take care to latch the lever in the desired position before operating the winch.

When the winch is under heavy load, there is a high pressure between clutch faces or between gear teeth. This makes it impossible to shift the sleeve and change the gear ratio. To make a change, it is necessary to remove the load from the winch and then turn the engine over very slowly while making the shift.

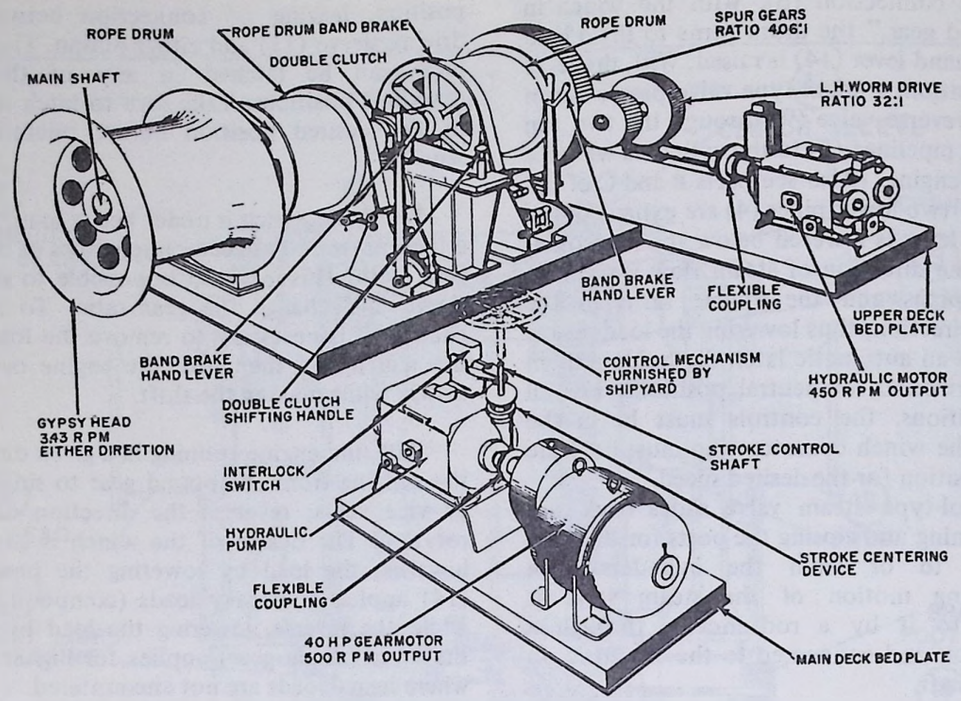
With the engine running in a given direction, the shifting from compound gear to single gear, or vice versa, reverses the direction of drum rotation. The design of the winch is such that lowering the load by lowering the hand lever (14) applies for heavy loads (compound gear), while the reverse, lowering the load by raising the lever (single gear) applies for higher speeds where heavy loads are not encountered.

The winch has a gypsy head (1) at each end of the main drive shaft. The gypsies are keyed to the shaft and turn with the hoisting drum. The drum (10) has a standard type of band brake (3) with a foot-operated control and ratchet lock. The locking device is controlled by springing the foot pedal (15) laterally. The brake band is secured to the winch bedplate in such a manner that the brakes may be conveniently taken up to compensate for wear.

Electrohydraulic Winches.—Electrohydraulic winches (fig. 14-4) are always drum type. The drive equipment is like most hydraulic systems: a constant-speed electric motor drives the A-end (variable-stroke hydraulic pump) which is connected to the B-end (hydraulic motor) by suitable piping. The drum shaft is driven by the hydraulic motor through reduction gearing.

Winches normally have one horizontally mounted drum and one or two gypsy heads. If only one gypsy is required, it may be easily removed from or assembled on either end of the drum shaft. When a drum is to be used, it is connected to the shaft by a clutch.

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Figure 14-4.—Electrohydraulic winch units.

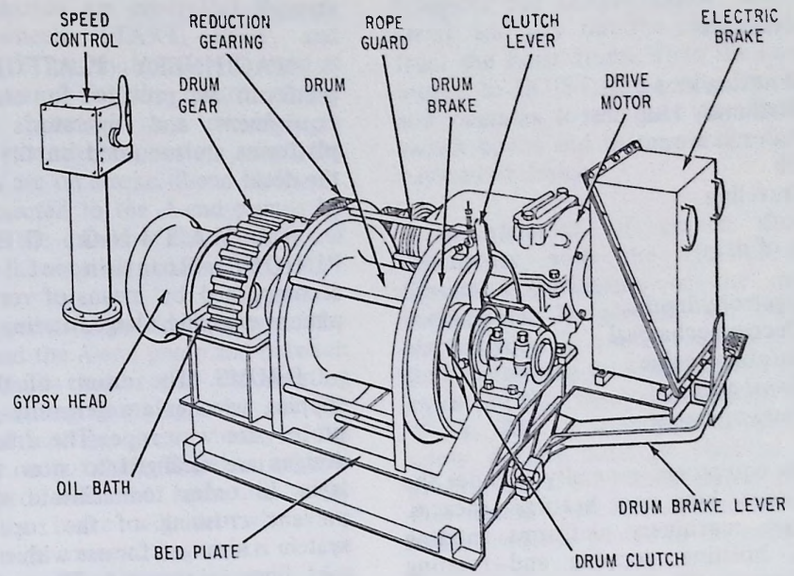
Electric Winches.—An electrically driven winch is shown in figure 14-5. This winch is a single-drum, single-gypsy type. The electric motor drives the unit through a set of reduction gears. A clutch is also provided to engage or disengage the drum from the drum shaft. Additional features include an electric brake and a speed control switch.

CAPSTANS.—The terms "capstans" and "winches" should not be confused. The primary difference between a winch and a capstan is that a winch has a horizontal shaft and a capstan has a vertical shaft. The type capstan installed aboard ship depends on the load requirements and type of power available. In general, a capstan consists of a single head mounted on a VERTICAL shaft, reduction gearing, and a power source. The types, classified according to power source, are electric and steam.

Electric Capstans.—Electric capstans are usually of the reversible type and develop the same speed and power in either direction. Capstans driven by alternating current motors have two speeds, full speed and one-half speed. Capstans driven by direct current motors usually have from three to five speeds in either direction of rotation.

Steam Capstans.—Steam capstans were formerly used extensively in Navy ships, but they are now used only occasionally where the electric power is insufficient.

Steam capstans are driven by twin cylinder, reciprocating, reversible steam engines. A hand-operated control valve reverses and controls the speed of the capstan. Steam-driven capstans generally operate on reduced steam pressure of between 100 psi and 135 psi.



47.227

Figure 14-5.—Electric winch.

Maintenance of Winches and Capstans

In several respects, the maintenance of a winch or a capstan is similar to that for a windlass. Where band brakes are used on the drums, the friction linings should be inspected regularly and replaced when necessary. Steps should be taken to prevent oil or grease from accumulating on the brake drums. The operation of brake-actuating mechanisms, latches, and pawls should be checked periodically.

Winch drums driven by friction clutches should be inspected frequently to determine if deterioration has occurred in the friction material, or if oil and grease are preventing proper operation. The sliding parts of positive clutches must be properly lubricated, and the locking device on the shifting gear should be checked to determine if it will hold under load. The oil of gear reduction units should be checked for proper amount, temperature, and purity. Periodic inspections should be made of the pressure lubrication fittings normally installed on slow moving parts. On installations that use hydraulic transmission, the pumps and lines are maintained in the same way as those of any other hydraulic system.

Cranes

Cranes are designed to meet the following conditions:

1. Hoist, lower, top, and rotate rated load at the specified speed and against a specified list of the ship.

2. Handle 150% rated load at no specified speed.

3. Withstand a static, suspended load of 200% rated load without damage or distortion to any part of the crane or structure.

The types of cranes installed on ships vary in accordance with the equipment handled. Cranes

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are classified as general type and type of drive as follows:

1. General type

   a. Rotating king post
   b. Stationary king post
   c. Pedestal mounted
   d. Jib
   e. Traveling

2. Type of drive

   a. Electrohydraulic
   b. Electromechanical
   c. Gasoline engine
   d. Diesel engine
   e. Hand operated

The crane equipment generally includes the boom, king post, king post bearings, sheaves, hook and rope, machinery platforms, rotating gear, drums, hoisting, topping and rotating drives, and controls. The important components are described in the paragraphs which follow.

BOOMS.—A boom, used as a mechanical shipboard appliance, is a structural unit for lifting, transferring, or supporting heavy weights. A boom is used in conjunction with other structure or structural members which support it, and various ropes and pulleys, called blocks, which control it.

KING POST BEARINGS.—On stationary king posts, bearings are provided for taking both vertical load and horizontal strain at the collar, located at the top of the king post. On rotating king posts, bearings are provided for both vertical and horizontal loads at the base and for horizontal reactions at a higher deck level.

SHEAVES AND ROPES.—The hoisting and topping ropes are led from the drums over sheaves to the head of the boom. The sheaves and ropes are designed in accordance with recommendations by the Naval Sea Systems Command, which give the criteria for selection of sheave diameter, size, and flexibility of the rope. Sufficient fair-lead sheaves are fitted to prevent fouling of the rope. A shock absorber is installed in the line, hoisting block or sheave at the head of the boom, to take care of shock stresses.

MACHINERY PLATFORMS.—Machinery platforms are provided for carrying the power equipment and operator's station. These platforms are mounted on the king post above the deck.

ROTATING GEAR AND PINIONS.—Rotation of the crane is accomplished by means of vertical shafts with pinions engaging a large rotating gear.

DRUMS.—The drums of the hoisting and topping winches are generally grooved for the proper size wire rope. The drums in the latest designs are arranged to stow the rope in one layer in order to facilitate spooling and to prevent crushing of the rope. The hoisting system is arranged for use with single or multiple part lines as required. The topping system is arranged for use with a multiple purchase as required.

Operation and Maintenance of Cranes

The hoisting whips and topping lifts of cranes are usually driven by hydraulic variable-speed gears, through gearing of various types. This provides the wide range of speed and delicate control required for load handling. The cranes are usually rotated by an electric motor connected to worm and spur gearing or by an electric motor and hydraulic variable-speed gear connected to appropriate reduction gearing.

Some electrohydraulic cranes have automatic slack line takeup equipment, consisting of an electric torque motor geared to the drum. When these cranes are used for lifting boats, aircraft, or other loads from the water, the torque motor assists the hydraulic motor drive to reel in the cable in case the load is lifted faster by the water than it is being hoisted by the crane.

Electrohydraulic equipment for the crane consists of one or more electric motors running

at constant speed. Each motor drives one or more A-end variable displacement hydraulic pumps whose strokes are controlled through operating handwheels. START, STOP, and EMERGENCY RUN pushbuttons are located at the operator's station for the control of the electric motors. Interlocks are provided to prevent starting the electric motors when the hydraulic pumps are on stroke. B-end hydraulic motors are connected to the A-end pumps by piping and drive the drums of the hoisting and topping units or the rotating machinery.

Reduction gears are provided between the electric motor and the A-end pump and between the B-end hydraulic motor and the rotating pinion. Each hoisting, topping, and rotating drive is provided with an electric brake on the hydraulic motor output shaft. The electric brake is so interlocked with the hydraulic pump control that the brake will set when the hydraulic control is on neutral or when electric power is lost. A centering device is provided for accurately finding and retaining the neutral position of the hydraulic pump.

Relief valves are installed to protect the hydraulic system. These relief valves are set in accordance with the requirements of Chapter 556 of the *NAVSHIPS' Technical Manual*.

A rapid slack-takeup device consisting of an electric torque motor, which is connected to the hoist drum through reduction gearing, is usually provided on cranes. This device works in conjunction with the pressure stroke control on the hydraulic pump and provides for fast acceleration of the hook in the hoisting direction under light hook conditions. Thus, slack is prevented in the cable when hoisting is started.

Some cranes have a light-hook paying-out device. This device is mounted on the end of the boom to pay out the hoisting cables when the weight of the hook and cable beyond the boom head sheave is insufficient to overhaul the cable as fast as it is unreeled from the hoisting drum.

When the mechanical hoist control is in neutral, the torque motor is not energized and the cable is gripped lightly by the action of a spring. Moving the hoist control to LOWER energizes the torque motor, and the sheaves clamp and pay out the cable as it is unreeled from the hoist drum. When the hoist control is moved to HOIST, the torque motor is reversed and operates to unclamp the sheaves. A limit switch opens and automatically deenergizes the paying-out device.

Maintenance of cranes should be in accordance with the Planned Maintenance System requirements or the manufacturers' instructions. In general, the maintenance of electrohydraulic cranes requires that the oil in the replenishing tanks be kept at the prescribed levels and that the system be kept clean and free of air. The limit stop and other mechanical safety devices must be checked regularly for proper operation. When cranes are not in use, they should be secured in their stowed positions, and all electric power to the controllers should be secured.

Elevators

Some of the hydraulic equipment that you may be required to maintain will be found in electrohydraulic elevator installations. Elevators of this type are in use in modern carriers. The elevators described in this chapter are of the type now in service in some of the ships of the CV class. These ships are equipped with four deck-edge airplane elevators which have a maximum lifting capacity of 79,000 to 105,000 pounds. The cable lift platform of each elevator projects over the side of the ship and is operated by an electrohydraulic plant.

ELECTROHYDRAULIC POWER PLANT.—The electrohydraulic power plant consists of the following:

1. Horizontal plunger-type hydraulic engine
2. Multiple variable-delivery parallel piston-type pumps
3. Two high-pressure tanks
4. One low-pressure tank

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5. Sump tank system
6. Two constant-delivery vane-type pumps (sump pumps)
7. Oil storage tank
8. Piping system and valves
9. Nitrogen supply

The hydraulic engine is operated by pressure developed in a closed hydraulic system. Oil is supplied to the system in sufficient quantity to cover the baffle plates in the high-pressure tanks and allow for piston displacement. Nitrogen is used because air and oil in contact under high pressure form an explosive mixture. Air should not be used except in an emergency; nitrogen, when used, should be maintained at 97% purity.

PRINCIPLES OF OPERATION.—The hydraulic engine is fitted with a balanced piston-type valve with control orifices and a differential control unit. This control assembly is actuated by an electric motor and can be operated by hand. To raise the elevator, the valve is moved off center, allowing high-pressure oil to enter the cylinder. High-pressure oil entering the cylinder moves the ram, which, through a system of cables and sheaves, moves the platform upward. The speed of the elevator is controlled by the amount of pressure in the high-pressure tank and the control valve.

When the elevator starts upward, the pressure in the high-pressure tank drops. The pressure drop automatically starts the main pumps which transfer oil from the low-pressure tank to the high-pressure system until the pressure is restored. An electrical stopping device automatically limits the stroke of the ram and stops the platform at the proper position at the flight deck level.

To lower the elevator, the control valve is moved in the opposite direction, which permits the oil in the cylinder to flow into the exhaust tank. As the platform descends, oil is discharged to the low-pressure tank (exhaust tank) and the original oil levels and pressures, except for leakages, are reestablished. The speed of lowering is controlled by the control valve and the cushioning effect of the pressure in the exhaust tank. Leakage is drained to the sump tanks and automatically transferred to the pressure system by the sump pumps. An electrically operated stopping device automatically slows down the ram and stops the platform at its lower level (hangar deck).

SAFETY FEATURES.—Some of the major safety features incorporated into modern deck edge elevators include the following:

1. If the electrical power fails while the platform is at the hangar deck, there will be enough pressure in the system to move the platform to the flight deck one time without the pumps running.

2. Some platforms are fitted with serrated safety shoes. If all the hoisting cable should break on one side, the shoes will wedge the platform between the guide rails and stop the platform with minimum damage.

3. Some main pumps are fitted with (1) pressure-actuated switches which stop the pump motors when the discharge pressure is excessive and (2) a relief valve which relieves the pressure when the pressure switch fails to operate.

4. The sump pump system has sufficient capacity to return the unloaded platform from the hangar deck to the flight deck.

5. The oil filter system may be used continuously while the engine is running, thus part of the oil may be cleaned with each operation of the elevator.

GALLEY AND LAUNDRY EQUIPMENT

The Navy uses a variety of equipment to perform laundry and galley functions. The type of equipment installed will depend on the size of the ship, the availability of steam, and other factors. Obtain and maintain for reference the

equipment manufacturer's technical manual for each different piece of gear aboard. Preventive maintenance is to be scheduled and performed according to the requirements of the 3-M system.

STEAM-JACKETED KETTLES

Steam-jacketed kettles (fig. 14-6) come in a variety of sizes from 5 gallons to 80 gallons. Kettles are made of corrosion-resisting steel. The kettles are constructed to operate at a maximum steam pressure of 45 psi. A relief valve is installed in the steam line leading to the kettles, set to lift at 45 psi. Maintenance on these units is normally limited to maintaining the steam lines and valves associated with the kettles.



48.18

Figure 14-6.—Steam-jacketed kettles.

Other steam-operated cooking equipment includes steamers (fig. 14-7) and steamtables (fig. 14-8). Steamers use steam at a pressure of 5 to 7 psi; steamtables use steam at a pressure of 40 psi or less.

DISHWASHING EQUIPMENT

Dishwashing machines used in the Navy are classified as one-tank, two-tank, or three-tank machines. The three-tank machine is a fully automatic, continuous racking machine which scrapes, brushes, and provides two rinses. It is used at large activities.

Single Tank

Single tank machines (fig. 14-9) are used on small ships where larger models are not feasible.

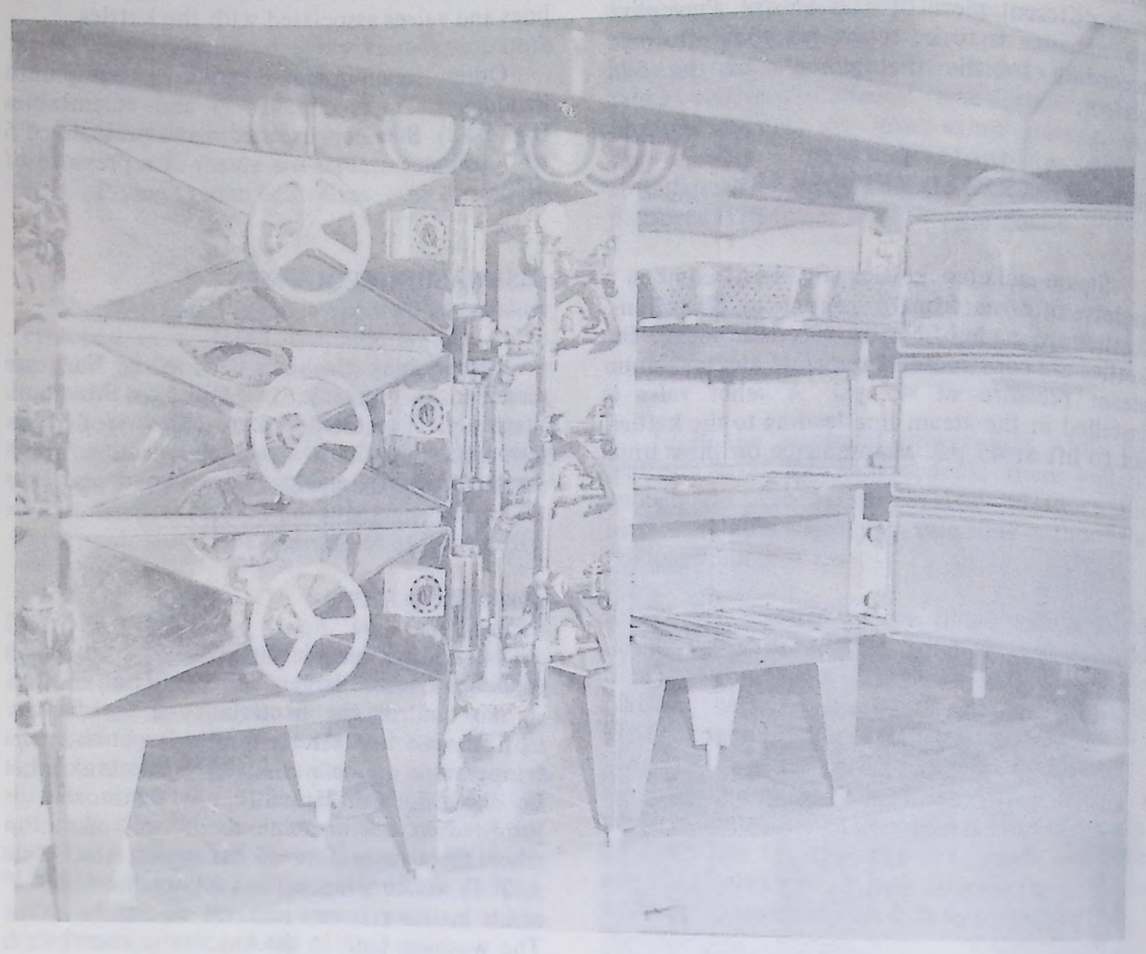
To control the bacteria to a satisfactory minimum in single-tank machines, the temperature of the washwater in the tank must be 140° F. Consequently, a thermostat is provided in the machine to prevent operation when the temperature of the water falls below 140° F. Water temperatures higher than 160° F result in less efficient removal of certain foods. The washing time in the automatic machines is 40 seconds.

For rinsing, hot water is sprayed on the dishes from an external source and is controlled by an adjustable automatic steam-mixing valve which maintains the rinse water between 180° F and 195° F.

To conserve freshwater, the rinse time interval is usually limited to 10 seconds. When water supply is not a problem, a rinse of 20 seconds is recommended.

Wash and rinse sprays are controlled separately by automatic, self-opening and closing valves in the automatic machine. The automatic machine provides a 40-second wash and a 10-second rinse.

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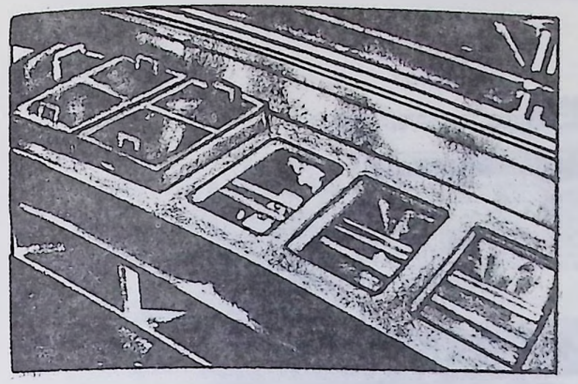


48.19

Figure 14-7.—Steamer.

Double Tank

Double tank machines (fig. 14-10) are available in several capacities and are used when more than 150 persons are to be served at one meal. These machines are provided with separate wash and rinse tanks. They also have a final rinse of hot water which is sprayed on the dishes from an outside source. This spray is opened by the racks as they pass through the machines. The spray automatically closes when the rinse cycle is completed. The final rinse is controlled by an adjustable automatic steam mixing valve which maintains the temperature between 180° and 195° F. Double tank machines are also equipped with a thermostatically operated switch in the rinse tank which prevents operation of the machine if the temperature of the rinse water falls below 180° F. The racks pass through the machine automatically by means of conveyor chains. The two-tank dishwashing machine should be timed so that the utensils are exposed to the machine sprays for not less than 40 seconds (20-second wash, 20-second rinse).



48.20

Figure 14-8.—Steamtable.

DESCALING DISHWASHERS

The accumulation of scale deposits in dishwashing machines should be prevented for at least two reasons. FIRST—excessive scale deposit on the inside of pipes and pumps will clog them and interfere with the efficient performance of the machine by reducing the volume of water that comes in contact with the utensils during the washing and sanitizing process. SECOND—scale deposits provide a haven for harmful bacteria.

The supplies needed for descaling are available through Navy supply channels. See the supply list below:

Stock Number	Description of Material
9G6810-00-264-6722	Orthophosphoric acid 85% technical, 7-lb bottle
9Q7930-00-282-9699	Detergent, general purpose 1-gal can
9Q7930-00-985-6911	Detergent, general purpose 5-gal pail

You should know the capacity of the dishwashing machine tanks. This may be determined by measuring (in inches) the inside dimensions of each tank and applying the following formula: length X width X depth (to water line) ÷ 231 = capacity in gallons.

Steps and key points in descaling the machine:

1. Fill the tanks halfway to the overflow level with hot, clean water. If tanks are not fitted with water level indicators, remove a section of the scrap tray in each tank so that you can see the overflow pipe.

2. Add the required amount of acid and detergent to the water to prepare the cleaning solution. Measure amounts carefully. Use 7 fluid ounces of orthophosporic acid 85% plus 1/2 fluid ounce detergent, general purpose, for each gallon capacity of the tank when filled to overflow level.

3. Complete filling the tanks. Fill to overflow level.

4. Put scrap screens, spray pipes, and splash curtains in place. Scale deposits on all attachments must be removed.

5. Turn on machine. Operate the machine at the highest permissible operating temperature for 60 minutes.

6. Turn off and drain the machine. Open the drain valves and allow all the cleaning solution to drain from the tanks.

7. Refill. Use fresh hot water.

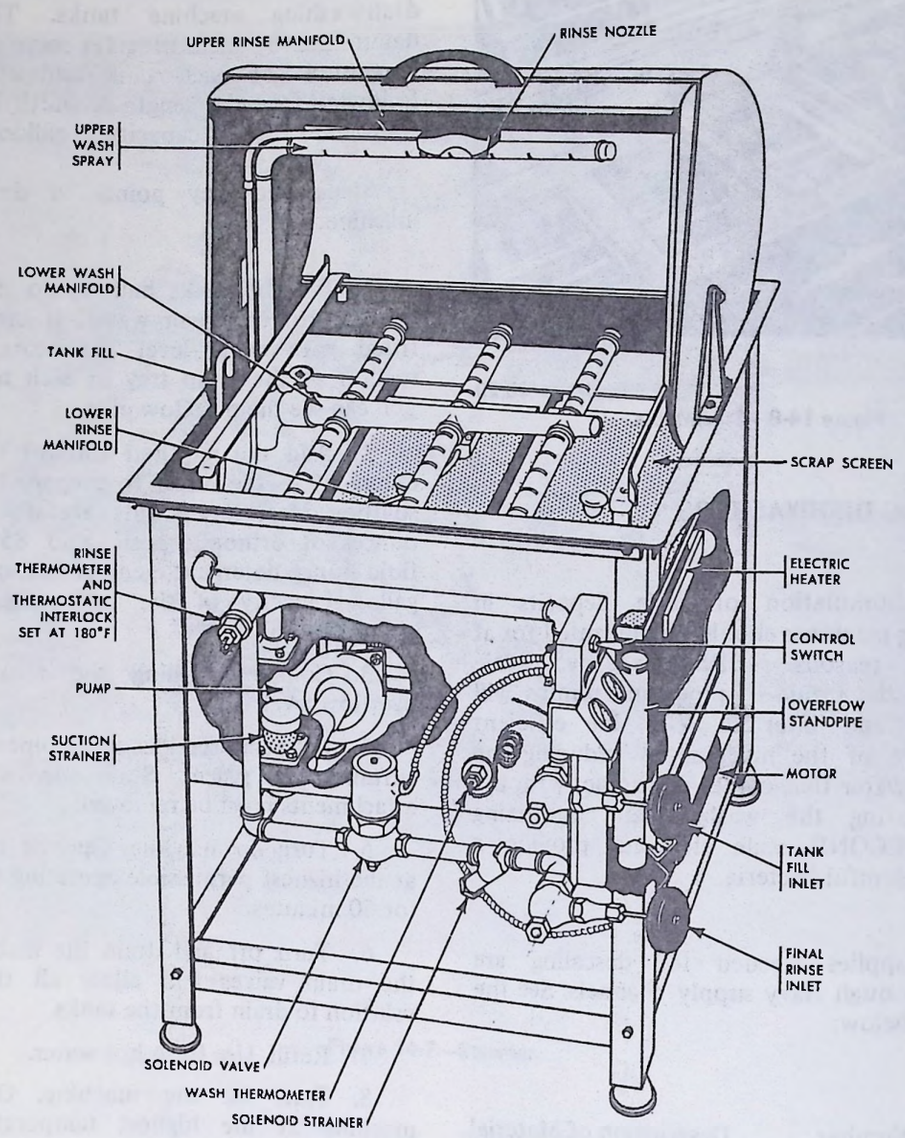
8. Turn on the machine. Operate the machine at the highest temperature for 5 minutes.

Repeat steps 7 and 8 several times. The entire method should be repeated at such intervals as may be required to assure efficient operation of the dishwashing machine.

LAUNDRY EQUIPMENT

Equipment used in the cleaning, drying, and pressing of clothing includes washers, extractors,

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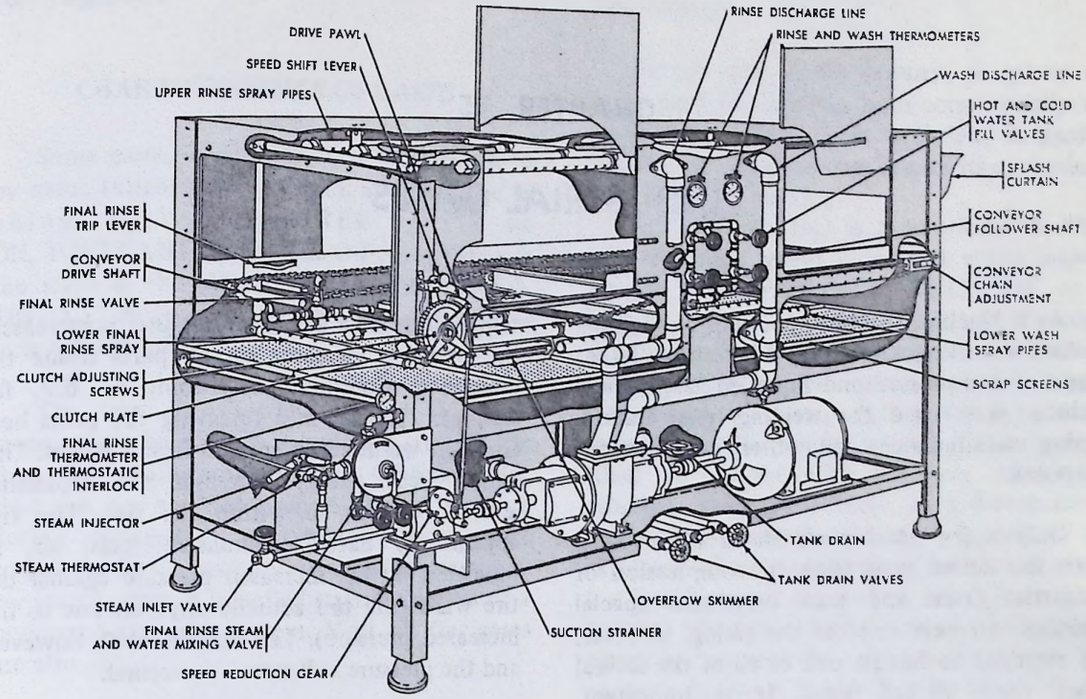
48.34

Figure 14-9.—Typical semiautomatic single-tank dishwashing machine.

dryers, dry-cleaning machines, and various types of presses.

Most of the maintenance associated with this equipment is concerned with inspecting and lubricating the various parts.

Most laundry equipment is equipped with a number of safety devices. If disabled, these safety devices can result, and have resulted, in shipboard fires, damage to equipment, damage to clothing, and in many cases to personnel injuries. Special attention should be given these safety devices during preventive and corrective maintenance with extra special attention being given those devices designed to protect operator personnel.



48.35

Figure 14-10.—Typical automatic double-tank dishwashing machine.

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CHAPTER 15

INDUSTRIAL GASES

As a Machinist's Mate, you will be required to have a working knowledge of several different types of compressed and liquefied gases. These include gases used for welding, refrigeration, piping maintenance and other miscellaneous purposes.

Only a few Machinist's Mates are involved with the actual generation or compression of industrial gases, and then only after special training. All personnel of the rating, however, are required to handle one or all of the several gases used aboard ship. It is important, therefore, that you have a good understanding of the characteristics as well as the uses of these gases.

GENERAL NATURE OF GASES

Before discussing the physical properties and characteristics of specific gases, let us briefly summarize the general nature of gases.

ALL GASES ARE COMPRESSIBLE; that is, they can be forced into spaces of lesser volume than they occupy under normal conditions. You are probably familiar with the two laws (discussed in *Fireman*, NAVEDTRA 10520) which express the relationship of the gas pressure with its volume and temperature: BOYLE'S LAW and CHARLES' LAW.

The TEMPERATURE FACTOR is important in handling gases because, when the temperature of a gas in a container is increased, the pressure increases on all parts inside the container. Consider an automobile tire, for example. The air in a revolving tire gains heat from the warm pavement and from friction. This added heat energy increases the molecular activity of the air within the tire. The tire appears to have accumulated more air, as indicated by the increased pressure against the tire walls (the tire actually expands due to the increased pressure). Let the tire cool, however, and the pressure will return to normal.

Gas cylinders are not elastic and do not expand when the pressure of the gas within them increases. Cylinders are, therefore, filled with compressed gases only to the maximum safe pressure at normal ambient temperatures. Storage of the cylinders in hot spaces will increase the pressure of the confined gases to a dangerously high point and the cylinders' safety devices, or the cylinders themselves, may rupture.

The boiling points for the various liquefied gases are important. Various gases have to be separated from each other. Their different boiling points make this possible. As an illustration of this principle, let's consider a mixture of water and alcohol in an automobile radiator. Alcohol boils at 172° F, but water boils at 212° F; the alcohol therefore begins to evaporate and separate from the water before the water nears the boiling point. As the water is never allowed to reach 212° F, the alcohol content grows less

and less as the temperature rises above 172° F. The same process is employed in separating and purifying gases.

CHARACTERISTICS OF GASES

Some gases, in addition to being referred to by name (nitrogen, argon, etc), are identified as being DRY, OIL-FREE (O.F.) or OIL-TOLERANT (O.T.). The O.F. designation is the same as the older term WATER-PUMPED. The O.T. designation is the same as the older term OIL-PUMPED.

The term DRY, when applied to a gas, means that the gas has a moisture content less than 0.02 milligrams per liter. Oil-free means that the gas has not been in contact with oil during processing and that it was either compressed by a water-lubricated compressor or converted from a liquefied state by means of a pump-and-exchange system. Most oil free gases are also dry.

The term oil-tolerant means that traces of oil may be carried in the gas since an oil-lubricated compressor was used in the processing. This term is used only when the gas is normally supplied in both O.F. and O. T. grades. In other words, a gas cylinder that is not labeled with O.F. or O.T. is considered to be O.T.

We will now discuss the individual properties of specific gases with which you will be concerned. Table 15-1 is a gas characteristics table showing some of the specific properties of individual gases.

ACETYLENE

Acetylene is a chemically produced gas which is not found in the natural state. In 1892, a method for the commercial production of the chemical calcium carbide was discovered, and it is from calcium carbide and water that acetylene is produced. In 1895, it was discovered that acetylene when combined with oxygen and burned, has the ability to produce high temperatures.

By the turn of the century, acetylene was being used for lighting, both commercially and domestically. Even today acetylene is used in lighthouses and buoys because of its exceptional brillance while burning.

Acetylene (C_2H_2) is a colorless gas. When pure it has a sweet odor, but when impure, usually with HYDROGEN SULPHIDE as an impurity, it has a disagreeable odor. Hydrogen sulphide is the gas that produces the well known "rotten eggs" smell. Acetylene is shipped dissolved in acetone in cylinders that contain a monolithic filler (meaning that the cylinder is filled throughout with the same mixture of asbestos, charcoal, cement, and diatomaceous earth. Diatomaceous means composed of the skeletons of various forms of sea life). Acetone is a liquid organic compound which is used as a solvent for many other organic compounds. Roughly, an organic compound is one that contains carbon (C); note that acetylene (C_2H_2) is an organic compound formed by combining two atoms of carbon with two atoms of hydrogen.

Acetylene is stable and safe to handle as long as it remains in a dissolved state. However, in the free gaseous state or if compressed in cylinders not designed for acetylene, the gas is very unstable and is likely to decompose violently. In large volumes, at pressures exceeding 15 psi, acetylene is dangerously explosive. This means that acetylene can "explode of its own accord" (spontaneous ignition) when improperly stored or handled. It does not always need air, or oxygen, or a spark to help it explode. Any shock or heat may be enough to set acetylene off, if it is stored at pressures higher than 15 psi.

When mixed with air or oxygen, chances of violent explosion are doubled. The explosive limits of acetylene in air range from 3% to 82% acetylene with maximum effect at approximately 7.8%. Acetylene in copper piping systems, or in piping systems with silver-brazed

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Table 15-1.—Characteristics of gases

Name	Symbol	Odor	Flammability (percent by volume in air) Lower	Flammability (percent by volume in air) Upper	Auto Ignition Temperature	Density Relative to Air (air = 1)	Vapor Pressure at 68°F (psi)	Weight in Pounds of 1 Cubic Foot at Standard Atmospheric Pressure and 68°F	Physical State When Shipped	Remarks
Acetylene	C_2H_2	Garlic	2.5	80	635	0.90	663.57	.06754	Dissolved	Shipped dissolved in acetone 250 psi at 70°F
Air	----	None	---	---	----	1.00	*	.07528	Gas	Critical point below 68°F
Ammonia	NH_2	Pungent	16	25	1,436	.59	124.34	.04420	Liquid	Inert gas
Argon	A	None	---	---	----	1.38	*	.10389	Gas	
Carbon dioxide	CO_2	None	---	---	----	1.52	830.47	.1142	Liquid	Inert gas
Chlorine	Cl_2	Pungent	---	---	----	2.44	96.58	.1839	Liquid	Reacts with hydrogen
Refrigerant 12	CCl_2F_2	None	---	---	----	4.17	67.54	.3136	Liquid	Inert
Refrigerant 22	$CHClF_2$	Sweet	3.6	14.8	----	2.99	122.00	.2243	Liquid	Inert
Ethyl chloride	C_2H_5Cl	Sweet	3	80	804	2.22	19.55	.1664	Liquid	
Ethylene oxide	C_2H_4O	None	---	---	---	1.52	---	.1142	Liquid	
Helium	He					.14	*	.01039	Gas	Critical point below 68°F
Hydrogen	H_2	None	4.1	74.2	1,076	.07	*	.00523	Gas	Critical point below 68°F
Inert gas	----	None	---	---	----	1.05 (approx)	*	.079	-----	Inert
Methyl chloride	CH_3Cl	Ether	8.2	19.7	----	1.74	69.82	.1309	Liquid	
Nitrogen	N_2	None	---	---	----	.97	*	.07274	Gas	
Nitrous oxide	N_2O	Ether	---	---	----	1.52	739.41	.1143	Liquid	
Oxygen	O_2	None	---	---	----	1.10	*	.08305	Gas	
Propane	C_3H_8**	Rotten cabbage†	2.37	9.5	871	1.55	129.36	.1143	Liquid	
Sulfur dioxide	SO_2	Pungent	---	---	----	2.21	47.78	.1663	Liquid	
Butane	C_4H_{10}**	Rotten cabbage†	1.6	8.5	806	2.04	30.6	.1507	Liquid	

*Gas can not be liquefied at 68°F. Cylinder pressure is determined by amount of gas in the cylinder.
**Fuels of which the major constituent has the indicated chemical symbol.
†Propane and butane generally are odorless in the natural state and are artificially odorized as an aid for detecting leaks.

47.176(47D)

joints, may form acetylides by combining with copper or silver. Acetylides so formed are violently explosive and are capable of being detonated by shock or heat.

Acetylene mixed in controlled proportions with oxygen in the acetylene torch produces an intensely hot flame. Its uses in welding and cutting are well known.

The SAFETY PRECAUTIONS for acetylene should be emphasized again and again. You will be held strictly accountable for knowing and observing these rules yourself, and you should make every effort to see that others handling acetylene know and observe them.

The safety rules for acetylene are as follows:

1. Acetylene should NEVER be discharged into hose lines and manifolds at a pressure greater than 15 psi. A suitable pressure-reducing regulator should be employed on all locations.

2. Acetylene cylinders shall be used or stored only in an upright position, valve end up, to avoid the possibility of withdrawing acetone when the cylinders are being discharged. Do NOT open the cylinder valve more than 1 1/2 turns of the spindle.

3. Do NOT recharge acetylene cylinders or transfer acetylene from one cylinder to another without specific approval from NAVSEASYSCOM. It is possible to charge or refill acetylene cylinders safely only with special equipment. Acetylene cylinders contain a porous material with minute cellular spaces, so that no pockets of appreciable size remain where free acetylene in the gaseous state may collect. In addition, acetone partially fills the cellular spaces and acts as a solvent for the acetylene. As long as it remains in the dissolved state, acetylene is stable. It should be clear by now that NO OTHER TYPE cylinder shall be used to store acetylene gas.

4. Keep sparks and flames away from acetylene cylinders. Do NOT, under any circumstances, allow a flame to come in contact with the safety devices. NEVER allow the cylinders to contact electric welding apparatus or electrical circuits.

5. Where it is necessary to test for leaks, use soapy water.

6. Do NOT interchange acetylene regulators, hoses, or other appliances with similar equipment intended for other gases.

7. Do NOT use acetylene manifolds that are not approved by NAVSEASYSCOM.

8. Do NOT use any wrench other than the one designed for opening the cylinder and keep the wrench on the cylinder while it is in use.

9. If a cylinder catches fire, use a wet blanket to extinguish the fire; if this fails, spray a stream of water on the cylinder.

ARGON

Argon is an inert gas (will not support combustion) slightly heavier than air, and it does not form flammable or explosive mixtures with air or oxygen. It is not poisonous, but, since it contains no oxygen, it will not support respiration and can cause asphyxiation. Argon is used for inert gas shielded welding and is furnished in the dry, oil-free condition.

CARBON DIOXIDE

Carbon dioxide (CO_2) is a colorless, odorless gas and 1.52 times heavier than air. It can be condensed into a colorless liquid and stored in this state, under pressure, in cylinders. When the cylinder valve is opened, gaseous CO_2 escapes and, due to the rapid drop in pressure and temperature, forms carbon dioxide snow. This snow, when compressed into blocks or cubes, is what we know as "dry ice." Dry ice, in solid form and at atmospheric pressure, sublimates (passes directly from solid to vapor), remaining at -109° F until it has disappeared. It is excellent for certain refrigeration uses.

Because it will neither support combustion nor form explosive mixtures, CO_2 is one of the

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chief fire extinguishing agents in use today. It is also used for inflatable lifesaving gear, such as life rafts and vests, and as a propellant or expelling agent.

Carbonated soft drinks contain carbon dioxide dissolved in water and kept under pressure in the container. When this pressure is relieved, CO_2 bubbles will rise to the surface.

Small percentages of carbon dioxide in the air will cause tiredness and perhaps headaches. Three percent in the air doubles breathing effort, and 5% causes panting. Eight percent causes marked distress, and 10% causes unconsciousness very quickly.

Since CO_2, in addition to being heavier than air, is both invisible and odorless, it presents a particular hazard to personnel aboard ship. It will tend to collect in low, unventilated places which might well be below decks aboard ship for instance. The fact is obvious that the more of any other gas, poisonous or not, that is present, the less breathable oxygen there will be present. Sailors entering these places, or left there, run the risk of suffocating to death.

Treatment of personnel exposed to CO_2 includes removal from the CO_2-laden atmosphere, artificial respiration (if necessary), administering oxygen, and keeping the patient warm and quiet.

The safety precautions to observe when entering spaces containing carbon dioxide gas are as follows:

1. Do NOT enter an area or compartment containing hazardous amounts of carbon dioxide without being equipped with a breathing mask and an independent supply of oxygen.
2. If this is not practicable, and the case is urgent, enter only when equipped with a life line and with an assistant standing by outside the area or compartment.

CHLORINE

Chlorine is 2.44 times heavier than air and is nonflammable. It will, however, react violently with hydrogen and ammonia. Chlorine is VERY TOXIC. Chlorine is used to purify water and to prepare bleaching solutions. The following safety precautions apply to the use of chlorine.

1. Chlorine should be used only by experienced and properly trained personnel. When chlorine is used, good ventilation should be maintained and exposed personnel MUST be furnished with gas masks approved for protection against chlorine.

2. The presence of chlorine may be detected by using a cloth wetted with aqua-ammonia. Ammonia in the presence of chlorine produces white fumes.

3. If it is necessary to immerse chlorine cylinders in a bath of warm water to facilitate discharge, be extremely careful not to generate a dangerous pressure in the cylinders. The temperature of the water bath should be maintained below 130° F because of the low melting point of the fusible plugs. Do NOT submerge the cylinder valve in the water; NO more than 20% of the surface area of the cylinder should be under water.

4. Treatment of personnel exposed to chlorine fumes:

a. Start artificial respiration (if required) immediately, pending arrival of Medical Officer. Keep the patient warm and quiet, covered with blankets if necessary. Rest is essential.

b. Place the patient back down with head and chest elevated. Call the Medical Officer immediately. Splashes of liquid chlorine or chlorinated water may cause skin irritation and acid burns. Remove clothing immediately and wash exposed skin with large amounts of water or soapy water. Milk may be given in mild cases as a relief from throat irritation.

OXYGEN

Oxygen is a colorless, odorless, tasteless gas that makes up about 21% of the atmosphere. Although oxygen is found in many compounds

such as water, limestone, sand, and iron ore, it occurs as free oxygen only in the atmosphere.

Probably the most important property of oxygen is that it is the element in the air that supports life. If the required amount of oxygen is not present in the atmosphere, it is not possible for people, animals, insects, and most bacteria to live. In high altitude flying or in confined spaces, it is necessary to supply air for breathing from some outside source. One of the important uses of oxygen, therefore, is to furnish a supply to persons who would otherwise face a lack of oxygen.

Another shipboard use for oxygen is for oxyacetylene welding. When mixtures of oxygen and acetylene burn, they furnish a very high heat which is easily controlled. This type of heat is also used to heattreat metals.

Oxygen is normally shipped in a gaseous state in cylinders and is one of two types, (1) aviators' breathing oxygen (99.5% pure oxygen) and (2) technical or industrial oxygen. The Navy buys only aviators' breathing oxygen. This not only simplifies the supply system but eliminates the possibility of industrial oxygen being charged into aviators' breathing apparatus. Industrial oxygen may have a small moisture content which will freeze at high altitudes.

While oxygen is itself nonflammable, it gives intensive support to combustion. If it should become mixed with hydrogen or with grease, it becomes highly explosive. No combustible material should ever be allowed to come into contact with compressed oxygen.

Oxygen plants are installed in all CV's and in some other types of ships. We will discuss the methods used to produce oxygen later in this chapter.

NITROGEN

Nitrogen (N_2) is considered to be an inert gas. It is not completely inert like helium or argon, because there are many nitrogen compounds such as the nitrates used in fertilizers and explosives. However, nitrogen is very slow to combine chemically with other elements under normal conditions. This is clearly seen when you consider that four-fifths of the atmosphere is nitrogen. Unlike oxygen, nitrogen, as a gas, does not support life or combustion, and causes no decomposition of most of the things with which it comes in contact. By chemical and electrical processes it can take and is taken from the air and combined with other substances. Such processes are known as nitrogen-fixation.

The Navy uses nitrogen for pressure-operated mechanisms such as recoil systems, as an expellent in flame throwers, in optical instrument applications, for testing pipelines, as a gas-blanket on the watersides of propulsion boilers (to prevent corrosion), and for preservation packing. Nitrogen for naval use is pumped by a water-lubricated compressor and is specially dried. Nitrogen cannot be used for inert gas shielded-metal arc welding because the high temperatures involved can cause nitrogen to combine with other substances.

Nitrogen is slightly lighter than air, and, as indicated, is neither flammable nor explosive. It is not poisonous, but unless oxygen is mixed with it, it cannot support life. Nitrogen gas is obtained by the fractional distillation of air. In aircraft carriers, nitrogen is a byproduct of the oxygen plant. The nitrogen is used extensively in these ships to maintain an inert blanket over aviation fuel and other special fuels in their respective storage tanks.

The safety precautions for nitrogen are similar to those for liquid oxygen. However, since nitrogen (liquid or gas) does not support combustion, the precautions regarding exposure to sparks, open flame, and combustible materials do not apply.

Safety rules concerning the use of gaseous nitrogen are similar to those cited for other nonflammable, nonoxidizing, and nontoxic compressed gases. Nitrogen should not be discharged in large quantities into closed compartments unless adequate ventilation protection is provided.

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CYLINDER DESIGN AND IDENTIFICATION

Gas cylinders are made of high quality steel. Cylinders for high-pressure gases, such as oxygen and hydrogen, are seamless. Cylinders for low-pressure gases, such as acetylene, may be welded or brazed. All cylinders are carefully tested at pressures above the maximum permissible charging pressure. Table 15-2 shows the characteristics of commonly used cylinders.

Gas cylinders are substantially the same, except those for acetylene. Acetylene cylinders are completely filled with a porous material impregnated with acetone which acts as a solvent. Acetylene cylinders are stubby, rather than slender, as shown in figure 15-1. All gas cylinders have safety devices in the valve, in the shoulder, or in the bottom of the cylinder, or in a combination of these places.

One type of safety device is the fusible plug, which may be described as a threaded hex head plug with a center filled with a fusible metal. If the cylinder is subjected to high temperatures, the fusible metal will melt, allowing the gas to vent to the atmosphere.

Another safety device, located in the valve of CO_2 cylinders, is the unbacked safety cap with rupture disk. These devices consist of a perforated safety cap covering a (breakable) disk firmly over the safety port. Under excessive pressure, the safety disk ruptures, allowing the gas to escape through the ports.

Backed safety caps with rupture disks are used in the valves of cylinders that contain air, helium, hydrogen, nitrogen and oxygen. These caps have a frangible disk supported by fusible metal (contained in the safety cap) blocking off escape ports. If the cylinder becomes heated above the melting point of the fusible metal, the pressure in the cylinder will increase and the frangible disk will rupture, venting the gas to the atmosphere.

To protect the valve of a gas cylinder, a threaded valve protection cap screws onto the cylinder neck ring.

Gas cylinders used by the Navy, Army, and Air Force carry certain standard identifying features in addition to markings required by the Interstate Commerce Commission. So much injury and damage can be, and has been, caused by mistaking one gas cylinder for another, that a national program has been established to make it almost impossible to confuse cylinders. Under this program, the identifying features used by the Armed Forces consist of a color code for painting the cylinders, stenciling the name of the gas along two sides of the cylinder, and affixing two decalcomanias to the shoulder of each cylinder. The official color code for marking compressed gas cylinders is given in the current MIL-STD-101. The color coding is revised from time to time. In checking the cylinder color code, always be certain you have the latest revision including ALL page changes.

The purpose of the color code is to identify gases by general hazards involved. The color code should NOT be used for specific identification of contents. Exact identification shall be made only by the stenciled name on the cylinder and the decal.

The following six colors are general warning colors used in conjunction with the materials indicated:

1. Yellow - flammable materials.
2. Brown - toxic and poisonous materials. (Materials extremely hazardous to life or health.)
3. Blue - anesthetics and harmful materials. (All materials which produce anesthetic vapors and all liquid chemicals and compounds which are liquid chemicals and compounds which are hazardous to life and property but do not normally produce dangerous quantities of fumes of vapors.)
4. Green - oxidizing materials. (All materials which readily furnish oxygen for combustion and fire producers which react explosively or with a large heat production in contact with many other materials.)

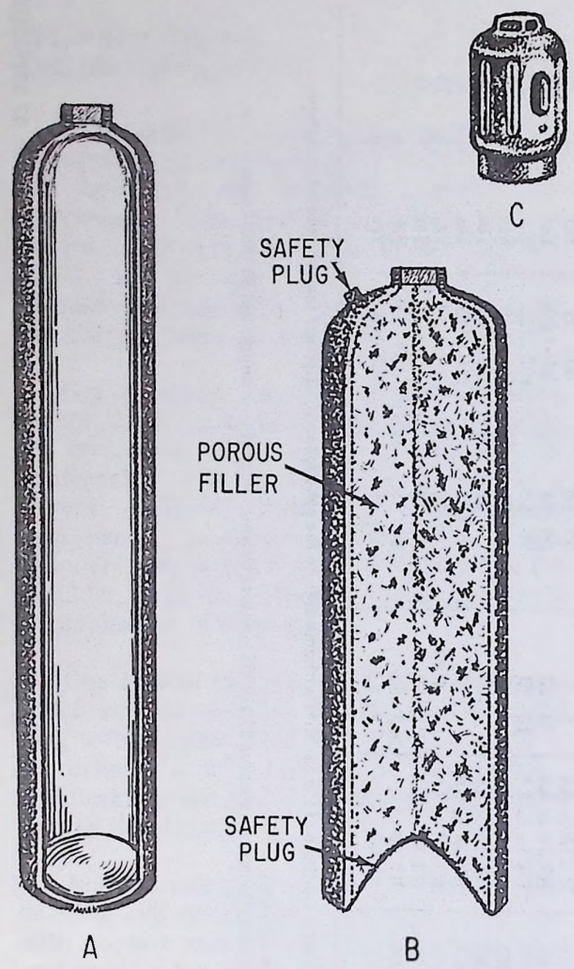
Table 15-2.—Characteristics of Commonly Used Cylinders

Service	Capacity* (approx. min.)	Working Pressure (psi)	DOT Spec.	Dimensions (approximate)		Empty Weight (approximate) (pounds)	Periodic Test Required	Outlet Connection (inches)	
				Diameter (inches)	Length (add 6 inches for cap) (inches)				
Acetylene	10 cu ft	250	ICC8	4	14	11**	No	.375	
	40 cu ft	250	ICC8	6	25		No	.375	1
	50 cu ft	250	ICC8	7	26.25	40**	No		1
	200 cu ft	250	ICC8	12	36	130 - 134**	No		
	225 cu ft	1,800 - 2,265	ICC3A or AA	9	51	110 - 115	Yes	.75	
Air	100 cu ft	480	ICC3A or AA	10 - 13	50 - 68	130 - 140	Yes	.75 and 1	
Ammonia	197 cu ft	1,800 - 2,265	ICC3A or AA	9	51	110 - 115	Yes	.75	
Argon	100 lb	240 - 300	ICC4B or AA	13 - 16	45 - 55	100 - 125	Yes	.75	
Butane	50 lb	1,800 - 2,015	ICC3A or AA	8.5	51	110 - 115	Yes	.75	
Carbon Dioxide (storage)	50 lb	2,015	ICC3A or AA	8.5	51	110†	Yes		1
Carbon dioxide (fire extinguisher)†	35 lb	2,015	ICC3A or AA	8.5	34	90	Yes		1
	15 lb	2,015	ICC3A or AA	6.25	26	35	Yes		1
Carboxide	30 lb	1,800 - 2,015	ICC3A or AA	8.5	26	65 - 70	Yes	.75	
	60 lb	1,800 - 2,015	ICC3A or AA	8.5	51	100 - 115	Yes	.75	
Chlorine	30 lb	480	ICC3A or AA	6 - 8	27 - 30	30 - 35	Yes	.75	
	120 lb	480	ICC3A or AA	9 - 12	34 - 44	85 - 90	Yes	.75	
	150 lb	480	ICC3A or AA	10 - 13	50 - 68	130 - 135	Yes	.75	
Helium	200 cu ft	2,015 - 2,265	ICC3A or AA	9	51	110 - 115	Yes	.75	
Nitrogen	184 cu ft	1,800 - 2,265	ICC3A or AA	9	51	110 - 115	Yes	.75	
Oxygen	200 cu ft	1,800 - 2,265	ICC3A or AA	5.375	18	19	Yes	.75	
	23.3 cu ft	2,015	ICC3A or AA	7	19	31	Yes	.75	
	38.4 cu ft	2,015	ICC3A or AA	4.5 - 5.5	14 - 16	13 - 15	Yes	.75	
Refrigerants 122, etc	10 lb	300	ICC4B	7.5 - 8.5	27 - 29	27 - 30	Yes	.75	
	50 lb	300	ICC4B						

*Where capacities are expressed in cubic feet, the volumes shown are those of the gas after withdrawal from the cylinder at atmospheric pressure and normal room temperature.
**Empty weight is normally stamped on the shoulder of the cylinders.
†For complete information on fire extinguisher carbon dioxide cylinders, see chapter 555 (9930). Actual weights, charged and empty, will be found stamped on cylinder valve.

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Figure 15-1.—Cutaway view of compressed gas cylinders. A. Oxygen cylinder. B. Acetylene. C. Valve protection cap.

5. Gray - physically dangerous materials. (All materials, not dangerous in themselves, which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.)
6. Red - fire protection materials.

Navy-owned gas cylinders are identified by indented serial numbers, preceded and followed by the letters USN. Navy serial numbers are augmented by a designated letter preceding the numerals. This letter identifies the cylinder in respect to the specific gas contained in that specific cylinder. The following are examples of serial numbers.

1. For an oxygen cylinder:

U U
SX618793S
N N

2. For an acetylene cylinder:

U U
SA54687S
N N

In the first example, the letter X identifies the cylinder as one containing oxygen. In the second example, the letter A identifies the cylinder as an acetylene cylinder. The LETTERS assigned to gases are for identification purposes only, they have no consistent connection with spelling of a gas name or of chemical symbols for gases. The acetylene symbol is C_2H_2 and for oxygen the correct chemical symbol is O_2.

In battle conditions, if the camouflage scheme of a ship is adversely affected by the cylinder colors, canvas covers painted with the camouflage colors shall be put over the cylinders.

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

OXYGEN-NITROGEN PRODUCING PLANTS

Oxygen-nitrogen (O_2-N_2) plants are installed aboard some ships, mostly CV's. Only specially trained Machinist's Mates (NEC 4282, 4283) or people working under their supervision are allowed to operate the plants. This training manual does not go into the details of the O_2-N_2 plants but merely explains the basic process of generating oxygen and nitrogen by the liquefaction of air.

Oxygen can be produced by chemical or physical processes. Chemically, oxygen can be produced in a number of ways by releasing it from different compounds. For large-scale production, however, oxygen is produced by the physical process of distilling liquid air.

Atmospheric air is a mixture of oxygen and nitrogen and is therefore a convenient and inexhaustible source of both of these gases. The problem is to separate them simply and economically.

Liquid mixtures can be separated by heating. The component with the lowest boiling point leaves the mixture before the components that have higher boiling points can be heated enough to boil off. This process is known as DISTILLATION. By first liquefying air, the process of distillation can be used to separate oxygen from nitrogen. Nitrogen has a lower boiling point than oxygen and, therefore, will leave the mixture first.

In the liquid-air process for producing oxygen, air is cooled until it becomes a liquid. The liquid is then distilled—that is, the nitrogen is boiled off as a gas, while the oxygen remains as a liquid.

The liquid oxygen can then be drained off of a storage tank and, when ready for use, converted to a gas.

LIQUEFYING AIR

At atmospheric pressure, the condensing temperature oxygen is -297° F and that of nitrogen is -321° F. You can readily see that a great amount of heat must be removed from air to cause oxygen to change state into a liquid.

A temperature of -297° F is hard to imagine. Ice feels very cold to the touch; it melts at 32° F. The North Pole is very cold, yet the air there is rarely below -70° F or -80° F. You can see how much colder air must be in order to liquefy.

There is a natural tendency to think of a boiling point as applied only to water. The boiling point of a substance is the temperautre at which it turns from a liquid to a gas. At a given pressure the boiling point is a fixed temperature for any one material. Pressure always affects the boiling point. A good example of this temperature-pressure relationship is that water or any other liquid will boil at lower temperatures on high mountains than at sea level.

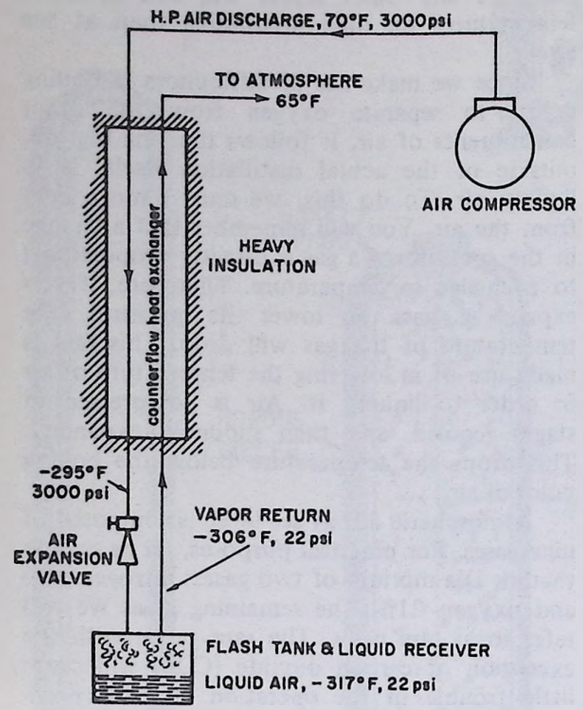
Since we make use of differences in boiling points to separate oxygen from the other consitituents of air, it follows that the big job, outside of the actual distillation itself, is to liquefy air. To do this, we must remove heat from the air. You will remember that a change in the pressure of a gas is directly proportional to a change in temperature. Therefore, if you expand a gas, or lower its pressure, the temperature of the gas will drop. This fact is made use of in lowering the temperature of air in order to liquefy it. Air is compressed in stages, cooled, and then suddenly expanded. This drops the temperature below the boiling point of air.

Atmospheric air, at sea level, is composed of nine gases. For practical purposes, let us assume that air is a mixture of two gases; nitrogen 78% and oxygen 21%. The remaining gases we will refer to as rare gases. The rare gases, with the exception of carbon dioxide (CO_2) will cause little trouble in the operation of an oxygen-nitrogen plant. CO_2 must be removed from the air stream because it will solidify at -109° F. When CO_2 becomes a solid, it can block the passage of air and reduce or stop the plant production. Solid particles of CO_2, if allowed to carry over into the oxygen, will lower the purity of the oxygen below the required 99.5%.

Figure 15-2 shows a simplified diagram of a high-pressure liquid air plant. The temperatures and pressures are only approximate values and are for purposes of explanation only. The main components of the high-pressure liquid air plant are: (1) high-pressure air compressor, (2) counterflow heat exchanger, (3) air expansion valve, and (4) liquid air receiver or flash tank. The expansion valve plays a major role in the liquefying process. To understand the function of this valve, you have only to know that air is cooled when allowed to expand from a high-pressure area to a low-pressure area. In figure 15-2, air is expanded from 3,000 psi down to 22 psi and the temperature drops from 70° F to -317° F. The expansion valve provides the fundamental source of cooling.

The flow of air must be continuous, but to simplify discussion we will consider the airflow

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Figure 15-2.—Simplified diagram of an oxygen plant.

as the first, second, and third pounds of air entering the plant. The air is discharged from the compressor at 3,000 psi. Trace the airflow in figure 15-2. The first pound of air enters the high-pressure side of the counterflow heat exchanger at about 70° F. It leaves the heat exchanger at the same temperature because the low-pressure side of the heat exchanger has no return flow with which it can exchange heat. The first pound of air blows through the expansion valve and its pressure is reduced to 22 psi and its temperature drops a small amount. The air continues downward into the flash tank, then out, and back through the low-pressure side of the heat exchanger.

Suppose now that the second pound of air, at high pressure, is just starting down the high-pressure side of the heat exchanger, as the first pound is passing up into the low-pressure side. Since each pound of air will be at a different temperature, a heat transfer will take place. The first pound of air, being cooler than the second, will cool the second pound. Thus the second pound of air will arrive cooler at the expansion valve than the first pound. The second pound of air will pass through the expansion valve and be cooled to a lower temperature than was the first pound.

The second pound of air will pass through the flash tank and up through the low-pressure side of the heat exchanger, where it will cool the third pound of air which is now entering the heat exchanger. The third pound of air will pass through the expansion valve and be cooled to a lower temperature than the second pound because it arrived at the expansion valve at a lower temperature and went through the same pressure drop.

This process goes on and on until the plant reaches a temperature low enough for the air to liquefy as it passes through the expansion valve (approximately -317° F).

With this process, about 9% of the air entering the plant will become useable liquid oxygen. The oxygen yield can be increased to 21% by the use of mechanical refrigeration. As previously explained, the lower the temperature of the air entering the expansion valve, the lower will be the temperature of the air leaving the expansion valve. The mechanical refrigeration is not essential, but it is used only to increase the yield of the plant.

SEPARATING OXYGEN AND NITROGEN

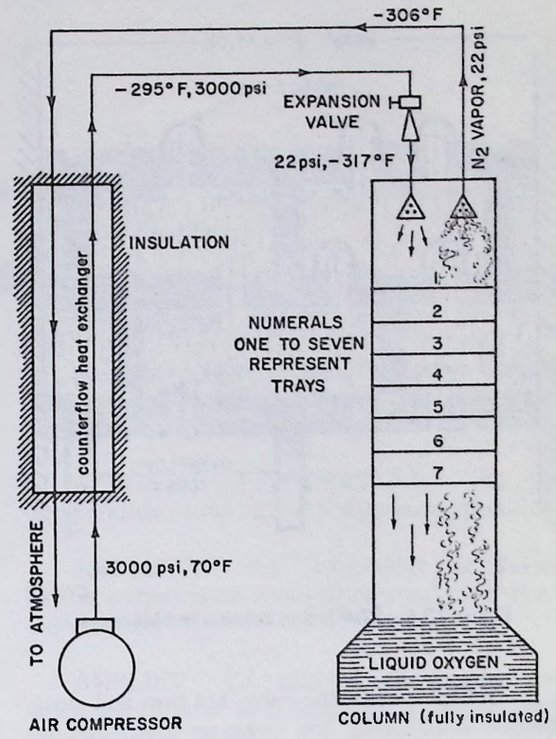
So that you more fully understand the distillation process that separates the oxygen from the nitrogen, we will first consider a container of water being heated. In time, vapor (steam) will rise from the container. The vapor will contain the same percentages of oxygen and hydrogen as the water remaining in the container. The vapor is the gaseous state and the water is the liquid state.

Let us now consider a container of liquid air instead of water. As heat is applied, a vapor is driven off. The vapor will be 5% oxygen and 95% nitrogen. If the boiling is continued, the

remaining liquid will become richer and richer in oxygen.

At the present time, all liquid oxygen plants used aboard ships operate by the distillation process. The liquid air leaves the expansion valve and enters at the top of a distilling column (fig. 15-3) and begins to fall down through a series of trays (7 in our illustration). The column is a towerlike affair with a coil in the bottom. Above the coil are tiers of bubble trays (fig. 15-4). The liquid air comes into contact with the warmer vapor rising off the liquid collected in the bottom of the column. This rising vapor gets richer in nitrogen because the nitrogen, having a lower boiling point, will boil first. The downflowing liquid will become richer in oxygen as the nitrogen continues to boil off. The liquid entering the top of the column is a mixture of oxygen and nitrogen, and one part of the mixture (nitrogen) is being released by boiling. The part of the mixture remaining in the bottom of the column is oxygen. This is the process going on inside a simple column. In a plant of this type, liquid oxygen can be drawn off from the bottom of the column and gaseous nitrogen is released (through the heat exchanger) to the atmosphere.

Some plants are designed to produce pure (99.5%) liquid oxygen and pure gaseous nitrogen. In this type of plant, two columns are used. The two products, liquid oxygen and gaseous nitrogen, are drawn off and stored until ready for use. Details of this type of plant are not given in this training manual.



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Figure 15-3.—Oxygen plant showing column and position of trays.

SAFETY PRECAUTIONS FOR INDUSTRIAL GASES

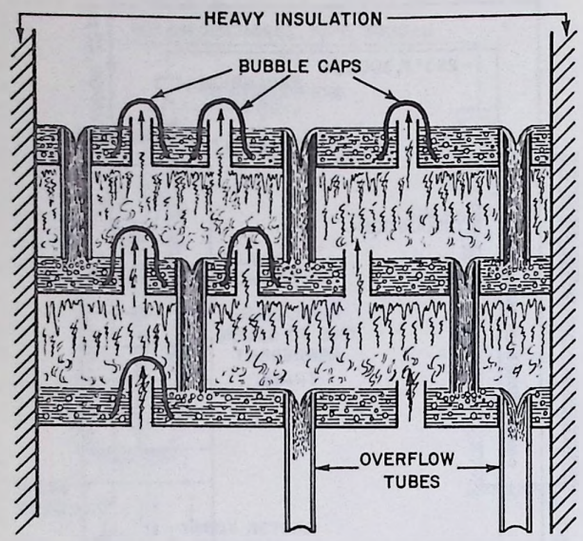
All compressed gases are hazardous. Detailed precautions regarding handling, storing, and transporting of these gases are too numerous to list here. Be sure that you observe all special precautions relating to the particular gas you are using. Some of the more important precautions to observe in handling ALL industrial gases are:

1. See that all required gas or chemical analyses are carefully made and recorded.
2. Be certain that all plant adjustments are made in accordance with these analyses.
3. Constantly inspect for leaks and immediately repair any leaks located.
4. Watch all pressure and temperature gages with extreme care.
5. NEVER permit any flames, sparks, or flammable material in the plant.

HANDLING COMPRESSED GASES

1. In handling the compressed gases, NEVER use gas from a cylinder except through a pressure regulator with its adjustment screw properly set.
2. Open the cylinders by hand. NEVER use hammers or wrenches.

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Figure 15-4.—Distillation column bubble trays.

3. Crack open the valve 1/4 turn and close, before connecting the pressure regulator; do NOT open the valve near sparks or other sources of ignition.

4. Do NOT let gas enter pressure regulators suddenly.

5. Open valves full when cylinder is in use (only 1 1/4 turns for acetylene valves).

6. NEVER tamper with safety devices; NEVER force-fit any of the connections.

7. Close valves which leak at the stem; release gas to outdoor atmosphere if safety device leaks.

8. When referring to a particular gas always use its identifying name—never refer to it as just "gas."

9. Make sure hoses and fittings are always tight; do NOT interchange fittings or hoses with similar equipment for other gases.

10. NEVER tighten an adjustment nut to stop a leak before first closing the valve and releasing any pressure in the system.

11. Close the valves and replace outlet caps when cylinders are not in use.

12. Before removing pressure regulators, close the valve and release all gas from the regulator.

HANDLING GAS CYLINDERS

When handling gas cylinders, you must observe the following precautions:

1. Refill cylinders with ONLY the gas for which they are intended and marked.

2. NEVER remove numbers or any other markings from cylinders.

3. Do NOT use cylinders for rollers or any other nonstandard purpose.

4. NEVER handle cylinders roughly or use them where they can be damaged by falling objects, etc; always handle all cylinders as though full (unknown pressure remaining may otherwise cause accidents).

5. Do NOT lift cylinders by valve caps but provide carrying devices—NEVER drag or slide.

6. In promoting more rapid discharge, NEVER immerse more than 20% of the cylinder surface area, and NEVER immerse in water over 125° F (fusible plugs will otherwise soften or melt).

7. NEVER store near flammable material (oil, gasoline, waste, etc), in damp locations, near live wires, near corrosive chemicals or fumes, near heaters, or near electronics equipment.

8. Erect fire-resistant partitions between flammable and nonflammable gas cylinders.

9. Store gas cylinders (except ammonia) upright.

10. Make sure storage rooms are ventilated to prevent accumulation of an explosive or otherwise harmful concentrations of gas.

11. Mark empty cylinders "EMPTY" or "MT," and segregate them from full cylinders.

Additional precautions and information on compressed gases are found in NSTM chapter 550 (9230).

APPENDIX I

GLOSSARY

ABATEMENT: A reduction or diminishing.

ABT (automatic bus transfer): An automatic electrical device that supplies power to vital equipment. This device will shift from the normal power supply to an alternate power supply anytime the normal supply is interrupted.

ACCIDENT: Any unplanned or unintended event that results in personal injury and/or property damage.

AFTERCOOLER: A terminal heat-transfer unit after the last stage.

AIR CHAMBER: A chamber, usually bulb-shaped, on the suction and discharge sides of a pump. Air in the chamber acts as a cushion and prevents sudden shocks to the pump.

AIR EJECTOR: A jet pump that removes air and noncondensable gases.

AIR LOCK SYSTEM: A system of control devices combined to hold all final operating elements in the position existing prior to loss of air supply pressure.

AIR REGISTER: A device in the casing of a boiler which regulates the amount of air for combustion and provides a circular motion to the air.

AISE: Association of Iron and Steel Engineers.

ALLOY: A mixture of two or more metals.

ALTERNATING CURRENT (a.c.): Current that is constantly changing in value and direction at regularly recurring intervals.

AMBIENT TEMPERATURE: The air temperature of the room or shipboard space.

AMPLIFIER: An instrument or device whose output is an enlarged reproduction of an input signal.

AMPLIFY: To increase the energy of information level of a signal by a proportional factor.

ANNEALING: The softening of metal by heating and slow cooling.

ANNUNCIATOR: See ENGINE ORDER TELEGRAPH.

ANTIFRICTION BEARING: A bearing containing rollers or balls plus an inner and outer race. The bearing is designed to roll, thus minimizing friction.

ARMORED CABLE: An electric cable that is protected on the outside by a metal covering.

ATSM: American Society for Testing Metals.

ATMOSPHERE ESCAPE PIPING: Piping that leads from safety or large volume relief valves in machinery spaces, up the outer stack to the atmosphere.

ATMOSPHERIC PRESSURE: The pressure exerted by the atmosphere in all directions, as indicated by a barometer. Standard atmospheric

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pressure is considered to be 14.7 pounds per square inch, which is equivalent to 29.92 inches of mercury.

ATOMIZATION: The spraying of a liquid through a nozzle so that the liquid is broken into tiny droplets or particles.

AUTOMATIC CONTROLLER: An instrument or device that operates automatically to regulate a controlled variable in response to a setpoint and/or input signal.

AUTOMATIC CONTROL SYSTEMS: A combination of instruments or devices arranged systematically to control a process or operation at a setpoint without assistance from operating personnel.

AUTOMATIC OPERATION: Operation of a control system and the process under control without assistance from the operator.

AUXILIARIES: Propulsion plant equipment not powered by main steam.

AUXILIARY: Systems or components functioning in a secondary capacity to the main boilers and propulsion turbines (such as pumps, air ejectors, blowers, etc).

AUXILIARY MACHINERY: Any system or unit of machinery that supports the main propulsion units or helps support the ship and the crew. Example: Pump, evaporator, steering engine, air-conditioning and refrigerator equipment, laundry and galley equipment, deck winch, etc.

AXIAL: In a direction parallel to the axis. Axial movement is movement parallel to the axis.

BABBITTED: Lined with a babbitt metal (containing tin, copper and antimony).

BACK PRESSURE: (1) Refers to the resistance to the flow of exhaust fluids through the exhaust system. (2) The pressure exerted on the exhaust side of a pump or engine.

BDC (bottom dead center): The position of a reciprocating piston at its lowest point of travel.

BAFFLE: A plate installed to disperse (scatter) motion and/or change direction of flow of fluids.

BALLASTING: The process of filling empty tanks with saltwater to protect the ship from underwater damage and to increase its stability. See DEBALLASTING.

BIAS OR BIASING: The act of adding to or subtracting from a control system signal.

BIMETALLIC: Two dissimilar metals with different rates of expansion when subjected to temperature changes.

BLOCK DIAGRAM: A drawing of a system using blocks for components to show the relationship of components.

BLOWING OF TUBES: A procedure that uses steam to remove soot and carbon from the tubes of steaming boilers.

BLUEPRINT: Reproduced copy of drawing (usually having white lines on a blue background).

BOILER: A strong metal tank or vessel composed of tubes, drums, and headers, in which water is heated by the gases of combustion to form steam.

BOILER BLOW PIPING: Piping from the individual boiler blow valves to the overboard connection at the skin of the ship.

BOILER CENTRAL CONTROL STATION: A centrally located station for directing the control of all boilers in the fireroom.

BOILER DESIGN PRESSURE: Pressure specified by the manufacturer, usually about 103% of normal steam drum operating pressure.

BOILER EFFICIENCY: The efficiency of a boiler is the ratio of the Btu per pounds of fuel

absorbed by the water and steam to the Btu per pound of fuel fired. In other words, boiler efficiency is output divided by input, or heat utilized divided by heat available. Boiler efficiency is expressed as a percentage.

BOILER FEEDWATER: Deaerated water in the piping system between the deaerating feed tank and the boiler.

BOILER FULL-POWER CAPACITY: The total quantity of design steam flow required to develop specified horsepower of the ship, divided by the number of boilers installed in the ship. Also expressed as the number of pounds of steam generated per hour at a specified pressure and temperature.

BOILER INTERNAL FITTINGS: All parts inside the boiler which control the flow of steam and water.

BOILER LOAD: The steam output demanded from a boiler, generally expressed in pounds per hour (lb/hr).

BOILER MASTER: A steam pressure controller.

BOILER OPERATING PRESSURE: The pressure required to be maintained in a boiler while in service.

BOILER OPERATING STATION: A location from which boilers are operated.

BOILER OVERLOAD CAPACITY: As specified in design of a boiler, usually 120% of boiler full-power capacity, either in steaming or firing rate as specified for the individual installation.

BOILER RECORD SHEET: A NAVSHIPS form maintained for each boiler, which serves as a monthly summary of operation.

BOILER REFRACTORIES: Materials used in the boiler furnace to protect the boiler from heat of combustion.

BOILER ROOM: A compartment containing boilers but not containing a station for operating or firing the boilers. Refers specifically to bulkhead enclosed boiler installations.

BOILER TUBE CLEANER: A cylindrical brush that is used to clean the insides of boiler tubes.

BOILER WATER: The water actually contained in the boiler.

BOURDON TUBE: A C-shaped hollow metal tube that is used in a gage for measuring pressures of 15 psi and above. One end of the C is welded or silver-brazed to a stationary base. Pressure on the hollow section forces the tube to try to straighten. The free end moves a needle on the gage face.

BRAKE HORSEPOWER (BHP): A measurement of the actual power produced by an engine.

BRANCH LINES (OR PIPING): Smaller piping branching off the main piping.

BRAZING: A method of joining two metals at high temperature with a molten alloy.

BRINE: Any water in which the concentration of chemical salts is higher than seawater.

BRITISH THERMAL UNIT (Btu): A unit of heat used to measure the efficiency of combustion. It is equal to the quantity of heat required to raise 1 pound of water 1° F.

BRITTLENESS: That property of a material which causes it to break or snap suddenly with little or no prior sign of deformation.

BUCKET WHEEL: The steel wheel or disc, fitted to a turbine shaft, to which the blading is attached.

BULL GEAR: The largest gear in a reduction gear train–the main gear, as in a geared turbine drive.

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BURNERMAN: Man in the fireroom who tends the burners in the boilers.

BUS: The common connection between a group of line cutout switches. The bus may be in one single piece or it may be divided; may be free or directly connected to a jack outlet.

BUSHING: A renewable lining for a hole through which a moving part passes.

BUS TRANSFER: A device for selecting either of two available sources of electrical power. It may be accomplished either manually or automatically.

BYPASS: To divert the flow of gas or liquid. Also, the line that diverts the flow.

CALIBRATION: The procedure required to adjust an instrument or device to produce a standardized output with a given input. The amount of deviation from the standard must first be determined in order to ascertain the proper correction requirements.

CANTILEVER: A projecting arm or beam supported only at one end.

CAPILLARY TUBE: A slender, thin-walled, small-bored tube used with remote-reading indicators.

CARBON MONOXIDE: A deadly, colorless, odorless, and tasteless gas formed by incomplete burning of hydrocarbons.

CARBON PACKING: Pressed segments of graphite used to prevent steam leakage around shafts.

CARRYOVER: (1) Boiler water entrained with the steam (by foaming or priming). (2) Particles of seawater trapped in vapor in a distilling plant and carried into the condensate.

CASING: A housing that encloses the rotating element (rotor) of a pump or turbine.

CASING THROAT: An opening in a turbine or pump casing through which the shaft protrudes.

CASUALTY: An event or series of events in progress during which equipment damage and/or personnel injury has already occurred. The nature and speed of these events are such that proper and correct procedural steps will serve only to limit damage and/or personnel injury.

CASUALTY POWER SYSTEM: Portable cables that are rigged to transmit power to vital equipment in an emergency.

CELSIUS: Thermometer scale on which the boiling point of water is 100° and the freezing point is 0°

CENTRIGRADE: see CELSIUS.

CENTRIFUGAL FORCE: The outward force on a rotating body.

CHARACTERIZER: A control system component that acts to alter a signal in a predetermined manner to match a nonlinear parameter in the process under control.

CHECK VALVE: A valve that permits a flow of liquid in one direction only.

CHEMICAL ENERGY: Energy stored in chemicals (fuel) and released during combustion of the chemicals.

CHILL SHOCKING: A method that uses steam and cold water to remove scale from the tubes of a distilling plant.

CHLORIDE: A compound of the chemical element chlorine with another element or radical.

CHLORINE: A heavy, greenish-yellow gas used in water purification, sewage disposal, and in the preparation of bleaching solutions. Poisonous in concentrated form.

CIRCUIT BREAKER: An electrical switching device that provides circuit overload protection.

CIRCULATING WATER: Water circulated through a heat exchanger (condenser or cooler) to transfer heat away from an operating component.

CLARIFIER: A water tank containing baffles that slow the rate of water flow sufficiently to allow heavy particles to settle to the bottom and light particles to rise to the surface. This separation permits easy removal, thus leaving the "clarified" water. The clarifier is sometimes referred to as a settling tank or sedimentation basin.

CLASSIFICATION AND/OR TYPE: A method of identifying and sorting various equipment and materials. For example;

a. Check valve-swing, stop, etc.
b. Valve-solenoid, manual, etc.

CLUTCH: A form of coupling that is designed to connect or disconnect a driving or driven member.

COLD IRON CONDITION: An idle plant as in a destroyer when all port services are received from an external source such as shore or tender.

COMBINING TUBES: Short open-ended tubes in which the inner surfaces are paralleled, or nearly so, and used to combine two inlets into a single outlet.

COMBUSTIBLE: A material that can burn.

COMBUSTION: The burning of fuel in a chemical process accompanied by the evolution of light and heat.

COMBUSTION AIR: The air delivered to the boiler furnace to support burning of the atomized fuel oil.

COMBUSTION CONTROL SYSTEM: A system that regulates fuel rate and combustion air flow to a boiler so that steam if produced at a constant pressure and fuel is burned with optimum combustion efficiency.

COMBUSTION EFFICIENCY: The ratio of the energy in the combustion gases, theoretically available for absorption by the boiler under actual operating conditions, to the energy available had the fuel been burned with the minimum theoretical combustion air.

COMPONENT: Individual unit, or part, of a system; also, the major units which, when suitably connected, comprise a system.

COMPONENT PART: The integral parts of a component.

CONDENSATE: Water produced in the cooling system of the steam cycle from steam that has returned from the turbine or from steam that has returned from various heat exchangers. The water is used over again to generate steam in the boiler for an endless repetitive cycle.

CONDENSATE DEPRESSION: The difference between the temperature of condensate in the condenser hotwell and the saturation temperature corresponding to the vacuum maintained in the condenser.

CONDENSATION: The process of cooling the vapors to produce a denser form (vapor to liquid).

CONDENSER: A heat transfer device in which vapor is condensed to liquid.

CONDUCTANCE: The ability of a substance to pass an electrical current.

CONDUCTION: Heat transfer by actual contact between substances or from molecule to molecule within a substance.

CONDUCTIVITY (of water): The ability of water to conduct an electric current. It is expressed in micromhos/cm. Generally, the amount of dissolved solids is directly proportional to the conductivity.

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CONSOLE: A panel equipped with remote manual controls and visual indicators of system performance.

CONSTANT-PRESSURE GOVERNOR: A device that maintains a constant pump discharge pressure under varying loads.

CONTROL ACTION: The nature of the change of the output of a control element or system affected by its input signal.

CONTROL AIR SUPPLY: Clean, dry air at proper pressure for operation of pneumatic control equipment.

CONTROLLER (AUTOMATIC): A device or group of devices arranged to automatically regulate a controlled variable in accordance with a command or setpoint signal.

CONTROLLER (ELECTRICAL): A device used to stop, start, and protect motors from overloads while they are running.

CONTROLLER (PNEUMATIC): (1) A control system component or group of components, arranged to sense two or more control system variables, which acts to provide a pneumatic (air) output signal, tending to reduce the difference between these signals to some predetermined value. (2) An arrangement of control system computing elements designed to perform a predetermined set of mathematical functions.

CONTROL POWER: Power that controls or operates a component or component part.

CONTROL SIGNAL (ELECTRICAL): A signal that activates control circuitry or indicators; for example: the signal from a pressure switch.

CONTROL SIGNAL (PNEUMATIC): A loading signal applied to a final control element.

CONVECTION: The transmission of heat by the circulation of a liquid or a gas such as air. Convection may be forced by use of a pump or fan, or it may occur naturally due to heated air or liquid rising and forcing the colder air or liquid downward.

COOLANT: Liquid in the cooling system.

COOLER: Any device that removes heat. Some devices, such as oil coolers, remove heat to waste in over-board seawater discharge; other devices, such as ejector coolers, conserve heat by heating condensate for boiler feedwater.

COOLING SYSTEM: Heat removal process that uses mechanical means to remove heat to maintain the desired air temperature. The process may also result in dehumidification.

CORROSION: A gradual wearing away or alteration of metal by a chemical or electrochemical process. Essentially, it is an oxidizing process, such as the rusting of iron by the atmosphere.

COUNTERSINK: A cone-shaped tool used to enlarge and bevel one end of a drilled hole.

CREEP-RESISTANT ALLOY: A metal that resists the slow plastic deformation which occurs at high temperatures when the material is under constant stress.

CRITICAL SPEED: The speed at which the centrifugal force of a rotating element tends to overcome the natural weight of the element, causing distortion and vibration.

CROSS-CONNECT: To align piping of systems to provide flow between machinery groups.

CROSS-CONNECTED PLANT: A method of operating two or more plants as one unit from a common steam supply.

CROSS PIPING (OR VALVES): Piping that provides flow between port and starboard systems or between systems having different purposes.

CURTIS STAGE: A velocity-compounded impulse turbine stage having one pressure drop

in the nozzles and two velocity drops in the blading.

CUTOUT VALVE: A valve that is intended normally to be fully open or fully closed.

DAMPER: A device for reducing the motion or oscillations of moving parts, air, or liquid.

DAMPING: A characteristic of a system that results in dissipation of energy and causes decay in oscillations. The negative feedback of an output rate of change.

DEAERATE: Process of removing dissolved oxygen.

DEAERATING FEED TANK (DFT): A unit in the steam-water cycle used to (1) free the condensate of dissolved oxygen, (2) heat the feedwater, and (3) act as a reservoir for feedwater.

DEBALLASTING: The process by which saltwater is emptied from tanks.

DEFORMATION: Permanent alteration of form or shape.

DEGREE OF SUPERHEAT: The amount by which the temperature of steam exceeds the saturation temperature.

DEHUMIDIFICATION: The mechanical process of removing water vapor from air.

DENTAL COUPLING: A flexible coupling assembly, consisting of a set of external/internal gear teeth, that compensates for slight shaft misalignment between a driver and a driven machinery component.

DESIGN PRESSURE (BOILER): The pressure specified by a manufacturer as a criterion in design. (In a boiler it is approximately 103% of operating pressure.)

DESIGN TEMPERATURE (BOILER): The intended operating steam temperature at the superheater outlet, at some specified rate of operation. The specified rate of operation is normally full-power capacity.

DESUPERHEATED STEAM: Steam from which some of the superheat has been removed.

DIAL GAGE OR INDICATOR: A precision micrometer-type instrument that indicates the reading via a needle moving across a dial face.

DIESEL ENGINE: An engine using the diesel cycle of operation; air alone is compressed and diesel fuel is injected at the end of the compression stroke. Heat of compression produces ignition.

DIFFUSER: A device that spreads a fluid out in all directions and increases fluid pressure while decreasing fluid velocity.

DIRECT CURRENT (d.c.); Current that moves in one direction only.

DIRECT DRIVE: One in which the drive mechanism is coupled directly to the driven member.

DIRECT-DRIVEN: Driven at the same speed as the driver (not having reduction gears).

DISTILLATE: The product (freshwater) resulting from the condensation of vapors produced by the evaporation of seawater.

DISTILLATION: The process of evaporating seawater, then cooling and condensing the resulting vapors. Produces freshwater from seawater by separating the salt from the water.

DISTILLING PLANTS: Units commonly called evaporators used to convert seawater into freshwater.

DOUBLE REDUCTION: A reduction gear assembly that reduces the high input rpm to a lower output rpm in two stages.

DOUBLE SUCTION IMPELLER: An impeller with suction inlet on each side.

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DRAWING: Illustrated plans that show fabrication and assembly details.

DRY PIPE: A perforated pipe, at the highest point in a steam drum, that collects dry steam from steam separators.

DUCTILITY: Property of metals that allows them to be drawn or stretched.

DUPLEX PUMP: A pump that has two liquid cylinders and is referred to as double-acting.

DUPLEX STRAINER: A strainer containing two separate elements, independent of each other.

ECONOMIZER: A heat transfer device that uses the gases of combustion to preheat the feedwater in the boiler before it enters the steam drum.

EDUCTOR: A jet-type pump (no moving parts) used to empty flooded spaces.

EFFICIENCY: The ratio of the output to the input. Also, the degree of conversion of heat of steam to usable mechanical power output.

ELASTICITY: The ability of a material to return to its original size and shape.

ELECTRICAL ENERGY: Energy derived from the forced induction of electrons from one atom to another.

ELECTRODE: A metallic rod (welding rod), used in electric welding, that melts when current is passed through it.

ELECTROHYDRAULIC STEERING: A system having a motor-driven hydraulic pump that creates the force needed to actuate the rams to position the ship's rudder.

ELECTROLYSIS: A chemical action that takes place between unlike metals in systems using saltwater.

ELECTROMOTIVE FORCE (emf): A force that causes electrons to move through a closed circuit; expressed in volts.

ELEMENT: A substance that consists of chemically united atoms of one kind.

EMERGENCY: An event or series of events in progress which will cause damage to equipment unless immediate, timely, and correct procedural steps are taken.

EMULSIFIED OIL: A chemical condition of oil in which the molecules of the oil have been broken up and suspended in a foreign substance (usually water).

ENERGY: The capacity for doing work.

ENGINEERING LOG: A legal record of important events and data concerning the machinery of a ship.

ENGINEER'S BELL BOOK: A legal record, maintained by the throttle watch, of all ordered main engine speed changes.

ENGINE ORDER TELEGRAPH: A device on the ship's bridge to give orders to the engineroom. Also called ANNUNCIATOR.

EPM (EQUIVALENT PER MILLION): A term used to describe the chemical concentration of dissolved material; used in reporting sample test results. It expresses the chemical equivalent unit weight of material dissolved in a million unit weights of solution. (The chemical equivalent weight of chloride is 35.5. If 35.5 pounds of chloride were dissolved in 1,000,000 pounds of water, the water would contain 1.00 epm chloride.)

ERROR: The difference between a setpoint and a feedback signal.

EVAPORATION: The action that takes place when a liquid changes to a vapor gas.

EVAPORATOR: A distilling device used to produce freshwater from seawater.

EXCESS FEED: Excess feedwater that is returned to storage tanks.

EXPANSION JOINT: A junction in a piping system which allows for expansion and contraction.

FAHRENHEIT: Thermometer scale on which the boiling point of water is 212°, and the freezing point is 32° above zero.

FAIL: (1) The loss of control signal or power to a component. (2) The breakage or breakdown of a component or component part.

FAIL POSITION: The operating or physical position to which a device will go upon loss of its actuating electrical, electronic, pneumatic, or hydraulic control signal.

FATIGUE: The tendency of a material to break under repeated strain.

FEEDBACK: Information about a process output which is communicated to the process input.

FEEDER: An electrical conductor or group of conductors between different generating or distributing units of a power system.

FEED HEATER: A heat transfer device that heats the feedwater before it goes to the boiler.

FEEDWATER: Water that meets the requirements of *NAVSHIPS' Technical Manual* Chapter 220 (9560) for use in a boiler.

FEEDWATER SYSTEM: A system for storing, heating, and delivering feedwater to boilers.

FERROUS METAL: Metal with a high iron content.

FILTER: A device through which gas or liquid is passed; dirt, dust, and other impurities are removed by the separating action.

FIREBOX: The section of a ship's boiler where fuel oil combustion takes place.

FIRELINE: Section of piping and hose on discharge side of a proportioner leading to fire location.

FIRE MAIN: The saltwater line that provides firefighting and flushing water throughout the ship. Raw water is used at Great Lakes in lieu of saltwater.

FIREROOM: A compartment containing boilers and the station for "firing" or operating same.

FIRE TUBE BOILER: Boiler in which the gases of combustion pass through the tubes and heat the water surrounding them.

FLAMMABLE: A combustible material that burns easily, intensely or quickly.

FLAREBACK: A backfire of flame and hot gases into a ship's fireroom from the firebox. Caused by a fuel oil explosion in the firebox.

FLASH POINT OF OIL: The temperature at which oil vapor will flash into fire although the main body of the oil will not ignite.

FLEXIBLE COUPLING: A coupling that transmits rotary motion from one shaft to another while compensating for minor misalignment between the two units.

FLEXIBLE I-BEAM: An I-shaped steel beam on which the forward end of a turbine is mounted; it allows for longitudinal expansion and contraction.

FLOAT ON THE LINE: Proportioner discharging through the fireline with foam liquid pump not picking up foam liquid.

FLOCCULATION: The separation of solids induced by the addition of chemicals in the clarifier.

FLOOR PLATES: The removable deck plating of a fireroom or engineroom aboard ship.

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FLUID: A substance capable of flowing or conforming to the shape of its container (a liquid or gas).

FOAMING: Failure of steam bubbles to break, caused by either dissolved solids or light suspended solids in the boiler water, causing small amounts of continuous boiler water carryover with the steam.

FOAM NOZZLE: A nozzle designed to entrain air and mix it with water and foam liquid to produce a foam blanket.

FORCE: Anything that tends to produce or modify motion.

FORCED DRAFT: A term that describes the combustion air supplied under pressure to the burners in a ship's boiler by the forced draft blowers.

FREQUENCY: The number of vibrations, cycles, or changes in direction in a unit of time.

FRESHWATER: Water of relatively low dissolved solids content as compared to seawater. There are two types of shipboard freshwater: feedwater (the low-pressure drains of the steam generator condensate system) and potable water (supplied from either a shore water source or a shipboard distilling plant).

FRESHWATER DRAINS: A collective term which refers to drainage from steam heating systems and warming-up drainage from other higher pressure steam systems. These drains are of feedwater quality and are returned to the boiler condensate system.

FRESHWATER SYSTEM: A piping system that supplies freshwater throughout the ship.

FRICTION: Resistance to relative motion between two bodies in contact with each other.

FUEL OIL: As referred to herein and unless otherwise specified means Navy Distillate Fuel MIL-F-24397, Diesel Fuel Marine MIL-F-16884, JP5-MIL-T-5624, or Navy Special Fuel Oil MIL-F-859.

FUEL OIL MICROMETER VALVE: A valve, installed at the burner manifold, that controls the fuel oil pressure to the burners.

FUEL OIL SERVICE TANKS: Tanks from which the fuel oil service pumps take suction for supplying oil to the burners.

FUNCTION: To perform the normal or characteristic action of anything, or special duty or performance required of a person or thing in the course of work.

FUSE: A protective device that will open a circuit if the current flow exceeds a predetermined value.

GAGE GLASS: A device for indicating the liquid level in a tank.

GAIN: The ratio of the signal change, which occurs at the output of a device, to the change at the input.

GAS FREE: A term that describes a space which has been tested and found safe for entry.

GEARED TURBINE: A turbine coupled to its driven unit through a gear assembly.

GEARED-TURBINE DRIVE: A turbine that drives a pump, generator, or other machinery through reduction gears.

GLAND SEAL REGULATOR: A device that automatically regulates the steam flow of the turbine glands to meet the flow requirements for the various operating conditions.

GLAND SEALING: Water piped to a pump casing stuffing box to maintain a seal against air entering the pump casing. Also, low pressure steam piped to the glands of steam turbines to prevent air leakage into turbines.

GRAVITY HEAD: A supply of fluid above the suction level of a pump. Also called static head.

GROUNDED PLUG: A three-pronged electrical plug used to ground portable tools to the ship's structure. It is a safety device which always must be checked prior to your using portable tools.

GUARDING VALVE: A valve installed upstream of the throttle valves. This valve permits stopping steam flow to the turbines if the throttle valves are leaking or damaged.

HANDHOLE: An opening large enough for the hand and arm to enter the boiler for making slight repairs and for inspection purposes.

HARDENING: The heating and rapid cooling (quenching) of metal to induce hardness.

HARDNESS: A quality exhibited by water containing various dissolved salts, principally calcium and magnesium. Can result in a heat transfer resistant scale on the steam generating surfaces.

HEADER: A chamber, or tank, located within a boiler, to which tubes are connected so that water or steam may pass freely from one tube to the other(s). Similar to, but smaller than, a water drum.

HEAT: A form of energy.

HEAT EXCHANGER: Any device that is designed to allow the transfer of heat from one fluid (liquid or gas) to another.

HEATING SURFACE: The exposed surface of a heating unit in a boiler or a furnace which is directly exposed to the heat of the flue gases.

HEATING SYSTEM: A system for adding heat to maintain the desired air temperature, as distinguished from heat added incidentally or unavoidably.

HELICAL: A spiraling shape such as that made by a coil spring.

HERTZ (Hz): Frequency per second of alternating current. Formerly referred to as "cycles per second."

HORSEPOWER: A unit to indicate the time rate of doing work equal to 550 foot-pounds per second or 33,000 foot-pounds per minute.

HOTWELL: Reservoir attached to the bottom of a condenser for collecting condensate.

HUMIDITY: The vapor content of the atmosphere. Humidity can vary depending on air temperature; the higher the temperature, the more vapor the air can hold.

HUNTING: An undesirable oscillation; such as in the speed of a machine or in the position of an automatic valve, etc.

HYDRAULICS: The study of liquid in motion.

HYDROCARBON: Chemical compound of hydrogen and carbon; all petroleum fuels are composed of hydrocarbons.

HYDROGEN: A highly explosive, light, invisible, nonpoisonous gas used in underwater welding and cutting operations.

HYDROMETER: An instrument used to determine the specific gravity of liquids.

HYDROSTATIC: Static (nonmoving) pressure generated by pressurizing liquid.

HYDROSTATIC TEST: A test using pressurized water to detect leaks in a boiler or other closed systems.

IGNITION, COMPRESSION: When the heat generated by compression in an internal-combustion engine ignites the fuel (as in a diesel engine).

IGNITION, SPARK: When the mixture of air and fuel in an internal-combustion engine is ignited by an electric spark (as in a gasoline engine).

IGNITION TEMPERATURE: The minimum temperature to which the substance (solid,

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liquid or gas) must be heated to cause self-sustained combustion.

IMPELLER: An encased, rotating element provided with vanes which draw in fluid at the center and expel it at a high velocity at the outer edge.

IMPULSE LINES: Piping that connects a sensing element to the point at which it is desired to sense pressure, flow, temperature, etc.

IMPULSE TURBINE: A turbine in which the major part of the driving force is received from the impulse of incoming steam.

INDICATORS: Panel-mounted pressure gages.

INDIRECT DRIVE: A drive mechanism coupled to the driven member by gears or belts.

INERT: Inactive.

INERTIA: The tendency of a stationary object to remain stationary and of moving objects to remain in motion.

INJECTOR: A device that uses a jet of steam to force water into the boiler. Injectors are also used in a diesel engine to force fuel into the cylinders.

INSULATION: A material that retards heat transfer.

INTERCOOLER: An intermediate heat transfer unit between two successive stages, as in an air compressor.

INTERFACE: Surface or area between two abutting parts usually of different materials or systems.

INTERLOCK: A feature or device in one system or component that affects the operation of another system or component. Generally, a safety device but it may be used to control the operating sequence of components.

JACKBOX: Receptacle, usually secured to a bulkhead, in which telephone jacks are mounted.

JACKING: Mechanically rotating a turbine at very low speed.

JOB ORDER: An order issued by a repair activity to its own subdivision to perform a repair job in response to work request.

JOURNAL: That part of a shaft that is prepared to accept a bearing (connecting rod, main bearing).

JUMPER: Any connecting pipe, hose, or wire, normally used in emergencies aboard ship to bypass damaged sections of a pipe, a hose, or a wire. (See BYPASS.)

JURY RIG: Any temporary or makeshift device.

KEY: A parallel-sided piece inserted into a groove cut part way into each of two parts, which prevents slippage between the two parts.

KEYWAY: A slot cut in a shaft, pulley hub, wheel hub, etc. A square key is placed in the slot and engages a similar keyway in the mating piece. The key prevents slippage between the two parts.

KINETIC ENERGY: Energy in motion, producing work.

LABYRINTH: A system of metal packing in which the inside diameter of a series of rings contacts the rotating surface of the turbine shaft. The passage of air or steam along the shaft is thereby reduced or inhibited.

LABYRINTH PACKING: A soft metal ring installed in the casing throat in such a manner that the lateral teeth of the inside diametrical surface will be presented to the surface of the rotating shaft. The teeth run either in close proximity to the shaft or in grooves machined in the shaft.

LAGGING: A protective and confining cover placed over insulating material.

LATENT HEAT: Heat that is given off or absorbed by a substance while it is changing its state.

LATENT HEAT OF CONDENSATION: The amount of heat (energy) required to change the state of a substance from a vapor to a liquid without a change in temperature.

LATENT HEAT OF VAPORIZATION: The amount of heat (energy) required to change the state of a substance from a liquid to vapor without a change in temperature.

LIFT CHECK VALVE: A valve having a guide-mounted, spring-loaded disc wherein a liquid exerting pressure on the bottom of the disc will lift the disc and pass through. Pressure exerted against the top of the disc shuts the disc and ensures only one direction of flow.

LIGHT OFF: Start. Literally, "to start a fire in," as in "light off a boiler."

LIMIT SWITCH: A switch that is actuated by the mechanical motion of an element.

LINE CUTOUT SWITCH: The device in a switchbox which disconnects an individual line from a group of circuits.

LOAD: Steam production demanded of a boiler by the operation of steam-driven equipment.

LOADING: The act of transferring energy into or out of a system.

LOADING SIGNAL: An input air signal to a control system element.

LOCAL MANUAL OPERATION: Direct manual positioning of a control valve or power operator by means of a handwheel or lever.

LOCKED TRAIN: A gear arrangement that has the high-speed pinions "locked" between the high-speed gears so that the only load on the pinion bearings is that of the weight of the pinion since the tooth loads cancel one another.

LOG BOOK: Any chronological record of events, such as an engineering watch log.

LOG ROOM: Engineer's office aboard ship.

LOOP SEAL: A vertical U-bend in drain piping in which a water level is maintained to create an airtight seal.

LUBRICANT: Any material, usually of a petroleum nature such as grease, oil, etc, that is placed between two moving parts in an effort to reduce friction.

LUBRICATING OIL PURIFIER: A unit that removes water and sediment from lubricating oil by centrifugal force.

MACHINABILITY: The ease with which a metal may be turned, planed, milled, or otherwise shaped.

MACHINERY GROUP: One single self-contained steam plant consisting of one engineroom and one fireroom.

MAIN CONDENSATE: Condensate from the main condenser. Although this is the principal source of feedwater, water from other drains as well as water from reserve makeup tanks and the SSTG condensers are also included in feedwater.

MAIN CONDENSER: A heat exchanger that converts exhaust steam to feedwater.

MAIN DRAIN SYSTEM: System used for pumping bilges; consists of pumps and associated piping.

MAIN INJECTION (SCOOP INJECTION): An opening in the skin of a ship designed to deliver cooling water to the main condenser and main lubricating oil cooler by the forward motion of the ship.

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MAIN STEAM: The major steam system which operates at boiler pressure.

MAKEUP FEED: Water from reserve feed tanks added to the condensate-feedwater system to make up for water losses from the steam generator system.

MALLEABILITY: That property of a material which enables it to be stamped, hammered, or rolled into thin sheets.

MANIFOLD: A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes.

MAXIMUM OPERATING PRESSURE: The highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shutoff pressures, pressure regulating valve lockup (no-flow) pressure, and maximum chosen pressure at the system source.

MAXIMUM SYSTEM PRESSURE: The highest pressure that can exist in a system or subsystem during any condition. Normal, abnormal, and emergency operation and casualty conditions shall be considered in determining the maximum system pressure. In any system or subsystem with relief valve protection, the nominal setting of the relief valve shall be taken as the maximum system pressure (relief valve accumulation may be ignored).

MECHANICAL ADVANTAGE (MA): The advantage (leverage) gained by the use of devices such as a wheel to open a large valve, chain falls and block and tackle to lift heavy weights, and wrenches to tighten nuts on bolts.

MECHANICAL CLEANING: A method of cleaning the firesides of boilers by scraping and wirebrushing.

MECHANICAL ENERGY: Energy derived from mechanical force or impact.

MICROMHO: Electrical unit used with salinity indicators for measuring the conductivity of water. Is equivalent to the quantity of one divided by the resistance of the water to electrical conductivity.

MONITORING POINT: The physical location at which any indicating device displays the value of a parameter at some control station. (See PARAMETER.)

MORPHOLINE: A chemical that prevents sludge in boilers by neutralizing the acidic quality of condensate, thereby reducing corrosion in condensate and feedwater piping, which forms as sludge in boilers.

MOTIVE STEAM: Steam that performs work in the turbine steam path.

MOTOR CONTROLLER: A device or group of devices that governs, in some predetermined manner, the operation of the motor to which it is connected.

MOTOR GENERATOR SET: A machine that consists of a motor mechanically coupled to a generator and usually mounted on the same base.

NAVAL STANDARDS: Requirements for advancement for all ratings including military conduct, naval organization, military justice, security, and watchstanding.

NAVY BOILER COMPOUND: A powdered chemical mixture used in boiler water treatment to convert scale-forming salts into sludge.

NAVY DISTILLATE FUEL: Navy Distillate (ND) fuel is used in steam-powered ships of the Navy. ND is a fuel of the middle to higher distillation range. Military specification MIL-F-24397 (ships), NATO Symbol F85 covers the requirements for Navy Distillate Fuel.

NAVY SPECIAL FUEL OIL: Navy Special fuel oil (NSFO) is used in steam-powered ships of the Navy. NSFO is a blend of heavy residuum and heavy distillates (both cracked and virgin) with cutter stock distillate, used to adjust viscosity. The blend is made at the refinery in proper proportions to comply with Military specification MIL-F-859 NATO Symbol F77.

NEAR ACCIDENT: An accident that almost happened.

NEEDLE VALVE: Type of valve with rod-shaped, needle-pointed valve body which works into a valve seat so shaped that the needle

point fits into it and closes the passage. Suitable for precise control of flow.

NIGHT ORDER BOOK: A notebook containing standing and special instructions from the engineer officer to the night engineering officer of the watch.

NITROGEN: An inert gas which will not support life or combustion. Used in recoil systems and other spaces that require an inert atmosphere.

NOMINAL OPERATING PRESSURE: The approximate pressure at which an essentially constant-pressure system operates when performing its normal function. This pressure is used for the system basic pressure identification.

NONFERROUS METAL: Metals that are composed primarily of some element or elements other than iron.

NOZZLE: That portion of a turbine that converts heat energy of steam into a directed steam and sets the amount of steam flow.

NOZZLE AREA: Smallest opening (area) of a nozzle that is at right angles to the direction of steam flow.

NOZZLE-BLOCK: Turbine part that takes steam from the turbine chest and directs it into the first stage of the turbine.

NOZZLE DIAPHRAGM: A removable metal ring inserted in the casing between the stages of the turbine. This ring contains the nozzles by which steam flows from one stage to another.

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

OFFICER OF THE WATCH (OOW): Officer on duty in the engineering spaces.

OIL KING: A petty officer who receives, transfers, discharges, and tests fuel oil and maintains fuel oil records.

OIL POLLUTION ACTS: The Oil Pollution Act of 1924 (as amended), the Oil Pollution Act of 1961, and the Water Quality Improvement Act of 1970 prohibit the overboard discharge of oil or water that contains oil, in port, in any sea area within 12 miles of land, and in special prohibited zones.

OIL STRAINER: A strainer placed at the inlet end of the oil pump to prevent dirt and other particles from getting into moving parts.

ONE-LINE SCHEMATIC DIAGRAM: A drawing of a system using only one line to show the tie-in of various components; for example, the three conductors needed to transmit 3-phase power are represented by a single line.

OPERATING CHARACTERISTICS: The combination of a parameter and its setpoints. (See PARAMETER.)

OPERATING PRESSURE: The constant pressure at which a component is designed to operate in service.

OPERATING TEMPERATURE: The actual temperature of a component during operation.

ORIFICE: A circular opening in a flow passage which acts as a flow restriction.

ORIFICE PLATE: A plate with an opening fitted between flanges in piping systems to reduce velocity and pressure in steam traps and steam supply to distilling plants.

OVERLOAD RELAY: An electrical protective device which automatically trips when a circuit draws excessive current.

OXIDATION: The process of various elements and compounds combining with oxygen. The corrosion of metals is generally a form of oxidation; rust on iron, for example, is iron oxide, or oxidation.

OXYGEN-FREE FEEDWATER: Water in which dissolved oxygen has been removed.

PANT, PANTING: A series of pulsations caused by minor, recurrent explosions in the

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firebox of a ship's boiler. Usually caused by a shortage of air.

PARALLEL CIRCUIT: An electrical circuit with two or more resistance units wired to permit current flow through both units at the same time. Unlike the series circuit, the current in the parallel circuit does not have to pass through one unit to reach the other.

PARALLEL OPERATION: Two or more units operating simultaneously and connected so their output forms a common supply, as opposed to series or independent operation.

PARAMETER: A variable such as temperature, pressure, flow rate, voltage, current, frequency, etc, which may be indicated, monitored, checked or sensed in any way during operation or testing.

PARTICULATE: Minute particles or quantities of matter resulting from incomplete combustion. Carbon, sulphur, ash, and various other compounds are all referred to as particulate, either collectively or individually, when discharged into a flue or into the atmosphere.

PERIPHERY: The curved line which forms the boundary of a circle (circumference), ellipse, or similar figure. Also, the outer bounds of something as distinguished from the center or internal regions.

pH: A chemistry term that denotes the degree of acidity or alkalinity of a solution. The pH of water solution may have any value between 0 and 14. A solution with a pH of 7 is neutral. Above 7, it is alkaline. Below 7, it is acidic.

PILOT VALVE: A small valve disk and seat, usually located within a larger disk, which opens to reduce the steam pressure across, and therefore reduce the effort required to unseat, the main disk.

PINION: A gear that meshes with a larger mating gear.

PIPING: An assembly of pipe or tubing, valves, fittings, and related components that forms a whole or a part of a system for transferring fluids.

PIPING MAIN: The larger or primary piping, extending throughout the boundaries of a system, to which components or subsystems are interconnected by smaller branch lines.

PITOMETER LOG: Device that indicates the speed of a ship and the distance traveled by measuring water pressure on a tube projected outside the ship's hull.

PLASTICITY: That property which enables a material to be excessively and permanently deformed without breaking.

PNEUMATIC: Driven, or operated, by air pressure.

PNEUMERCATOR: A type of manometer that measures the volume of liquid in tanks.

POSITIONER: That part of a control drive, loaded by a control signal, which supplies energy to an actuator in such manner that the final control element is positioned in accordance with the control signal.

POTENTIAL ENERGY: Energy at rest; stored energy.

POTABLE WATER: Water that is suitable for drinking. The potable water system supplies scuttlebutts, sinks, showers, sculleries, and galleys and provides makeup water for various freshwater cooling systems.

POWER: The time rate of doing work.

PPM (PARTS PER MILLION): Concentration of the number of parts of a substance dissolved in a million parts of another substance. Used to measure the salt content of water. If 1 pound of sea salt were dissolved in 1,000,000 pounds of water, the sea salt concentration would be 1.00 ppm.

PREHEATING: The application of heat to the base metal before it is welded or cut.

PRESSURE FEED SYSTEM: A system in which pressure (rather than gravity) is used to maintain flow.

PRESSURE RELIEF VALVE: A valve designed to open when pressure in the system exceeds a certain limit.

PRESSURE-TIME FUEL SYSTEM: A system in which fuel is injected into the cylinders at a specific pressure in separately timed events.

PRIMARY ELEMENT: That part of a measuring device that affects, or is affected by, the quantity being measured in order to produce a signal capable of being sensed by a transmitter or indicator.

PRIMARY SENSING ELEMENT: The control component that transforms energy from the controlled medium to produce a signal which is a function of the value of the controlled variable.

PRIME MOVER: The source of motion, such as a turbine, automobile engine, etc.

PRIMING: Unevaporated boiler water carried out of the steam drum with the steam. It is caused by malfunctioning steam drum internals, high water level, sudden steam demand, or rough weather.

PROPULSION OR STEAM PLANT: The entire steam propulsion plant.

PROTECTED COMPARTMENT: A compartment with a fixed (total flooding) carbon dioxide system installed.

PROTECTIVE FEATURE: A feature of a component or component part designed to protect a component or system from damage.

PULSATION: A rhythmical throbbing or vibrating.

PUMP: A device that raises, transfers, or compresses fluids or gases.

PUMP CAPACITY: The amount of fluid a pump can move in a given period of time, usually stated in gallons per minute (gpm).

PUMP RISER: The section of piping from the pump discharge valve to the piping main.

PUNCHING TUBES: Process for cleaning the interiors of boiler tubes.

PURPLE-K-POWDER (PKP): A purple powder composed of potassium bicarbonate that is used on class B fires. Can be used on class C fires; however, CO_2 is a better agent for such electrical fires because it leaves no residue.

QUILL SHAFT: A reduction gear shaft that connects the first reduction gear to the second reduction pinion.

RABBET: A machined joint that fits a protruding part of one joint into a groove in another joint.

RACE (BEARING): The inner or outer ring that provides a contact surface for the balls or rollers in a bearing.

RADIAL BEARINGS: Bearings designed to carry loads applied in a plane perpendicular to the axis of the shaft and used to prevent movement in a radial direction.

RADIAL THRUST BEARINGS: Bearings designed to carry a combination of radial and thrust loads. The loads are applied both radially and axially with a resultant angular component.

RADIATION: Transfer of heat in the form of waves similar to light and radio waves, without physical contact between the emitting and the receiving regions.

RADIATION, HEAT: Heat emitted in the form of heat waves.

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RATE ACTION: That action of a control system component whose output is proportional to the rate of change in its input for slowly changing signals and proportional to the input for rapidly changing signals.

RAW WATER: City water used in lieu of saltwater.

REACH ROD: A length of pipe or bar stock used as an extension on valve stems.

REACTION TURBINE: A turbine in which the major part of the driving force is received from the reactive force of steam as it leaves the blading.

RECEIVER INDICATORS: Pressure sensitive instruments indicating the loading pressure signals in percentage.

RECIRCULATION SYSTEM: The process of removing heat and moisture with cooled air by means of mechanical or natural distribution ductwork. The process may include filtering, heating, and dehumidifying.

RECTIFIER: A device for converting alternating current into direct current.

RECTIFY: To make an alternating current flow in one direction only.

REDUCER: (1) Any coupling or fitting that connects a large opening to a smaller pipe or hose. (2) A device that reduces pressure in a fluid (gas or liquid) system.

REDUCING STATION: An assembly consisting of a reducing valve, isolation valves, and bypass valves for the reducer.

REDUCING VALVES: Automatic valves that provide a steady pressure lower than the supply pressure.

REDUCTION GEARS: Combination of gears and shafting that reduce the speed of input shaft to the output shaft.

REFRACTORY: Various types of heat-resistant, insulating material used to line the insides of boiler furnaces.

REFRIGERATION TON: Unit of measure for the amount of heat removed. (12,000 Btu per hour)

REGULATOR (gas): An instrument that controls the flow of gases from compressed gas cylinder.

RELATIVE HUMIDITY: The ratio of the weight of water vapor in a quantity of air to the weight of water vapor which that quantity of air would hold if saturated at the existing temperature. Usually expressed as a percentage; for example, if air is holding half the moisture it is capable of holding at the existing temperature, the RH is 50%.

RELAY: A magnetically operated switch that makes and breaks the flow of current in a circuit. Also called "cutout and circuit breaker."

RELAY SENDER: A control system component that provides a means for manually setting a signal.

REMOTE MANUAL OPERATION: Human operation of a process by manual manipulation of loading signals to the final control elements.

REMOTE OPERATING GEAR: Rods or flexible cables attached to valve wheels so the valves can be operated from another compartment or level.

RESERVE FEEDWATER: Water stored in tanks for use in the boiler feedwater system as needed.

RISER: A vertical pipe leading off a large one; for example, fire main riser.

ROOT VALVE: A valve located where a branch line comes off the main line.

ROTARY SWITCH: An electrical switch that closes or opens the circuit by a rotating motion.

ROTOR: The rotating element of a motor, pump, or turbine.

SAE: Society of Automotive Engineers.

SAFETY VALVE: An automatic, quick opening and closing valve that has a reset pressure lower than the lift pressure.

SALINE/SALINITY: (1) Constituting, or characteristic of, salt. (2) Relative salt content of water.

SALINOMETER: A hydrometer that measures the concentration of salt in a solution.

SATURATED AIR: Air that contains the maximum amount of moisture it can hold at a specified temperature.

SATURATED STEAM: Steam at the saturation temperature.

SATURATION PRESSURE: The pressure corresponding to the saturation temperature.

SATURATION TEMPERATURE: The temperature at which a liquid boils under a given pressure. For a given pressure there is a corresponding saturation temperature.

SAYBOLT VISCOMETER: An instrument that determines the fluidity or viscosity (resistance to flow) of an oil.

SCALE: Undesirable deposit, mostly calcium sulfate, which forms in the tubes of boilers.

SEAWATER: Seawater is an aqueous solution of various minerals and salts (chlorides). In suspension also, but not dissolved in the water, may be various types of vegetable and animal growths, including in many cases bacteria and organisms harmful or actually dangerous to health.

SECURE: (1) To make fast or safe. (2) The order given on completion of a drill or exercise. (3) The procedure followed with any piece of equipment that is to be shut down.

SEDIMENT: An accumulation of matter which settles to the bottom of a liquid.

SELECTOR SWITCH: Usually a rotary-type switch with more than two line connections. The selector switch permits the connection of a permanently connected handset to any other circuit selected–that is, wired in, by means of a jack outlet. In some stations, where only two circuits are involved, a double-throw toggle switch is sufficient.

SENSIBLE HEAT: Heat that is given off or absorbed by a substance without changing its state.

SENSING POINT: The physical and/or functional point in a system at which a signal may be detected and monitored or may cause some automatic operation to result.

SENTINEL VALVE: A relief valve designed to emit an audible sound; does not have substantial pressure-relieving capacity.

SEQUENTIALLY: In a predesigned sequence, not necessarily in numerical order.

SERIES CIRCUIT: A circuit with two or more resistance units so wired that the current must pass through one unit before reaching the other.

SERIES-PARALLEL CIRCUIT: A circuit of three or more resistance units in which a series and a parallel circuit are combined.

SERVICE TANKS: Tanks in which fluids for use in the service systems are stored.

SETPOINT: The level or value at which a controlled variable is to be maintained.

SHAFT ALLEY: The long compartment of a ship in which the propeller shafts revolve.

SHAFT GLANDS AND PACKING: Used to minimize steam leakage from the turbine casing and/or the entrance of air into the turbine casing.

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SHELL INSERT BEARING: A bearing in which the wearing surface is installed on a thin shell. This shell is removable from the bearing body.

SHORE WATER: A broad term for classifying water originating from a source ashore.

SHRINK: (In a boiler) a short-term decrease in drum water level which results from a change in the firing rate or steam flow without any corresponding change in the feeding rate. Since flow of water into the boiler must correspond to the outflow of steam, the feeding rate must be decreased when shrink occurs.

SIMPLE SKETCH: A simplified pictorial illustration of a system.

SIMPLEX PUMP: A pump that has only one liquid cylinder.

SKETCH: A rough drawing indicating major features of an object to be constructed.

SLIDING FEET: A mounting for turbines and boilers to allow for expansion and contraction.

SLUDGE: (1) The sediment in the lower portion of a secured boiler resulting from the settling of suspended solids in the boiler water. The sediment may include, besides the suspended solids, oil and other contaminants. (2) The sediment left in fuel oil tanks.

SOLID COUPLING: A device that joins two shafts rigidly.

SOOT BLOWER: A soot removal device using a steam jet to clean the firesides of a boiler.

SPECIAL FUNCTION: A unique service performed by a system usually above and beyond the intended design of the system. Special functions are usually provided by small modifications to a simple system as opposed to making a separate system to perform a single operation.

SPECIFIC GRAVITY: The relative weight of a given volume of a specific material as compared to the weight of an equal volume of water.

SPECIFIC HEAT: The amount of heat required to raise the temperature of 1 pound of a substance 1° F. All substances are compared to water which has a specific heat of 1 Btu/1b/° F.

SPEED-LIMITING GOVERNOR: A device for limiting the rotational speed of a prime mover.

SPEED-REGULATING GOVERNOR: A device that maintains a constant speed on a piece of machinery that is operating under varying load conditions.

SPLIT PLANT: A method of operating propulsion plants so that they are divided into two or more separate and complete units.

SPRING BEARINGS: Bearings positioned at varying intervals along a propulsion shaft to help keep it in alignment and to support its weight.

STANDING CASING: The half of a split casing that is bolted to the foundation, as opposed to the half, or cover, which can be removed with minimum disturbance to other elements of the equipment.

STANDARD PRINT: A standard drawing, schematic, or blueprint produced in the applicable technical manual, or other official technical publication.

STANDBY EQUIPMENT: Two identical auxiliaries that perform one function. When one auxiliary is running, the standby is so connected that it may be started if the first fails.

STATIC: A force exerted by reason of weight alone as related to bodies at rest or in balance.

STATIC FORCE: A balanced force characteristic of bodies at rest.

STATOR: The stationary element of a motor or generator.

STEAM: Vapor of water, invisible, odorless, tasteless, and expansive.

STEAM DRUM: The large tank in which the steam collects in the boiler.

STEAM DRUM PRESSURE: The actual steam pressure in the boiler steam drum.

STEAM LANCE: A device for using low-pressure steam inside boilers to remove soot and carbon from boiler tubes.

STEAMING WATCH: Watches stood when the main engines are in use and the ship is underway.

STEP-TOOTHED LABYRINTH: Labyrinth type packing having each alternate tooth ring installed on the shaft and running in close proximity to the fixed packing ring.

STEERING ENGINE: The machinery that turns the rudder.

STERN TUBE: A watertight enclosure for the propeller shaft.

STERN TUBE FLUSHING WATER: Water circulated through the stern tubes from inboard to prevent accumulation of debris in the stern tube while the ship is at rest or backing down.

STRAIN: The deformation, or change in shape, of a material which results from the weight of the applied load.

STRENGTH: The ability of material to resist strain.

STRESS: A force which produces, or tends to produce, deformation in a metal.

STRIPPING SYSTEM: A system provided to strip all oil tanks and service systems of water and sediment.

STUFFING BOX: A device to prevent fluid leakage between a moving and a fixed part in a steam engineering plant.

STUFFING TUBE: A packed tube that makes a watertight fitting for a cable or small pipe passing through a bulkhead.

SUMP: A container, compartment, or reservoir used as a drain or receptacle for fluids.

SUPERHEAT: Amount of heat applied to steam to raise its temperature above the saturation temperature, while maintaining constant pressure.

SUPERHEATED STEAM: Steam heated to a temperature above the saturated temperature of the given pressure.

SUPERHEATER: That part of the boiler specifically designed to raise the temperature of the steam to a predetermined figure above the saturation point for the design pressure of the boiler.

SUPERHEATER OUTLET PRESSURE: The actual steam pressure measured at the boiler superheater outlet.

SUPERHEAT TEMPERATURE: Temperature of steam heated above the saturated temperature of the given pressure.

SUPPLY AIR: Compressed air required for the proper operation of pneumatic control components.

SWASH PLATES: Metal plates in the lower part of the steam drum that prevent the surging of boiler water with the motion of the ship.

SWELL: A short-term increase in boiler drum water level which results from a change in the firing rate or steam flow without any corresponding change in the feeding rate. Since flow of water into the boiler must correspond to the outflow of steam, the feeding rate must be increased when swell occurs.

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SWING CHECK VALVE: A valve having a guide-mounted disc swung from the top by a horizontal pin. A liquid exerting pressure against the disc will cause it to open, allowing a flow. Pressure exerted in the opposite direction will close the valve, ensuring only one direction of flow.

SWITCHBOARD: A panel or group of panels with automatic protective devices, used to distribute the electrical power throughout the ship.

SWITCHGEAR GROUP: Two or more switchboards in close proximity, mechanically independent but electrically connected, to form a designated unit.

SYNCHRO: An electromagnetic device for the transmission of mechanical motions to a remote location.

SYNTHRON SEAL: A rubber strip seal installed on the shaft to prevent seawater from leaking into the ship along the shaft.

SYSTEM: A grouping of components or equipment joined to serve a common purpose.

SYSTEM ALIGNMENT: The operation or adjustment of components within a system to route flow to a designated point.

SYSTEM DESIGN PRESSURE: The pressure used in the calculation of minimum section thickness of piping and piping components.

SYSTEM DESIGN TEMPERATURE: The temperature for which all equipment in the system or subsystem is intended.

SYSTEM INTERRELATION: Specific individual operations in one system affecting the operation in another system under normal conditions which are not fully described in emergency or casualty procedures or in the functional discussion of the system.

TAKE LEADS: A method of determining bearing clearance.

TANK TOP: Top side of tank section of double bottom of a ship.

TDC (top dead center): The position of a reciprocating piston at its uppermost point of travel.

TEFLON: A plastic with excellent self-lubricating bearing properties.

TEMPERING: The heating and controlled cooling of a metal to produce the desired hardness.

THERMAL CYCLE: The cycle in which the water is formed into steam, back to water and back to steam again by the addition or removal of heat.

THERMAL ENERGY: Energy contained in, or derived from, heat.

THIEF SAMPLE: A sample of oil or water taken from a ship's tank for analysis.

THREE-ELEMENT FEEDWATER CONTROL: An automatic feedwater flow control system which senses steam flow, feedwater flow and drum water level, and acts to maintain boiler drum water level at a constant setpoint.

THROAT: Openings in the cylinder block through which the crankshaft ends are extended.

THROTTLEMAN: Person in the engineroom who operates the throttles to control the main engines.

THROTTLE VALVE: A type of valve especially designed to control rate of flow.

THROTTLING: Operating a valve partially open such as to produce a pressure drop with flow.

THRUST BEARINGS: Bearings that serve to limit the axial (longitudinal) movement of the rotor within the casing and to absorb the thrust imparted to the rotor by the steam.

TIE CUTOUT SWITCH: Normally closed, the tie cutout switch is opened to disconnect a tie line, usually under casualty conditions.

TIE LINES: The connection between the tie and the tie cutout switches.

TIE SWITCH: Connects two circuits when closed.

TOP OFF: To fill up, as a ship tops off, with fuel oil before leaving port.

TOUGHNESS: The property of a material which enables it to withstand shock as well as to be deformed without breaking.

TRANSFER SWITCH: (1) Used to transfer the connections of individual lines from one group of circuits to another group. Used primarily in fire control telephone circuits. (2) When used with a sound-powered telephone amplifier, the transfer switch selects a single line from two or more lines for amplification. Communications on the remaining lines continue at normal level of volume.

TRANSFER VALVE: Manually operated valve used to switch automatic control systems from automatic to manual operation and vice versa.

TRANSFORMER: An electrical device used to step up or step down an a.c. voltage.

TRANSMITTER: A device that produces an output signal proportional to the measured variable.

TUBE EXPANDER: A tool that expands replacement tubes into their seats in boiler drums and headers.

TURBINE: A multibladed rotor, driven by steam, hot gas, or water.

TURBINE AHEAD ELEMENT: Bladed section of turbine that provides torque or power to drive the ship ahead (fwd).

TURBINE ASTERN ELEMENT: Bladed section of turbine that provides torque or power to drive the ship aft (astern).

TURBINE CASING: Shell that houses blading and other internals.

TURBINE JACKING GEAR: A motor-driven gear arrangement that slowly rotates idle propulsion shafts and turbines.

TURBINE STAGE: The term applied to one set of nozzles and the succeeding row or rows of moving blades.

UNBURNABLE OIL: That quantity of oil below the stripping suction in storage tanks and below the service suction in service tanks.

UNSTABLE: That action of an automatic control system and controller process that is characterized by a continuous cycling of one or more system variables to a degree greater than a specified maximum.

UPTAKES (EXHAUST TRUNKS): Large enclosed passages for exhaust gases from boilers to the stacks.

VACUUM: Pressures lower than atmospheric; in steam plant, a mixture of very little air and low density steam.

VALVE: A mechanism that can be opened or closed to control or stop the flow of a liquid, gas, or vapor from one to another place.

VALVE SEAT: The surface, normally curved, against which the valve disc operating face comes to rest to provide a seal against leakage of liquid, gas or vapor.

VALVE SEAT INSERT: Metal ring inserted into valve seat; made of special metal that can withstand operating temperature satisfactorily.

VALVE SPRING: The compression-type spring that closes the valve when the valve-operating cam assumes a closed-valve position.

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VANE: A thin plate that is affixed to a rotatable unit either to throw off air or liquid (in a pump) or to receive the thrust imparted by moving air or liquid striking the vane (in a turbine).

VAPOR: The gaseous state of a substance that is usually a liquid or solid at atmospheric temperature and pressure.

VELOCITY: Speed in a definite direction.

VENT: A valve in a tank or compartment used primarily to permit air to escape.

VENTILATION SYSTEM: The process of removing heat and stale air and providing fresh air by means of mechanical or natural distribution ductwork. The process may also include filtering and heating.

VENTURI: That part of a tube, channel, pipe, etc tapered to form a smaller or constricted area. A liquid, or a gas, moving through this constricted area, will speed up and, as it passes the narrowest point a partial vacuum will be formed. The taper facing the flow of air is much steeper than the taper facing away from the flow of air.

VENTURI INJECTOR: A device used to wash the firesides of boilers.

VISCOSIMETER: A device that determines the viscosity of a given sample of oil. The oil is heated to a specific temperature and then allowed to flow through a set orifice. The length of time required for certain amount to flow determines the oil's viscosity.

VITAL CIRCUITS: Electrical circuits that provide power or lighting to equipment and spaces necessary for propulsion, ship control, and communications.

VOID: A small empty compartment below decks.

VOLATILE: The term that describes a liquid that vaporizes quickly.

VOLTAGE TESTER: A portable instrument that detects electricity.

VOLUTE: A gradually widening spiral.

WATCHSTATION: Duties, assignments or responsibilities that an individual or group of individuals may be called upon to carry out. Not necessarily a normally manned position with a "watchbill" assignment.

WATER DRUM: A tank at the bottom of a boiler, sometimes called MUD DRUM, that equalizes distribution of water to the generating tubes and collects loose scale and other solids in boiler water.

WATER JACKET: Internal passages and cavities cast into the cylinder block of engines or air compressors through which water is circulated around and adjacent to friction (heat) areas.

WATER LEG: The water that condenses in a dead-end pressure gage line.

WATER TUBE BOILER: Boilers in which the water flows through the tubes where it is heated by the gases of combustion.

WATER WASHING: A method of cleaning the firesides of boilers to remove soot and carbon.

WIPED BEARINGS: A bearing in which the babbitt has melted because of excess heat.

WIREWAYS: Passageways between decks and on the overheads of compartments that contain electric cables.

WORK: The result of force moving through distance.

WORK REQUEST: Request issued to naval shipyard, tender, or repair ship for repairs.

WYE GATE: A fitting with two separately controlled hose fittings, designed to connect to an outlet.

ZERK FITTING: A small fitting to which a grease gun can be applied to force lubricating grease into bearings or moving parts of machinery.

ZINC: A metal placed in saltwater systems to counteract the effects of electrolysis.

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APPENDIX II

METRIC TABLE

THESE PREFIXES MAY BE APPLIED TO ALL SI UNITS

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr′ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ′gȧ)	G
1 000 000 = 10^{6}	mega (mĕg′ȧ)	M*
1 000 = 10^{3}	kilo (kĭl′ō)	k*
100 = 10^{2}	hecto (hĕk′tō)	h
10 = 10	deka (dĕk′ȧ)	da
0.1 = 10^{-1}	deci (dĕs′ĭ)	d
0.01 = 10^{-2}	centi (sĕn′tĭ)	c*
0.001 = 10^{-3}	milli (mĭl′ĭ)	m*
0.000 001 = 10^{-6}	micro (mī′krō)	μ*
0.000 000 001 = 10^{-9}	nano (năn′ō)	n
0.000 000 000 001 = 10^{-12}	pico (pē′kō)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm′tō)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt′tō)	a

*Most commonly used

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT

COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile†	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= l
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	l X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

†nautical mile = 1.852 kilometers

* exact

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MACHINIST'S MATE 3 & 2

NAVEDTRA 10524-E

Prepared by the Naval Education and Training Program Development Center, Pensacola, Florida

Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, Machinist's Mate 3 & 2, NAVEDTRA 10524-E, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided,

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mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards (NAVPERS 18068-D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The standards for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068-D and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 30 Naval Reserve retirement points. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel. Points will be credited in units as follows: Unit 1; 12 points upon satisfactory completion of Assignments 1 through 6; Unit 2; 12 points upon satisfactory completion of Assignments 7 through 12; Unit 3; 6 points for satisfactory completion of Assignments 13 through 15. Naval reserve retirement credit will not be given if the student has previously received credit for any Machinist's Mate 3 & 2 NRCC or ECC.

COURSE OBJECTIVE

When you complete this course you will be able to: name the requirements for advancement to Machinist's Mate 3 and 2. You will be able to point out safety requirements for engineering spaces, explain and trace the steam cycle of an engineering plant, identify operating features of distilling plants, turbines and auxiliary equipment. Finally, you will be prepared to assume greater responsibility as an Engineering Petty Officer.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

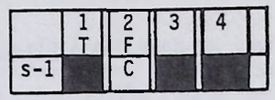
MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:



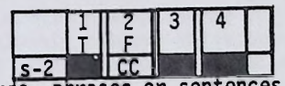
TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without the commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:



MATCHING ITEMS

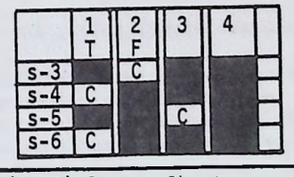
Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

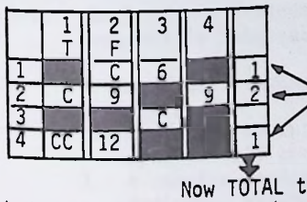
In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:



How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets



Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	3.9	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

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Assignment 1

Advancement and General Engineering Safety

Assignment: Chapters 1 and 2

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 nonresident career course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Identify the Machinist's Mate rating, listing some of the duties and responsibilities of the personnel who hold this rating. Textbook pages 1 and 2.

1-1. Which of the following describes the Machinist's Mate rating?

1. A general rating in the engineering group
2. A special rating held by those who operate only one kind of lathe
3. A service rating within the Engineman rating
4. A service rating within any engineering and hull group rating

1-2. A general rating identifies a/an

1. individual's job qualifications
2. specialty used in wartime
3. broad occupational field of related duties and functions
4. individual's performance in completing his Personnel Advancement Requirements (PAR)

1-3. A Machinist's Mate in the M Division will most probably be assigned to maintain

1. steering engines
2. laundry equipment
3. propulsion machinery
4. refrigeration equipment

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1-4. As you move up the promotion ladder to MM3 or MM2, which of the following describes your technical leadership responsibilities?

1. They will be more general in nature
2. They will be more directly related to your work
3. They will include more military responsibilities than for personnel who hold other ratings
4. They will require only that you tell others what to do

1-5. A Machinist's Mate demonstrates technical leadership best by

1. performing work with integrity and increasing knowledge
2. developing military leadership
3. taking pride in military appearance
4. demonstrating the manual of arms

1-6. How can you demonstrate integrity of work?

1. By standing watches
2. By repairing leaky valves
3. By cleaning your equipment
4. By performing each of the above as well as you can

Learning Objective: Discuss the purpose of Navy Enlisted Classification Codes (NEC's). Textbook page 2.

1-7. Which of the following is a purpose of the Navy Enlisted Classification Codes (NEC's)?

1. To recruit Navy men and women
2. To identify skills and training required for specific types of operations or equipment
3. To determine who will advance
4. To classify information about ships

● NAVPERS 18068, The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards lists the NEC's that you are eligible to try for.

1-8. Where can you find a copy of NAVPERS 18068?

1. In the Log Room
2. In the Personnel Office
3. In the Supply Office
4. In the Operations Office

Learning Objective: Identify the essentials of the Navy Enlisted Advancement System. Textbook pages 2 through 9.

1-9. Which of the following is/are required for advancement in rating to MM3 or MM2?

1. Recommendation of your commanding officer
2. Passing a written examination on occupational standards applicable to your rate
3. Length of time in paygrade
4. All of the above

1-10. Which of the following is NOT a requirement for advancement in rating to MM3 or MM2?

1. Demonstrate ability to do everything listed for MM3 or MM2 in the Personnel Advancement Requirement (PAR) Program (NAVPERS 1414/4)
2. Pass a written E-4 or E-5 Military/Leadership examination
3. Complete the mandatory Rate Training Manual, Machinist's Mate 3&2
4. Demonstrate knowledge of subject matter in related ratings at the same paygrade

1-11. What factor(s) determine(s) your final multiple score?

1. Score on advancement examination
2. Length of time in rate
3. Performance marks
4. Each of the above

1-12. To find the required and recommended training courses to study for advancement in rating, what publication should you consult?

1. Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068 (current series)
2. Bibliography for Advancement Study, NAVEDTRA 10052 (current series)
3. Guide for Enlisted Classification
4. Shipboard Training Manual

1-13. When studying for advancement, remember that you will be tested on the standards that apply to

1. the rate level to which you seek advancement
2. your present and lower rate levels
3. the rate level you seek and higher levels
4. the rate level to which you seek advancement and lower levels

1-14. Who schedules the Military/Leadership Examinations?

1. Chief of Naval Personnel
2. Commanding Officer
3. Division Officer
4. Education Services Officer

1-15. What do Occupational Standards identify?

1. Military requirements
2. Leadership requirements
3. Work requirements
4. Each of the above

1-16. Where are (a) Naval Standards and (b) Occupational Standards found in NAVPERS 18068?

1. (a) Section I (b) Section II
2. (a) Section II (b) Section I
3. (a) Section I (b) Section I
4. (a) Section II (b) Section II

● In answering items 1-17 and 1-18, refer to figures 1-3 and 1-4 of the text.

1-17. After studying piping and valves what topic should you study next?

1. Propulsion
2. Casualty control
3. Auxiliary machinery
4. Distilling

1-18. What information is found in block (2) of your Profile Information Form?

1. Examination status
2. Your final multiple
3. Minimum multiple required
4. Standing

1-19. Which of the following replaces the Record of Practical Factors?

1. Personnel Qualification Standards
2. Engineering Operations Sequencing System
3. Personnel Advancement Requirement (PAR) Program
4. Occupational Standards

1-20. What paygrades, if any, are exempted from the Personnel Advancement Requirement (PAR) program?

1. E-3 apprenticeships, E-8, and E-9
2. E-8 and E-9 only
3. E-3 apprenticeships only
4. None

1-21. What information is found in Section II of the PAR?

1. Formal School and Training Requirements
2. Administration Requirements
3. Occupational Requirements
4. Military Ability Requirements

Learning Objective: Describe the functions of the Engineering Operational Sequencing System (EOSS). Textbook page 9.

1-22. Which of the following describes EOSS?

1. A group of general procedures that covers all ships of the same class
2. Details the sequential operational functions for the complete cycle of plant evolutions
3. Includes PMS and PQS
4. Improves everything except watchstanding

1-23. EOSS will standardize watchstanding between ships.

1-24. The primary goal of EOSS is to improve operational readiness by improvements in operation and casualty control procedures. What is a secondary feature of EOSS?

1. To provide a PAR checkoff procedure
2. To provide aid in training new men
3. To improve 3-M procedures
4. To standardize proficiency

Learning Objective: Discuss the purposes of Personnel Qualification Standards. Textbook pages 9 and 10.

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1-25. Which of the following functions is NOT served by the Personnel Qualifications Standards?

1. Describing the knowledge and skills a trainee must have to perform duties correctly
2. Providing a petty officer to teach the learner in each step of work
3. Individualizing learning
4. Placing responsibility for learning on the learner

1-26. Personnel Qualifications Standards support the advancement in rating requirements which are given in the

1. Basic Military Requirements, NAVTRA 10054-D
2. Bibliography for Advancement Study, NAVEDTRA 10052 series
3. Navy Enlisted Manpower and Personnel Classifications and Occupational Standards NAVPERS 18068 series
4. Personnel Advancement Requirement (PAR) Program, NAVPERS 1414/4

1-27. Which subject section is NOT contained in the Personnel Qualification Standards?

1. 100 series - Theory
2. 300 series - Watchstanding
3. Feedback forms
4. Maintenance

Learning Objective: Identify the purposes, benefits, and limitations of the Planned Maintenance System. Textbook page 10.

1-28. Which of the following is NOT a purpose of the Planned Maintenance System (PMS)?

1. To administer examinations on maintenance theory
2. To provide for detection and prevention of impending casualties
3. To describe the methods and tools to be used
4. To estimate and evaluate material readiness

1-29. Which of the following actions is NOT required for the Planned Maintenance System to be successful?

1. Professional guidance from several available sources
2. Obtaining a degree in management
3. Direction at each echelon of the organization
4. Training in the maintenance steps and in the system

Learning Objective: List sources of information for Machinist's Mates who wish to advance in their careers. Textbook pages 11 through 14.

1-30. When studying for advancement, which of the following publications will be a hinderance?

1. NAVSEA Journal
2. Blueprint Reading and Sketching
3. Naval Ships' Technical Manual
4. Obsolete rate training manuals

1-31. If extensive changes occur in the qualifications for a rating between the annual publications of NAVEDTRA 10052, where can you find a list of study material?

1. NAVAL SEA SYSTEMS Notices
2. BUPERS Notice
3. NAVEDTRA 10052 supplements
4. Naval Ships' Technical Manual

1-32. Which of the courses listed in NAVEDTRA 10052 for your rating must you complete to be eligible to take the advancement in rating examinations?

1. All courses listed for the Engineering and Hull group
2. All courses listed for the next higher rate
3. Courses marked with an asterisk at the next higher rate
4. Unmarked courses listed for the next higher rate

1-33. Assume that you are a MM3 preparing to take the servicewide advancement in rate examination for MM2. Which courses and references listed in NAVEDTRA 10052 series will you be examined on?

1. All courses and references listed for E-4 and E-5 for the MM rating
2. All courses listed for E-5 Engineering ratings
3. Courses marked with an asterisk for E-5 and E-6 in the MM rating
4. Courses marked with an asterisk for E-5 Engineering/Hull ratings and all references for E-5 Engineering/Hull rating

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In items 1-34 through 1-36, select the publication from column B that is a source of the information in column A.

	A. Information	B. NAVEDTRA Publications
1-34.	Knowledge and skills applicable to each paygrade within the Machinist's Mate rating	1. Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
1-35.	Latest edition of a given Rate Training Manual	2. Bibliography for Advancement Study, NAVEDTRA 10052 series
1-36.	References used for source material for advancement examinations	3. List of Training Manuals and Correspondence Course, NAVEDTRA 10061 series
		4. The Metric System, NAVEDTRA 475-01-00-75-1

1-37. Each rate training manual contains information relating directly to the occupational qualifications of several ratings.

1-38. What is the best source of definitions to the technical terms used in your textbook?

1. Your leading chief
2. Glossary at the end of the text
3. Webster's New Collegiate Dictionary
4. Each chapter of your text

1-39. Which of the following hints for studying should help you get the most from your Navy training course?

1. Devote your time exclusively to important military topics
2. Try not to cover a complete unit in any one study period
3. Omit easy material; study only the most difficult and the unfamiliar
4. Make notes as you study, putting the main ideas in your own words; then review your notes

1-40. As you study a Navy training course, what study practice should you follow?

1. Set up a fixed number of pages to study in each and every study period
2. Tie in new information with things you know already
3. Memorize as much as you can from a chapter and repeat it to a shipmate
4. Skip over the illustrations and save them until the end of your course

1-41. Which of the following is a monthly publication that contains useful articles about shipboard engineering and information concerning new developments?

1. Change to NAVSHIPS' Technical Manual
2. NAVSEA Journal
3. Supplement to applicable Navy Training Course
4. Bibliography for Advancement Study

1-42. Aboard ship, blueprints are filed according to

1. month and year of issue
2. SHIPALT number
3. numerical sequence in the ship's drawing index (SDI)
4. revision number or letter

Learning Objective: Point out features of accident prevention. Textbook pages 15 through 17.

1-43. Accident prevention produces waste.

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In items 1-44 through 1-46, match the definition in column B with the term in column A.

Column A	Column B
1-44. Accident	1. The process of eliminating accident-producing causes
1-45. Near-accident	2. Any unplanned event that results in property damage
1-46. Accident prevention	3. An accident that almost happened
	4. Unsafe conditions leading to accidents

1-47. Which of the following must be eliminated if we wish to prevent accidents?

1. Unsafe acts
2. Orderliness
3. Inspections
4. Good work habits

1-48. Which of the following contribute to the number of accidents?

1. Good housekeeping
2. Inspections
3. Unsafe conditions
4. Intelligent work habits

1-49. The greatest number of accidents can be traced directly to

1. unsafe conditions
2. misfortune
3. acts of God
4. unsafe acts

1-50. Almost everything we know about safety has been learned from accidents. Therefore, we can say safety precautions are written in blood.

1-51. What is the single biggest cause of accidents?

1. Speed
2. Carelessness
3. Lack of knowledge or skill
4. Excitement

1-52. When does accident prevention training begin in the Navy?

1. During orientation
2. During indoctrination
3. During on-the-job training
4. When assigned to X Division

1-53. When is it permissible to violate established procedures?

1. When you discover a shortcut
2. When the job is an emergency
3. When the immediate supervisor says it is permissible
4. Only when the person responsible for the consequences gives an order

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Learning Objective: Point out the responsibility for safety at all levels of command, identifying some helpful types of assistance in carrying out this responsibility. Textbook pages 18 through 21.

1-54. The Maintenance Material Management System as a vehicle for management control, policy direction, and technical supervision contributes to shipboard safety by developing a flow of accomplishments between managers.

1-55. Which action on your part as a supervisor will probably have the most lasting effect on your personnel with respect to safety?

1. Posting posters showing accidents caused by unsafe practices
2. Showing films of actual accidents
3. Incorporating safety practices in daily routine
4. Publishing comprehensive safety rules

When you teach personnel that the unexpected can be expected, they will avoid that hazard, if possible. For instance, we must teach sailors that they can expect foreign objects in their eyes if they fail to wear goggles when using a grinder.

1-56. Why must a Machinist's Mate wire and tag air valves when he is working on an air compressor?

1. To prevent the unexpected
2. To protect the equipment
3. To protect the operator of the valve
4. Each of the above is correct

1-57. Thinking of accidents as unexpected contacts will enable you to perform a better job of which of the following?

1. Observing for unsafe practices
2. Inspecting for unsafe conditions
3. Analyzing jobs for safer methods
4. Doing all of the above

In items 1-58 through 1-62, select from column B the safe act exemplified in column A.

A. Examples	B. Safe Acts
1-58. Walking around instead of under crane lifts	1. Using tools and equipment for their intended purposes
1-59. Avoiding shortcuts on a job to hurry it along	2. Taking safe positions and postures
1-60. Disconnecting the controller of an electric pump before making repairs	3. Operating or working at safe speeds
1-61. Lifting a heavy object with back straight and legs bent	4. Securing against unexpected movement
1-62. Using a screwdriver only as a screwdriver	

1-63. Which of the following is NOT a recommended safe practice?

1. Securing equipment or materials against slipping or drifting
2. Operating machinery at its recommended speed
3. Seeing that tools with loose handles are repaired before they are used
4. Using tools for purposes for which they were not designed

1-64. Safety is dependent on orderliness and cleanliness. Order may be maintained by

1. storing all items in an assigned place, keeping them there when not in use, and stowing the items in ready-for-sea condition
2. storing all items in a common storage container except those which must be maintained in ready-for-sea condition
3. tagging all items according to their age and then storing them together
4. disposing of wornout items

Learning Objective: Describe some principles and procedures for accident prevention. Textbook pages 21 through 25.

1-65. If it should become necessary to abandon a compartment because of danger of steam, which, if any, is the best avenue of escape?

1. To another compartment on a higher level
2. To another compartment on a lower level
3. Up a fireroom ladder to the outer deck
4. Any of the above is as good as another

1-66. A casualty resulting in injury to personnel must be reported to the Engineering Officer of the Watch when underway and to the Duty Engineering Officer when in port in order that the correct entry can be made in the

1. Monthly Summary
2. Engineer's Bell Book
3. Engineering Log
4. Commanding Officer's weekly record

1-67. Personnel who are handling material aboard ship should NOT observe which of the following practices?

1. Signaling that all personnel are clear before lifting or lowering material
2. Examining material for sharp edges or protruding points before handling
3. Closing, tagging, or securing valves that permit entrance of steam, water or air into the fitting or equipment
4. Throwing materials from high places to the deck

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1-68. Which practice must you follow at all times when using an electric grinding machine?

1. Wear goggles or a face shield
2. Be sure that the frame is grounded
3. Have adequate instruction for using the grinding machine and the proper authorization
4. Each of the above practices

1-69. All of the electrically driven portable handtools listed below must be considered unsafe for use EXCEPT which of the following?

1. Tools equipped with ground wire connections between the metal housings and the steel structure of the ship
2. Tools without an approved type grounding plug
3. Tools with exposed insulated conductors
4. Tools that have not been inspected and tested weekly by a qualified Electrician's Mate

1-70. How often should electrically operated hobby equipment be inspected and tagged by the Electrician's Mate?

1. Every 2 years
2. Every year
3. Every 6 months
4. Any of the above, depending on the instructions issued by the command

1-71. Why must fuel oils with a flashpoint lower than 140° F NOT be used on Navy vessels?

1. These fuels leave pollutants in the atmosphere
2. An explosive mixture with the air may be produced
3. Their viscosity characteristics are unfavorable
4. They are more apt to leak than other fuels

1-72. Why must you draw and wear recommended oxygen breathing apparatus when you work on a stack?

1. Height necessitates oxygen to prevent dizziness
2. Stack gas contains carbon monoxide and other toxic substances
3. Oxygen can give you extra energy
4. Oxygen will keep you alert and prevent your falling

1-73. Which condition could cause a dangerous reduction in oxygen in a shipboard compartment?

1. Fire
2. Rusting or the drying of paint
3. Decomposing organic material
4. Any of the above conditions

A Final Note on Safety

Oily rags should be placed in a steel can with a self-closing lid until disposed of in accordance with your Commanding Officer's instructions. Report all unsafe electrical conditions to the duty electrician, that is, faulty wiring, open electrical boxes, etc.

Assignment 2

General Safety (Continued); Steam Turbines

Textbook Assignment: Chapter 2 (Continued) and Chapter 3

Learning Objective: Identify symptoms of electric shock, specifying recommended procedures for administering cardiac massage and artificial respiration. Textbook pages 25 through 29.

2-1. There is no danger from electrical shock from 115-volts or lower.

2-2. Personnel should be especially careful around electrical equipment aboard ship because shipboard conditions can contribute to the danger of severe shocks.

For items 2-3 through 2-5, suppose that you find MM3 Young prone and not breathing. You see that an electric wire is touching him, and it appears that he is a victim of electric shock.

2-3. What is the first thing that you should do?

1. Shut off the voltage or remove the wire from Young, using dry, non-conductive material
2. Start artificial respiration
3. Start cardiac massage
4. Go for medical assistance

2-4. After Young is removed from the wire, artificial respiration must be applied to reestablish breathing.

2-5. If you have assistance at hand, you should take turns breathing into Young's mouth and, if required, massaging his heart.

2-6. Which of the following symptoms may be observed in a victim of cardiac arrest as a result of electric shock?

1. Pulse at wrist or neck
2. Flushed face
3. Weak or stopped respiration
4. All of the above symptoms

2-7. Cardiac arrest is not as serious as lack of respiration. Therefore, artificial respiration has top priority for shock victims.

2-8. Suppose that you are preparing to administer closed chest cardiac massage on a victim of electric shock. Which of the following actions is NOT a necessary part of the procedure?

1. Placing the victim on his or her back and exposing the chest
2. Giving cardiac massage without artificial respiration
3. Rocking so that a controlled amount of body weight goes through your arms and hand to his breastbone
4. Placing one hand across victim's breastbone so that the heel of the hand covers the lower part

2-9. Which of the following must be done in addition to cardiac massage, in case of cardiac arrest?

1. Place warm wet cloths on victim's head
2. Perform artificial respiration
3. Prop the victim upright
4. Do both 2 and 3 above

2-10. The back pressure arm lift method of artificial respiration is the most effective method to restore breathing to an accident victim.

2-11. In figure 2-2 of the text, which view shows dislodging foreign matter from the victim's air passages?

1. A
2. B
3. C
4. G

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2-12. In figure 2-2 of the text, which views show positioning the jaw to move the tongue from the upper air passage?

1. A, B
2. B, C
3. C, F
4. A, B, C

Learning Objective: Use the terms energy, work, and power correctly. Textbook pages 30 through 32.

In items 2-13 through 2-15 select the definition from column B that best describes the term in column A.

Column A	Column B
2-13. Energy	1. A force acting upon matter and moving it
2-14. Power	2. Ability to do work
2-15. Work	3. Energy within an object waiting to be released
	4. Work done in a period of time

2-16. What type of energy is found in water of an operating boiler?

1. Chemical
2. Thermal
3. Mechanical
4. Specific

2-17. In figure 3-1 of the text, where is chemical energy converted to thermal energy?

1. Furnace
2. Superheater
3. Steam drum
4. Economizer

2-18. In figure 3-1 of the text, where is thermal energy converted to mechanical work?

1. Turbine
2. Condenser
3. Air ejector, condenser
4. In each of the above

In items 2-19 through 2-21 select the definition from column B that best describes the term in column A.

Column A	Column B
2-19. Kinetic energy	1. Stored energy in steam
2-20. Enthalpy	2. Energy that has been released
2-21. Potential energy	3. Stored energy in an object
	4. Moving an object through resistance

2-22. In figure 3-2 in the text, if you are operating at 30% speed, what percentage rated horsepower are you using?

1. 1%
2. 10%
3. 40%
4. 4%

2-23. In figure 3-2 in the text, if you increase the percentage speed to 60%, how much horsepower is required?

1. 10%
2. 20%
3. 30%
4. 40%

Learning Objective: Specify distinguishing features of different turbines, indicating the part, staging, compounding, and direction of steam flow play in classification; define necessary nomenclature used to identify turbine construction and operation principles. Textbook pages 30 through 41.

2-24. The velocity of a stream of water, after it leaves the nozzle of a hose, is equal to the decrease from hose pressure to atmospheric pressure.

2-25. What parts of a reaction turbine serve the same purpose as the nozzles of an impulse turbine?

1. Fixed nozzles
2. Moving nozzles
3. Fixed blades and moving blades
4. Moving blades only

2-26. What, if anything, changes thermal energy into kinetic energy in the reaction turbine?

1. The fixed blades
2. The moving blades
3. The fixed and moving blades
4. None of the above

2-27. Why are convergent-divergent nozzles used in high-pressure turbine applications?

1. They are easy to manufacture
2. They direct the steam flow more efficiently than other types
3. They produce a larger pressure drop and therefore are more efficient than other types
4. They are less susceptible to steam erosion than other types due to their shape

2-28. In addition to direction of steam flow, in which way may turbine types be classified?

1. Manner in which the steam causes the turbine rotor to rotate
2. Type of staging and compounding of steam pressure and velocity
3. Division of the steam flow
4. All of the above ways

2-29. What is a Rateau stage?

1. One set of nozzles and two rows of moving blades
2. Two sets of nozzles and one row of moving blades
3. Two sets of nozzles and two rows of moving blades
4. One set of nozzles and one row of moving blades

2-30. Which of the following is an essential feature of the Rateau type turbine?

1. Two or more simple impulse stages in a row in one casing
2. Large pressure and temperature drop in first stage
3. Alternate rows of fixed and moving blades
4. Velocity-compounded impulse stage at high-pressure end of turbine

2-31. Large temperature and pressure drops in the first stage nozzles of a combination impulse and reaction turbine are caused by

1. two rows of moving blades
2. steam passing through a single row of blades more than once
3. a velocity-compounded impulse stage at the high-pressure end of the turbine
4. using a dummy piston and cylinder to offset axial thrust

2-32. In which type of turbine does the same turbine wheel use the steam more than once?

1. Axial flow
2. Helical flow
3. Axial and radial flow
4. Helical and axial flow

2-33. Why do double-flow type reaction turbines have very little axial thrust?

1. Because no axial thrust develops
2. Because the axial thrusts developed at each end couterbalance each other
3. Because partially expanded steam is exhausted to a low-pressure turbine where the expansion is completed
4. Because equalizing holes are provided in the turbine wheel

2-34. Axial thrust in a reaction turbine is the result of a steam pressure drop in

1. the nozzles
2. the moving blades
3. the stationary blades
4. both the moving and stationary blades

Learning Objective: Point out turbine mounting features as well as bearings and seals of turbines. Textbook pages 42 through 47.

2-35. What part of the turbine assembly in textbook figure 3-15 relieves strain on the turbines caused by thermostress?

1. Curved steam lines
2. Rigid I-beam
3. Rigid mountings
4. Babbitt lined bearings

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2-36. In figure 3-15 of the textbook, why is the flexible I-beam at the forward end of the turbine?

1. To relieve stress on the hull
2. To relieve stress at the light end of the turbine
3. To allow expansion away from the reduction gears
4. To prevent reaction developed in the turbine from being transmitted to the hull

2-37. Because of the pressure drop existing across each diaphragm, the flow of steam between the nozzle diaphragm and the rotor of a turbine is held to a minimum by

1. a fluid seal
2. a labyrinth packing ring
3. a babbitt liner
4. deflector rings

2-38. The transfer of friction heat from bearings to lube oil is helped through the use of

1. rollers
2. Monel linings
3. babbitt linings
4. a dowel

2-39. The adjustable spherical-seated self-aligning bearing housings in main turbines are provided with oil deflector rings. What is the purpose of the rings?

1. To ensure efficient lubrication of the bearing
2. To prevent the leakage of steam into the oil
3. To prevent the leakage of oil out of the bearing
4. To do both 2 and 3 above

2-40. Which bearing is used in some Navy turbines to absorb axial stress?

1. Cylindrical bearing
2. Adjustable spherical-seated self-aligning bearing
3. Journal bearing
4. Pivoted shoe-type thrust bearing

2-41. The Kingsbury bearing is equipped with pivoted shoes in order to

1. absorb radial stress
2. compensate for shaft misalignments
3. maintain oil film
4. keep the sleeve from turning

2-42. Gland sealing steam in steam turbines is used to prevent the loss of

1. vacuum
2. temperature
3. oil
4. air

2-43. The labyrinth packing alone will prevent air from passing along the shaft and into the turbine.

2-44. Why does steam pressure drop as it passes through a labyrinth seal?

1. The steam is low pressure steam
2. The labyrinth causes turbulence in the steam
3. The flax packing seals the gland
4. Both 2 and 3 are correct

2-45. Refer to textbook figure 3-20. In what position are the air-operated regulating valves when the steam in the gland seal supply line is excessive?

1. Both valves are open
2. Both valves are closed
3. The excess steam unloading valve is shut and the supply pressure control valve is open
4. The excess steam unloading valve is open and the supply pressure control valve is shut

2-46 What causes the gland leak-off steam in a propulsion turbine to pass through the gland exhaust condenser?

1. Gland exhauster fan
2. Steam pressure from the high-pressure turbine
3. Compressed air in the air pilot
4. Steam pressure from the low-pressure turbine

2-47. In the hydraulic turbine gland seal regulator, shown in figure 3-22 of the text, what is the sensing unit called?

1. Pilot valve
2. Pivot rods and block
3. Bellows
4. Manifold

2-48. In the hydraulic turbine gland seal downward regulator the piston is operated by a/an

1. bellows
2. spring
3. pilot valve
4. exhaust valve

2-49. The steam from the glands of a main propulsion unit may be exhausted to which of the following?

1. Auxiliary air ejector
2. Feed system
3. Air ejector condenser
4. Either 2 or 3 is correct

Learning Objective: Identify the components of a turbine control unit, specifying safety devices applicable to turbogenerators. Textbook pages 50 through 55.

2-50. What holds the poppet valves closed in the nozzle control valves shown in figure 3-24 of the text?

1. Lifting beam
2. Springs
3. Steam pressure
4. Oil pressure

2-51. When valves #1 and #2 in figure 3-21 of your textbook are wide open, the steam pressure in the steam chest is

1. about the same as the line pressure
2. in excess of the line pressure
3. increasing in intensity
4. sufficient for maximum turbine speed and power

2-52. Which of the cam-operated valves admits steam directly into the 6th stage?

1. 5
2. 2
3. 3
4. 4

2-53. For turbine-driven ships, what is the range of economic operation?

1. 8 - 12 knots
2. 12 - 15 knots
3. 12 - 20 knots
4. 15 - 20 knots

2-54. Maximum efficiency in steam turbine operation is realized by use of

1. all auxiliary equipment
2. maximum speed and power
3. cruising speed
4. full power for long periods of time

2-55. Constant-speed governors are normally employed with

1. Cruising turbines
2. High-pressure turbines
3. Turbine-generator units
4. Variable-speed turbines

2-56. The steady frequency required from a ship's service generator for electrical power and lighting is maintained by means of a

1. throttle-control mechanism
2. constant-speed governor
3. speed-limiting governor
4. cam-operated nozzle control valve

2-57. What happens when there is an increase on a ship's service generator that is equipped with a centrifugal type governor?

1. Governor weights move outward
2. Operating piston lowers
3. Oil enters the operating cylinder
4. Steam flow to the turbine decreases

2-58. What reaction is caused in the governor by an increase in the speed of a ship's service generator turbine?

1. Governor weights move inward
2. Lifting beam is raised
3. Bushing is lowered
4. Oil is pumped into the operating cylinder

2-59. The safety device on turbogenerators that closes the throttle automatically when exhaust pressure reaches a set level is called

1. a back-pressure trip
2. a low-pressure oil trip
3. an emergency hand trip
4. an overspeed trip

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2-60. In case of failure of the electro-hydraulic load-sensing speed governor, what will happen to the steam valve?

1. The position of the valve will remain where it was at the time of the failure
2. The control of the steam valve will automatically shift to manual
3. The steam valve will close
4. The steam valve will travel open so the turbine can trip on overspeed

---

Learning Objective: Identify propulsion turbines by class and type. Textbook pages 56 through 58.

2-61. What ship type has a Class A propulsion turbine?

1. Auxiliary
2. Mine warfare
3. Destroyer
4. Submarine

Select the characteristic in column B that best identifies the type of propulsion unit listed in column A.

Column A	Column B
2-62. Type II-A	1. Single-casing
2-63. Type II-B	2. Series-parallel
2-64. Type III	3. Straight-through
	4. External-Bypass

2-65. What element of a series-parallel turbine system operating in series receives steam that has already passed through two other turbines?

1. Low-pressure turbine
2. High-pressure turbine
3. Cruising turbine
4. Astern turbine

2-66. The reversing turbine is used for which of the following?

1. Emergency stopping
2. Backing
3. Maneuvering
4. Each of the above

Learning Objective: Identify the most commonly used types of auxiliary turbines. Textbook page 58.

2-67. Most of the Navy's auxiliary turbines are either helical-flow or axial-flow impulse turbines EXCEPT those used to drive which of the following?

1. Air compressors
2. Electric generators
3. Forced-draft blowers
4. Pumps

Learning Objective: Specify turbine maintenance requirements, indicating how maintenance is accomplished. Textbook pages 59 through 61.

2-68. In figure 3-30 of the text, how many man-hours are required to measure turbine thrust?

1. 1
2. 10
3. 11
4. 21

2-69. Inefficient operation or faulty condition of turbine components is indicated by variation from the normal in which of the following?

1. Speed
2. Pressure
3. Lubricating oil temperature
4. Any of the above variations

2-70. Saltwater in lubricating oil is damaging to units containing oil-lubricated ball bearings.

Assignment 3

Reduction Gears and Related Equipment

Textbook Assignment: Chapter 4

Learning Objective: Identify fundamentals of main reduction gears, ways they are classified, their construction features, and functions of major components. Textbook pages 62 through 70.

3-1. What are reduction gears designed to do?

1. To change rotary motion into linear motion
2. To combine several high speeds into a single low speed
3. To reduce high speed to low speed
4. To do both 2 and 3 above

3-2. What type reduction gear is generally used in combatant ships?

1. Articulated, double reduction gear
2. Nested, double reduction gear
3. Locked train, double reduction gear
4. Two pinion, single reduction gear

3-3. What type reduction gear is normally used in auxiliary and amphibious warfare ships?

1. Nested or articulated double reduction gear
2. Locked train, double reduction gear
3. Two pinion, single reduction gear
4. One pinion, single reduction gear

3-4. In older ships, what factor permitted the use of single reduction gears for main propulsion plants?

1. Small turbine shaft
2. Low turbine speed
3. Less demand for flexibility
4. Each of the above

3-5. What types of reduction gear arrangements are usually used in ships where the gears are driven by electric motors?

1. One or two pinion single reduction gears
2. One pinion single reduction gear for electric motors and two pinion single reduction gear for diesel engines
3. Articulated and nested type double reduction gears
4. Articulated double reduction gear for electric motors, and nested type double reduction gear for diesel engines

3-6. Of what form are most main reduction gears in combatant ships?

1. Internal spur
2. External spur
3. Single helical
4. Double helical

3-7. What does the term "axial float" mean in reference to reduction gears?

1. The gears are capable of free motion, neither supporting nor supported by other gears axially
2. The gears are double-helical and axial thrust is eliminated
3. The gears are capable of free motion, neither supporting nor supported by other gears radially
4. The gears are not subject to excessive tooth loads due to mismatch of the journal bearing halves

3-8. What is the purpose of the groove around the center of a double-helical gear?

1. To allow the gears slight axial movement without gear damage
2. To prevent excessive axial thrust loads on the teeth
3. To allow a path for oil to flow
4. To do each of the above

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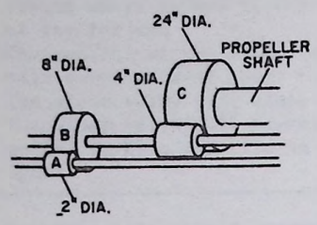


Figure 3A.

3-9. Which statement is true if gear A is the driving gear in figure 3A?

1. Gear A rotates faster than gear C
2. Gear B rotates slower than gear C
3. The speed of gear B is equal to that of gear C
4. The speed of gear A is equal to that of gear C

3-10. Assume that a gear train with only two gears, a 2-inch driving gear, and a driven gear (bull gear), drives the ship's propeller at 200 rpm. If the speed of the driving gear is 4,800 rpm, what is the diameter of the driven gear?

1. 6 in.
2. 12 in.
3. 24 in.
4. 48 in.

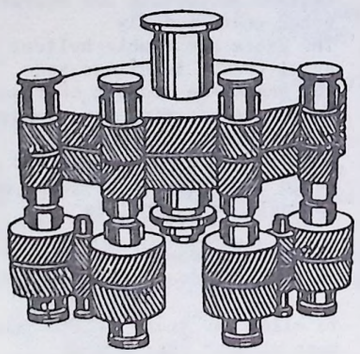


Figure 3B.

3-11. Which type of reduction gear is illustrated by figure 3B?

1. Articulated, double reduction gear
2. Locked train, double reduction gear
3. Nested type, double reduction gear
4. Two pinion, single reduction gear

3-12. In combatant ships, the turbine shaft is linked to a high-speed pinion by means of a

1. quill shaft
2. flexible coupling
3. movable sleeve
4. nested casing

3-13. In figure 4-2 of the text, the second reduction pinions are coupled to the first reduction gears by solid shafts.

3-14. The simplest of the various double reduction gears used in naval ships is illustrated in textbook figure

1. 4-1
2. 4-2
3. 4-3
4. 4-4

3-15. By what means are rotating parts sighted in main reduction gear casings?

1. Inspection plates
2. Removable covers
3. RT junction boxes
4. Tachometer drives

3-16. In an articulated, double-reduction, divided-power path gear set, the first- and second-reduction gears are usually of a fabricated construction. Why are the teeth cut in a temperature-controlled room?

1. To prevent stress buildup
2. To prevent ambient temperature from affecting roundness
3. To control the size of the journals
4. To control stress in the webbing

3-17. In propulsion systems, what type metal is used for making the shaft for a main reduction gear?

1. Aluminum-bronze
2. Forged steel
3. Aluminum
4. Any of the above

3-18. The pinions used in reduction gear mechanisms are generally made of

1. aluminum
2. bronze
3. forged steel
4. cast steel

3-19. Which factor determines the type of construction for gear wheels used in reduction gear mechanisms aboard ship?

1. Size of the gear wheel
2. Type of the reduction gear mechanism
3. Type of ship in which used
4. Each of the above

3-20. What type of flexible couplings is used in most turbine reduction gear installations?

1. Friction clutch type
2. Gear tooth type
3. Bend type
4. Flange type

3-21. What device compensates for the expansion and minor misalignments that occur between the main turbines and the reduction gears?

1. Sleeve
2. Flexible coupling
3. Expansion gear
4. Pinion gear

3-22. In a gear train, a quill shaft of high torsional flexibility provides

1. self-adjustment of the pinion gear shaft
2. rigidity between the elements of the gear train
3. efficient distribution of oil to the various elements of the gear train
4. equal distribution of the load among the various elements of the gear train

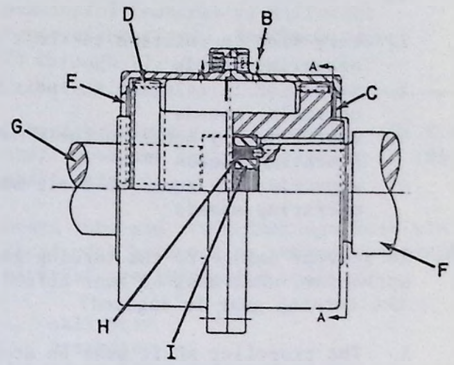


Figure 3C.

3-23. Compare figure 3C in your course with figure 4-11 in your textbook. The setscrew for this flexible coupling is located at

1. A
2. B
3. H
4. I

3-24. Failure to use the turning gear when warming up a main turbine will damage the

1. thrust bearings
2. gland seals
3. turbine rotor
4. nozzle diaphragms

3-25. Why are geared turbine installations equipped with turning mechanisms?

1. For jacking the main engine periodically when secured
2. For turning the main engine during routine inspections
3. For turning the main engine during warmup and securing periods
4. For all the above purposes

3-26. In the type of turning gear discussed in the text, what connects the turning gear to the HP high-speed pinion?

1. Manually operated band brake
2. Manually operated jaw clutch
3. Sleeve coupling
4. Quill shaft

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3-27. The turning gear mechanism of a geared turbine installation is designed to turn the main engines at a rate of speed that is

1. very slow in relation to their normal operating speeds
2. very fast in relation to their normal operating speeds
3. approximately equal to their normal operating speeds
4. approximately equal to their maximum operating speeds

3-28. To prevent damage to the turning gear mechanism, what must be done before the turning gear is engaged?

1. The propeller shaft must be stopped and held stationary until the brake is set
2. The brake on the first reduction worm shaft must be set
3. The ship must be stopped
4. The speed of the astern turbine must be reduced

Learning Objective: Discuss significant features of reduction gears for auxiliary machinery. Textbook page 71.

3-29. What type of reduction gearing is used for turbogenerators in modern combatant ships?

1. External spur
2. Single helix
3. Double helix
4. Bevel

3-30. In the reduction gearing for a typical ship's turbogenerator, the gear that drives the oil pump and governor is mounted on the turbine end of the

1. pinion shaft
2. turbine shaft
3. generator shaft
4. gear wheel shaft

3-31. The reduction gearing for turbine-driven main circulating pumps aboard ship is lubricated by

1. hand
2. gravity feed
3. a gear-type pump
4. a centrifugal pump

Learning Objective: List some essentials in the care and operation of reduction gears. Textbook pages 71 through 73.

3-32. The maintenance of reduction gear units is principally concerned with keeping

1. constant the reduction ratio between speed of turbine and speed of driven element
2. the gears supplied with pure oil at proper pressure and temperature
3. the upper half of the gear casing secured to the lower half
4. drive gears aligned with drive shaft

3-33. Dirt and/or metallic particles in a reduction gear lubrication system may cause which of the following?

1. Scored journals
2. Clogged spray nozzles
3. Eroded gear teeth
4. All of the above

3-34. If saltwater leaks into and contaminates a ship's main lubricating oil system, what remedial action should be taken?

1. Locate the leak and seal it off when time permits
2. Seal off the leak and promptly remove all contaminated oil from steel parts and surfaces
3. Secure the engines and prevent the circulation of contaminated oil
4. Disengage the jacking gear and allow contaminated oil to cool to engine-room temperature

3-35. When securing a ship's main engine, what should be done to remove condensation from the interior of the main reduction gear casing?

1. Circulate oil until oil and gear casing reach required temperature
2. Operate purifier until water discharge discontinues
3. Operate oil cooler and rotate engine continuously with turning gear
4. All of the above

3-36. What precaution should you take when checking the oil level of, or adding oil to, the oil sump of a reduction gear mechanism?

1. Ensure that all parts of the reduction gearing are submerged in the oil
2. Ensure that the rotating bull gear does not contact the oil in the sump
3. Ensure that the bull gear just dips into the oil
4. Ensure that the oil level is sufficient to cover the bull gear

3-37. What will happen if the bull gear is permitted to churn the oil in the sump?

1. Aeration of the oil
2. Temperature rise in oil
3. Shaft cannot operate at full speed
4. Each of the above

3-38. When the bull gear is churning the oil in the sump, what should be done with the main engine?

1. Slow it down or stop it
2. Speed it up
3. Maintain ordered turns
4. Either 2 or 3

Learning Objective: Point out security measures taken when access is required to propulsion reduction gears. Textbook pages 73 and 74.

3-39. Whose presence is required when the reduction gear casings are opened?

1. Division Officer
2. Officer of the deck
3. Damage Control Officer
4. Engineer Officer

3-40. Which of the following is required when you are working on reduction gears?

1. Work in a T-shirt
2. Work in clothes with all buttons and pockets taped
3. Tools secured to the person with a lanyard
4. Each of the above

Learning Objective: Describe meaningful features of different types of bearings. Textbook pages 74 through 77.

3-41. Thrust bearings are used to provide free shaft movement in the direction of the shaft axis.

3-42. Stern tube and strut bearings that are lined with hardwood or rubber composition material are lubricated with

1. saltwater
2. graphite
3. light lubricating oil
4. heavy lubricating oil

3-43. In the main engine installations, in what way are the main reduction gear bearings identical to other radial bearings?

1. They are of the single casting type
2. They are babbitt-lined
3. They are self-aligning
4. They are spherical seated

3-44. What is used to rigidly mount reduction gear bearings into their housings?

1. Keyways and keys
2. Spherical housings
3. Dowels or locking screws
4. Notched construction

3-45. The splits in main reduction gear bearings are mounted at an angle to the horizontal in order to resist

1. oil loss
2. steam loss
3. axial stress
4. wiping

3-46. Turbine bearings and reduction gear bearings have separate lubrication systems.

3-47. What is the purpose of the main thrust bearing of a ship's propulsion plant when the bearing is located in the reduction gear casing?

1. To support the weight of the reduction gears
2. To absorb the radial thrust developed when power is transmitted
3. To absorb the axial thrust transmitted through the shaft from the propeller
4. To do all the above

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3-48. What is the principle of operation of the Kingsbury type thrust bearing?

1. A flat film of oil is more readily formed and maintained than a wedge-shaped film
2. A flat film of oil can carry heavier loads than a wedge-shaped film
3. A wedge-shaped film of oil absorbs less heat than does a flat film
4. A wedge-shaped film of oil is more readily formed and maintained than is a flat film

3-49. Refer to textbook figure 4-17. What part of the bearing equalizes the thrust load between the shoes; what part transmits the thrust to the ship's structure, respectively?

1. Base ring; collar
2. Collar; oil wedge
3. Leveling plates; base ring
4. Oil wedge; leveling plates

3-50. What feature of the Kingsbury thrust bearing prevents the base ring from turning and secures it to its housing?

1. Pin
2. Dowel
3. Combination of pin and dowel
4. Keyed construction

3-51. What type of bearings are used on the main line shafting?

1. Ring-oiled, babbitt-faced, spherical seat, shell
2. Nonself-aligning, babbitt-lined, split type radial
3. Segmental-pivoted, shoe-thrust
4. Rigidly mounted, radial sleeve

3-52. While underway, how often should the temperatures and oil levels of spring bearings be checked?

1. Hourly
2. Daily
3. Weekly
4. Monthly

Learning Objective: Point out the care of the stern tube and stuffing box and discuss the design features of each. Textbook pages 77 through 80.

3-53. What prevents water from entering a ship's hull via the propulsion shaft?

1. Stern tube packing or automatic shaft seal
2. Deflector ring and drain
3. Spring bearings
4. Oiler rings

3-54. Water flowing through the after part of the stern tube stuffing box is used for which of the following?

1. Cooling
2. Lubrication
3. Flushing
4. All of the above

3-55. What action, pertaining to the stern tube stuffing box, is usually taken when the ship is in port?

1. Box is flushed
2. Drain connection is opened
3. Gland is tightened
4. Packing is adjusted or replaced

3-56. When packing is added to the stern tube, what should you do to be sure that the gland is taken up evenly?

1. Listen for a smooth, regular sound
2. Measure distance between gland and stuffing box with a rule
3. Judge by the feel of the gland as it is being tightened up
4. Open the drain connection to let seawater flow in and make the distance even

3-57. Which of the following is an advantage of the automatic shaft sealing system over the stuffing box and packing method of shaft sealing?

1. It eliminates the repairing or renewing of the shaft sleeve
2. It is fully automatic in operation
3. It allows for the removal and reinstallation of all parts without dismantling the shafts
4. Each of the above

3-58. What is the purpose of the split inflatable seal installed aft of the prime seal assembly shown in figure 4-20 of your textbook?

1. To serve as a seal when adding packing to the stuffing box
2. To allow repair or replacement of the prime sealing elements when the ship is waterborne
3. To eliminate leakage via the propeller shaft when the shaft is not rotating
4. To provide a ready means for the entry of cooling water

3-59. All of the following are listed in the text as being used in underwater bearings EXCEPT which of the following?

1. Lignum vitae
2. Laminated phenolic material
3. Rubber composition bushings
4. Oil-lite bushings

Learning Objective: Specify essentials in care of bearings and journals, emphasizing certain safety precautions. Textbook pages 81 and 82.

An alternate method of obtaining clearance is with a Plastigage (fig. 3D). The use of Plastigage eliminates the possibility of leaving an impression in soft bearing metal because the gage is softer than the bearing. To use this method, place a length of the Plastigage of proper gage across the bearing. Then, assemble the bearing cap and tighten it in place; when using this method, DO NOT TURN the crankshaft, as that would destroy the Plastigage. Now, remove the bearing cap; the width of the Plastigage, after crushing, will give a reading of the exact clearance, by reference to the accompanying chart on the Plastigage packing.

Measurements must be taken at specified intervals, usually at every overhaul, to establish the amount of bearing wear.

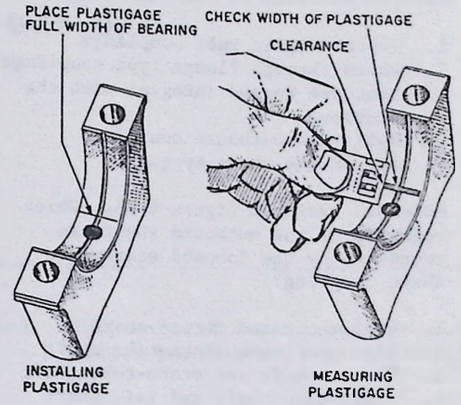


Figure 3D.

3-60. Bearing clearances aboard ship are measured with which of the following?

1. The depth gage
2. The dial indicator
3. Leads
4. All of the above

3-61. What immediate action should you take when the temperature of a shaft bearing increases above its normal operating temperature?

1. Stop the unit and carefully inspect the bearing
2. Stop the unit and replace the bearing
3. Check bearing lubrication
4. Check water circulation to the coolers

3-62. What characteristic must you be sure of in a bearing's lubricant before you begin to operate a unit of machinery?

1. Suitable quality
2. Suitable quantity
3. Both 1 and 2 above
4. Suitable temperature

Learning Objective: Discuss the functions and distinguishing features of propellers and main propulsion shafting. Textbook pages 82 through 84.

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3-63. What components are used to connect the several sections of line shafting?

1. Inboard stern tube couplings
2. Bolts through flange type couplings that are forged integral with the sections
3. Muff type outboard couplings
4. Any of the above types

3-64. Refer to textbook figure 4-23. Which segments of the outboard shaft are connected by the inboard stern tube shaft coupling?

1. Line shaft and thrust shaft
2. Line shaft and stern-tube shaft
3. Thrust shaft and stern-tube shaft
4. Stern-tube shaft and tail shaft

3-65. The exposed portion of the outboard shaft is protected against seawater corrosion by which of the following?

1. A heavy lubricant
2. A covering of plastic or rubber
3. A shrunk-on composition sleeve
4. Either 2 or 3 above

3-66. The circular steel or composition shields known as fairwaters do which of the following?

1. Reduce turbulence
2. Help with lubrication
3. Protect against corrosion
4. All of the above

3-67. On a twin-screw ship, steaming in an ahead direction, what is the normal rotation of the propellers when viewed from astern?

1. Clockwise
2. Counterclockwise
3. Starboard propellers clockwise; port propellers counterclockwise
4. Starboard propellers counterclockwise; port propellers clockwise

3-68. Which of the following statements with regard to propellers is true?

1. The number of blades on ship propellers varies from two to four
2. The number of blades on ship propellers varies from three to seven
3. Controllable pitch propellers are of the single casting typing
4. Left-hand helices propellers, as viewed from astern, turn clockwise to move the ship forward

Assignment 4

Pumps

Textbook Assignment: Chapter 5

Learning Objective: Identify some principles of pump operation, including the meanings of various terms used to describe pumps. Textbook pages 85 and 86.

4-1. All of the following statements about pump operation are true EXCEPT which of the following?

1. In order to be pumped, a substance must be made to flow
2. A substance must be cold in order to be pumped
3. The kinetic energy transformed by the pump can be used to force a substance through a hydraulic system
4. A pump must receive its energy from an external source

4-2. Which of the following are common to all kinds of pumps?

1. Power end and fluid end
2. Propeller and eductor
3. Volute and impeller
4. Turbine and piston

4-3. If you subtract the vapor pressure from the suction pressure at the pump suction, you obtain the

1. pump head
2. suction head
3. discharge head
4. net positive suction head

4-4. What term indicates the pressure of the liquid entering a pump?

1. Suction head
2. Pump head
3. Discharge head
4. Net positive suction head

4-5. Which units of measurement are used to express positive and negative suction head?

1. Inches of mercury for positive; feet of water for negative
2. Feet of water for positive; inches of mercury for negative
3. Inches of mercury for both positive and negative
4. Feet of water for both positive and negative

4-6. The pressure of liquid leaving a pump is called the

1. head
2. discharge head
3. net positive suction head
4. suction head

4-7. Which of the following will prevent a shipboard pump from achieving its maximum suction lift?

1. Leaks
2. Friction in the pipes
3. Gases or vapor in the liquid
4. Any of the above

4-8. Centrifugal pumps are self-priming.

4-9. The suction force principle of operation is most characteristic of

1. centrifugal pumps
2. rotary pumps
3. propeller pumps
4. reciprocating pumps

4-10. Which of the following creates the suction force in a jet pump or eductor?

1. Centrifugal force
2. Reciprocating plunger
3. Jet of fluid passing through a nozzle
4. Propeller

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Learning Objective: Specify some ways of classifying centrifugal pumps, giving essential construction features of the different components. Textbook pages 87 through 91.

4-11. A liquid is being transferred by a centrifugal pump like the one illustrated in figure 5-2 of your textbook. As it passes through the volute of the pump, its velocity decreases and

1. its pressure decreases
2. its pressure increases
3. the potential energy decreases
4. the kinetic energy increases

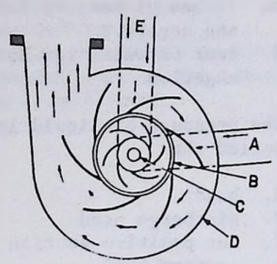


Figure 4A.

4-12. What part of the pump in figure 4A is the volute?

1. A
2. B
3. C
4. D

4-13. With respect to impellers, centrifugal pumps are classified as which of the following?

1. Single stage
2. Multistage
3. Both 1 and 2 are correct
4. Horizontal or vertical

4-14. Closed impellers, used by the Navy on most centrifugal pumps, differ from open impellers in that closed impellers

1. allow liquid to enter the eye from one direction only
2. have small impeller eyes
3. have side walls which extend from the eye to the outer edge of the vane tips
4. are not vented above the impeller eye

4-15. The main feed pump aboard ship can handle high temperature water without becoming vapor bound because the

1. pump operates at a high discharge pressure
2. booster pump provides a positive suction pressure
3. area above the impeller eye is vented to the main condenser
4. constant-pressure governor controls the discharge pressure

4-16. Condensate pumps may be identified by their

1. speed-limiting governors and closed impellers
2. multiple impellers and pump shaft positions
3. open impellers and power ends
4. large suction chambers and larger impeller eyes

4-17. Because of its location below the condenser, the condensate pump has a positive suction head into the impeller eye.

4-18. The discharge pressure of a main feed pump usually exceeds the maximum steam drum pressure of the 1200 psi boiler by

1. 100 to 150 psi
2. 150 to 200 psi
3. 175 to 250 psi
4. 200 to 300 psi

4-19. The discharge pressure in a main feed pump is controlled by the steam admitted to the turbine. The admission of steam is regulated by a

1. regulating valve
2. nozzle arrangement
3. constant-pressure governor
4. speed-limiting governor

4-20. Which of the following construction features is/are necessary in centrifugal pumps and why?

1. Carefully machined impellers to minimize friction
2. Balanced impellers to prevent vibration
3. Close radial clearance between outer hub of impeller and the part of the pump casing in which the hub rotates so as to minimize leakage from the discharge side of the pump casing to the suction side
4. All of the above features for the reasons given

4-21. What feature of a centrifugal pump reduces the need for renewing worn impeller and pump casings?

1. Close radial clearance between impeller hub and casing
2. Low rotational speed of impeller
3. Removable end plate
4. Replaceable impeller wearing ring and casing wearing ring

4-22. Why are removable sleeves put on a centrifugal pump shaft?

1. They make it easier to maintain the pump
2. They can be replaced economically when they wear out
3. They can be removed when there is need to lighten the weight of the pump
4. They increase the strength of the shaft

4-23. Air leakage between the shaft and stuffing box packing in a centrifugal pump is prevented by

1. a compressed packing gland
2. lantern rings between the packing rings
3. a liquid seal
4. the stuffing box gland

4-24. The seal piping takes liquid from the discharge side of the pump. The seal piping leads to the

1. stuffing box
2. wearing ring
3. stuffing
4. lantern ring

4-25. In figure 5-6 of the text, what maintains a snug fit between the rotating and stationary seal?

1. Notch and keyway
2. Spring pressure
3. A bellows
4. Seal retaining ring

4-26. What type of material is used in the mechanical seal of most centrifugal water pumps?

1. Copper
2. Copper and carbon
3. Carbon
4. Bronze

4-27. When replacing a carbon seal, feel the sealing surfaces with your fingers to ensure a smooth fit.

4-28. Turbine-driven centrifugal pumps used in Navy ships are usually powered by

1. two-stage impulse turbines
2. single-stage impulse turbines
3. reaction turbines
4. combination impulse and reaction turbines

4-29. Which pump aboard ship will most likely be a propeller type pump?

1. Hydraulic transmission pump
2. Main circulating pump
3. Steering mechanism pump
4. Fuel oil booster pump

4-30. Propeller pumps are used primarily where there is a large volume of liquid, but their use is usually limited to a total head of

1. 20 to 40 ft
2. 30 to 50 ft
3. 40 to 60 ft
4. 50 to 70 ft

4-31. The main difference between a propeller pump and a centrifugal pump is the absence of a

1. volute in the centrifugal pump
2. volute in the propeller pump
3. velocity nozzle in the centrifugal pump
4. reciprocating piston in the centrifugal pump

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4-32. An axial piston pump differs from a radial piston pump in that the axial piston pump has its pistons positioned

1. radially from the shaft
2. parallel to each other and to the shaft
3. parallel to each other but at a right angle to the shaft
4. at an angle to each other and to the shaft

Learning Objective: List the classes of variable stroke pumps, explain how the pump operates, and identify the systems in which it is used. Textbook pages 91 through 93.

4-33. In which of the following is the variable stroke pump used with electrohydraulic units?

1. Steering systems
2. Wellin davits
3. Both 1 and 2 are correct
4. Catapaults

4-34. The usual number of single-acting pistons in the variable stroke axial-piston pump is

1. 3 or 5
2. 5 or 7
3. 7 or 9
4. 9 or 11

4-35. When the tilting box of a variable stroke axial-piston pump is at right angles to the shaft while the pump is rotating, which condition exists?

1. The pistons reciprocate
2. The B-end cylinder barrel rotates
3. No liquid is pumped
4. Power is transmitted hydraulically

4-36. In the hydraulic speed gear described in figure 5-7 in the textbook, the A-end pump performs the same function as the B-end pump.

4-37. In figure 5-7 of the textbook, the tilting box in the B-end differs from the one in the A-end in that the one in the B-end is

1. free to tilt in one direction only
2. free to tilt in either direction
3. installed in a fixed position at a right angle to the shaft
4. installed at a permanently fixed angle to the shaft

4-38. In figure 5-7 of the textbook, which of the following is shown in section AA?

1. Ball bearings
2. Valve plate port
3. Trunion
4. Socket ring

4-39. Which statement about the operation of the speed gear in figure 5-7 of the textbook is true?

1. Hydraulic fluid pressure against the A-end pistons causes rotation of the A-end cylinder barrel and socket ring
2. Hydraulic fluid pressure against the B-end pistons causes rotation of the B-end cylinder barrel and socket ring
3. When the A-end tilting box is in the position shown, fluid is pumped to the B-end
4. The B-end shaft is driven by a constant-speed motor

4-40. For a variable stroke radial-piston pump to function, which of its parts is moved off center?

1. Nonrevolving ring
2. Floating ring
3. Cylinder body
4. Central cylindrical valve

4-41. In the variable stroke radial-piston pump, both the direction and amount of fluid flow are determined by the relative positions of the

1. pump shaft and central valve
2. pump shaft and horizontal ports
3. floating ring and pump shaft
4. floating ring and cylinder body

Learning Objective: Describe the operating principles of rotary pumps, the ways of classifying them, and their various uses by the Navy. Textbook pages 93 through 98.

4-42. Increasing the speed of rotary pumps above the rated speed will cause which of the following?

1. Loss of suction
2. Increased clearances
3. Decreased clearances
4. Decreased slippage

4-43. What advantage do rotary pumps have over reciprocating pumps?

1. Rotary pumps are able to pump more fluid than reciprocating pumps of the same weight
2. The high discharge pressure of the rotary pumps permits a larger volume of fluid per unit time than the reciprocating pump
3. Rotary pumps occupy only one-half the space of reciprocating pumps
4. Rotary pumps eliminate slippage of liquid from the discharge side of the pump; reciprocating pumps do not

4-44. Why is the discharge pressure of a herringbone gear pump steadier than the discharge pressure of a simple gear pump?

1. Clearance between the gear teeth and casing is smaller
2. One discharge phase starts before the previous discharge phase is completed
3. The gear teeth are smaller than those of the simple gear pump
4. The herringbone gear pump has four spur gears instead of two

4-45. An advantage of a helical gear pump over a simple gear pump is that a helical type pump is capable of

1. maintaining a steadier speed
2. producing a smoother discharge flow
3. operating for longer periods of time
4. delivering liquids over greater distances

4-46. Liquid is kept from leaking at the shaft of a helical gear pump by

1. a stuffing box
2. a roller bearing
3. overlapping spaces between gear teeth
4. large gear teeth

4-47. Which parts of a lobe-type rotary pump reduce wear of the lobe ends?

1. Spur gears
2. Gibs
3. Casing seals
4. Liner plates

4-48. One of the main differences between the various types of screw pumps is in the

1. pitch of the screws
2. length of the screws
3. direction of rotation of the screws
4. type of driving gears

4-49. What part of a rotating plunger pump serves as a piston?

1. Drive shaft
2. Hollow arm
3. Eccentric strap
4. Eccentric plunger

4-50. What part of a rotating-plunger pump closes the discharge port during the suction phase?

1. Slide pin
2. Rotating plunger
3. Hollow arm
4. Drive shaft

4-51. What is/are the function(s) of the vanes of a moving-vane type pump?

1. To maintain a minimum clearance between the rotor and the cylinder wall
2. To maintain sealed spaces between the rotor and the volute
3. To trap liquid on the suction side of the pump and carry it to the discharge side
4. To do both 2 and 3 above

4-52. How do the vanes move in the pump shown in figure 5-12 of your textbook?

1. They swing on pivots
2. They are always in contact with the cylinder
3. Both 1 and 2 above are true
4. They roll on cylindrical bases

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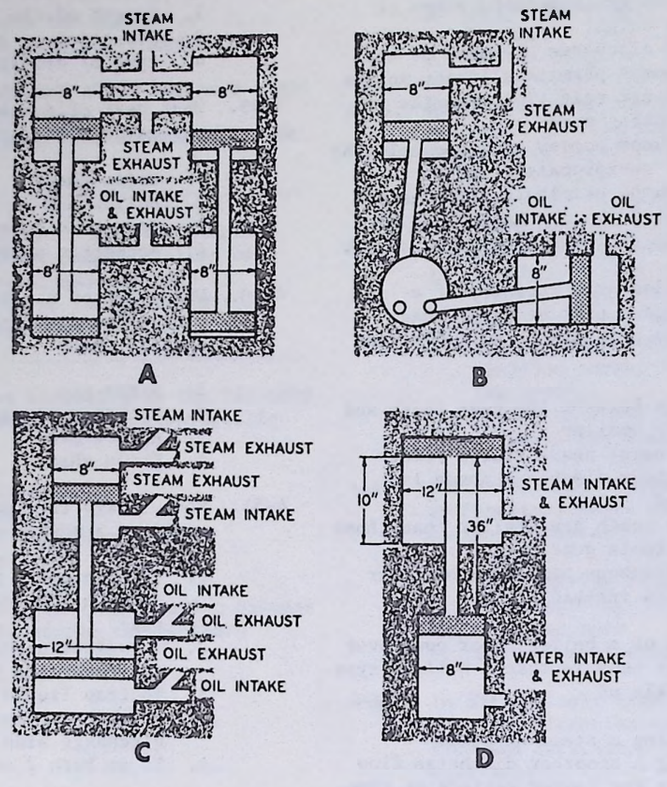


Figure 4B.

4-53. Which of the following describes all the pumps in figure 4B?

1. Simplex
2. Horizontal
3. Rotary
4. Reciprocating

4-54. All of the pumps in figure 4B are direct acting EXCEPT which of the following?

1. A
2. B
3. C
4. D

4-55. Which pump in figure 4B is a duplex pump?

1. A
2. B
3. C
4. D

Learning Objective: Give the classification methods and uses of reciprocating pumps. Textbook pages 98 through 101.

4-56. In a double-acting, reciprocating pump liquid is drawn in and discharged with each stroke.

4-57. The reciprocating pump shown in figure 5-13 of your textbook is a vertical, positive displacement, high-pressure pump.

4-58. The plunger in the liquid cylinder of a high-pressure reciprocating pump has a larger diameter than the steam piston.

4-59. Which pump in figure 4B is a low-pressure pump?

1. A
2. B
3. C
4. D

4-60. What is the size of pump D in figure 4B?

1. 8" X 12" X 36"
2. 8" X 12" X 10"
3. 12" X 8" X 10"
4. 12" X 8" X 36"

Items 4-61 and 4-62 relate to the valve operating gear for a reciprocating pump. Refer to figure 5-14 in your textbook.

4-61. The moving tappet slides down the pilot valve operating rod until it comes in contact with what component?

1. Link
2. Adjustable tappet collar
3. Moving tappet
4. Crosshead

4-62. What component admits steam to the steam cylinder?

1. Valve operating assembly
2. Crosshead arm
3. Pump rod
4. Pilot valve operating rod

4-63. What part of a reciprocating pump controls the position of the pilot slide valve?

1. Moving tappet
2. Adjustable tappet collars
3. Stay rod
4. Main piston in the steam cylinder

4-64. Which arrangement of valves lets the reciprocating pump take suction from the suction chamber and discharge through the discharge chamber on both the up and down strokes?

1. Two sets of suction and discharge valves in the liquid cylinder
2. Two sets of suction and discharge valves in the water chest
3. One set of valves in the water chest and another set in the liquid cylinder
4. Two relief valves, one on each end of the liquid cylinder

4-65. Which characteristic(s) make(s) the reciprocating pump especially useful for emergencies?

1. Relatively simple
2. Reliable
3. Easy to start and operate during cold conditions
4. All of the above

4-66. Poor functioning of a reciprocating bilge pump is most often caused by

1. defective intake valves
2. clogged suction strainers
3. scarred cylinder walls
4. clogged drain valves

4-67. Which of the following is NOT a characteristic of the reciprocating pump shown in figure 5-13 of your textbook?

1. Direct-acting
2. Duplex
3. High-pressure
4. Vertical

Learning Objective: Identify characteristics of eductors and their uses aboard ship. Textbook pages 93 through 101.

4-68. A distinguishing feature of eductors is the

1. discharge end which is larger than the suction end
2. retractable crank handle
3. lack of moving parts
4. rotating plunger

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4-69. In modern ships, the primary means for dewatering compartments are

1. fire and bilge pumps
2. reciprocating pumps
3. eductors
4. moving-vane type pumps

In items 4-70 through 4-73, select from column B the type of pump the Navy generally uses for the purpose given in column A.

	A. Purposes	B. Pumps
4-70.	Auxiliary feed pump	1. Centrifugal
4-71.	Feed booster	2. Propeller
4-72.	Main circulating	3. Reciprocating
4-73.	Lube oil service	4. Positive displacement rotary

Assignment 5

Pumps (Continued)

Textbook Assignment: Chapter 5 (Continued)

Learning Objective: Identify fundamentals of centrifugal pumps, operation, and maintenance.
Textbook pages 101 through 109.

5-1. Since the principle of operation is the same for all types of centrifugal pumps used by the Navy, you should follow the same operating instructions for all types.

5-2. The pump stuffing box packings are lubricated by

1. gravity and feed oil cups
2. grease cups
3. leaking stuffing boxes or seals
4. hand during installation

5-3. The factors that determine the service life of packing in a centrifugal pump include which of the following?

1. The type of pump
2. The condition of the shaft sleeve
3. The hours in use
4. All of the above

5-4. Which of the following indicate(s) that a finishing cut should be taken on the shaft of a pump?

1. Deep ridges
2. Roughness
3. Corrugations
4. Any of the above

5-5. Where can you find the symbol number of the packing rings for a pump?

1. On the MRC
2. In NAVSHIPS' Technical Manual
3. In Chapter 3 of this manual
4. In all of the above references

5-6. To prevent heating and scoring of the shaft after repacking a stuffing box, what should you do?

1. Lubricate the packing with oil before installing
2. Tighten the packing in small increments while the pump is operating
3. Tighten the packing by turning the gland in all the way and then backing it off slightly
4. Operate the pump slowly and apply oil freely to the shaft until the packing is properly seated

5-7. If the packing gland has been tightened in small increments until the gland can NOT be further tightened and there is excessive leakoff, which of the following do you do next?

1. Replace all packing
2. Replace with larger packing
3. Add more packing
4. Replace with harder packing

5-8. Mechanical seals eliminate gland leakoff, thereby protecting the stuffing box from deterioration.

5-9. Why are mechanical seals ideal for pumps used in closed systems?

1. The pumps can be run faster
2. The pumps can be run slower
3. There is no loss of fluid
4. Both 2 and 3 are correct

5-10. Seawater pumps for submarine applications have backups for mechanical seals. Which of the following is classified as a backup?

1. Lantern ring
2. Inflatable seal
3. Fusible disk
4. Stuffing box

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5-11. In fire pumps, the mechanical seal can be described as

1. one solid copper-nickel seal ring
2. two solid copper-nickel seal rings
3. two split rings of tungsten carbide
4. two solid rings of tungsten carbide

5-12. Mechanical shaft seals for water pumps require lubrication of the seal faces to minimize deposits of foreign matter on the seal faces. Which of the following pressures and lubricants are used?

1. Water under positive pressure
2. Water under negative pressure
3. Oil under positive pressure
4. Oil under negative pressure

5-13. When repacking a stuffing box fitted with a lantern ring, which of the following precautions should you observe?

1. Replace the packing beyond the lantern ring
2. Do not blank off the sealing water connection
3. Be sure that sleeves are fitted tightly at the packing
4. All of the above

5-14. Water from leaking stuffing box glands is kept out of the bearing housing by

1. shaft sleeves
2. lantern rings
3. water seals
4. water flingers

5-15. How does the renewal of shaft sleeves on large centrifugal pumps differ from that on some of the small pumps?

1. On large pumps the old sleeve is usually machined off and the new one is pressed on, while on some small pumps the sleeve is a slip fit
2. On large pumps the sleeve is a slip fit and is easy to remove, while on some of the small pumps the sleeve is a press fit and must be machined off
3. On large pumps the sleeve can be replaced by removing the water end casing, while on some of the small pumps the pump must be completely disassembled
4. On large pumps the sleeve can be replaced by loosening a nut, while on small pumps the sleeve is pressed in place

5-16. Before you check the shaft alignment of a centrifugal pump, you must be sure that

1. spare parts for the pump are available
2. the shaft sleeve fits snugly
3. all piping is in place
4. some water is leaking between shaft and sleeve

5-17. Excessive misalignment of shafting and couplings in a centrifugal pump can be taken care of adequately by a grid-type flexible coupling like the one shown in figure 5-18 of your textbook.

5-18. When a flange coupling is used to connect a centrifugal pump to its driving unit, you can expect that the pump shaft will seldom need to be realigned.

5-19. Assume that the flanges are NOT in alignment. How do you make the necessary adjustments?

1. Raise or lower the pump with shims
2. Raise or lower the motor with shims
3. Raise or lower either unit with shims and shift them horizontally by means of the jacks welded to the foundation
4. Move the two units in the direction necessary by means of the jacks welded on the foundation

5-20. Shaft and coupling alignment can be checked by which of the following instruments?

1. Thickness gage
2. Strobotac
3. Strobe light
4. Reed tachometer

5-21. Which of the following troubles can be caused by misalignment of shafts of a pump and its prime mover?

1. Cracked casing
2. Broken impeller
3. Improper wear of throat bushings
4. Each of the above is correct

5-22. The bearing clearance of oil-lubricated sleeve bearings should be measured according to the MRC.

5-23. For low-pressure pumps, wearing rings should be renewed if the diametrical clearance is more than 0.030 inch over the designed amount.

5-24. What is the maximum permissible wear of the wearing rings of a pump with a discharge pressure of 75 psi?

1. 0.015 in.
2. 0.030 in.
3. 0.050 in.
4. 0.075 in.

5-25. The actual wearing ring diametral clearance is equal to

1. the inside diameter of the casing wearing ring minus the outside diameter of the impeller wearing ring
2. the inside diameter of the impeller wearing ring minus the outside diameter of the casing wearing ring
3. the difference between the inside diameter of the wearing rings and the outside diameter of the impeller
4. the difference between the inside diameter of the impeller and outside diameter of the wearing rings

5-26. In addition to obstructions in the discharge line and in the clogged impeller passages, which of the following can also cause a pump to fail to deliver liquid?

1. Wrong direction of rotation
2. Ruptured suction line
3. Insufficient priming
4. All of the above

5-27. A centrifugal pump is operating at a lower capacity than it should and sometimes fails to deliver any liquid at all. Which condition is probably causing the trouble?

1. A shaft is bent
2. The stuffing box is packed too tightly
3. The discharge pressure is too low
4. There is air leakage

5-28. Which of the following indicates that a motor-driven centrifugal pump is using too much power?

1. Speed of the pump decreases
2. Viscosity of the liquid being pumped decreases
3. Motor overheats
4. Stuffing box packing is loose

5-29. Insufficient suction pressure in a pump may cause

1. excessive power requirements
2. pump vibration
3. excessive discharge pressure
4. a failure to deliver liquid

5-30. A vibrating and noisy pump could indicate a loss of suction. What should you do to eliminate this possibility?

1. Check alignment
2. Prime the pump
3. Check foundation bolts
4. Check lubrication of bearings

5-31. If the wiring to an electric-driven pump has been disturbed or reconnected after overhaul, there is a possibility the pump will rotate in the wrong direction.

Learning Objective: Discuss the essential construction, operation, and maintenance principles of reciprocating pumps. Textbook pages 109 through 113.

5-32. If you are preparing to repair a reciprocating pump, which of the following must you consult?

1. NAVSHIPS' Technical Manual
2. Planned Maintenance System requirements
3. Manufacturer's technical manual
4. Ship's Information Book

5-33. Before examining or repairing a reciprocating pump, you should first

1. mark the piston stroke adjustment
2. take micrometer and caliper measurements of the valve cylinders
3. study all available data on the pump including blueprints and drawings
4. dismantle the suction end of the pump

5-34. When you open a reciprocating pump for repair, you should measure the main cylinders and valve chest cylinders with a micrometer or calipers. Where should you make these measurements?

1. At the top and bottom on the fore and aft diameters
2. At the top and middle on the fore and aft diameters
3. At the top, middle, and bottom on the fore, aft, and athwartships diameters
4. At the bottom on the fore and aft diameters

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5-35. How far does a full stroke of the piston travel in relation to the counterbore of a steam cylinder?

1. Slightly short of the counterbore
2. To the start of the counterbore
3. To the end of the counterbore
4. Slightly beyond the counterbore

5-36. To lengthen the stroke of a reciprocating pump, what should you do?

1. Turn the tappet collars so that they move away from the tappet
2. Turn the tappet collars so that they move towards the tappet
3. Turn the tappet so that it will move away from the piston
4. Turn the tappet so that it will move towards the piston

5-37. Which condition may be indicated if it is necessary to constantly adjust the stroke of a reciprocating pump?

1. Faulty operating linkage
2. Improperly operating auxiliary piston valve
3. Improperly operating main piston valve
4. Any of the above conditions

5-38. The piston in the water end of a reciprocating pump is usually made of

1. steel
2. bronze
3. copper
4. lead

5-39. What, if anything, should be used to prevent liquid from leaking between the water plunger and cylinder walls of a reciprocating pump?

1. Removable sleeve
2. Packing rings
3. Tappet collars
4. Nothing; the piston should be a tight fit

5-40. To condition fibrous packing for installation, you should soak it in

1. hot water for 8 to 12 hours
2. hot oil for 8 to 12 hours
3. hot water for at least 12 hours
4. hot oil for at least 16 hours

5-41. When trouble occurs in the steam cylinder of a reciprocating pump, the cause is usually

1. faulty piston rings
2. improper pump packing
3. a too long piston stroke
4. a too short piston stroke

5-42. Symptoms of worn piston rings in a reciprocating pump include which of the following?

1. Pump groans
2. Steam leaks by the piston
3. Pump stops in the middle of a stroke while operating slowly
4. Both 2 and 3 above

5-43. Reboring of a reciprocating pump water cylinder is usually justified by which of the following conditions?

1. A slight leakage from wear
2. Faulty packing
3. Scoring that causes rapid wearing of the packing
4. All of the above conditions

5-44. What happens when the steam valves of a reciprocating pump are permitted to leak?

1. Wear on cylinder walls is reduced
2. Main piston valve becomes steam bound
3. The steam packing is more effective
4. Steam pressures in valve chest and valve chest cylinder become unequal

5-45. What precaution should you take when scraping flat steam slide valves?

1. Scrape in one direction only
2. Scrape with a circular motion
3. Scrape with back and forth strokes
4. Scrape so that the scraper strokes cross

5-46. A metal-to-metal joint is blued and tested before being made up to ensure that

1. it is properly marked for identification
2. all particles of dirt are removed from the joint
3. it makes proper contact at all points
4. a uniform clearance exists

5-47. In making up a steam chest joint of a reciprocating pump, you should perform all of the following steps EXCEPT which of the following?

1. Blue the joint faces
2. Tighten hold-down bolts gradually
3. Tighten hold-down bolts after pump is operating
4. Install gaskets between the joint faces

5-48. What procedure should you follow to test valves after they have been ground in?

1. Close suction valve, open discharge valve, start pump and note vacuum
2. Open suction valve, close discharge valve, start pump and note vacuum
3. Close suction valve, open discharge valve, start pump and note maximum pressure
4. Open suction valve, close discharge valve, start pump and note maximum pressure

5-49. What are the most frequent causes of trouble in the liquid end of a reciprocating fire and bilge pump?

1. Clogged suction strainers
2. Foreign matter in the water chest suction valves
3. Foreign matter in the water chest discharge valves
4. All of the above

5-50. What is indicated if a reciprocating pump races without any appreciable increase in discharge pressure?

1. Improper suction
2. Excessively tight packing
3. A broken piston ring
4. A damaged follower plate

5-51. A groaning sound in the steam end of a reciprocating pump may indicate

1. water in the steam cylinder
2. a misaligned steam cylinder
3. a stroke that is too long
4. an air-bound pump

5-52. Which of the following can cause knocking in the steam end of a reciprocating pump?

1. An excessively long stroke
2. Water in the steam cylinder or difficulty in the piston-type valve gear
3. Loose pistons or piston rings
4. Any of the above

5-53. In a reciprocating pump, what are the symptoms of pump strokes that are too long and too short respectively?

1. Groaning in the liquid end; racing of the pump
2. Racing of the pump; groaning in the liquid end
3. Knocking in the steam end; shoulders worn into the cylinder
4. Worn cylinder shoulders; knocking in the steam end

Learning Objective: Discuss construction features and operating principles of some pump control and safety devices. Textbook pages 113 through 120.

5-54. A speed-limiting governor is being used on a turbine-driven condensate pump whose maximum operating speed is 10,000 rpm. The governor controls the speed of the pump when it reaches

1. 6,500 rpm
2. 7,500 rpm
3. 8,500 rpm
4. 9,500 rpm

5-55. The governor described in textbook figure 5-24 is operated by

1. spring pressure
2. centrifugal force and spring pressure
3. a camming action
4. centrifugal force and a camming action

5-56. What should be the total distance that a speed-limiting governor valve travels from fully open to fully closed, and by what means can it be adjusted to determine the turbine's speed?

1. 1/8 in; by rotating governor push rod
2. 1/4 in; by changing spring tension
3. 1/2 in; by rotating governor push rod
4. 3/4 in; by changing spring tension

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5-57. What is the function of a constant-pressure pump governor on a turbine-driven pump, and how is the function accomplished?

1. To maintain a constant turbine speed; by controlling the pump discharge pressure
2. To control the load of the pump; by controlling the pump discharge pressure
3. To maintain a constant pump discharge pressure; by controlling the steam input to the driving turbine
4. To control the steam admitted to the driving turbine; by controlling the discharge pressure

5-58. Constant-pressure governors of the Leslie type, which are used for different applications, differ mainly in the size of their

1. crosshead connecting rods
2. operating pistons
3. indicator plates
4. upper diaphragms

● For items 5-59 and 5-60, refer to textbook figure 5-26 and assume that the main feed pump is operating.

5-59. What happens when fluid pressure against the upper diaphragm becomes less than the adjusting spring pressure?

1. The operating piston is forced down, and the main valve is opened by increased steam pressure against the top of the piston
2. The upper and lower crossheads move up as steam pressure against the top of the operating piston is decreased
3. The controlling valve is forced up and closed, decreasing the supply of steam to the driving turbine
4. The main valve is forced up and closed, decreasing the supply of steam to the driving turbine

5-60. The speed of the driving turbine increases when the

1. governor operating piston moves up
2. lower diaphragm moves down
3. fluid pressure against the upper diaphragm increases
4. steam to the controlling valve decreases

5-61. As the speed of the turbine increases, what force initiates the action to reduce the steam supply to the operating turbine?

1. Discharge pressure
2. Operating piston movement
3. Intermediate diaphragm
4. Steam chamber pressure

5-62. The top of the intermediate diaphragm of the pump governor will function at the required pressure because of a continuous supply of steam at the required pressure supplied by the

1. turbine
2. crosshead
3. controlling valve
4. steam chamber

5-63. The crosshead and the intermediate and lower diaphragms of the pump governor prevent extreme reactions of the controlling valve when

1. an upward force only is exerted on the upper diaphragm
2. unequal steam pressure acts on the diaphragm surfaces
3. the pump discharge pressure varies greatly
4. the steam supply to the turbine is reduced

5-64. The Leslie automatic shutdown device is essentially a Leslie constant-pressure governor equipped with a

1. steam chamber
2. crosshead
3. pull open device
4. special top cap

5-65. Steam is supplied to the controlling valve of the Leslie automatic shutdown device through

1. a port
2. an auxiliary pilot valve
3. a main feed valve
4. a needle valve

5-66. A leakage test of a pump governor poppet valve is made by

1. pushing the valve onto its seat by hand while the pump is operating
2. pushing the valve off its seat by hand while the pump is operating
3. increasing the steam pressure to the valve without operating the pump
4. gaging the steam pressure to the turbine during full load condition

5-67. All diaphragms of a constant-pressure governor should be carefully inspected

1. each time the governor is disassembled
2. daily
3. monthly
4. before each operation of the pump

5-68. After repair and reassembly of the Leslie pump governor, you notice a considerable reduction in pump capacity. What possible malfunction exists and what must you do to remedy it?

1. Control valve bushing leaks; correct by replacing bushing
2. Control valve is held open; correct by increasing the clearance between the control valve stem and lower diaphragm
3. Control valve will not fully open; correct by decreasing the clearance between the control valve stem and lower diaphragm
4. Control valve is held closed; correct by increasing the clearance between the control valve stem and lower diaphragm

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Learning Objective: Point out safety precautions for pump operators. Textbook page 120.

5-69. Which of the following must you check before jacking over a pump by hand?

1. Be sure that the throttle valve is open
2. Be sure that the throttle valve is closed
3. Be sure that the power is shut off
4. Be sure that both 2 and 3 are done

5-70. Before you operate a pump you must be sure that the speed-limiting and constant-pressure governors are operable and properly set.

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Assignment 6

Piping, Valves, Gaskets, and Packing

Textbook Assignment: Chapter 6

Learning Objective: Identify the method of classifying Navy pipe and tubing, giving the different types of metals used. Textbook pages 121 and 122.

6-1. The Navy makes a distinction between tubing and piping based on the size of the product.

6-2. Which dimension(s) is/are important in classifying a tubular product as either pipe or tubing?

1. Inside diameter (ID)
2. Outside diameter (OD)
3. Wall thickness
4. All of the above

6-3. The Navy designates a product as tubing when its size is identified by actual measured dimension(s) of its

1. wall thickness
2. inside diameter
3. circumference
4. outside diameter and wall thickness

6-4. Which of the following tubular products is identified as tubing in the Navy?

1. 1/8-inch stainless steel with an outside diameter of 0.405 inch and a wall thickness of .049 inch
2. 1 1/4-inch stainless steel with an outside diameter of 1 1/4 inches and a wall thickness of .083 inch
3. 8-inch wrought-iron with an outside diameter of 8.625 inches, a wall thickness of .148 inch, and an inside diameter of 8.329 inches
4. 14-inch wrought-iron with an outside diameter of 14 inches, a wall thickness of 1/4 inch, and inside diameter of 13 1/2 inches

6-5. Which of the following is/are a nominal pipe size?

1. 2.375 inches
2. 3.500 inches
3. Both 1 and 2 are correct
4. 14.000 inches

6-6. Pipe designations that refer to the wall thickness of the pipe include which of the following?

1. Standard
2. Extra strong
3. Double extra strong
4. All of the above

6-7. The type of seamless carbon steel tubing used in a steam propulsion system depends on the

1. service conditions
2. superheater outlet temperature
3. working pressure of the system
4. boiler operating pressure

6-8. In new ships, what type of tubing is normally used for high-pressure, high-temperature steam service?

1. Seamless carbon steel
2. Seamless carbon-molybdenum alloy steel
3. Seamless chromium-molybdenum alloy steel
4. Welded carbon steel

6-9. What type of piping is generally used in submarine heat exchangers?

1. Seamless carbon-molybdenum alloy steel tubing
2. Copper-nickel alloy tubing (70% copper and 30% nickel)
3. Welded carbon steel tubing
4. Seamless copper tubing

Learning Objective: Discuss the construction and use of common types of pipe fittings used by the Navy. Textbook pages 123 through 128.

6-10. Why are unions used in a piping system?

1. To join two pipes of unequal size
2. To join two pipes so that they may be disconnected for repairs or alterations
3. To provide a joint that will expand or contract with changes in temperature
4. To provide a joint that can withstand high pressure and heavy expansion strains

6-11. In constructing a joint, the ends of pipes are sometimes silver-brazed or welded to tail pieces of the union. Why?

1. To increase the strength of the joint
2. To prevent contact of the carried fluid or gas with the union threads
3. To prevent disassembly of a gas-tight joint
4. To provide insulation between the pipes and the union

In items 6-12 through 6-14, select from column B the use that applies to the type pipe joint given in column A.

A. Type Pipe Joint	B. Uses
6-12. Van Stone type	1. On piping that is subjected to high pressure and heavy expansion strains
6-13. Silver-brazed joint	2. On piping that is subjected to both radial and axial movement with respect to the bulkhead
6-14. Bulkhead expansion joint	3. For joining non-ferrous piping in steam lines subjected to temperatures up to 425° F and pressures up to 3,000 psi

6-15. Which of the following is a type of expansion joint?

1. Right-angle bend
2. Corrugated joint
3. Union
4. Each of the above is correct

6-16. Which of the following prevents an oil mist from a flange from striking a hot surface?

1. Oil safety shield
2. Flange safety shield or spray shield
3. Asbestos shield on oil flanges
4. Each of the above is correct

Learning Objective: Identify requirements of piping care and maintenance with pertinent safety reminders. Textbook pages 127 through 129.

6-17. The external surfaces of which type of piping should be kept properly painted?

1. Copper
2. Brass
3. Ungalvanized steel
4. Both 2 and 3 above

6-18. If there is a leak at a joint that is apparently caused by vibration, what should you do?

1. Alter the anchorage
2. Alter leads to the joint
3. Realign flanges
4. Install additional supports

6-19. When leakage in a threaded water pipe joint can NOT be corrected with a reasonable amount of pullup, which method should you use?

1. Replace distance pieces missing from the joint
2. Clean and recoat the threads
3. Install a hanger or two near the joint
4. Paint the joint with white lead and oil

6-20. Permanent repairs to copper piping may be made by

1. brazing
2. soldering
3. wire wrapping
4. wire wrapping and soldering

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6-21. One way you can help to increase the life of a shipboard saltwater piping system is to be sure that

1. water in the system is always circulated at maximum velocity
2. compressed air is blown through the system quarterly
3. open valves in the system are fully opened unless they are to be purposely throttled
4. the system is electrically grounded at each pipehanger

6-22. When breaking a flange joint in a steam line, you lessen the chances of scalding someone by taking which of the following precautions?

1. Drain the line
2. Relieve the line of all pressure
3. Lock, in the closed position, cutoff valves on both sides of the joint
4. Do all of the above

Learning Objective: Discuss the fundamentals of valves, including identification of different kinds, principles of construction, operation, maintenance, and repair. Textbook pages 130 through 141.

6-23. Valves used in high-pressure systems and suitable for temperatures above 550° F are usually made of

1. steel
2. cast iron
3. copper
4. brass

6-24. Valves used in systems carrying saltwater are usually made of

1. steel
2. copper
3. bronze
4. brass

6-25. Which of the following is shown in the upper right of figure 6-8 in the textbook?

1. Ball stop
2. Straight-flow globe
3. Angle-flow globe
4. Cross-flow globe

6-26. What is the usual shape of the gate in the gate valve?

1. Spherical
2. Wedge
3. Rectangular
4. Ball

6-27. Gate valves are suitable as throttling valves because they close in small increments.

6-28. There is nothing that indicates that a rising-stem valve is open or closed.

6-29. Which of the following explains why gate valves do NOT become wedged in place when a steam line and valve body expand around the cold gate?

1. Gate valves are bimetallic
2. There is a clearance between the gate and seat
3. Gate is flexible
4. Gate is a part of an expansion valve

6-30. Which of the following is a frequently encountered hazard in gate valves used in steam systems?

1. Wire-drawing
2. Valve body neck ruptures
3. Bypass valve collapses
4. Vent valve clogs

6-31. Which of the following is NOT a suggested use for the butterfly valve?

1. Chill water
2. Oil
3. Low-pressure steam
4. Saltwater

6-32. How do you open a butterfly valve?

1. Turn a handle 180°
2. Turn a handle 90°
3. Turn a handwheel
4. Either 2 or 3 is correct

6-33. Ball valves sometimes are used as a check valve. Which of the following allows the ball valve to be used as a check valve?

1. Planetary gear
2. Swing check
3. Rising gate
4. Flexible gate

6-34. Which of the following valves is classified as an automatic pressure control valve?

1. Globe
2. Relief
3. Ball
4. Each of the above

6-35. What component tends to keep the valve, shown in figure 6-16 of the textbook, closed?

1. Adjusting nut
2. Spring
3. Disk
4. Spring plate

6-36. Under what pressure condition will the valve shown in textbook figure 6-16 open?

1. Spring pressure exceeds the inlet pressure
2. Inlet pressure exceeds the spring pressure
3. Spring and inlet pressures are equal
4. Inlet and outlet pressures are equal

6-37. Spring-loaded valves that are attached to the inlet chamber of relief valves to warn of dangerous pressures are designated as

1. sentinel valves
2. spring-loaded reducing valves
3. pressure-reducing valves
4. air-operated valves

6-38. Reducing valves used in reduced pressure lines aboard ship are designed to

1. prevent damage to the lines due to excessive pressure
2. keep the operating pressure equal to the supply pressure
3. vary operating pressure according to the demand
4. provide a steady pressure lower than the supply pressure

6-39. Which of the following is a basic type of pressure reducing valve?

1. Spring-loaded
2. Hydraulic-loaded
3. Hydraulic-diaphragm
4. Floating disk

6-40. If a spring-loaded reducing valve fails to close after the outlet pressure is at the desired value, which of the following is a probable cause?

1. Diaphragm rupture
2. Adjustment screw broken
3. Spring has lost tensile strength
4. Handwheel backseated

6-41. Refer to textbook figure 6-18. The position of the controlling diaphragm is determined by the pressures exerted by

1. the adjusting spring and reduced-pressure steam
2. main valve spring and the auxiliary valve spring
3. high-pressure steam and the auxiliary valve spring
4. high-pressure steam and the adjusting spring

For items 6-42 and 6-43 assume that the valve shown in textbook figure 6-19 is installed in the cooling water main aboard your ship.

6-42. By what means is the water passing through the valve controlled?

1. A constant outlet pressure
2. An adjusting spring
3. A pilot valve
4. A pressure difference on the inlet and outlet sides of the valve

6-43. If the outlet pressure of the valve is constant, what occurs when this pressure is reduced?

1. The diaphragm is forced down to open the pilot valve
2. The spring forces the valve down
3. The valve disk is forced against its seat momentarily
4. The valve is moved upward by the diaphragm

6-44. What is the principle of operation of an air-controlled regulator?

1. The pressure of an enclosed gas is directly proportional to its temperature
2. The pressure of an enclosed gas varies inversely as its temperature
3. The pressure of an enclosed gas is directly proportional to its volume
4. The pressure of an enclosed gas varies inversely as its volume

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6-45. In a low-temperature, gas-loaded reducing valve, the pressure equalizing orifice admits fluid under pressure to the

1. reduced pressure line
2. loading chamber
3. separation plate orifice
4. underside of the diaphragm

6-46. Refer to textbook figure 6-20. The pressure on the outlet side of the valve remains fairly constant when that pressure is

1. equal to the loading pressure in the dome
2. equal to the pressure on the inlet side
3. greater than the air pressure in the dome
4. less than the pressure on the inlet side

6-47. Diaphragm control valves with air-operated control pilots may be used for which of the following?

1. Air pressure control
2. Liquid-level control
3. Temperature control
4. Each of the above

6-48. With a direct-acting air-operated control pilot, an increase in controlled pressure that moves the pilot valve stem causes the

1. pilot adjusting spring to expand
2. pilot valve stem to move upward
3. operating air pressure to increase
4. operating air pressure to decrease

6-49. Diaphragm control valves with reverse-acting diaphragm superstructures are actuated by air pressure applied to the

1. top side of the diaphragm
2. underside of the diaphragm
3. pilot valve stem
4. pilot valve spring-seat

6-50. A direct-acting upward seating valve opens when the operating air pressure applied to the top of the diaphragm is increased.

6-51. Assume that the control pilot in figure 6-24 of the textbook is direct-acting. Will a direct-acting, downward seating diaphragm control valve supply reduced or increased steam pressure, and why?

1. Reduced; because the control pilot will decrease the amount of operating air pressure to the bottom of the valve diaphragm which will permit the spring to push the valve stem down towards the closed position
2. Reduced; because the control pilot will increase the amount of operating air pressure to the top of the valve diaphragm which will push the valve stem down toward the closed position
3. Increased; because the control pilot will decrease the amount of operating air pressure to the top of the valve diaphragm which will permit the valve to open wider
4. Increased; because the control pilot will increase the amount of the operating air pressure to the bottom of the valve diaphragm and open the valve wider

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Learning Objective: Discuss the fundamentals of valves, including identification, principles of construction, operation, maintenance, and repair. Textbook pages 143 through 150.

6-52. During normal operation, the thermostatic recirculating valves are actuated by the temperature of the condensate from

1. the main condensate pump
2. the main condenser
3. the air ejector aftercondenser
4. a hand-controlled valve

6-53. What is the approximate range of adjustment, in degrees Fahrenheit, of the thermostatically controlled recirculating valve?

1. 10°
2. 20°
3. 30°
4. 40°

● The size of the opening in a thermostatically controlled valve varies according to the pressure applied by the thermostat on the bellows.

6-54. Under normal operating conditions the bypass and thermostatic valves are respectively

1. open and fluctuating according to demand
2. closed and fluctuating according to demand
3. open and wide open
4. closed and wide open

6-55. In which of the following will you find combined exhaust and relief valves?

1. Forced-draft blowers
2. Reciprocating pumps
3. Recirculating pumps
4. Each of the above

6-56. When the combined exhaust and relief valves, shown in figure 6-26 of the textbook, is in the relief position, which of the following conditions exist?

1. Auxiliary valve is open; main valve disk is open
2. Auxiliary valve is locked open; main valve disk is closed
3. Auxiliary valve is closed; main valve disk is locked closed
4. Auxiliary valve is locked closed; main valve disk is free to open

6-57. In the normal operating position of the combined exhaust and relief valves, which of the following conditions exist?

1. Auxiliary valve is open; main valve disk is backseated
2. Auxiliary valve is closed; main valve disk is backseated
3. Auxiliary valve is open; main valve disk is seated on bonnet yoke
4. Auxiliary valve is closed; main valve disk is seated on main disk

6-58. In the safety position of the combined exhaust and relief valves, which of the following conditions exist?

1. Auxiliary valve is open; main valve disk is backseated
2. Auxiliary valve is closed; main valve disk is backseated
3. Auxiliary valve is open; main valve disk is seated on bonnet yoke
4. Auxiliary valve is open; main valve disk is locked shut

6-59. In the seal regulator shown in figure 6-27 of the textbook, the bellows assembly applies pressure to the

1. pivot rods
2. pivot block
3. pilot valve
4. piston

6-60. In the seal regulator, when the pilot valve is raised, which of the following takes place?

1. The spring forces the piston down
2. Oil lifts the piston up
3. The exhaust valve opens
4. Each of the above takes place

6-61. If the bellows in the seal regulator leaks, the steam to the seal is shut off automatically.

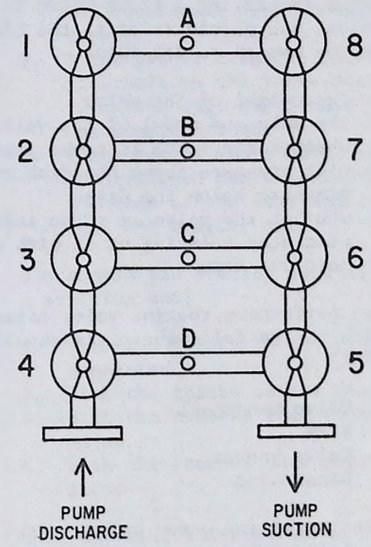


Figure 6A

6-62. In figure 6A, if tank A is to be filled from tank C, which of the following manifold valves should be open?

1. 1 and 8
2. 8 and 3
3. 1 and 6
4. 1, 5, and 6

6-63. In figure 6A, if tank C is to be filled from tank A, which of the following manifold valves should be open?

1. 8 and 3
2. 1 and 6
3. 1 and 8
4. 1, 5, and 6

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6-64. In case of a steam leak in the main engineroom, there is usually a handle for the main steam stop installed at a remote station outside the engineroom.

6-65. Which of the following is most likely to cause a leak at a flange?

1. Loose packing nut
2. Cracked packing gland
3. Loose pipe hangers
4. Loose scale

6-66. When possible, valves should be installed so that the valve stems will be

1. pointing upward
2. pointing downward
3. facing right
4. facing left

6-67. Before installing a globe valve in a system, you should refer to the blueprints for the system to determine

1. the weight of the valve
2. the make and model of the valve
3. whether the valve is to be installed with pressure above the disk or with pressure below the disk
4. whether the valve is to be installed with stem pointing up or with stem pointing down

6-68. When performing routine valve maintenance, which of the following parts should you paint?

1. Valve handwheel
2. Stem
3. Valve bonnet
4. Gland stud

6-69. When installing a new valve, which of the following parts should you lubricate with silicone lubricant?

1. Valve bonnet
2. Strong back retainer
3. Valve body
4. Yoke

6-70. A thorough visual inspection indicates that a valve disk and seat are in good condition. What should you do to be sure?

1. Grind them in
2. Spot them in
3. Reface them
4. Lap them

6-71. To spot-in a valve disk, coat it with prussian blue, insert it into the valve, rotate the disk one-quarter turn, and then remove it. What should you look for to determine the points where the disk makes contact with the seat?

1. Blue areas on the disk
2. Blue areas on the seat
3. Shiny areas on the disk
4. Shiny areas on the seat

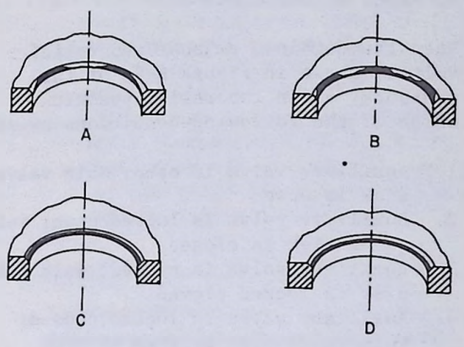


Figure 6B

6-72. Which valve seat in figure 6B is correctly spotted-in?

1. A
2. B
3. C
4. D

6-73. Very small irregularities are removed from a valve disk by grinding the disk against

1. a lapping tool
2. a hand reseating tool
3. a chisel
4. the valve seat

6-74. To broaden seat contacts, what process should follow machining of valve seats or disks?

1. Grinding-in
2. Spotting-in
3. Refacing
4. Lapping

Assignment 7

Piping, Valves, Gaskets and Packing (Continued); Heat Exchangers and Air Ejectors

Textbook Assignment: Chapter 6 (Continued) and Chapter 7

Learning Objective: Point out maintenance and repair procedures for valves. Textbook pages 150 through 152.

7-1. Which method of repairing a valve seat should you use when small irregularities in the valve seat cannot be removed by grinding-in?

1. Spotting-in
2. Filing
3. Lapping
4. Machining

7-2. What action should follow a valve lapping job?

1. Grind-in the disk to the seat
2. Spot-in the disk to the seat
3. Spot-in and grind-in
4. Spot-in and reface

7-3. When refacing a disk, which of the following should you use?

1. Lathe
2. Reseating machine
3. Valve grinder
4. Lapping tool

7-4. When resurfacing a valve with a steel seat, which of the following should you use?

1. Lathe
2. Reseating machine
3. Valve grinder
4. Each of the above is correct

7-5. How do you perform the rough method of spotting-in a valve seat and disk?

1. Coat the valve disk with prussian blue; place it on the seat and rotate the disk one complete turn
2. Coat the valve seat with prussian blue; place the disk on the seat and rotate the disk one-quarter turn
3. Place pencil marks at 1/2-inch intervals on the valve disk; place it on the seat and rotate the disk one complete turn
4. Place pencil marks at 1/2-inch intervals on the valve seat; place the disk on the seat and rotate the disk one-quarter turn

7-6. How should you install packing rings in a stuffing box?

1. With the joints of the rings staggered
2. With the joints of the rings aligned
3. With the rounded ends towards the gland
4. With the rounded ends away from the gland

7-7. When internal pilot-actuated steam-reducing valves are disassembled, what should you use to clean the guide stems?

1. Steam
2. Solvent
3. Crocus cloth
4. Both 2 and 3 are correct

7-8. What should you use to clean the control ports of internal pilot-actuated steam reducing valves?

1. Wire brush and compressed air
2. Soft copper wire and compressed air
3. Aluminum oxide cloth and steam
4. Soft copper wire and steam

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7-9. Assume that you are to install and adjust a steam reducing valve. After installing the valve in the line, you should slowly open the inlet stop valve wide after

1. opening any stop valves between the regulating outlet and the discharge pressure gage
2. backing off the adjusting screw to release compression on the adjusting spring
3. securing the bypass valve
4. bringing the regulator up to full flow

7-10. The outlet pressure of an internal pilot-actuated steam reducing valve is increased by turning the

1. adjusting screw clockwise
2. adjusting screw counterclockwise
3. pilot valve diaphragm clockwise
4. pilot valve diaphragm counterclockwise

Learning Objective: Identify the kinds of steam traps, their purposes, construction features, and maintenance and repair requirements. Textbook pages 152 through 156.

7-11. In the bucket type steam trap shown in figure 6-32 of the textbook, the valve disk is fastened to the

1. valve rod
2. valve seat
3. bucket
4. valve cap

7-12. In the ball and the bucket traps, the float rises to close their valves.

The following alternatives apply to items 7-13 through 7-17.

1. Impulse steam trap
2. Bimetallic steam trap
3. Orifice-type steam trap
4. Thermostatic steam trap

7-13. Which steam trap depends upon the expansion of sealed bellows for its operation?

7-14. Which steam trap operates on the principle that hot water under pressure flashes into steam when the pressure is reduced?

7-15. Which steam trap maintains an open balanced position due to the difference in working areas when the pressure in one chamber is 86% of the pressure in the other chamber?

7-16. Which steam trap is made of material that reacts to close the trap when steam is present and to open the trap when condensate is present?

7-17. Which steam trap has no moving parts and is suitable only for services in which the condensate formation is continuous?

7-18. Which of the following methods is recommended for checking the operation of steam traps?

1. Cut out traps one at a time
2. Listen for a blowing sound
3. Check the pressure in the drain system
4. Each of the above

Learning Objective: Point out significant construction and operating features of steam whistles. Textbook page 156.

7-19. What part of the diaphragm-type steam whistle produces the audible sound?

1. Baffles
2. Diaphragm disks
3. Valve orifice
4. Nozzle

7-20. Which of the following should be done before the whistle is operated?

1. Lubricate
2. Clean orifice
3. Open the drain
4. Each of the above

Learning Objective: Identify different types of packing. Textbook pages 157 through 163.

7-21. What parts of the packing identification symbol number will help you make the proper selection with respect to the type of joint and type of packing material respectively?

1. First and second digits
2. First and third digits
3. Second and third digits
4. Second, third, and fourth digits

7-22. What material listed on the packing and gasket chart is suitable for gaskets for fixed joints?

1. Material with a symbol number that starts with the digit 1
2. Material with a symbol number whose second digit is a 1
3. Material with a symbol number that starts with the digit 2
4. Material with a symbol number whose third or fourth digit is a 2

7-23. If given the following types of packing to choose from, which one should you use to pack a valve in a 300-psi steam line?

1. 1430
2. 2100
3. 2103
4. 2430

7-24. If you were required to replace a flange valve gasket in a 300-psi steam line, which of the following materials should you choose?

1. 1100
2. 1103
3. 1400
4. 2150

7-25. After replacing a pressure-seal gasket in a valve you should make it a practice to

1. tighten the bonnet joint only before applying line pressure to the joint
2. tighten the bonnet joint only after applying pressure
3. operate the valve a specified number of hours before completely tightening the bonnet joint
4. tighten the bonnet joint before operation, tighten immediately after applying pressure to the joint, and again after two or three days of operation

7-26. Wire-inserted, square-braided asbestos packing is now generally used for packing sliding joints where pressures and temperatures will not exceed

1. 200 psi and 350° F
2. 300 psi and 525° F
3. 400 psi and 700° F
4. 500 psi and 875° F

7-27. Which of the following precautions is/are applicable in packing a rotating joint?

1. Do not tighten the packing tight enough to bind the shaft
2. Do not shut off all leakage
3. Each of the above is correct
4. Prevent all leakage unless there is a flinger ring

7-28. Which of the following is suitable packing for a valve in a system with 1200° F operating temperature?

1. Teflon packing
2. Inserted square-braided asbestos
3. Plastic nonmetallic asbestos encased in a braided wire covering
4. Corrugated packing

7-29. How should packing rings be prepared and installed in stuffing boxes?

1. The ends of the rings should be beveled with the joints in alignment
2. The ends of the rings should be cut square with allowance for elongation and with the joints staggered
3. The ends of the rings should be notched, with each joint flush with the adjacent joint
4. The ends of the rings should be rounded and cupped, with allowance for elongation, and with the joints staggered

7-30. What procedure should you follow before installing rock hard hydraulic rod packing in a pump?

1. Cut it and fit it into the pump plunger; then soak in water for 12 hours
2. Soak it for 12 hours before cutting and fitting
3. Install it dry but leave a specified amount of clearance to provide for swelling
4. Install it dry but make sure a minimum clearance exists when fitting it into the pump plunger

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7-31. When repacking a pump shaft you can ignore a scored shaft because the packing will fill grooves in the shaft.

7-32. What type of gaskets are presently being used by the Navy in high-temperature, high-pressure installations?

1. Sheet metallic cloth asbestos
2. Sheet compressed asbestos
3. Spiral-wound metallic asbestos
4. All of the above

7-33. Which of the following precautions should you take before breaking a joint in a hot water line?

1. Ensure that all line pressure valves are wired closed
2. Ensure that the compartment is properly ventilated
3. Ensure that two diametrically opposite flange-securing bolts are left in place while the others are removed
4. Ensure that all of the above precautions are taken

7-34. When cutting a plain full-faced gasket for a flange, what is the correct sequence?

A. Cut bolt holes
B. Scribe outline of gasket
C. Cut center and outside circles

1. A, C, B
2. C, A, B
3. A, B, C
4. B, A, C

7-35. Which piece of equipment is packed with rubber packing?

1. Centrifugal pump shaft
2. Rotary compressor
3. Hydraulic ram
4. Rotary pump shaft

7-36. Soft packing is used against thick or sticky liquids.

Learning Objective: Indicate the purpose and identifying features of different types of insulation with precautions for installation and maintenance. Textbook pages 163 through 165.

7-37. Which of the following is a purpose of insulation?

1. To retard transfer of heat
2. To prevent sweating
3. To prevent personal injuries
4. Each of the above is correct

7-38. The lagging for piping insulation serves to

1. resist the flow of heat
2. secure the insulating material to the pipe
3. repel moisture
4. protect and confine the heat resistant material

7-39. Which of the following is a desirable feature of insulation?

1. Moisture absorbent
2. Combustibility
3. Vermin proof
4. Each of the above is desirable

7-40. Which of the following is an application for lagging cement?

1. Patch work
2. Surface finish
3. Seal blocks of insulation
4. Each of the above is correct

7-41. Removable type insulation is usually installed on all

1. pipe joints and valve bonnets
2. valve bonnets of valves larger than 2 inches, IPS, that operate at 240° F and above
3. low-pressure pipes that are subjected to low temperatures
4. valve bonnets of valves 1 inch or smaller, IPS, that operate at 300 psi and below

7-42. Why is sheet-metal pipe covering kept unpainted?

1. To increase heat radiation
2. To decrease heat radiation
3. To reduce danger of fire
4. To avoid condensation

7-43. Lagging on the fire main piping system aboard ship serves to

1. keep the heat in
2. keep the heat out
3. prevent moisture condensation on the outside of the pipes
4. protect the pipes against accidental damage

Learning Objective: Identify some uses of heat exchangers, indicating the classification of heat exchangers used in the Navy. Textbook pages 166 through 168.

7-44. Between which of the following objects or substances is the rate of heat transfer fastest per unit of time?

1. An iron at 200° F and a metal sheet at 150° F
2. A brick at 200° F and a block of ice
3. Ice, and saltwater at 35° F
4. Boiling water, and a steel rod at 230° F

7-45. A condenser changes a gas to a liquid by causing the gas to

1. gain sensible heat
2. lose its latent heat
3. gain latent heat
4. lower the rate of heat flow

7-46. Boilers aboard ship are designed to change water into steam. When the water in a boiler is at a temperature of 250° F, what is the approximate temperature of the steam, and why?

1. 250° F because it is in contact with the water
2. 275° F because steam cannot exist at the water temperature
3. 300° F because this is the normal temperature of steam
4. 325° F because this is the temperature at which evaporation occurs

7-47. On what basis are heat exchangers classified?

1. Construction features
2. Path of heat flow
3. Relative direction of fluid flow
4. Each of the above

7-48. Which heat exchangers are classified as direct contact heat exchangers?

1. Deaerating feed tanks
2. Lube oil coolers
3. Air ejector condensers
4. Air coolers

7-49. Which type of surface heat exchanger is usually used for the main condensers aboard ship, and why?

1. Multipass counterflow, because it is most suitable when large changes in temperature are required
2. Parallel, because equalization of temperatures between the two fluids is more easily maintained
3. Single-pass counterflow, because it is particularly useful for changing a vapor to a liquid
4. Crossflow, because it is especially useful for removing latent heat

7-50. A heat exchanger is classified as a plain surface unit when the surface is

1. fitted with rings
2. fitted with studs
3. fitted with fins
4. relatively smooth

For items 7-51 through 7-54, select from column B the feature that is characteristic of the type of shell-and-tube heat exchangers listed in column A.

A. Types of Heat Exchangers	B. Distinctive Feature
7-51. Return bend	1. Coils of tubing
7-52. Helical tube	2. Pairs of flat oblong strips
7-53. Double-tube	3. One tube inside another
7-54. Strut tube	4. U-shaped tube, on one tube sheet

Learning Objective: Trace the flow of steam and saltwater through a main condenser, pointing out construction features, and identifying the basic factors that ensure the proper operation of the condenser. Textbook pages 169 through 174.

7-55. Noncondensable gases are removed from the vapor-condensate circuit through the

1. ejector scoop
2. steam exhauster
3. condensate pump suction
4. air ejector suction opening

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7-56. The two separate circuits involved in the condensation of steam in a main condenser are the vapor condensate and the cooling water circuits.

7-57. After leaving the bottom of the main condenser, the condensate drains into the

1. circulating pump
2. condensate pump
3. hot well
4. overboard discharge valve

7-58. What units in the sea chest of a main condenser prevent debris in the water from fouling the condenser tubes?

1. Strainer bars
2. Revolving paddles
3. Tube sheets
4. Baffles

7-59. What device provides cooling water for the main condenser when the ship is at anchor?

1. Condensate pump
2. Main circulating pump
3. Injector scoop
4. Vent manifold

7-60. When the circulating pump is operating, what is the function of the large swing-check valve in the main injection line?

1. To permit water to flow through the pump
2. To permit water to flow through the main injection line
3. To prevent backflow of water through the pump
4. To prevent backflow of water through the main injection line

7-61. Main condensers equipped with scoop injection are of what type?

1. Curved-tube, single-pass
2. Straight-tube, single-pass
3. Straight-tube, double-pass
4. Curved-tube, double-pass

7-62. What part of a main condenser serves as a divider between the saltwater circuit and the vapor-condensate circuit?

1. Baffle arrangement
2. Strainer bars
3. Tube sheet
4. Monel metal plates

7-63. What part of a main condenser collects the condensate as the steam condenses on the tube?

1. Receiving tray
2. Hot well
3. Air baffles
4. Condensate pump

7-64. Air and steam mixtures are separated in main condensers by means of

1. air ejectors
2. baffle arrangements
3. a receiving tray
4. strainer bars

7-65. In a properly operating single-pass main condenser, how should the overboard temperature compare with the injection temperature?

1. Overboard temperature should be higher
2. Overboard temperature should be lower
3. Overboard temperature should be alternately higher and lower
4. Overboard temperature should be approximately the same

7-66. In the scoop injection system, what valve throttles the flow of circulating water when operating conditions warrant such action, and how much should it be opened?

1. Inlet valve, fully open
2. Inlet valve, at least one-fourth open
3. Overboard valve, fully open
4. Overboard valve, at least one-fourth open

7-67. Which of the following may cause a condenser to function improperly?

1. Air is not being properly removed from the condenser
2. An air leakage exists in the condenser
3. The condensate level remains excessively high
4. Any of the above conditions

7-68. In the main condenser, a condensate level that reaches the bottom row of tubes usually causes

1. an increase in condenser shell temperature
2. an increase in exhaust trunk temperature
3. a decrease in condensate temperature
4. sudden loss of vacuum

7-69. To avoid possible damage to the main condenser and engine, when an increase in condensate pump speed or an additional pump fails to reduce an excessively high condensate level, what should you do?

1. Decrease main engine speed
2. Increase main engine speed
3. Decrease cooling water circulation
4. Increase cooling water circulation

7-70. What usually happens when the water circulating system in the condenser fails?

1. A decrease in steam pressure
2. A high condensate level
3. A dangerous loss of vacuum
4. Either 2 or 3 above

7-71. When obstructions cannot be cleared from the sea chest by means of the pressure method provided, what must be done?

1. The water flow must be reversed
2. The obstruction must be removed manually by a diver
3. All air vents must be closed until the sea chest has cleared
4. Engines must be stopped to permit water to flush away the obstruction

7-72. What action should you take immediately after starting a shipboard main circulating pump operating on bilge suction?

1. Slowly increase pump speed to maximum
2. Slowly decrease pump speed to about one-half of its rated speed
3. Gradually close the main injection valve and open the bilge suction valve
4. Gradually open the main injection valve and close the bilge suction valve

7-73. Most auxiliary condensers are of single-pass construction.

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Assignment 8

Heat Exchangers and Air Ejectors (Continued); Lubrication and Associated Equipment

Textbook Assignment: Chapter 7 (Continued) and Chapter 8

Learning Objective: Identify the major source of air leaks in condensers, pointing out steps in the procedure for cleaning the freshwater side of a condenser. Textbook pages 174 through 176.

8-1. When a ship is in port, auxiliary exhaust steam is directed to the

1. auxiliary condenser
2. main condenser or auxiliary condenser
3. deaerating feed tanks
4. distilling plants or deaerating feed tanks

8-2. One acceptable means for temporarily stopping air leakage at the flanged joints of a condenser is to apply shellac when the condenser is under vacuum.

8-3. Although a lighted candle is sometimes a satisfactory device for locating condenser leaks, a more reliable method is to coat the suspected area with

1. shellac, while the condenser is under vacuum
2. shellac, while the condenser is under pressure
3. soapsuds, while the condenser is under vacuum
4. soapsuds, while the condenser is under pressure

8-4. In investigating for possible leaks in heat exchangers and associated equipment, where should a Machinist's Mate look?

1. Drain collecting system drain line and thermometer connections
2. Makeup feed line and air-removal suction line
3. Evaporator drain line and boiling out connection at bottom of shell
4. All of the above places

8-5. Fouling conditions on the seawater side of the condenser tubes are best determined by

1. noting the heat transfer rate
2. a visual inspection
3. taking pressure gage readings
4. taking vacuum gage readings

8-6. Boiling out the steam side of a condenser to remove grease and dirt is usually necessary once every

1. 3 to 6 weeks
2. 6 to 9 weeks
3. 1 to 2 years
4. overhaul cycle

Learning Objective: Specify the condition the main condenser should be in for the various securing times, indicating the methods of detecting saltwater leaks. Textbook pages 176 and 177.

8-7. What method(s) is/are acceptable for cleaning the seawater side of the condenser tubes?

1. Force soft rubber plugs through the tubes by means of compressed air
2. Scrub the tubes with a rotating bristle brush
3. Push an air lance through the tubes
4. All of the above

8-8. When the ship is at anchor in waters that are highly polluted and a condenser is not being used, the seawater side of the condenser should be

1. kept filled
2. filled, and the water circulated daily
3. drained
4. drained and thoroughly washed out

8-9. If a condenser is to remain idle for 2 weeks and ship's instructions do not permit the seawater side to remain dry, what should you do?

1. Fill the seawater side with saltwater
2. Fill the seawater side with either air pressure or saltwater
3. Fill the seawater side with freshwater
4. Fill both sides with either air pressure or freshwater

8-10. What is indicated by a chloride buildup in the steam generator of a newly constructed conventional propulsion plant?

1. Poor ventilation of the seawater side of the condenser
2. Excessive foreign matter deposits on the condenser tube walls
3. Seawater leakage in the active condenser tube lengths between the tube sheets
4. Poor water circulation in the steam side of the condenser

Learning Objective: Specify safety precautions related to all steam condensers in the engineering plant. Textbook pages 177 and 178.

8-11. In the interest of safety, when a loss of vacuum occurs in a hot condenser you should

1. increase the pressure in the seawater chest
2. close all sea connections
3. slow down or stop the engine
4. partly close the sea suction line valve

8-12. Water chest relief valves are always tested when starting up condensers.

8-13. Safety precautions pertaining to steam condensers in the engineering plant include

1. keeping at least 15 psig pressure in the seawater chest
2. avoiding metal contact with the zincs
3. ensuring that no open flame or sparking object is near a condenser being opened
4. keeping air pressure in the saltwater sides of condensers that are in use

8-14. An open flame is dangerous to personnel working around a newly opened condenser because hydrogen or sewer gas may be present and cause an explosion.

Learning Objective: Specify the purpose and operating principle of a deaerating feed tank, listing operating procedures, and identifying the maintenance required to ensure proper operation. Textbook pages 178 through 180.

8-15. What is a purpose of deaerating feed tanks?

1. To store water to take care of fluctuations in feedwater demand or condensate supply
2. To add oxygen to the feedwater for a higher degree of purification
3. To cool feedwater
4. To condense steam

8-16. The water at the operating pressure in a deaerating feed tank must be kept below its boiling point. Why?

1. To ensure a good water and steam mixture
2. To prevent it from flashing into steam
3. To prevent the removal of noncondensable gases
4. To maintain good atomization at low pressures

8-17. In the DFT shown in figure 7-9 of the textbook, what is the purpose of the spring-loaded poppet valves.

1. To form the steam into a conical spray
2. To form the condensate into a conical spray
3. To remove gas from the steam
4. To remove gas from the condensate

8-18. How is the water removed from the deareating compartment?

1. Gravity
2. Eductor action
3. Booster pump suction
4. Each of the above is correct

8-19. In the DFT, where does initial aeration take place?

1. Gas collection chamber
2. Baffle section
3. Spray chamber
4. Storage compartment

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8-20. Why must the proper water level be maintained in a deaerating feed tank during operation?

1. Steam and water will not mix properly unless the tank is at least 3/4 full
2. Excessive water will prevent the efficient removal of air
3. With insufficient water, damage to the main feed pumps and boilers may result
4. Both 2 and 3 above are true

8-21. In the DFT the ideal mixture of steam and water brings the feedwater just above the boiling point.

8-22. Which action occurs when the inside pressure of an operating deaerating tank is less than the pressure in the exhaust line?

1. Auxiliary exhaust steam flows into the tank through the check valve
2. Auxiliary exhaust steam flows into the tank through the main circulating valve
3. Water flows into the auxiliary exhaust line through the check valve
4. Water flows into the auxiliary exhaust line through the main circulating valve

---

Learning Objective: Identify the purpose and main construction features of the auxiliary heat exchangers most often encountered in maintaining engineroom equipment. Textbook pages 180 through 182.

8-23. When the DFT is operating, how is the gland leak-off steam disposed of?

1. It flows to the freshwater drain collection tank via the exhaust condenser
2. It vents to the atmosphere via the exhaust condenser
3. It flows to the main condenser via the recirculating connection
4. It vents to the atmosphere via the high-pressure drains

8-24. What type of coolant is used in lube oil coolers aboard ship to cool the lubricant?

1. Air
2. Water
3. Oil
4. Either water or oil depending upon the amount of heat that must be removed

8-25. In the oil line of a turbogenerator oil cooler, what is the purpose of the three-way valve?

1. To bypass the strainer
2. To bypass the heater
3. To bypass the cooler
4. Each of the above is correct

8-26. One difference between a strut-tube type oil cooler and a plate-type cooler is that in the strut-tube type

1. water passes through the tubes
2. oil passes through the tubes
3. the transfer of heat is accelerated by a grid distributor strip
4. the core assembly is a replaceable unit

8-27. Which heat exchanger has tubes with fins?

1. Main condenser
2. Turbogenerator lube oil cooler
3. Pump lube oil cooler
4. Generator air cooler

The following alternatives pertaining to air coolers are for items 8-28 and 8-29.

1. Bottom of the front header
2. Internal ribs of the outer tube
3. Inner tube
4. Outer tube

8-28. What part is in contact with the water in the cooler?

8-29. What part supports the cooling fins?

Learning Objective: Point out important features in the construction of an air ejector assembly, giving the principles of operation and maintenance. Textbook pages 182 through 189.

8-30. Flow through an air ejector aboard ship is maintained by

1. high velocity air pressure
2. low velocity air pressure
3. low velocity steam from the 150-psi auxiliary steam system
4. high velocity steam from the auxiliary steam system

8-31. In the after condenser section of a main air ejector condenser, what deflects the air and vapor downward over the lower bank of tubes?

1. A wall of water
2. A column of steam
3. A baffle at the gland vapor inlet
4. A moving vane

8-32. How are the two sets of nozzles and diffusers for each stage used?

1. Both sets are used simultaneously to ensure maximum efficiency and continuous operation
2. The two sets are used alternately, to enable effective maintenance and continuous operation
3. One set is used for normal operation, and the second set is a standby for emergency use
4. One set is used for normal operation and cruising speeds; the second set is used to supplement the first set during long range or high speed operations

8-33. The atmospheric vent of an air ejector is usually connected to the suction of a small motor-driven fan. One of the purposes of this connection is to

1. provide a positive discharge of the steam, via piping, to the atmosphere when the cooling water supply fails
2. ensure an uninterrupted flow through the air ejector under all operating conditions
3. provide for a positive flow of steam through the intercondenser and after-condenser during normal operations
4. ensure discharge of the steam-air mixture from the second stage to the aftercondenser

8-34. In a two-stage air ejector, air is vented to the atmosphere from the

1. intercondenser
2. aftercondenser
3. gland exhaust condenser
4. aftercondenser or the gland exhaust condenser

8-35. Coolant for the air ejector aftercondenser is provided by

1. condensate from the main condenser
2. condensate from the intercondenser
3. condensate from the gland exhaust condenser
4. water from the firemain

8-36. When a ship is cruising at low speeds, how is adequate cooling provided for air ejectors?

1. Main condenser condensate is recirculated
2. Condensate pump is energized
3. Auxiliary steam-air mixture is pumped to the main condenser
4. Seawater is cut into the air ejector

8-37. Condensate formed in the intercondenser is discharged to the

1. aftercondenser via the second-stage air ejector
2. main condenser via the loop seal
3. aftercondenser and gland exhaust condenser via the condensate pump
4. main condenser via the condensate pump

8-38. When starting an air ejector, the second-stage discharge valve is opened

1. before admitting steam to second stage
2. after admitting steam to second stage
3. after admitting steam to first stage
4. before opening the aftercondenser drains

8-39. Which of the following is necessary to keep an air ejector operating properly?

1. Fill the intercondenser with water
2. Provide cooling water to air ejector condenser tubes
3. Fill the aftercondenser with water
4. Each of the above is correct

8-40. To shift from an operating two-stage air ejector to a standby two-stage air ejector, it is essential that you

1. close the first-stage discharge valve of the standby ejector before opening the first-stage discharge valve of the operating ejector
2. open the steam inlet valve to the first-stage nozzle of the standby ejector before closing the steam supply valve to the second stage of the operating ejector
3. open the second-stage discharge valve of the standby ejector at the same time you close the second-stage discharge valve of the operating ejector
4. close the first-stage suction valve of the operating ejector before opening the second-stage suction valve of the standby ejector

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8-41. To secure an air ejector assembly, you should close the second-stage discharge valve before closing the

1. first-stage steam inlet valve
2. second-stage suction valve
3. second-stage steam valve
4. intercondenser and aftercondenser drains

8-42. A shipboard air ejector assembly consistint of units A and B is losing vacuum due to clogged strainers in unit B. To clear the strainers, while the rest of the system is operating, it is essential that you

1. shut down the ejector assembly
2. close the steam supply valves of unit A
3. close the steam supply valve and the interstage valves of unit B
4. close the steam supply valve of unit A, and the interstage valves of units A and B

The following alternatives pertaining to two-stage air ejectors are for items 8-43 through 8-46:

1. Air leaks through the discharge valves
2. Fouled nozzles
3. Insufficient cooling water circulating through the air ejector
4. Excessively high steam pressure

8-43. The condenser units are likely to become overloaded when an improper vacuum is due to which of the above?

8-44. The second-stage ejector will probably become overloaded when a loss in vacuum is due to which of the above?

8-45. A loss in vacuum due to an overloaded air ejector is often caused by which of the above?

8-46. Wet steam admitted to the equipment is indicative of improper vacuum due to which of the above?

8-47. Which of the following is a safe practice with respect to starting an air ejector?

1. Close the discharge valves before admitting steam to the nozzles
2. Close the steam supply valves after closing the discharge valves
3. Drain the steam supply line before starting an ejector
4. Close drain valves in the condenser drain lines before starting an ejector

---

Learning Objective: Identify the various kinds of friction, giving principles that apply to the exchange of one type for another. Textbook pages 190 and 191.

8-48. What is kinetic friction?

1. Friction between two bodies at rest
2. Friction that must be overcome to generate motion
3. Friction between moving bodies or between a moving body and a stationary surface
4. Friction that must be overcome to stop a body in motion

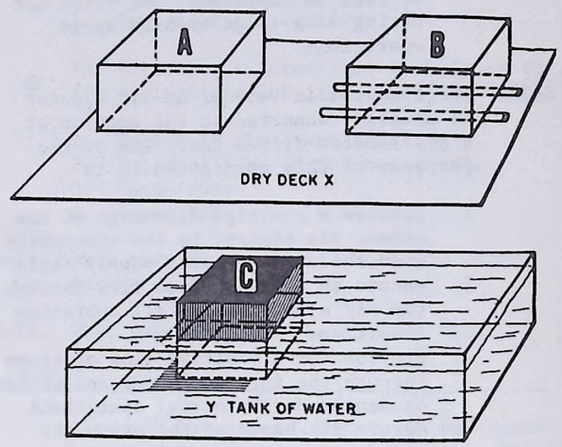


Figure 8A.

For items 8-49 through 8-53, refer to figure 8A.

8-49. What type of friction must be overcome to put boxes A and B in motion?

1. Fluid
2. Rolling
3. Sliding
4. Static

8-50. What type of friction exists between the deck and the bottom of box A as the box is dragged to point X?

1. Fluid
2. Rolling
3. Sliding
4. Static

8-51. What type of friction exists between the deck and the pipes under box B as the box is pushed to point X?

1. Fluid
2. Rolling
3. Sliding
4. Static

8-52. What type of friction exists between the water and the sides and bottom of box C as the box is floated to point Y?

1. Fluid
2. Rolling
3. Sliding
4. Static

8-53. Friction exists between the water and the sides and bottom of the floating box C. This friction is created by the forces that cause molecules of water to do which of the following?

1. Attract one another
2. Stick to the box
3. Do both of the above
4. Repel one another

8-54. Assume that boxes A and B in figure 8A are identical in every respect. Compare the amounts of power consumed and heat produced to overcome friction in moving box A with the corresponding amounts for overcoming friction in moving box B. What conclusion should you draw from the comparison?

1. More power is consumed and more heat is produced in moving box A
2. More power is consumed and more heat is produced in moving box B
3. More power is consumed and less heat is produced in moving box A
4. More power is consumed and less heat is produced in moving box B

8-55. Grease under pressure resists breakdown because of its cohesive properties.

8-56. By introducing an unbroken film of oil between two parts that are making metal-to-metal contact, you reduce the friction between them. Theoretically, what kinds of friction are exchanged?

1. Sliding to rolling
2. Rolling to sliding
3. Sliding or rolling to fluid
4. Fluid to sliding or rolling

Learning Objective: Specify types and fundamentals of lubrication, including various affecting factors, and identify terms used to describe characteristics of lubricating oils and greases. Textbook pages 191 through 193.

8-57. According to the Langmuir theory, lubricating oil between two moving surfaces consists of

1. several layers--the outside layers adhering to the moving surfaces and the inside layer(s) sliding between the outside layers and remaining out of contact with the moving surfaces
2. two layers--one sliding on the other and each layer clinging to one of the moving surfaces
3. one layer that prevents metal-to-metal contact and acts as a roller between the two moving surfaces
4. a wedge-shaped layer of oil that forces the moving surfaces apart as does a solid wedge

8-58. What effect, if any, does a change in temperature have on the oil film between two moving surfaces?

1. The film thickness changes with no change in viscosity
2. The film thickness changes due to a change in viscosity of the oil
3. The film thickness decreases with any change in temperature due to a change in the viscosity of the oil
4. Temperature changes have no affect on the thickness of the oil film

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8-59. Compare the cohesive and adhesive properties of a lubricant, X, that is suitable for high-speed operations and minimum clearances between bearing surfaces with those of another lubricant, Y, suitable for low-speed operations and maximum clearances between bearing surfaces. What conclusion should you draw from the comparison?

1. X is more adhesive and more cohesive than Y
2. Y is more adhesive and more cohesive than X
3. X is more adhesive but less cohesive than Y
4. Y is more adhesive but less cohesive than X

8-60. To meet the required specifications, what must a lubricating oil do for diesel engines:

1. Provide proper lubrication for long periods of time between oil changes
2. Keep the engines clean
3. Prevent corrosion of bearing surfaces
4. Do all of the above

8-61. The compound type of lubricating oil prevents corrosion and foam because of

1. a higher viscosity
2. a higher specific gravity
3. a lower pour point
4. additives

8-62. In which component is a water-base glycol hydraulic fluid chiefly used?

1. Catapult retracting gears
2. Deck-edge elevators
3. Refrigeration compressors
4. Machinery reduction gears

8-63. The digit 2 in the lubricating oil symbol 2190T represents the

1. principal synthetic additive in the oil
2. class of the oil according to type and use
3. diameter, in centimeters, of the standard orifice used to measure the oil's viscosity
4. number of minutes it takes a 60-ml sample of the oil to flow through a standard orifice at a specified temperature

8-64. Which part of lubricating oil symbol 2190T represents the viscosity of the oil?

1. 19
2. 90
3. 190
4. 219

8-65. What do the letters TEP indicate when they form part of the identifying symbol for a lubricating oil?

1. Oil has a high pour point
2. Oil contains a special additive
3. Oil is to be used for lubricating refrigerant compressors
4. Oil is to be used for lubricating 2-cycle internal-combustion engines

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Learning Objective: Identify pertinent characteristics of lubricating oils and greases. Textbook pages 193 and 194.

8-66. How does the temperature affect the viscosity of oil?

1. An increase in temperature causes a higher viscosity and a decrease in temperature causes a lower viscosity
2. A decrease in temperature causes a higher viscosity and an increase in temperature causes a lower viscosity
3. A change in temperature affects the viscosity of the various oils differently; the resulting effects depend upon the type of oil and other factors
4. A change in temperature has no significant effect on the viscosity of oil

8-67. The viscosity index of a lubricating oil indicates the change in oil viscosity, other conditions remaining the same, due to variation in

1. temperature
2. pressure
3. moisture content
4. density

8-68. A change in temperature causes a change in the body of an oil. How does this change in the body of an oil having a high viscosity index compare with that of an oil having a low viscosity index?

1. The change in the high viscosity index oil is the same
2. The change in the high viscosity index is smaller
3. The change in the high viscosity index oil is greater
4. The change in the high viscosity index oil is smaller if the oil has a high pour point, and greater if the oil has a low pour point

8-69. The pour point of an oil is the highest temperature at which it will flow without flashing.

8-70. The minimum flashpoint temperature that is allowed for Navy lube oils is above

1. 315° F
2. 400° F
3. 500° F
4. 600° F

8-71. The lowest temperature at which the vapors of an oil will burn in the absence of a spark or flame is known as the

1. fire point
2. flashpoint
3. combustion point
4. auto-ignition point

8-72. Which index of a lube oil indicates the tendency of the oil to damage metal surfaces by oxidation?

1. Precipitation number
2. Flashpoint
3. Neutralization number
4. Pour point

8-73. Which type of content is shown by the precipitation number of an oil?

1. Acid
2. Additive
3. Moisture
4. Asphalt or carbon residue

8-74. What grade of grease is used to lubricate parts that rotate at slow speeds under high pressure?

1. Soft
2. Medium
3. Hard
4. Medium-soft

8-75. At temperatures between 0° F and 140° F what type of grease is suitable for lubricating sliding surfaces subjected to moisture and high loads?

1. Ball and roller bearing grease, MIL-G-18709
2. Extreme pressure grease MIL-G-17740
3. Graphite grease, grade 1
4. Graphite grease, grade 2

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Assignment 9

Lubrication and Associated Equipment (Continued); Engineroom Operating Procedures

Textbook Assignment: Chapter 8 (Continued) and Chapter 9

Learning Objective: Identify various components in a main engine forced-feed lubricating system, giving the purpose of each. Textbook pages 195 through 198.

9-1. When a lubricating oil service system aboard ship includes three lube oil service pumps, how are the motor-driven and turbine-driven pumps used?

1. As regular lube oil service pumps
2. As lube oil service pumps when the ship is getting underway
3. As standby, at normal speeds, for the shaft-driven pump
4. Both 2 and 3 are correct

9-2. On submarines, how is the standby lube oil pump driven?

1. Steam
2. A.C. electrical power
3. D.C. electrical power
4. Either 2 or 3 is correct

9-3. In figure 8-3 of the textbook, which of the following types of valves is shown between the strainers?

1. Four-way plug cock
2. Ball valve
3. Check valve
4. Both 2 and 3 are correct

The differential pressure across the strainer can be found by comparing gage pressures at the inlet and outlet of the strainer.

9-4. Which of the following differential pressures indicates a need to shift strainers?

1. 1/4 psi
2. 1/2 psi
3. 3/4 psi
4. 1 1/4 psi

9-5. In a forced-feed lubrication system, oil leaves the cooler and flows to individual bearings through

1. the parts to be lubricated
2. the main engine sump
3. spray nozzles or fixed orifices
4. needle valves or fixed orifices

9-6. Which statement pertaining to the purification of oil by the settling tank method is true?

1. The main engine should be operating at normal speeds
2. The oil is heated for several hours, causing the impurities to settle so they can be drawn from the bottom of the tanks
3. The required temperature of the oil is maintained by normal operation of the engines
4. The oil should remain in the settling tanks for at least 12 hours before it is discharged to the storage tanks

9-7. What condition is usually indicated by foaming lubricating oil at bearings?

1. Insufficient supply of oil
2. Contaminated oil
3. Insufficient oil pressure
4. Excessive oil pressure

9-8. While observing the oil supply at a main engine bearing through the sight-flow glass, you notice an interrupted flow. Further inspection reveals excessive oil temperature. What immediate action should you take?

1. Check the cooling water circulation through the coolers
2. Stop and lock the main shaft and notify the bridge
3. Start and cut in the main lubrication system standby pumps
4. Increase engine speed momentarily and if the oil pressure fails to stabilize, notify the bridge

9-9. Forced-feed lubrication oil coolers should be placed in operation when the temperature of oil from the coolers reaches

1. 90° F
2. 120° F
3. 150° F
4. 180° F

Learning Objective: Point out procedures for ensuring that lubricating oil is free of impurities. Textbook pages 198 and 199.

9-10. If rusty metal is found in the lube oil strainer, which of the following is indicated?

1. Wiped bearing
2. Thrust shoe is broken
3. Corrosion is taking place
4. Overheated bearing

9-11. When main propulsion machinery has been secured aboard ship, oil is circulated through the lubrication system for at least an hour in order to

1. cool the oil
2. cool the machinery
3. pump dirt and foreign matter from the main engine sump
4. minimize the effects of freshwater condensation

9-12. Lube oil that is continuously purified by removal of moisture and other impurities may be used under constant operating conditions for

1. 30 days
2. 60 days
3. 90 days
4. unlimited periods of time

9-13. Main propulsion shaft spring bearings are self-lubricated by means of

1. pressure feed
2. gravity feed
3. oiler wicks
4. oiler rings

9-14. Recommended care of spring bearing oil includes which of the following?

1. Drain and purify the oil at least once a quarter
2. Sample the oil in the sump hourly
3. Renew the oil every 10 days or after each extended run
4. All of the above

Learning Objective: Specify the fundamentals of grease lubrication, differentiating between the grease cup and pressure fittings types of systems. Textbook page 200.

9-15. Although pressure fittings are a convenient means of lubrication, they should not be used for lubricating which of the following?

1. Low-speed bearings
2. Electric generator bearings
3. Sleeve bearings
4. Both 2 and 3 above

9-16. If you are careless while using pressure fittings to lubricate bearings, what might result?

1. Abrasive particles in the lubricant
2. Broken seals
3. Unseated needle in needle type bearings
4. Any of the above

Learning Objective: Indicate the methods of purifying lube oil, identifying operation and maintenance principles for the various types of centrifugal purifiers. Textbook pages 200 through 207.

9-17. The principal source of lube oil contamination is

1. dirt
2. sludge
3. water
4. carbon

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9-18. In what sequence is batch oil purifying performed?

A. Heat oil
B. Water and other impurities are removed from settling tanks
C. Lubricating oil is transferred from sump to settling tank
D. Oil is centrifuged and returned to sump

1. A, B, C, D
2. C, A, B, D
3. C, B, A, D
4. B, C, A, D

9-19. An oil purifier is referred to as a separator when the substance being removed from the oil is

1. sludge
2. water
3. metal particles
4. sediment of any nature

9-20. The disk-type purifier differs from the tubular-type purifier mainly in

1. design of rotating unit
2. principle of operation
3. position assumed by the separated oil
4. capacity

9-21. Refer to figure 8-8 in your textbook. Dirty oil flows from the bottom of the regulating tube through the inside of a tubular shaft into a

1. bowl shell
2. stack of disks
3. centrifugal tube
4. discharge ring

9-22. Refer to figure 8-7 in your textbook. Water that is separated from oil in a disk-type purifier is discharged through the discharge ring located at the

1. top of the purifier bowl
2. bottom of the purifier bowl
3. center of the purifier bowl
4. between the driving bushing and the top disk

9-23. What happens during the purification process when a disk-type purifier is used?

1. Clean oil is discharged through the discharge ring; water mixed with sludge and dirt flows upward and is discharged from the neck of the top disk; most of the dirt and sludge collects on the vertical surface of the bowl shell
2. Clean oil is discharged through the discharge ring; water and most dirt and sludge is discharged through the drains; some dirt collects on the vertical surface of the bowl
3. Clean oil flows inward and upward through the disk and is discharged through the neck of the top disk; water mixed with dirt and sludge passes through the discharge ring; most of the dirt and sludge is collected on the vertical walls of the bowl shell
4. Clean oil flows inward and upward and is discharged through the top disk; water, dirt, and sludge, is discharged through the drains

9-24. What is the function of the three-wing device in the tubular-type centrifugal purifier?

1. To maintain a constant oil pressure
2. To cause the liquid to rotate at bowl speed
3. To restrain movement of the bottom of the bowl
4. To accelerate emulsification

9-25. During the purification process, what happens to solid particles that are separated from the dirty oil?

1. They are retained in the drains
2. They are retained in the bowl
3. They are discharged with the water when the purifier is of the disk-type
4. They are discharged with dirt and sludge when the purifier is of the tubular-type

9-26. Oil purifiers are designed to give maximum efficiency when the purifier is operating at

1. minimum speed
2. a speed determined by prevailing conditions
3. a speed between minimum and maximum, and at the rated capacity
4. maximum design speed and rated capacity

9-27. When a purifier is operated as a separator, what essential action precedes the admittance of oil, and why?

1. Priming the bowl with freshwater to prevent losing the oil
2. Priming the bowl with air to prevent water from entering the oil
3. Removing condensate from the bowl to prevent contamination of the oil
4. Venting the bowl to the atmosphere to ensure free flow of oil into the bowl

9-28. The amount of time required to purify a lube oil is largely determined by its

1. density
2. specific gravity
3. viscosity
4. degree of emulsification

9-29. Although heating oil facilitates its purification, excessive heating should be guarded against because oil has a tendency to do which of the following?

1. Oxidize
2. Emulsify
3. Evaporate excessively
4. Do all of the above

9-30. When heating oil for purifying, you should add enough heat to decrease its viscosity to

1. 60 SSU
2. 75 SSU
3. 90 SSU
4. 120 SSU

9-31. If the discharge ring size for the oil in use fails to give satisfactory purification, what should you do?

1. Substitute different size rings until you find the largest possible size that will produce oil-free water discharge
2. Substitute different size rings until you find the smallest possible size that will produce oil-free water discharge
3. Use the next smaller size
4. Use the next larger size

Learning Objective: Identify various sections of the Personnel Qualification Standards (PQS). Textbook pages 208 through 212.

9-32. One objective of PQS is to teach sailors how to do their job through the use of formal classroom instruction.

9-33. PQS describes the knowledge and skills required for a duty assignment.

9-34. In what section of the PQS will you find the basic knowledge to understand specific equipment?

1. Theory
2. System
3. Safety
4. Operation

9-35. Which of the following will you find in section 200.5, Major Parameters?

1. Components of a meter
2. System interrelations
3. Rate of flow
4. System components

9-36. A PQS number of 200.3 indicates that the component parts listed are only

1. those for reference listing
2. those not essential to understanding
3. those essential to understanding
4. those pertaining to emergency systems

9-37. In the PQS usage, people are considered to be at their watchstation anytime they face the equipment and cause it to perform correctly or analyze malfunctions.

9-38. A PQS number of 300.2, operator watchstation, indicates that you will be directed to describe a system's

1. abnormal operation
2. emergency operation
3. normal operation
4. infrequent operation

9-39. What section of the PQS does 300.4 require you to become familiar with?

1. Technician watchstation
2. Normal operation
3. Emergencies and casualties
4. Operating instructions

Learning Objective: Identify the basic concept of the Engineering Operational Sequencing System (EOSS). Textbook page 212.

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9-40. What system has been developed to make the job of supervision and training easier and more effective and also to enhance the operational capabilities of shipboard engineering personnel?

1. Maintenance Data Collecting System
2. Engineering Operational Sequencing System
3. Preventive Maintenance System
4. Maintenance Requirement Cards

9-41. The EOSS is comprised of two subsystems. One consists of a set of detailed written operating procedures using charts, instructions and diagrams developed for a specific ship's engineering plant and configuration. Which of the following is the other subsystem of EOSS?

1. Operational function of all ships
2. Casualty control functions of a specific ship
3. Casualty control functions of all ships
4. PMS schedule of a specific ship

9-42. The operational portion of the EOSS contains all the information necessary for proper operation of a ship's engineering plant.

Learning Objective: Identify several factors necessary for good engineroom watchstanding. Textbook pages 214 and 215.

9-43. Which of the following activities is a part of your duties in standing an engineroom watch?

1. Reading or interpreting measuring instruments
2. Finding out the night orders after relieving the watch
3. Operating a defective piece of equipment
4. Each of the above

9-44. Which of the following knowledge factors are required when standing a main engine throttle watch?

1. Operating procedures for control valves
2. Correct readings for control board gages
3. Steps to be taken if a material casualty occurs
4. Each of the above

Learning Objective: Identify procedures for using the Engineer's Bell Book. Textbook pages 215 through 217.

9-45. Assume that repairs to a drydocked ship have been completed and the ship departs the drydock to head out to sea. During the time that the personnel are at their special sea detail stations, entries in the Engineer's Bell Book should be made by the

1. engineer officer
2. engineering officer of the watch
3. auxiliary man
4. assistant throttleman

9-46. A ship's Engineer's Bell Book is a legal record concerning the time of any change in the movement of the ship's propellers.

When answering items 9-47 through 9-51 assume you are at a throttle control station recording times, signals, and orders on a separate sheet of the Engineer's Bell Book. At the same time, you receive two signals from the bridge -- ahead 1/3 on the engine order telegraph and 35 turns on the engine revolution telegraph.

9-47. What entry do you make in column 1 of your Bell Book sheet?

1. Engine counter reading
2. Time you received the signals
3. Number of propeller turns resulting from the number ordered
4. Number of propeller turns corresponding to the engine order telegraph signal

9-48. What are the respective column 2 and column 3 entries on your sheet?

1. I; 35
2. 35; I
3. 1/3; 35
4. 35; 1/3

9-49. The next signal transmitted by the engine revolution telegraph is for 40 turns. The engine order telegraph stays at 1/3. How should you handle the entries for column 2 and 3 on your sheet?

1. Leave column 2 blank; enter 40 turns in column 3
2. Enter 40 in column 2; leave column 3 blank
3. Enter 1/3 in column 2 and 40 in column 3
4. Enter 40 in column 2 and 1/3 in column 3

9-50. The initials alongside deleted entries are written by the

1. throttleman of the watch
2. engineering officer of the watch
3. engineer officer
4. operations officer

9-51. How do you correct an error you made in recording a signal on a Bell Book sheet?

1. Erase the wrong entry and insert the correction
2. Draw a line through the wrong entry and enter the correction on the next line
3. Circle the wrong entry and insert the correction at the bottom of the sheet
4. Blank out the wrong entry and insert the correction in an adjacent column

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Learning Objective: Identify procedures for placing a steam-driven propulsion plant in readiness to get underway. Textbook page 218.

Your textbook provides a typical procedure for placing a steam-driven propulsion plant in readiness for getting underway. Items 9-52 and 9-53 are concerned with the steps of this procedure.

9-52. When you are readying a steam propulsion plant for operation, the first step is to

1. open funnel drains in main steam line
2. measure cold turbine rotor positions
3. reseat throttle valves slightly
4. open hand-operated nozzles

9-53. Before turning the main engine with steam, which of the following temperatures is required for the lube oil?

1. 50° F
2. 70° F
3. 90° F
4. 100° F

9-54. When must you put the turning gear in operation?

1. Before admitting steam to the sealing glands
2. Before admitting oil to the bearings
3. Before checking the axial clearance of the rotor
4. Before unseating the throttle valves for the first time

Learning Objective: Identify procedures for warming-up and spinning main engines. Textbook pages 218 and 219.

9-55. When should the gland sealing steam be cut in on a steam propulsion plant that is being readied for getting underway?

1. After (or at the same time as) the second stage main air ejector is placed in operation
2. Before the gland exhauster is started
3. Before the turning gear is engaged and functioning
4. Before starting condensate pump

9-56. Steam admitted to the turbine casing or glands when the rotor is stationary is likely to cause

1. distortion of the rotor
2. damage to the gland packing
3. contamination of the lubricating oil
4. water hammer in the steam lines

9-57. The first rotation of a turbine during warming-up operations is normally accomplished by

1. admitting steam to the astern stages of the turbine
2. admitting steam to the main stages of the turbine
3. jacking the turbine manually as steam is admitted to the glands
4. turning the motor-driven turning gear

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9-58. Which procedure should you use to avoid putting way on the ship when the turbines are spun in preparation for getting underway?

1. Alternating between astern and ahead spinning of the engines
2. Cracking the throttle very slightly
3. Admitting steam through the throttle in short bursts
4. Leaving the turbine drains open

9-59. When the main engines have been warmed and tested, what is the next step prior to getting underway?

1. Take the hot rotor positions
2. Spin the main engines
3. Cut-in the first stage of the air ejector
4. Re-align turbine drains

9-60. When a turbine is in operation, why is a steam pressure, ranging usually between 1/2 and 2 psi, maintained on the glands?

1. To eliminate the need for a vacuum
2. To keep air from leaking into the turbine, and steam from leaking from the turbine
3. To increase the pressure and/or vacuum within the turbine
4. To prevent steam leakage at the astern throttle

Learning Objective: Identify the actions to be taken when a turbine begins to vibrate, the use of nozzles to the turbine, and the methods of determining turbine blade clearances. Textbook pages 219 and 220.

9-61. As you increase the speed of your ship's turbine, it begins to vibrate, but vibration ceases with a decrease in speed. What should you do if this condition continues to exist?

1. Discontinue turbine operation except in emergencies
2. Maintain speed below vibration level for several minutes then gradually build up speed
3. Limit speed of turbine below vibration level until the trouble is corrected
4. Alternate between high and low speeds until ship acquires sufficient momentum to eliminate vibration

9-62. How are axial clearances of turbine rotors determined ?

1. By finger pieces
2. By clearance indicators
3. By rotor-position indicators
4. By all of the above

9-63. When checking the fore-and-aft position of the rotor with a finger piece, if the indicator extends into a groove in the shaft, how do you take the readings?

1. From the scale
2. With a feeler gage
3. With a dial indicator
4. Either 2 or 3 is correct

9-64. On the clearance indicator, the positions for maximum and minimum blade clearance of the turbine rotor can be determined by means of

1. feelers
2. a finger piece
3. a contact surface
4. scribed lines on the scale plate

Learning Objective: Recognize periodic checks and inspections which must be made at frequent intervals while the ship is underway. Textbook pages 211 and 212.

9-65. Within what range should the temperature of the lube oil from the cooler be maintained when a ship is underway?

1. 90° to 100° F
2. 100° to 110° F
3. 110° to 120° F
4. 120° to 130° F

9-66. Which of the following conditions is an indication that water is entering a lube oil system?

1. Increase in oil pressure
2. Decrease in oil temperature
3. Rise in oil level
4. Drop in oil level

9-67. When a ship is underway, an immediate result of admitting large quantities of cold water to the deaerating feed tank is a

1. temporary loss of a main engine
2. gain of pressure in the tank
3. loss of main feed booster pressure
4. sudden demand for feedwater for the boilers

9-68. You are the Machinist's Mate on duty in the engineroom of a ship underway. Which of the following conditions should indicate to you that an investigation of possible trouble is in order?

1. The turbine vibrates as you increase its speed, but the vibration is eliminated after operating the turbine at a slower speed for a few minutes before increasing the speed again
2. Sound of the main engine differs from the normal sound of the engine
3. The gland sealing steam pressure is 1.5 psi
4. The oil temperature is 125° F

9-69. Assume that the temperature of a bearing on the main engine shaft rises rapidly. What step should you take first to guard against a casualty due to overheating?

1. Cool the bearing with water from a fire hose
2. Check the amount and quality of the oil at the bearing
3. Slow the engine down
4. Shift the lube oil strainers

Learning Objective: Identify the various facets of Engineering Casualty Control. Textbook pages 223 through 225.

9-70. Why should vacuum never be broken through the turbine glands?

1. Foreign matter may enter and contaminate the condenser
2. The turbine glands may be damaged
3. The turbine rotor may be distorted
4. Foreign matter may be carried into the bearings and cause scoring

9-71. Which of the following is the best form of casualty control?

1. Continuous inspections
2. Effective organization
3. Casualty training
4. Casualty prevention

9-72. After an engineering casualty occurs, it is too late to study. Which of the following is the best source material for studying casualty control?

1. The NAVSHIPS' Technical Manual
2. This Rate Training Manual
3. The Watch Quarter Station Bill
4. The Engineering Operation and Casualty Control Manual

9-73. On a drop in fire main pressure, wood chips were found in the strainer. Which of the following actions should be taken?

1. Check the sea chests
2. Check all strainers
3. Check all injectors
4. Each of the above is correct

9-74. A leaking condenser can disable its associated boiler and turbine. Which of the following would be affected by the loss of one boiler?

1. Mobility
2. Habitability
3. Ability to control flooding
4. Each of the above

9-75. Who has the responsibility for deciding whether or not to steam the ship in a casualty condition?

1. Engineer Officer of Watch
2. Division officer
3. Damage control officer
4. Commanding officer

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Assignment 10

Steam-Operated Distilling Plant

Textbook Assignment: Chapter 10

Learning Objective: Specify operating principles and functions of components of the submerged tube distilling plant. Textbook pages 227 through 233.

10-1. A steam-operated distilling plant produces distilled water from seawater through the use of an evaporation process followed by condensation.

10-2. Naval distilling plants are NOT able to remove all biological contaminants.

10-3. Distilling plants are able to separate volatile gases from distillate.

10-4. Distilling plants will NOT kill all microorganisms because the water is NEVER brought to a boil.

10-5. Saltwater in the distillate because of carryover is most likely caused by

1. faulty salinity cells
2. leaks in the tube nests
3. leaks in the basket
4. improper operation

10-6. Why is carryover undesirable?

1. Chemical salts cause corrosion of boiler tubes
2. Coliform bacteria may be present
3. The distillate is not sterilized
4. Each of the above is correct

10-7. Why are Navy distilling plants operated at low pressure?

1. To prevent carryover
2. To increase efficiency
3. To sterilize the distillate
4. Each of the above is correct

In items 10-8 through 10-10 select the term from column B that is defined in column A.

	Column A	Column B
10-8.	The end product of an evaporator	1. Distillation
10-9.	The saltwater that is boiled to produce a vapor	2. Evaporation
10-10.	The process of separating seawater into vapor and brine	3. Feed
		4. Distillate

In items 10-11 through 10-13 select the term from column B that is defined in column A.

	Column A	Column B
10-11.	A measurement of the concentration of chemical salts	1. Brine
10-12.	The stage of an evaporator	2. Salinity
10-13.	Any water in which the salt content is higher than it is in seawater	3. Effect
		4. Evaporator feed

10-14. What is the degree of superheat of steam at 100.82° C with 23.81 in. Hg gage?

1. 60.82° C
2. 50.22° C
3. 30° C
4. 40° C

10-15. The vapor compressor type evaporator uses electrical energy to heat the water and to operate the compressors.

10-16. Which of the following ships have vapor compression distilling units?

1. Aircraft carriers
2. Frigates
3. Nuclear submarines
4. Destroyers

10-17. Why are the low-pressure distilling units called low pressure?

1. Because they use low-pressure steam
2. Because they operate below atmospheric pressure
3. Because of both 1 and 2 above
4. Because of the low pressure on the feed

10-18. In the submerged tube evaporator the tubes contain

1. feed
2. low-pressure steam
3. brine
4. distillate

10-19. In the Soloshell evaporator, which of the following controls the amount of steam admitted to the tubes?

1. Relief valves
2. Reducing valve
3. Each of the above
4. Orifice plate

When answering items 10-20 through 10-37, refer to figure 10-3 in your textbook.

10-20. Which device maintains a pressure of approximately 5 psi to the tube nest of the first-effect evaporator?

1. Relief valve
2. Orifice plate
3. Spring-loaded back-pressure valve
4. Reducing valve

10-21. The volume of distilled water produced by the plant depends on the

1. setting of the regulating valve in the exhaust steam line to the first-effect evaporator
2. size of the orifice plate in the exhaust steam line to the first-effect evaporator
3. capacity of the vapor feed heater in the first-effect shell
4. number of baffles in the vapor separator of the second-effect shell

10-22. To which process is low-pressure exhaust steam subjected before it passes into the first-effect tube nest?

1. Heating by steam from the 150-psi system
2. Superheating by a spray of water
3. Desuperheating by a spray of water
4. Volume reducing by increased steam pressure

10-23. Condensate from the first-effect tube nest is pumped to the

1. distillate cooler
2. vapor feed heater
3. air ejector condenser
4. freshwater drain tank or the main or auxiliary condenser

10-24. The condensate from the first-effect tube nest which is returned to the boiler feed system is used to

1. generate vapor from the feedwater in the second-effect evaporator shell
2. provide feed to the first-effect evaporator
3. desuperheat the auxiliary exhaust steam
4. help stabilize the heat and water content of the system

10-25. Steam generated in the evaporator shells by the evaporation of feedwater is referred to as

1. distillate
2. vapor
3. superheat
4. drain

10-26. What is the purpose of the baffles and vanes in the evaporator shell?

1. To cool off the vapor
2. To slow down the vapor
3. To separate small amounts of unevaporated feedwater from the vapor
4. To desuperheat the vapor

10-27. Before entering the second-effect evaporator, vapor from the first-effect separator passes into the

1. first-effect drain regulator
2. vapor feed heater
3. boiler feed system
4. freshwater tanks

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10-28. What change takes place in the first-effect vapor which reaches the tube nests of the second-effect evaporator?

1. It gains latent heat of vaporization from the second-effect feed
2. It gains latent heat of vaporization from a second-effect steam supply
3. It loses its latent heat of vaporization to the second-effect feed
4. It loses its latent heat of vaporization to a second-effect steam supply

10-29. Why is first-effect vapor able to boil and vaporize the seawater feed in the second-effect shell?

1. Pressure is higher in the first-effect shell than in the second-effect shell
2. Pressure is lower in the first-effect shell than in the second-effect shell
3. Vapor and distillate are superheated on entering the second-effect shell
4. Vapor and distillate are desuperheated on entering the second-effect shell

10-30. Latent heat of vaporization given off in the distilling condenser is used to

1. desuperheat incoming vapor
2. boil feedwater in the first-effect shell
3. heat incoming seawater
4. superheat vapor in the first-effect separator

10-31. The distillate pump is used to pump the distillate from the flash chamber to which of the following?

1. Feedwater tank
2. Test tank
3. Potable water system
4. Each of the above

10-32. What happens to the seawater that passes through the tubes of the distilling condenser?

1. All is discharged overboard
2. All is directed to the boiler feed system
3. Part is used as first-effect feed; the rest is discharged overboard
4. Part is directed to the boiler feed system; the rest goes to the second-effect shell

10-33. After entering the first-effect shell, some of the feedwater is evaporated. The rest of the feedwater (brine) is forced into the second-effect shell by

1. gravity
2. the condenser circulating pump
3. the pressure difference between the first effect and second effect
4. a tube-nest drain pump

10-34. What means is provided to permit the first- and second-effect shells to be drained rapidly?

1. Regulating valves in the piping
2. Perforated pipes in each effect
3. Portable pump connections
4. Suction connections leading directly to the brine overboard pump

10-35. What is the function of the circulating water at the brine overboard pump?

1. To provide cooling
2. To dilute the brine
3. To seal the gland
4. Each of the above is correct

10-36. Which of the following maintains the vacuum in the second effect?

1. Air ejector
2. Condensation of steam in the vapor feed heater
3. Cooling effect of carbon dioxide
4. Steam condensed by the evaporator feed

10-37. A salinity cell is located at the discharge of the tube nest drain pump. Where is the tube nest drain pump located in figure 10-3 of the textbook?

1. Lower right-hand side
2. Upper right-hand side
3. Lower left-hand side
4. Upper left hand side

10-38. Salinity cells are installed in a pipe joint similar to a thermometer fitting.

Learning Objective: Point out operating principles of a flash-type distilling plant and specify functions of the components. Textbook pages 234 through 239.

Items 10-39 through 10-52 pertain to a two stage, flash-type distilling plant. Refer to figure 10-6 in your textbook.

10-39. Feedwater for the distilling plant is preheated before reaching the feedwater heater as it circulates through which of the following?

1. The distillate cooler
2. The air ejector condenser
3. The stage distilling condensers
4. All of the above

10-40. As feedwater passes through the evaporator feedwater heater, final heating of the feed is done by

1. an electric heater
2. auxiliary exhaust steam
3. high-pressure steam
4. brine overflow

10-41. Heated feedwater enters the first-stage shell by way of spray pipes located in the

1. stage distilling condensers
2. stage vapor separators
3. bottom of the first-stage shell
4. second-stage internal feed box

10-42. Water in the feed circuit absorbs latent heat of condensation from which of the following?

1. Vapor condensed by the feed in the first-stage condenser
2. Vapor condensed by the feed in the second-stage condenser
3. Steam condensed by the feed in the air ejector condenser
4. All of the above

10-43. Unvaporized feedwater in the first-stage flash chamber passes to the

1. brine overboard line
2. evaporator feedwater heater
3. second-stage shell
4. low-pressure drain system

10-44. Why does the heated seawater vaporize in the shells of the distilling plant?

1. Pressure in the shell is higher than the saturation pressure corresponding to the temperature of the seawater
2. pressure in the shells is lower than the saturation pressure corresponding to the temperature of the seawater
3. Temperature of the seawater is decreased
4. Pressure in the shell is higher than atmospheric pressure

10-45. Brine from the second-stage shell is discharged to the

1. brine overboard line
2. evaporator feedwater heater
3. first-stage flash chamber
4. low-pressure drain system

10-46. The water from the demisters of the first stage drains to the

1. distillate of the first stage
2. feed section of the first stage
3. feed section of the second stage
4. hotwell

10-47. If the maximum allowable salinity of the distillate is exceeded, a salinity cell automatically trips the solenoid valve, dumping the contaminated distillate to the bilge. This salinity cell is located in the

1. inlet to the distillate pump
2. outlet from the distillate pump
3. inlet to the first-stage drain regulator
4. outlet to the feedwater heater drain pump

10-48. After distillate from the second stage leaves the distillate pump outlet, it travels to the ship's tanks by way of the solenoid trip valve and a flowmeter.

10-49. One of the functions of the air ejector is to

1. remove heat from the feed
2. regulate the brine density
3. maintain the required vacuum at the second-stage distilling condenser
4. discharge noncondensible gases to the atmosphere

10-50. When the distilling plant is being started, to which process is supply steam subjected before it enters the shell of the evaporator feedwater heater?

1. Heating by steam from a 150-psi system
2. Superheating by a spray of cold water
3. Desuperheating with water from the feedwater heater
4. Desuperheating with water from the ship's condensate system

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10-51. The drain regulator in textbook figure 10-6 maintains the required level in the suction line between the feedwater heater and its drain pump by throttling the pump discharge which passes through the control valve.

10-52. In the two-stage flash type evaporator, where are the two three-way solenoid trip valves located?

1. At the loop seal and the distillate pump
2. At the loop seal and the air ejector drain
3. At the distillate pump outlet and the air ejector drain
4. At the seawater heater drain and at the loop seal

When answering items 10-53 through 10-57, refer to the five-stage flash type distilling unit in textbook figure 10-8.

10-53. 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

10-54. What must be done to control the rise of feed temperature?

1. Manually control the amount of feedwater flowing through the feedwater heater
2. Keep all valves in the feed line wide open
3. Keep the steam pressure above the orifice at a constant 5 psig
4. Manually control the temperature in the first-stage flash box

10-55. The five-stage flash unit rate of feed is constant if the plant is producing its normal capacity. How is the feed rate indicated?

1. Brine overflow
2. Feedwater temperature
3. Feed rotameter
4. Steam pressure

10-56. What is the maximum design feedwater temperature?

1. 75° F
2. 85° F
3. 165° F
4. 175° F

10-57. How can the capacity of a flash type evaporator be increased?

1. Increase the volume of feed to the first stage
2. Increase the heat of the feedwater
3. Decrease vacuum in the first stage
4. Decrease the heat of the feedwater

Learning Objective: Point out operating principles of the vertical basket distilling plant and specify functions of the components. Textbook pages 239 through 244.

10-58. Vertical basket distilling plants are rated at 7,000 gpd.

10-59. The corrugated basket and evaporator shell are one and the same shell.

10-60. In figure 10-10 in the textbook, the trip valve and the pressure switch or sensor are shown on each side of the reducing valve. What is the normal steam pressure on each?

	Trip Valve	Trip Sensor
1.	220 psig	20 psig
2.	180 psia	5 psia
3.	194.7 psia	20 psig
4.	180 psig	5 psia

10-61. The condensed steam in the bottom of the basket flows into the

1. distiller condenser
2. main condenser
3. distillate outlet
4. distillate trough

10-62. Which of the following is called the first stage of moisture separation?

1. Perforated plate
2. Mist eliminator
3. Distiller condenser
4. Air ejector

10-63. Which of the following changes the vapor to distillate?

1. Perforated plate
2. Mist eliminator
3. Distiller condenser
4. Each of the above

10-64. There is a salinity cell on each side of the distillate cooler. If the salinity cell on the discharge side of the cooler reads considerably higher than the inlet side, which of the following is probably the cause?

1. The discharged distillate is cooler
2. The cooling water is leaking into the distillate
3. The salinity cells are faulty
4. The distillate pump is leaking

10-65. In a submarine, whenever the brine becomes too salty, it is dumped into the brine tank and diluted.

10-66. Seawater is fed to several units of the 8K evaporator. In what sequence should these units receive the seawater?

A. Air ejector
B. Distillate cooler
C. 8K evaporator
D. Distiller condenser

1. B, A, D, C
2. B, C, A, D
3. B, D, A, C
4. D, B, C, A

10-67. Which of the following is used to measure the rate of flow of feedwater to the 8K evaporator?

1. Flowmeter
2. Differential pressure gage
3. Differential flowmeter
4. Sight glass

10-68. Which of the following establishes the vacuum in the 8K evaporator shell?

1. Distiller condenser
2. Air vent
3. Distillate cooler
4. Air ejector

10-69. Which of the following normally receives the chemicals from the feed treatment tank?

1. Distiller condenser
2. Distillate cooler
3. Air ejector condenser
4. 8K evaporator

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Assignment 11

Steam Operated Distilling Plant (Continued); Refrigeration

Textbook Assignment: Chapter 10 (Continued); and Chapter 11

Learning Objective: Point out operating principles and specify function of components of the distilling plant. Textbook pages 245 through 248.

11-1. What weight of seawater, when evaporated, will yield about 1 pound of salt?

1. 16 lb
2. 32 lb
3. 48 lb
4. 64 lb

11-2. The usual effect of a too high brine concentration in the evaporator is an increase in the

1. air ejector suction
2. amount of brine pumped overboard
3. pressure of the steam line
4. rate of evaporator tube scaling

11-3. Brine salinometers indicate the salinity when the brine temperature is

1. 110°, 115°, 120°, or 125° F
2. 130°, 135°, 140°, or 145° F
3. 150°, 155°, 160°, or 165° F
4. 170°, 175°, 180°, or 185° F

11-4. The salinometer in figure 10-12 in your textbook is calibrated to read directly in thirty-seconds.

11-5. How often should a salinometer be checked?

1. Daily
2. Weekly
3. Monthly
4. Semiannually

11-6. The results of tests of distillate for salt is stated in either ppm or ekm.

11-7. A salinity cell reading is based on the conductivity of saltwater and pure water; the more salt, the higher the reading.

11-8. Foreign substances (other than salt) in distillate can cause a false reading in a salinity indicator.

11-9. When the salinity of the distillate from an evaporator reaches 0.5 ppm the three-way solenoid valve will trip and cause the distillate to go to the contaminated waterline. Which of the following operates the trip mechanism?

1. Magnetism
2. Spring pressure
3. Gravity
4. Hydraulic pressure

11-10. A salinity cell in the loop seal between the first and second stage of a flash-type evaporator will operate which of the following?

1. An alarm
2. A meter
3. Both 1 and 2 are correct
4. A valve

11-11. A low concentration of chloride in boiler feedwater indicates that saltwater has leaked into the system.

Learning Objective: Specify and identify methods and techniques to be used in maintenance, feedwater treatment, and cleaning of the distilling plants. Textbook pages 249 to 252.

11-12. Scale deposits on the evaporator tubes of a submerged tube distilling plant will cause a reduction in output which becomes measurable when the deposits reduce the first-effect, tube-nest vacuum to

1. 1 or 2 inches of mercury
2. 4 or 6 inches of mercury
3. 8 or 10 inches of mercury
4. 12 or 14 inches of mercury

11-13. Under normal operating conditions, what is the usual interval between cleaning of air ejector condenser tubes?

1. 3 months
2. 6 months
3. 9 months
4. 12 months

11-14. In a distilling plant that uses seawater feed, what condition should be maintained to keep the formation of hard scale to a minimum?

1. Steam pressure above orifice not to exceed 5 psi
2. High vacuum
3. Brine density not to exceed 1.5 thirty-seconds
4. Each of the above

11-15. Evaporator feedwater is treated with PD-8 or Ameroyal for the purpose of reducing the

1. rate of tube scaling
2. amount of insoluble suspended matter
3. quantity of soluble carbonates
4. priming

11-16. PD-8 solution is prepared by dissolving the required amount of PD-8 in warm water and diluting with enough cold water to make a batch totaling

1. 12 gal
2. 18 gal
3. 24 gal
4. 30 gal

Items 11-17 through 11-23 pertain to the procedure for injecting chemicals into the distilling plants.

11-17. A duplex pump may be used to inject chemicals into two separate distilling plants when the plants

1. are in different compartments
2. vary in output by not more than 4,000 gpd
3. are in separate compartments but have equal distilling capacity
4. are equal in distilling capacity and are in the same compartment

11-18. You find that a pump stroke of 15% will be required to empty the mixing tank in 24 hours. You should adjust the stroke so that the tank will empty in

1. 4 or 8 hours
2. 8 or 12 hours
3. 12 or 16 hours
4. 16 or 20 hours

11-19. If the proportioner pump fails, the operator feeds the chemical solution into the evaporator by means of a vacuum injection line and controls the flow by the use of

1. a standby pump
2. a feed control valve
3. an adjusting screw
4. a needle valve

11-20. How much PD-8 is recommended for a 12,000 gpd submerged tube type distilling plant?

1. 1.2 pounds every 24 hours
2. 1.5 pounds every 12 hours
3. 2.0 pounds every 24 hours
4. 2.6 pounds every 12 hours

11-21. What is the correct injection rate for Ameroyal?

1. 1 pint per day for a 10,000 gpd plant
2. 2 pints per day for an 18,000 gpd plant
3. 1 pint per day for a 12,000 gpd plant
4. 3 pints per day for a 12,000 gpd plant

11-22. You can determine how well the PD-8 feedwater treatment is functioning by

1. examining the evaporator for sludge
2. examining the evaporator for scale
3. checking the shell temperature in the feedwater heater
4. observing the condition of the mixing tank during draining and flushing

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11-23. In accordance with the Planned Maintenance System, when will the mixing tank for PD-8 evaporator treatment be drained and flushed?

1. Quarterly
2. Weekly or more often if necessary
3. Annually
4. Monthly

11-24. What is an indication that the flash-type unit needs cleaning?

1. A 4-psig steam pressure in the evaporator feedwater heater is required to produce rated capacity
2. A 4-psig steam pressure in the first-effect steam chest is required to produce rated capacity
3. The first-effect, tube-nest vacuum is near zero
4. The first-effect, tube-nest temperature approaches that of the steam supply

11-25. Which of the tube nests of a distilling plant tends to collect scale most rapidly?

1. First-effect
2. Second-effect
3. Third-effect
4. Fourth-effect

11-26. How do you chill shock the first-effect evaporator tube-nest of a distilling plant?

1. Cut out steam flow to the tubes and quickly flood them with cold water
2. Cut out flow of water to the tubes and increase the flow of steam
3. Drain brine from the shells and admit water into the tubes
4. Drain brine from the shells, reflood them with water and admit steam into the tubes

11-27. How often should a distilling plant be chill shocked when no feed treatment is used?

1. Daily
2. Weekly
3. Semimonthly
4. Semiannually

11-28. What causes scale, on the outside of the corrugations of the vertical basket or the tubes of the submerged tube type evaporator, to break loose during chill shocking?

1. Pressure changes
2. Temperature changes
3. Expansion and contraction of the metal
4. Saturation of the scale by the condensation

11-29. After the tube nest has been removed from a submerged tube type evaporator, the tubes are cleaned mechanically by a/an

1. electric torch
2. scaling tool
3. abrasive
4. electric vibrator

11-30. After cleaning and before placing the tube nest in service, you subject the bundle to a hydrostatic test of

1. 25 psi
2. 50 psi
3. 75 psi
4. 100 psi

11-31. Which of the following units can be cleaned only after it is removed from the distilling plant?

1. Distilling condenser on soloshell double-effect plants
2. Distilling condenser on triple-effect plants
3. Air ejector condenser on two-shell double-effect plants
4. Air ejector condenser on soloshell double-effect plants

11-32. Which of the following types of distilling plants has a minimum amount of scale formation?

1. Vertical basket type
2. Submerged tube double-effect type
3. Submerged tube triple-effect type
4. Flash type

11-33. The acids commonly used for the chemical cleaning of evaporator parts are

1. nitric and sulfuric
2. sulfamic and nitric
3. hydrochloric and sulfamic
4. sulfuric and hydrochloric

11-34. Under which of the following conditions may sulfamic acid be stored safely aboard ship?

1. When transferred from original to special containers
2. When stored in original containers
3. When in solution form
4. Under all the above conditions

Learning Objective: Identify the terms related to principles of refrigeration and heat. Textbook pages 255 and 256.

11-35. The refrigerant R-12 has been known to contaminate eggs.

11-36. Refrigeration is a general term that describes which process?

1. Removes heat from spaces, objects, or materials
2. Allows heat to flow in its natural direction, that is, from warmer material to the colder material
3. Both 1 and 2 above
4. Converts heat into work

11-37. How does a refrigeration unit freeze water?

1. Reduces the pressure of the water
2. Removes heat from the water
3. Adds coolness to the water
4. By doing both 2 and 3 above

11-38. Select the statement below that correctly differentiates between heat and temperature.

1. Heat is a form of energy, and temperature is a measurement of the energy
2. Heat is a form of energy, and temperature is the intensity of the heat
3. Heat is thermal energy measured in Btu's, and temperature is thermal energy measured in degrees
4. Heat is thermal energy absorbed by a substance, and temperature is thermal energy given off by a substance

11-39. The amount of heat removed from a material is measured in terms of a standard unit called

1. a refrigeration ton
2. a total heat
3. a British thermal unit
4. a sensible heat

For items 11-40 through 11-42, select from column B the definition or example that applies to the heat identification term in column A.

A. Terms	B. Definitions or examples
11-40. Sensible heat	1. Heat absorbed by a man's body after he steps from a cold room into a warm room
11-41. Latent heat	2. Quantity of heat required to raise the temperature of unit mass of a substance
11-42. Specific heat	3. Heat absorbed by a block of melting ice
	4. The ability of a substance to absorb or give off heat without change in temperature

---

11-43. Heat flows from hot objects to cold objects by

1. convection
2. conduction
3. radiation
4. one or more of the above methods

11-44. What is the latent heat of fusion of a pound of ice?

1. 36 Btu
2. 72 Btu
3. 144 Btu
4. 288 Btu

11-45. Approximately how much heat must be removed from 1 ton of water at 32° F to change the water to ice at 32° F?

1. 36 Btu
2. 72 Btu
3. 12,000 Btu
4. 288,000 Btu

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Learning Objective: Identify the basic relationship of pressure, temperature, and volume of a gas. Textbook pages 246 through 257.

11-46. At which of the following temperatures will water boil?

1. 100° F at 14.7 psia
2. 80° F at 29 in. vacuum
3. 450° F at 600 psig
4. Both 2 and 3 are correct

11-47. At which of the following temperatures will R-12 boil?

1. -20° F at 14.7 psig
2. -21° F at 14.7 psia
3. +45° at 46.49 psig
4. Both 2 and 3 are correct

11-48. Before a confined quantity of vapor can be superheated, it must be

1. separated from the liquid from which it was generated
2. in contact with the boiling liquid
3. held at a constant pressure
4. allowed to decrease in volume

● For items 11-48 through 11-59 assume that a cylinder with a floating piston contains 5 cubic feet of air on each side (a and B) of the piston. The absolute air pressure on each side of the piston is 200 psi and the absolute temperature is 500° F.

11-49. If you pump air into side A to increase the pressure in side B to 250 psia, and constant temperature is maintained, what is the new volume in side B?

1. 7 cu ft
2. 6 cu ft
3. 5 cu ft
4. 4 cu ft

11-50. If you decrease the temperature in side A to 400° F absolute without changing its pressure, and with no increase in temperature in side B, what is the new volume in side A?

1. 7 cu ft
2. 6 cu ft
3. 5 cu ft
4. 4 cu ft

11-51. What is the effect of a 30° F temperature increase on both sides of the piston?

1. A small decrease in both pressure and volume
2. A small increase in both pressure and volume
3. A 12-psia decrease in pressure
4. A 12-psia increase in pressure

11-52. When the gas in a tank has an increase in temperature, the column will (a) and the pressure will (b)

1. (a) decrease. (b) decrease
2. (a) remain the same. (b) remain the same
3. (a) increase. (b) remain the same
4. (a) increase, (b) decrease

11-53. When the pressure on a gas increases the temperature will (a); however, when the pressure decreases the temperature will (b)

1. (a) rise, (b) lower
2. (a) lower, (b) rise
3. (a) lower, (b) remain the same
4. (a) remain the same, (b) lower

Learning Objective: Point out the most common type of refrigeration plant used aboard Navy ships, and identify the major components and their functions. Textbook pages 258 through 270.

11-54. What type of refrigeration system is generally used for shipboard refrigeration?

1. Vapor compression cycle with centrifugal compressors
2. Steam-jet systems with reciprocating compressors
3. Vapor compression cycle with reciprocating compressors
4. Steam-jet systems with centrifugal compressors

● Items 11-55 through 11-70 refer to figure 11A.

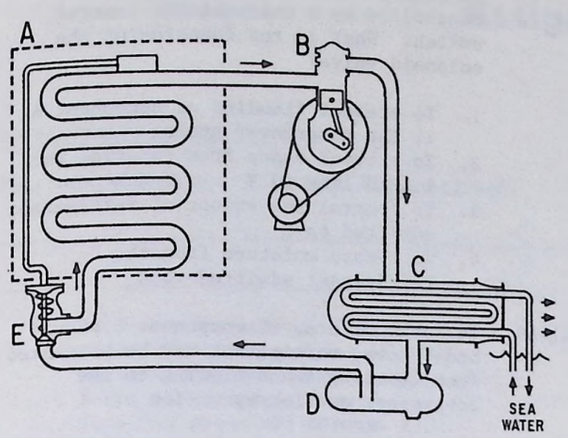


Figure 11A

11-55. Which of the following is the correct sequence of flow of refrigerant through the system?

1. Receiver, expansion valve, evaporator, compressor, condenser, receiver
2. Receiver, evaporator, expansion valve, condenser, compressor, receiver
3. Receiver, condenser, compressor, evaporator, expansion valve, receiver
4. Receiver, expansion valve, compressor, condenser, evaporator, receiver

11-56. Pressure of the liquid is reduced in part

1. B
2. C
3. D
4. E

11-57. Heat is absorbed by the R-12 refrigerant in part

1. A
2. C
3. D
4. E

11-58. R-12 is in liquid form in the system when it is between components

1. A and B
2. B and C
3. D and E
4. E and A

11-59. The low-pressure side of the refrigeration system lies between components

1. A and B
2. B and C
3. B and D
4. E and B

11-60. The operation of component E is controlled by a device located in component

1. A
2. B
3. C
4. D

11-61. What causes component E to open and permit the flow of liquid into A?

1. A decrease in pressure in the cooling coil
2. A decrease in pressure in the control bulb
3. An increase in pressure on the top of the diaphragm
4. An increase in pressure on the bottom of the diaphragm

11-62. What changes occur in the physical state of the R-12 as it passes through component A?

1. It changes from a boiling liquid to superheated vapor
2. It changes from superheated vapor to a boiling liquid
3. It changes from a cool liquid to a hot vapor
4. It changes from a hot vapor to a cool liquid

11-63. Which component pumps heat, absorbed by the refrigerant, from the evaporator to the condenser?

1. A
2. B
3. C
4. D

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11-64. What is the primary function of component B?

1. To raise the temperature of liquid R-12 to the point where it will boil and vaporize completely before entering component C
2. To raise the pressure of liquid R-12 to the point where its temperature at this pressure is high enough to cause it to boil and vaporize completely before entering component C
3. To raise the pressure of vaporized R-12 to the point where its temperature at this pressure is high enough above the temperature of the cooling seawater to cool the R-12 and condense it as it passes through component C
4. To raise the pressure of vaporized R-12 to the point where its superheat at this pressure amounts to 10° F

11-65. What is/are a subsidiary function(s) of component B?

1. To condense the vapor
2. To keep the required pressure differential between the low side of the system and the high side
3. To circulate the R-12 through the system
4. To do both 2 and 3 above

11-66. What is the result of the changes that take place in the R-12 on passing through component C?

1. It evaporates and, as a vapor, absorbs its latent heat of vaporization
2. It condenses and, as a liquid, gives off its superheat
3. It absorbs its latent heat of vaporization, evaporates completely, and in the vaporized state, absorbs sensible heat
4. It gives up its sensible heat, condenses and gives off its latent heat

11-67. The entrance of vapor into the liquid line leading to the expansion valve is prevented by component

1. A
2. B
3. C
4. D

11-68. In a system having more than one evaporator, the solenoid valve is located between D and E and is controlled by a thermostatic control switch. What is the function of the solenoid valve?

1. To prevent flooding of component A if the compressor stops
2. To prevent vapor from entering the liquid line to E
3. To control the amount of refrigerant admitted to E
4. To remove moisture from the refrigerant admitted to E

11-69. In large plants, if component B should break down, refrigerant may be prevented from flooding A and flowing to the compressor suction by action of

1. an evaporator pressure-regulating valve between A and B
2. a low-pressure cutout switch between B and C
3. a spring-loaded relief valve between C and D
4. a solenoid valve between D and E

11-70. A regulating valve that is used for adjusting the temperature difference between the compartment and the surface of the cooling coils is located between

1. A and B
2. B and C
3. D and E
4. E and A

Assignment 12

Refrigeration (Continued)

Textbook Assignment: Chapter 11 (Continued)

Learning Objective: Identify the principles of operation of the various accessories and controls for a refrigeration system. Textbook pages 263 through 273.

12-1. Which of the following types of lubrication is used on high-speed compressors?

1. Gravity feed lubrication
2. Splash lubrication
3. Pressure lubrication
4. Self-lubrication

12-2. Where is the rotary seal shown in figure 11-6 of the textbook, adjusted?

1. Between the crankshaft and the rotating carbon rings
2. Between the cover plate and carbon rings
3. Between the crankshaft shoulder and compression spring
4. Between the crankshaft and cover plate

12-3. Where is the stationary bellows seal shown in figure 11-7 of the textbook, adjusted?

1. Between the crankshaft and the bellows
2. Between the crankshaft and the shaft seal collar
3. At the factory
4. Between the surface of the seal collar and bellows nose

12-4. In the rotating bellows seal, shown in figure 11-8 of the textbook, what is used to seal the surfaces between the removable shaft seal shoulder and the crankcase?

1. Neoprene gasket
2. Shaft seal clamping nut
3. Lapped surfaces
4. Nitralloy collar

12-5. In the diaphragm-type seal, shown in figure 11-9, which of the following sealing points are made at the factory?

1. Between the diaphragm and the crankcase
2. Between the fulcrum ring and the rotating shaft seal collar
3. Between the diaphragm and the fulcrum ring
4. Between the shaft seal collar and the crankshaft shoulder

12-6. Which of the following is used to load compressors?

1. Oil pressure
2. Refrigerant pressure
3. Refrigerant suction
4. Water pressure

12-7. When does the compressor take on a load?

1. When the compressor is at 1/3 speed
2. When the compressor is at 1/2 speed
3. When the compressor is up to speed
4. When the compression valve is closed

12-8. After the compressor has reached full speed, when does the capacity control system start to unload the compressor?

1. When the shaft seal bursts
2. When the system is overcharged
3. When the pulldown period is completed
4. When the pulldown period begins

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12-9. In figure 11-10 of the textbook the working pressures that operate the hydraulic relay (C) are developed by the

1. spring and the control oil pressure
2. spring and the oil pump pressure
3. control oil pressure and the oil pump pressure
4. control oil pressure and the crankcase pressure

12-10. In figure 11-10 of the textbook, what forces piston (F) of the unloader power element E first up, then down?

1. Oil pump pressure; crankcase pressure
2. Oil pump pressure; spring
3. Crankcase pressure; spring
4. Spring; oil pump pressure

12-11. Which of the following controls the capacity control system?

1. Unloader power element
2. Capacity control valve
3. Hydraulic relay
4. Suction valve

12-12. Which of the following controls the amount of oil that reaches the unloader power element?

1. Hydraulic relay piston (D)
2. Lifting fork (G)
3. Suction valve (I)
4. Orifice

12-13. A moisture indicator will detect an excess of moisture if humidity is high in the ice machine room.

12-14. When temperatures in the refrigerated space drop below the setpoint, the solenoid control valve (a) and the flow of refrigerant (b).

1. (a) opens, (b) stops
2. (a) closes, (b) stops
3. (a) opens, (b) starts
4. (a) closes, (b) starts

Items 12-15 through 12-21 pertain to the following control and safety devices:

A. Spring-loaded relief valve
B. Water regulating valve
C. Low-pressure cutout switch
D. Evaporator pressure regulating valve
E. High-pressure cutout switch
F. Water failure switch
G. Oil failure switch

12-15. If the pressure setting of the device is too low, water will freeze in a water cooler equipped with a

1. B
2. D
3. E
4. F

12-16. Which device controls operation of the compressor under normal conditions?

1. C
2. D
3. E
4. G

12-17. The compressor will stop when the pressure reaches cutout point and start when the pressure drops to reset point provided you correctly set the

1. B
2. C
3. D
4. E

12-18. Functioning of which device is dependent upon failure of the high-pressure cutout switch?

1. A
2. B
3. D
4. F

12-19. The proper rate of cooling water flow through the condenser is maintained by the

1. A
2. B
3. D
4. F

12-20. The primary function of the water regulating valve is to maintain a constant refrigerant condensing pressure.

12-21. What device will perform the intended function of F, if F fails to function?

1. A
2. B
3. C
4. E

12-22. What device in the refrigerant liquid line protects the solenoid valve and thermostatic expansion valves from foreign matter?

1. TXV
2. Liquid strainer
3. Dehydrator
4. Thermometer

12-23. Why is copper used to make refrigerator tubing for modern naval installations?

1. Copper internal surfaces are smooth enough to minimize friction
2. Copper is not corroded by refrigerant
3. Copper tubing is easily shaped to meet refrigeration requirements
4. For all the above reasons

12-24. Refer to textbook figure 11-19. The upper cavity of the packless valve is sealed off from the lower cavity by a

1. diaphragm
2. ball check
3. balancing port
4. lower stem

Learning Objective: Specify the procedures for starting, operating, and securing a refrigeration system. Textbook pages 274 through 276.

12-25. How often should a refrigeration system's temperatures and pressures be checked in the absence of specific instructions that state otherwise?

1. Hourly
2. Every 2 hours
3. Once each watch
4. Daily

12-26. When water is taken from a firemain, the pressure reducing valve ahead of the water regulating valve should be set so that the water pressure will NOT be more than

1. 15 psi
2. 25 psi
3. 35 psi
4. 45 psi

12-27. When starting an air-cooled compressor unit, ensure that all valves to the water failure switch are closed.

12-28. Before setting the controls on automatic, you should check the operating condition of the motor and compressor by

1. cracking the compressor-suction valve
2. starting and stopping the units several times
3. bringing the discharge pressure to 125 psi
4. checking the temperatures of the unit with all refrigerant system valves closed

12-29. Which of the following indicates that liquid refrigerant is being drawn into the compressor?

1. Frost on the compressor crankcase
2. Frost on suction valve
3. Unusual knocking of compressor
4. Each of the above is correct

12-30. When lubrication of the compressor is provided by forced feed, in what range above compressor suction pressure should the operating oil pressure generally be?

1. 15 to 30 psi
2. 30 to 45 psi
3. 45 to 60 psi
4. 60 to 75 psi

12-31. The condensing pressure of refrigeration systems equipped with water regulating valves should be maintained at

1. 50 to 60 psi
2. 125 psi
3. 100 to 110 psi
4. 175 psi

12-32. An R-12 refrigeration plant is supplied with cooling water from either a centrifugal pump or from the fire and flushing main. When, if ever, is the pump controller switch of this plant opened manually?

1. When cooling water is from the pump
2. When cooling water is from both the pump and the main
3. When cooling water is from the main
4. Never

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12-33. When securing the compressor of an R-12 refrigeration system for a short period of time, you should first slowly close the

1. main liquid valve after the receiver to prevent a rapid fluctuation in suction pressure
2. water supply to the condenser to limit the quantity of water to the condenser
3. compressor suction valve to prevent a rapid reduction in crankcase pressure
4. compressor discharge shutoff valve to prevent a rapid increase in crankcase pressure

12-34. When an R-12 compressor is NOT in use, it should be operated at least once

1. daily
2. weekly
3. every 2 weeks
4. monthly

12-35. Why should two compressors serving the same cooling coil NOT be operated at the same time?

1. Because oil may be transferred from one compressor to another and cause serious damage
2. Because of the compressor discharge differential pressure
3. Because of the compressor motor electrical interlock
4. Because of all of the above

Learning Objective: Describe the types of maintenance and procedure required for a properly operating refrigeration system. Textbook pages 276 through 283.

12-36. An MM3 and MM2 are responsible for which of the following maintenance jobs on R-12 systems?

1. Purging a system of noncondensible gases
2. Testing for refrigerant leaks with a halide torch
3. Adjusting refrigeration system controls
4. All of the above

12-37. A recommended defrosting practice for effective cooling with the average cold-storage refrigeration installation is to defrost

1. daily
2. weekly
3. cooling coils before the average frost thickness reaches 3/16 inch
4. when the frost thickness at any location on the cooling coils is 1/2 inch or more

12-38. Which diagram in figure 12A shows the proper connection of system elements for normal defrosting in which the temperature of the refrigerated space is allowed to rise above 32° F?

1. A
2. B
3. C
4. D

12-39. It is possible to defrost cooling coils in some systems without raising the temperature of the refrigerated space above 32° F. Which diagram in figure 12A shows the proper connection of system elements for accomplishing this task?

1. A
2. B
3. C
4. D

12-40. When hot-gas defrosting has been completed and you are ready to start the compressor, which of the following valves will control the suction pressure to the compressor?

1. Defrosting valve
2. Compressor suction valve
3. Tail-coil suction valve
4. Manual expansion valve

12-41. What action must be taken before repairs are made to the receiver of a refrigeration system?

1. The entire system must be drained
2. The receiver must be pumped down to return all refrigerant to the condenser
3. All valves in the lines leading to the receiver must be opened
4. Line valves must be closed and the refrigerant in the receiver must be released to the atmosphere

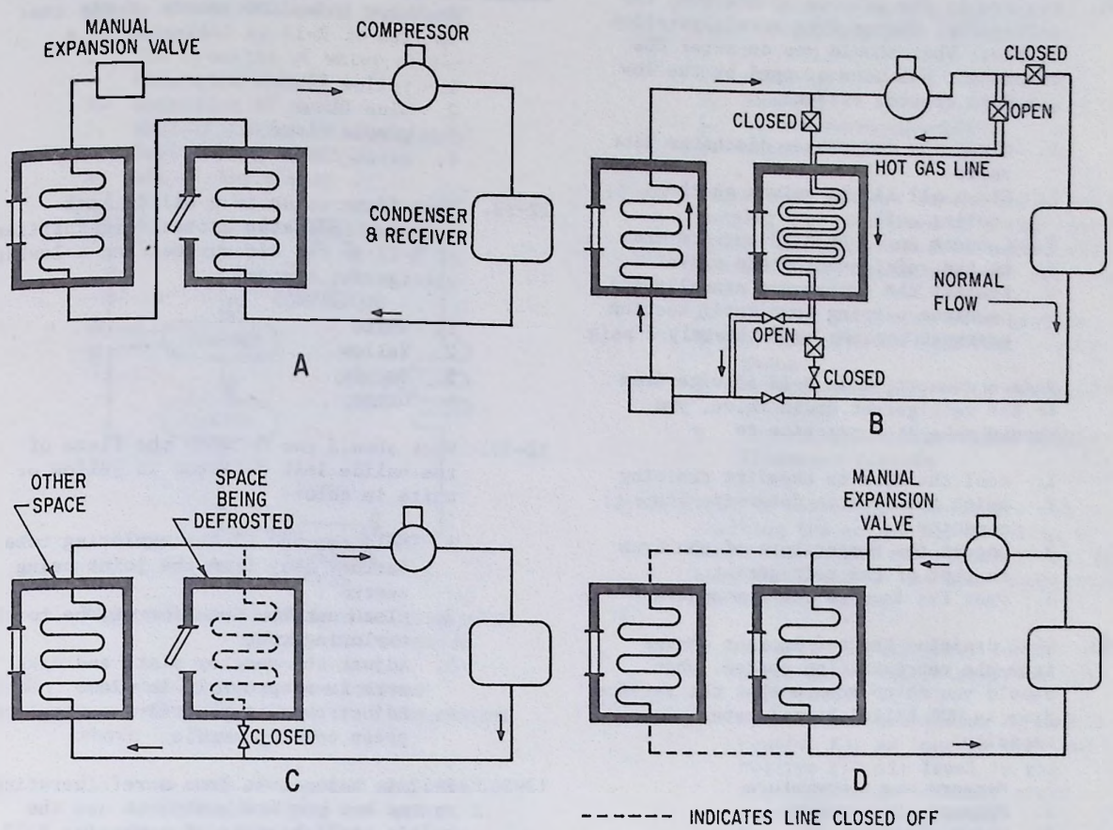


Figure 12A.

12-42. You are pumping down a system for minor repairs on lines between the receiver and cooling coils. Which of the following precautions should you observe before making repairs?

1. Blow out all R-12 gas from the isolated section that has been opened
2. Allow the lines to return to normal temperature after pumping them down and before opening them
3. Pump the lines down to a few pounds above atmospheric pressure before opening them
4. Cap removed sections of line to prevent loss of refrigerant from them

12-43. When a refrigerant system is opened, the free ends of the refrigerant lines should be temporarily plugged to prevent the entrance of air and dirt.

12-44. After a line in the refrigerant system has been opened, it must be purged with gas from a cylinder.

12-45. When you must pump down an entire refrigeration system for major repairs, you should begin the pumping operation by interrupting the flow of R-12 at the

1. compressor suction line stop valve
2. compressor discharge line stop valve
3. main liquid-line shutoff valve
4. cooling-coil solenoid valve

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12-46. You are in the process of draining the refrigerant charge from a refrigeration system. What should you do after the compressor has been stopped by the low pressure control switch?

1. Close the compressor discharge line valve
2. Close all liquid valves at the cooling coil
3. Connect an empty R-12 service drum to the refrigerant drain valve
4. Restart the compressor manually and continue pumping down until suction pressure reaches approximately 2 psig

12-47. Before connecting an R-12 service drum to the refrigerant drain valve, you should make it a practice to

1. cool the drum to expedite draining
2. weigh the drum to determine its capacity
3. adjust the temperature of the drum to that of the refrigerant
4. vent the drum to the atmosphere

12-48. When draining the refrigerant charge from the refrigeration system, what should you do to ensure that the service drum is NOT filled beyond rated capacity?

1. Measure the temperature
2. Measure the pressure
3. Weigh the drum
4. Both 2 and 3 above

12-49. After draining a refrigeration system, what should you do with the R-12 vapor remaining in the condenser and receiver?

1. Discharge it to the atmosphere
2. Condense and release it slowly
3. Compress and return it to the evaporator
4. Remove it by pumping air into the system

12-50. Which of the following conditions may indicate loss of refrigerant from a refrigerating system?

1. Short cycling
2. Frosting of the compressor suction line
3. Excessive lubrication oil pressure
4. Relatively low crankcase and cylinder temperatures

12-51. Normal operation of the halide leak detector in an atmosphere of air that is free of R-12 is indicated by a

1. yellow flame
2. blue flame
3. purple flame
4. green flame

12-52. What flame color in a halide leak detector indicates excessive quantities of R-12 in the air surrounding a leaking refrigerant system?

1. White
2. Yellow
3. Purple
4. Green

12-53. What should you do when the flame of the halide leak detector is yellow or white in color?

1. Hold the end of the exploring tube farther away from the joint being tested
2. Clean out the interior of the torch exploring tube
3. Adjust the reactor plate and make sure it is properly in place
4. Adjust the flame until a neutral or green color prevails

12-54. R-12 is being lost from a refrigerating system but you are unable to use the halide torch because of excessive R-12 in the atmosphere. What should you do?

1. Recharge the system to normal capacity
2. Pump down the system and apply compressed air through an atmosphere vent
3. Apply soapsuds to all joints in the system and look for bubbles
4. Apply light oil to all joints in the system and repeat the halide torch tests

12-55. When soap testing, prepare the liquid soap to the consistency of No. 1 fuel oil.

12-56. When searching for leaks with the soap test, how long should you wait for bubbles to form from a small leak?

1. 15 seconds or less
2. 30 seconds or less
3. 45 seconds or less
4. 60 seconds or more

12-57. The refrigerant system must be kept as moisture-free as possible to eliminate which of the following troubles?

1. The freezing of water at the expansion valves
2. Corrosion of parts
3. Emulsification or sludging of lubricating oils
4. All of the above

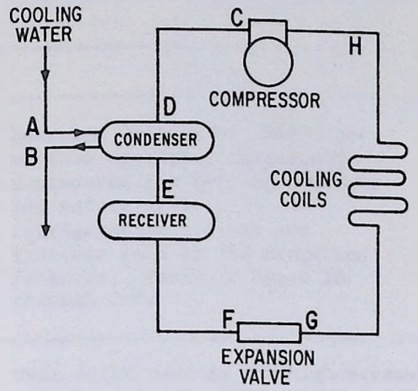


Figure 12B.--Simplified diagram of a refrigeration system.

12-58. How should you remove trapped noncondensible gases from the system shown in figure 12B?

1. Pump down the system and bleed off compressed liquid and gas at E
2. Open the line at F to the atmosphere while the system is operating
3. Stop the compressor and vent gases to the atmosphere at D
4. Briefly open the gage connection at C while the system is operating

12-59. You can determine whether the system shown in figure 12B contains excessive amounts of noncondensible gases by comparing the temperature at E with the pressure temperature at C. However, purging is necessary only when the difference between the two temperatures exceeds a maximum of

1. 1°
2. 3°
3. 5°
4. 7°

12-60. A mixture of air and R-12 containing 20% or more of refrigerant has an odor resembling that of

1. chlorine
2. ammonia
3. carbon tetrachloride
4. methane

12-61. Since R-12 gas can escape while you are purging the condenser of a refrigeration system of noncondensible gases, what precautionary measure should you take?

1. Protect your eyes with goggles
2. Prevent its contact with oil or gases
3. Protect your skin with suitable clothing
4. Prevent its contact with highly flammable liquids

12-62. What is the correct procedure for checking the actual oil level in a force-lubricated compressor if oil has been added and it has been inoperative for several weeks?

1. Observe the oil level in the sight glass before starting the compressor
2. Operate the compressor on manual control for an hour or more and observe the oil level in the sight glass immediately after stopping the compressor
3. Stop the compressor and check the oil level with the crankshaft and connecting rod ends immersed in the lubricating oil
4. Stop the compressor and check the oil level with the crankshaft and connecting rod ends out of the lubricating oil

12-63. If you wish to check the oil level in the crankcase of a compressor, it is necessary to stop the compressor.

12-64. What should you do to remove oil from a compressor that has NO drain valve?

1. Stop the compressor and close the suction and discharge line valves
2. Reduce crankcase pressure to about 1 psi by slowly closing the suction line stop valve
3. Loosen the drain plug just enough for oil to seep out
4. All of the above

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12-65. On a refrigeration system with steel connections, how often should oil in a compressor crankcase be checked for contamination?

1. Annually
2. Every 3 months
3. Semiannually
4. Weekly

12-66. When checking the tightness of V-belts on compressors, you are able to depress certain belts, with one finger, to the amounts indicated below. Which of these belts is adjusted correctly?

1. 1/8 in.
2. 3/8 in.
3. 5/8 in.
4. 7/8 in.

12-67. What should you do when one of the belts in a multiple V-belt drive is stretched excesively?

1. Replace the defective belt
2. Replace all the belts
3. Tighten the defective belt
4. Treat the defective belt with belt dressing

Assignment 13

Refrigeration (Continued); Air Conditioning

Textbook Assignment: Chapter 11 (Continued); Chapter 12

Learning Objective: Point out various operating ranges and procedures for setting controls and safety devices in refrigeration systems and indicate some of the operating features. Textbook pages 284 through 288.

13-1. What adjustment in the high-pressure switch will raise the cutout point without affecting the cut-in point?

1. Turning the range adjusting screw clockwise
2. Turning the range adjusting screw counterclockwise
3. Turning the differential adjusting screw clockwise
4. Turning the differential adjusting screw counterclockwise

13-2. You are in the process of adjusting the high-pressure switch of a refrigeration plant. What action do you take immediately after raising the compressor discharge to 10 psig above the desired cut-in pressure?

1. Turn the range screw clockwise until the contacts close
2. Turn the range screw counterclockwise until the contacts open
3. Turn the differential screw counterclockwise all the way
4. Turn the differential screw clockwise all the way

13-3. When setting the high-pressure switch, the differential switch is turned in which of the following directions?

A. Counterclockwise
B. Clockwise

1. B, A, B
2. A, B, A
3. B, A
4. A, B

13-4. You wish to set the low-pressure switch of a refrigeration plant so that it will cut out at 50 psig. With the compressor operating you should set the suction pressure to

1. 30 psig and turn the range screw clockwise until the switch contacts close
2. 50 psig and turn the range screw counterclockwise until the switch contacts open
3. 30 psig and turn the differential screw clockwise until the switch contacts close
4. 50 psig and turn the differential screw counterclockwise until the switch contacts open

13-5. The water failure switch is set properly when it cuts out at

1. 5 psig and cuts in at 15 psig
2. 10 psig and cuts in at 20 psig
3. 15 psig and cuts in at 5 psig
4. 20 psig and cuts in at 10 psig

13-6. If the temperature on the outlet side of a thermostatic expansion valve is lower than the temperature at the inlet, this indicates that the valve seat is probably dirty and clogged with foreign matter.

13-7. Adjusting the thermal expansion valve will increase or decrease the refrigerant flow into the cooling coil without affecting the amount of superheat.

13-8. What is likely to happen if an expansion valve is adjusted for a too low degree of superheat?

1. Coil operation at reduced capacity
2. Damaged expansion valve
3. Excessive refrigerant in the coil
4. Damaged compressor

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13-9. Which of the following control or safety devices is controlled by pressure changes that are brought about by changes in temperature in the refrigerator compartment?

1. Water failure switch
2. Thermostatic switch
3. Thermal expansion valve
4. Automatic reducing valve

13-10. If the refrigeration plant is not operating satisfactorily, what is normally the first step in checking the system?

1. Test the discharge valves
2. Test the suction valves
3. Shift the compressors
4. Short cycle the compressor

13-11. When testing for a leaking discharge valve, which of the following are the first and last procedures?

A. Stop the compressor
B. Pump the compressor down to 2 psig
C. Close the suction and discharge valves
D. Check the rate of drop of discharge pressure

1. A, C
2. B, D
3. A, D
4. B, C

13-12. If a faulty discharge valve is found, it will NOT normally be relapped aboard ship.

13-13. If a compressor can pump a suction of 20 inches of mercury, why can't it hold this vacuum?

1. The discharge valve leaks
2. The suction valve leaks
3. The oil in the crankcase gives off R-12
4. The shaft seals leak

13-14. A leaking shaft seal is an indication of dirty or acidic oil. Before replacing the seal, you must identify and rectify the cause of trouble. Which of the following steps are required for acidic oil?

1. Clean piping, valves, and strainers
2. Insert a dryer in the system
3. Replace the seals
4. Both 2 and 3 are correct

13-15. When a seal is being replaced on the compressor, why should the oil drain be left open?

1. To allow the oil to continue to drain
2. To prevent pressure buildup from R-12 in the oil
3. To prevent foaming of the oils
4. Each of the above is correct

13-16. After replacing a shaft seal on the compressor, how do you check for a leak?

1. Pump down compressor and look for oil
2. Fill the crankcase and look for oil
3. Open suction and discharge valves and check with a halide leak detector
4. Each of the above is correct

Learning Objective: Identify the safety precautions to be taken when handling refrigerants. Textbook pages 288 and 289.

13-17. Gaseous R-12 is a health hazard because it

1. poisons on contact any food that contains milk or eggs
2. irritates the eyes unless it is diluted with at least an equal amount of air
3. will not support respiration
4. explodes when it comes in direct contact with a high-temperature open flame

13-18. When R-12 comes in contact with an open flame or a high temperature, it becomes a health hazard. Which of the following will indicate this condition?

1. A pungent odor
2. An irritant to breathing
3. Both 1 and 2 are correct
4. The smell of new mown hay

13-19. Immediately after removing refrigerant from a storage cylinder, you should weigh the cylinder and record the weight of the refrigerant left in the cylinder.

13-20. What percentage of capacity is the limit to which an R-12 cylinder should be filled?

1. 75%
2. 80%
3. 85%
4. 90%

13-21. Which of the following articles of safety gear must be worn when you work with R-12?

1. Apron and gloves
2. Goggles
3. Mouthpiece
4. All of the above articles

13-22. What first-aid treatment should you administer in case R-12 comes in contact with your skin?

1. Rub or massage the affected area
2. Immerse the affected part in a warm bath
3. Apply nonirritating oil to the affected skin
4. Bathe the affected area with strong soap and water

Learning Objective: Specify the purpose of air conditioning, identifying the various principles affecting its efficiency. Textbook pages 291 through 297.

13-23. In addition to contributing to the comfort and fitness of the crew aboard ship, air conditioning also performs which of the following?

1. Prevents deterioration of ammunition in storage spaces
2. Maintains temperature at specified levels in electrical and electronic equipment spaces
3. Prevents excessive pressure buildup in containers in gas storage spaces
4. Does all of the above

13-24. The dewpoint of air is defined as the temperature at which

1. the specific humidity is 100 grains per pound of dry air
2. the air is saturated with moisture
3. any increase in temperature will cause moisture to condense
4. dew vaporizes into the air

13-25. Which condition will occur if the temperature of the air increases while the amount of moisture in the air remains constant?

1. The specific humidity will increase
2. The specific humidity will decrease
3. The relative humidity will increase
4. The relative humidity will decrease

13-26. The relative humidity of air is the ratio between the actual amount of water vapor in a sample of air and the

1. weight of the sample
2. volume of the sample
3. amount of water vapor the sample would hold if it were saturated
4. dewpoint of the sample

13-27. When the air above a body of water is at 70% of saturation the water and air is in a state of equilibrium.

13-28. It is possible to feel more comfortable at 90° F than at 70° F.

13-29. The total heat of air consists entirely of latent heat of vaporization in which, if any, of the following types of air?

1. Dry air (no water vapor)
2. Saturated air (100% relative humidity)
3. Saturated air at a temperature corresponding to its dewpoint
4. None

13-30. Some of the total heat of humid air is latent heat of vaporization and the rest is sensible heat.

13-31. Which atmospheric condition can be directly measured with a sling psychrometer?

1. Latent heat
2. Dewpoint
3. Wet-bulb temperature
4. Specific humidity

13-32. Which condition will occur when the relative humidity is 100%?

1. The wet-bulb temperature will be below the dewpoint temperature
2. The dry-bulb temperature will be below the dewpoint temperature
3. The wet-bulb depression will be zero degrees
4. The wet-bulb depression will be greater than 0° F

Items 13-33 and 13-34 refer to figure 12-3 in your textbook.

13-33. If the wet-bulb reading is 80° F and the dry-bulb reading is 95° F, what is the relative humidity?

1. 50%
2. 52%
3. 42%
4. 48%

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13-34. If the wet-bulb reading is 75° F and the dry-bulb reading is 90° F, what is the relative humidity?

1. 50%
2. 20%
3. 30%
4. 40%

13-35. If you go into a compartment where the temperature is 110° F, you will radiate heat to the room.

13-36. From what source does most of the body heat come?

1. Surroundings that radiate heat
2. Currents of heated air
3. Physiological processes within the body
4. Objects that transmit heat by contact

13-37. The loss of latent heat from the human body is by

1. evaporation
2. radiation
3. conduction
4. convection

13-38. What type of heat loss is the direct result of being exposed to circulating air?

1. Radiation
2. Convection
3. Conduction
4. Evaporation

13-39. When you remain stationary in a space where the air is perfectly still, what happens to the envelope of air that surrounds your body?

1. It absorbs water vapor from your body
2. Its relative humidity increases
3. Its temperature increases
4. All of the above

13-40. The quantity of heat that will be given off by a group of 20 sailors seated in a classroom will average about

1. 5,800 Btu per hour
2. 6,400 Btu per hour
3. 7,000 Btu per hour
4. 7,600 Btu per hour

13-41. What is the year-round range of relative humidity for the best conditions of health and comfort?

1. 15 to 50 percent
2. 30 to 50 percent
3. 40 to 60 percent
4. 15 to 70 percent

Learning Objective: Identify the components of ventilation equipment, indicating the functions of each. Textbook pages 297 through 299.

13-42. Why are axial flow fans used instead of centrifugal fans in duct systems in Navy ships?

1. Axial flow fans usually require less space for installation
2. Axial flow fans blow more air than centrifugal fans blow
3. Axial flow fans are less complicated than centrifugal fans are
4. Axial flow fans tend to decrease the humidity

13-43. Vane-axial ventilating fans should be operated with the air ducts open so that

1. less electrical current will be used
2. a large volume of air can be moved
3. the motors will not overheat
4. air distribution can be limited

When a Red Devil fan is used to exhaust gases from a compartment, the fan is placed in the compartment and the flexible hose is led to the atmosphere.

13-44. Where is the flexible hose connected to the Red Devil?

1. To the inlet
2. To the outlet
3. Both 1 and 2 are correct

13-45. Excess water accumulated in heavy seas is sealed out of waterproof ventilators automatically by

1. sump valves
2. the weight of the water in the bucket
3. drain tubes
4. scupper valves draining onto the deck

Learning Objective: Indicate the distinguishing features of three mechanical systems used for cooling. Textbook pages 301 through 306.

13-46. Which spaces in modern combatant ships are unlikely to be air conditioned?

1. Messing
2. Machinery
3. Berthing
4. Stowage

13-47. Cool dry air blown into a compartment by a refrigeration system cools the compartment by

1. raising the humidity
2. holding the humidity at a constant level
3. forcing the warm air out
4. absorbing heat and moisture from the air

13-48. Compared to air conditioning systems, refrigeration systems have suction pressures and evaporator temperatures that are

1. higher
2. lower
3. about equal
4. higher and lower, respectively

13-49. The size and type of compressor installed will determine whether R-11, R-12, or water is used as the primary refrigerant in an air conditioning system.

13-50. Lithium bromide is used as an absorbent in chilled water circulating systems where water is the primary and secondary refrigerant.

13-51. In figure 12-8 in the textbook, where is the heat removed from the secondary refrigerant?

1. In the water chiller
2. In the condenser
3. In the refrigerant receivers
4. In the float chambers

13-52. In a centrifugal refrigeration plant, what releases the refrigerant to the chiller?

1. Compression valve
2. Suction valve
3. Float valve
4. Differential compression valve

13-53. In the centrifugal compressor, which of the following controls the position of the prerotation vanes?

1. Electrohydraulic controls
2. Hydraulic controls
3. Electropneumatic controls
4. Pneumatic controls

13-54. In a refrigerating system that has a centrifugal compressor, what pressure actuates the high-pressure switch?

1. High condenser pressure
2. Low lube oil pressure
3. Evaporator pressure
4. Seawater pressure

13-55. When a compressor has two oil pumps, when is the auxiliary pump used?

1. During normal operation
2. During starting operations
3. During securing operations
4. During both 2 and 3 above

13-56. Oil heaters are used when the compressor is off. What is the purpose of the oil heater?

1. To heat the oil when the compressor is on standby
2. To prevent refrigerant from entering the oil
3. To reduce viscosity of the oil
4. To do both 2 and 3 above

13-57. When there is a 29.8 inch vacuum in the container of a lithium bromide absorption unit, what is the lowest temperature at which water will boil?

1. 212° F
2. 100° F
3. 35° F
4. 10° F

13-58. In the unit shown in figure 12-11 in your textbook, the lithium bromide solution that has been diluted by the continued absorption of water vapor is regenerated by

1. receiving an extra charge of lithium bromide
2. having a generator pump circulate weak lithium bromide solution through the regenerative heat exchanger to the generator
3. forcing it in and out of the condenser
4. forcing it through the absorber pump

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13-59. A regenerative heat exchanger is used to remove water from lithium bromide. Which of the following describes the two functions of the regenerative heat exchanger?

1. To cool both the weak and the strong solutions of lithium bromide
2. To cool the weak, and to heat the strong solutions of lithium bromide
3. To heat the weak and to cool the strong solutions of lithium bromide
4. To heat both the weak and the strong solutions of lithium bromide

● A spot cooler is shown in figure 12-12 in the textbook. The vent cock is used to remove air from the chilled water. Air in the cooler will reduce the cooling effect of the spot cooler.

13-60. What is/are the purpose(s) of the collection tray on the spot cooler?

1. To collect water from the vent cock
2. To collect condensation from the air around the cooling coils
3. To allow condensate to evaporate
4. To do both 2 and 3 above

Learning Objective: Specify distinguishing features of the various heaters used in ventilating systems, and identify some composite parts of the heaters. Textbook pages 306 through 309.

13-61. Which components of the ventilation heater shown in figure 12-13 in your textbook are made of copper?

1. Supply and return connections
2. Fins, tubes, and headers
3. Casing and end cover
4. Flanges

13-62. A shipboard ventilation system and its constituent parts should be isolated from other component systems in a complete air conditioning system for maintenance.

Learning Objective: Recognize the types of maintenance required for air conditioning equipment. Textbook pages 306 through 311.

13-63. Why should dirt be kept out of a ventilation system?

1. It restricts airflow
2. It creates a fire hazard
3. It does both 1 and 2 above
4. It damages the filters

13-64. After dirty air filters are washed, steamed, and rinsed, they should be re-oiled before they are reinstalled.

13-65. Proper maintenance of air conditioning equipment includes oiling flame arresters and grease filters.

Assignment 14

Compressed Air Systems and Additional Auxiliary Equipment

Textbook Assignment: Chapters 13 and 14

Learning Objective: Point out the classifications, operating principles, and functions of air compressors and identify their component parts. Textbook pages 313 through 332.

14-1. Aboard Navy ships, compressed air is used for which of the following?

1. Charging and firing torpedoes
2. Starting steam turbines
3. Operating hydraulic tools
4. All of the above

14-2. Air compressors are classified as single-acting, double-acting, single-stage, multistage, horizontal, angle, and vertical. The compressor shown in view E, figure 13-1, of your textbook is classified as

1. multistage
2. horizontal
3. double-acting
4. angle

14-3. When compression takes place in both strokes per revolution of a cylinder, the compressor is classified as

1. single-stage
2. multistage
3. single-acting
4. double-acting

14-4. Which type of air compressor is generally selected when the capacity and pressure requirements are 2,000 cfm and 80 psi respectively?

1. Centrifugal
2. Reciprocating
3. Rotary
4. Each of the above

14-5. What is the usual source of power of operating air compressors aboard ship?

1. Steam turbines
2. Internal-combustion engines
3. Electric motors
4. Reciprocating steam engines

14-6. What device is generally used to connect the source of power to an air compressor when the speed of the driving unit and compressor is the same?

1. Rigid coupling
2. Flexible coupling
3. V-belt
4. Reduction gear mechanism

14-7. A medium-pressure air compressor is classified as

1. two-stage, vertical V-type, with a discharge pressure of 150 psi or less
2. two-stage, vertical, duplex, single-acting, with a discharge pressure of 151 psi to 1,000 psi
3. three-stage, vertical, single-acting with a discharge pressure of 1,500 psi or higher
4. three-stage, vertical, double-acting, with a discharge pressure of 1,500 psi to 10,000 psi

14-8. Which cylinder arrangement is used in two-stage, W-type air compressors?

1. One cylinder per stage
2. Two cylinders per stage
3. One cylinder for the first stage, two cylinders for the second stage
4. Two cylinders for the first stage, one cylinder for the second stage

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14-9. How many strokes does a piston make in its cylinder during each operating cycle of a single-stage, single-acting air compressor?

1. One
2. Two
3. Three
4. Four

14-10. The air inlet valve of a single-stage, single-acting reciprocating air compressor is forced open by the

1. movement of the piston as it starts the suction stroke
2. movement of the piston as it starts the compression stroke
3. difference in pressure produced by the piston as it moves away from TDC
4. difference in pressure produced by the piston as it moves toward TDC

14-11. When does cylinder pressure force open the discharge valve of a single-stage, single-acting reciprocating air compressor?

1. When the piston is nearing the end of a suction stroke
2. When the piston is nearing the end of a compression stroke
3. When the piston is starting a suction stroke
4. When the piston is starting a compression stroke

14-12. The compressing element of an air compressor includes all of the following parts EXCEPT the

1. cylinder
2. piston
3. air valves
4. unloader

14-13. The operation of the automatic valves of an air compressor is initiated by

1. an air pressure differential
2. a lack of air pressure
3. a high air pressure
4. a camming action

14-14. What is the advantage of fitting an air compressor with a differential piston-and-cylinder arrangement?

1. More even distribution of side pressure
2. Less heat of compression to dissipate
3. Single-stage compression by a lighter compressing element
4. Multistage compression by one piston

14-15. What device is used to lubricate the high-pressure air compressor cylinders?

1. Cylinder splash lubricator
2. Compressor oil pump
3. Adjustable mechanical force-feed lubricator
4. Sight-glass oil flow indicator

14-16. A feed line check valve prevents compressed air from forcing lube oil back into the forced-feed lubricator of an air compressor.

14-17. The cylinder lubricator must be started before the air compressor starts up.

14-18. What is the flow path of lube oil for the running gear in a modern air compressor?

1. Oil sump to filter to cooler, then to main bearings, spray nozzles, and outboard bearings
2. Oil sump to cooler to main bearings, then to filter, spray nozzles, and outboard bearings
3. Filter to cooler to sump, then to main bearings, spray nozzles, and outboard bearings
4. Filter to sump to cooler, then to main bearings, spray nozzles, and outboard bearings

14-19. What is the cooling medium for most high- and medium-pressure air compressors aboard ship?

1. Oil
2. Seawater
3. Freshwater
4. Either 2 or 3 above

14-20. Why are the cylinders and heads of some shipboard air compressors made of bronze alloy?

1. To promote cooling
2. To reduce wear
3. To minimize corrosion
4. To do all of the above

14-21. What is the function of the intercoolers of an air compressor?

1. To remove heat generated during compression and to condense existing vapor
2. To remove heat from the incoming water and to condense existing vapor
3. To cool the air before compression
4. To cool the air after the final stage of compression

14-22. The advantages of interstage cooling in an air compressor include which of the following?

1. Increased effectiveness in piston and valve lubrication
2. Reduction in amount of power required to run the compressor
3. Reduction in amount of heat to be removed by the cylinder jackets
4. All of the above

14-23. Baffles are used in a straight shell-and-tube type of water-cooled intercoolers to

1. remove oil contaminants from the air
2. deflect air or water passing through the cooler
3. prevent the tube nest from expanding
4. prevent the tube nest from contracting

14-24. By what means do the separators in compressor intercoolers and aftercoolers remove moisture and oil from the air stream?

1. Centrifugal force
2. Impact
3. Sudden changes in velocity
4. All of the above means

14-25. The quantity of water that passes through the oil cooler can NOT be regulated without changing the quantity that passes through the intercoolers.

14-26. To which parts of a compressed air cooling system are temperature-detecting devices fitted?

1. Circulating water inlet and outlet connections
2. Intake and discharge of each stage of compression
3. Final air discharge and oil reservoir
4. All of the above

14-27. The control system for an electrically driven reciprocating air compressor will stop the compressor automatically when the pressure in the receiver causes a

1. governor valve to open
2. governor valve to close
3. pressure switch to open
4. pressure switch to close

14-28. The automatic temperature shutdown device of a high-pressure reciprocating air compressor functions to stop the compressor when the

1. accumulator temperature rises a predetermined amount
2. accumulator temperature drops a predetermined amount
3. cooling water temperature rises above a preset limit
4. cooling water temperature drops below a preset limit

14-29. A compressor unit equipped with an automatic unloading system is capable of which of the following?

1. Removing its compression load while it is starting
2. Applying its compression load after it reaches operating speed
3. Doing both 1 and 2 above
4. Removing its friction load after it is started

14-30. Which of the following methods is used to unload an air compressor?

1. Holding intake valves closed
2. Closing cylinder clearance pockets
3. Venting intercoolers to the atmosphere
4. Each of the above

14-31. The rotary-centrifugal compressor is usually used to supply

1. high-pressure, nonoil-free air
2. low-pressure, oil-free air
3. high-pressure, oil-free air
4. low-pressure, nonoil-free air

14-32. Which of the following causes the air to compress in the rotary-centrifugal compressor?

1. Water
2. Centrifugal force
3. Impeller
4. Piston

14-33. Which of the following is a function of the air receiver in an air compressor system?

1. To cool the air
2. To reduce pressure variations
3. To do both 1 and 2 above
4. To filter the air of moisture and oil

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14-34. Vertically mounted receivers have concave bottoms to permit draining.

14-35. When two or more air flasks are connected together they constitute a manifold.

14-36. Which of the following is a relief valve?

1. 
2. 
3. 
4. 

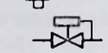
14-37. In figure 13-15A, what is the air pressure of the ship's service low-pressure air?

1. 3,000 psi
2. 150 psi
3. 168 psi
4. 180 psi.

14-38. Which of the following is the symbol for a locked open globe valve?

1. 
2. 
3. 
4. 

14-39. Which of the following is the symbol for a differential pressure gage?

1. 
2. 
3. 
4. 

14-40. Which of the following systems is supplied nonvital air?

1. Automatic boiler control
2. Water level control
3. Air pilot-operated control valves
4. Laundry equipment

14-41. What type of compressor is used to supply air to the prairie-masker system?

1. Turbocompressor
2. Multistage compressor
3. Angle compressor
4. Vertical compressor

14-42. When a large volume of high-pressure air is throttled to a low pressure, the throttling valve may become frozen. What causes the freezing?

1. Charles' effect
2. Venturi effect
3. Herbst effect
4. Boyle's effect

14-43. What type of dryer or desiccant dehydrator does NOT require heat or a separate heat source?

1. Boss' dryer
2. Mueller's dryer
3. Heat-Les dryer
4. Heat-Lyn dryer

Learning Objective: Identify effective inspection and maintenance procedures, troubleshooting procedures, and applicable safety precautions. Textbook pages 332 and 333.

14-44. The Maintenance Index Page (MIP) indicates the various maintenance tasks, the rating responsible for performing the tasks, and the time required for the tasks. How long should it take to clean the air intake filter?

1. 1.0 man-hour
2. 0.2 man-hour
3. 0.5 man-hour
4. 1.5 man-hour

14-45. When an air compressor is operating, how often should the crankcase oil level be checked?

1. Hourly
2. Every 4 hours
3. Every 24 hours
4. Weekly

14-46. Rapid pressurization with high-pressure air may generate heat high enough to ignite oil and other impurities.

14-47. Which of the following safety precautions should you observe before starting to work on an air compressor?

1. Blow down the compressor
2. Secure all valves between the compressor and receiver
3. Make sure compressor cannot be started
4. All of the above

14-48. The use of gasoline or a similar liquid to clean compressor intake filters is prohibited because the liquid has the ability to do which of the following?

1. Reduce the efficiency of the filters
2. Damage the filter material
3. Vaporize easily and form a highly explosive mixture with the air under compression
4. Do all of the above

Learning Objective: Identify significant features of the electrohydraulic speed gear. Textbook pages 336 through 338.

14-49. Electrohydraulic drives used for auxiliary machinery aboard ship have which of the following advantages?

1. The ability to shift rapidly from no load to full load without excessive strain on the machinery
2. A high rate of efficiency
3. Flexibility in the location of components including locations requiring power transmission around corners
4. All of the above

14-50. The movement of the A-end of an electrohydraulic speed gear is controlled by a

1. throttle
2. tilt box
3. piston
4. hydraulic ram

14-51. The A-end hydraulic pump and B-end hydraulic motor combination provide rotary motion. What change is made in the hydraulic system to provide reciprocating motion?

1. The angle of tilt of the socket ring is reversed
2. The tilt box is placed in a neutral position
3. The A-end is replaced by a piston or ram
4. The B-end is replaced by a piston or ram

● The tilt box controls the direction and amount of oil that is pumped in a variable-stroke pump.

14-52. The amount of oil pumped is controlled by the tilt box which varies the length of the piston strokes of the

1. ram
2. A-end
3. B-end
4. electric motor

Learning Objective: Identify fundamentals of steering gears and their controls, ways they are classified, their construction features, and functions of major components. Textbook pages 338 through 340.

14-53. In figure 14-2 of the textbook, which of the following is the equivalent of a B-end?

1. Remote steering input
2. Main hydraulic pump
3. Tiller
4. Ram

14-54. In figure 14-2 of the textbook, when the ram is moving, oil is forced into one ram cylinder and out the other cylinder. Where does the oil from the ram go?

1. To the operating tank
2. To the output of the main pump
3. To the suction side of the auxiliary pump
4. To the suction side of the main hydraulic pump

14-55. Hydraulic fluid pressure is maintained in the ram type electrohydraulic steering gear by

1. centrifugal pumps
2. a rudder yoke
3. a variable-stroke pump
4. a hydraulic ram

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14-56. What part of the steering gear illustrated in textbook figure 14-2 regulates the rate of fluid delivery?

1. Control shaft
2. Relief valve
3. Differential control box
4. Rack and pinion

14-57. Refer to textbook figure 14-2 and assume that the steering wheel is turned three degrees to starboard and held in that position. Which of the following conditions result after the rudder moves three degrees?

1. Oil flow to the cylinders continues and the rudder moves farther to the right
2. Oil flow to the cylinders continues, but movement of the rudder is stopped by the planetary differential gear via the rack and pinion
3. Oil flow is stopped as the tilting box is returned to neutral by action of the followup rack and pinion
4. Oil flow is stopped, but the tilting box remains tilted until the steering wheel is returned to its original position

14-58. Which device in textbook figure 14-2 operates as the followup mechanism?

1. Self-synchronous receiver
2. Rack and pinion
3. Planetary differential gear
4. Six-way plug cock

14-59. In case of failure of the remote steering system, which of the following is used for local hydraulic control of the steering gear?

1. Hand pump
2. Auxiliary pump
3. Trick wheel
4. Differential control box

14-60. In the event electrical power is lost to the hydraulic pump motors, which of the following can be used to control the steering gear?

1. Hand pump
2. Auxiliary pump
3. Trick wheel
4. Differential control box

Learning Objective: Specify and identify the principle of operation of the different types of winches and capstans. Textbook pages 340 through 345.

14-61. Some electrohydraulic anchor windlass installations are provided with two motors, one for driving each of the pumps which normally drives one wildcat. However, each pump is capable of driving either wildcat with the use of

1. a locking head
2. 3-way plug cock type valves
3. multiple spur gearing
4. a special coupling

14-62. In maintaining an electrohydraulic windlass, you will be concerned mainly with the electrical part of the system rather than the hydraulic part.

14-63. Before operating a windlass that has been idle for several months, you should

1. lubricate the equipment
2. adjust the brakes
3. remove, clean, and lubricate the locking head
4. replace the friction shoes

14-64. Which of the following types of winches will probably be used to hoist aircraft aboard?

1. Steam
2. Electric
3. Electrohydraulic
4. Each of the above

14-65. What device is used to control the speed and direction of rotation of a steam winch engine (textbook figure 14-3)?

1. Hydraulic motor
2. Electrohydraulic pump
3. Hand lever
4. Electric motor

14-66. Refer to textbook figure 14-3 and assume that the winch is in compound gear and operating. What happens when you raise part 14, hand lever control?

1. Drums turn to lift the load
2. Drums turn to lower the load
3. A spool-type valve passes steam to the reverse valve
4. A reverse valve passes steam to the spool-type valve

14-67. The speed control lever on some steam winches is held in neutral position by

1. a brake
2. a compound gear
3. an automatic latch
4. a spur gear

In items 14-68 through 14-70 select the shifter lever position from column B that causes the action in column A. Refer to textbook figure 14-3 and assume the winch is operating.

	A. Actions	B. Lever Positions
14-68.	Speed of drum decreases; available line pull increases	1. To the right
14-69.	Driving sleeve moves to the right disengaging the pinion from the intermediate gear	2. To the left
14-70.	Driving sleeve disengages pinions	3. Vertical position
		4. Horizontal position

14-71. The drum locking device of the winch illustrated in textbook figure 14-3 is controlled by part number

1. 7, shifter lever
2. 8, steam connection
3. 14, hand lever control
4. 15, brake foot pedal

14-72. The horizontally mounted drum of an electrohydraulic winch is connected to the shaft by a

1. chain drive
2. key
3. ratchet lock
4. clutch

14-73. Electric capstans are usually of the reversible type. Those powered by direct current motors usually have how many speeds in either direction of rotation?

1. One to three
2. Two to four
3. Three to five
4. Four to six

14-74. Which of the following is a step in the proper care and maintenance of winches and capstans?

1. Check the condition and amount of oil in the reduction gears
2. Check the operation of the brake actuating mechanisms
3. Check the condition of the friction clutches
4. Each of the above

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Assignment 15

Additional Auxiliary Equipment (Continued) and Industrial Gases

Textbook Assignment: Chapter 14 (Continued) and Chapter 15

Learning Objective: Identify classifications, functions, and operating procedures of various components of the cranes. Textbook pages 346 and 347.

15-1. Which crane classification is NOT included in the general types?

1. Stationary king post
2. Hand operated
3. Traveling
4. Jib

15-2. The boom of a crane is controlled by the

1. king post
2. blocks
3. rotating gear
4. sheaves

15-3. To prevent fouling of the hoisting rope, a crane is provided with

1. fair-lead sheaves
2. blocks
3. a king post
4. a grooved drum

15-4. The delicate control often required for handling loads with a crane is usually provided by

1. an electric motor for rotating the crane
2. reduction gearing in the crane rotating mechanism
3. hydraulic variable-speed gears for driving the hoisting whips and topping lifts
4. electric motors for driving the hoisting whips and topping lifts

15-5. The hoisting units of a crane are driven by

1. constant-speed electric motors
2. variable-speed electric motors
3. B-end hydraulic motors
4. A-end hydraulic pumps

15-6. What device on a crane is provided to hold the load when electric power fails?

1. A-end hydraulic pump
2. Hydraulic torque motor
3. Hand brake
4. Electric brake

15-7. The neutral position of the A-end hydraulic pump on a crane is found and retained by

1. a B-end hydraulic motor
2. a centering device
3. an electric torque motor
4. a slack-takeup device

15-8. When a crane is used to raise light loads, the cable has a tendency to develop slack when hoisting is started. To prevent slack, the crane is provided with

1. an electric torque motor
2. a hydraulic torque motor
3. a light-hook paying-out device
4. a pressure stroke control device

Learning Objective: Identify distinguishing features of the electrohydraulic elevator. Textbook pages 347 and 348.

15-9. Aircraft carriers of the CV class are equipped with airplane elevators with a lifting capacity of at least

1. 135,000 lb
2. 125,000 lb
3. 115,000 lb
4. 79,000 lb

15-10. In the closed hydraulic system of an electrohydraulic power plant, why is nitrogen used instead of air with the oil?

1. To increase the efficiency of the oil
2. To prevent a possible explosive mixture
3. To ensure a constant pressure within the system
4. To eliminate contamination of the oil usually caused by air

15-11. An electrohydraulic elevator is raised by high-pressure oil acting directly against the

1. hydraulic engine valve piston
2. high-pressure tank baffle plates
3. ram
4. platform

15-12. An electrical device stops the platform of an electrohydraulic elevator by controlling the

1. flow of oil
2. valve action
3. ram stroke
4. air supply in the system

15-13. The lowering speed of an electrohydraulic elevator is controlled by the combined action of the control valve and the

1. pressure in the exhaust tank
2. pressure in the high pressure tank
3. electrically operating stopping device
4. ram

15-14. On modern deck edge elevators, what built-in safety feature limits the damage caused by the possible breaking of all hoisting cables on one side of the elevator?

1. Electrical stopping device which will block the platform
2. Serrated safety shoes which will wedge the platform between the guide rails
3. Pressure-actuated switches which will disconnect the electrical power source
4. High-pressure tank which will cushion the platform as it lowers

15-15. In the electrohydraulic elevator installation the oil filter system may be used continuously while the engine is running, thus part of the oil may be cleaned with each operation of the elevator.

Learning Objective: Identify the principle of operation and maintenance procedures required for proper operation of galley equipment. Textbook pages 349 through 351.

15-16. The primary concern of a Machinist's Mate for the maintenance of steam cooking equipment is the

1. cookers
2. full-floating doors
3. steam jacket
4. valves or piping

15-17. In a single tank dishwasher, the washing and rinse sprays differ in temperature and are controlled by separate valves.

15-18. In a double-tank dishwasher, the final rinse is activated by

1. manual control
2. a thermostat control
3. the movement of dish racks
4. a cam on the conveyor belt

15-19. The rinse tank of a double-tank dishwashing machine contains a thermostatically operated switch which prevents machine operation if the temperature of the rinse water drops below

1. 180° F
2. 190° F
3. 200° F
4. 210° F

15-20. You are preparing to descale a dishwasher whose tanks have a capacity of 36 gallons. How much orthophosphoric acid 85% and detergent, respectively, do you add to the water in each tank to make up the proper cleaning solution?

1. 7 fluid ounces; 18 fluid ounces
2. 18 fluid ounces; 36 fluid ounces
3. 126 fluid ounces; 9 fluid ounces
4. 252 fluid ounces; 18 fluid ounces

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15-21. When descaling, after operating a dishwasher with cleaning solution in its tanks for 60 minutes, what should you do?

1. Repeat the cleaning procedure with a fresh cleaning solution
2. Drain the cleaning solution and rinse the tanks several times with fresh hot water
3. Drain the cleaning solution and rinse the tanks for 5 minutes; first with hot water and then with cold water
4. Drain the cleaning solution, rinse thoroughly with cold water and blow dry with air under pressure

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Learning Objective: Point out the general nature and characteristics of some of the gases most commonly used in the Navy. Textbook pages 354 and 355.

15-22. All gases are compressible to the extent that they will occupy less space than they occupy under normal conditions.

15-23. Temperature is an important factor to consider when storing containers of gas because an increase in temperature causes

1. an increase in volume
2. a decrease in volume
3. an increase in pressure
4. a decrease in pressure

15-24. The separation of liquefied gases from each other is possible because

1. gases in the liquid state will not mix
2. the gases evaporate when subjected to high temperatures
3. gases in the liquid state are not compressible
4. the gases have different boiling points

Identify the term in column B that is defined in column A.

	Column A	Column B
15-25.	An oil lubricated compressor is used to compress the gas	1. Dry
15-26.	Gas has been less than 0.02 milligrams per liter of moisture	2. O.T.
		3. O.F.
		4. Water-pumped

15-27. What is the chemical symbol for ammonia?

1. NH_2
2. CL_2
3. A
4. N_2O

15-28. What is the weight in pounds per cubic foot of refrigerant R-12?

1. .3136 lb
2. .1839 lb
3. .2243 lb
4. .079 lb

15-29. Which of the following is a colorless gas that has a sweet odor when in its pure state?

1. Hydrogen sulphide
2. Acetylene
3. Acetone
4. Carbon dioxide

15-30. Which, if any, of the following conditions, must exist to make large volumes of acetylene gas, which is under pressure in excess of 15 psi, dangerously explosive?

1. In contact with air
2. In contact with oxygen
3. In contact with a spark
4. None of the above; any shock or heat is sufficient

15-31. What will happen if oxygen is mixed with acetylene gas?

1. The chance of explosion is doubled
2. The chance of explosion is lessened
3. Explosive acetylides will form
4. A colorless, nonexplosive liquid will form

Learning Objective: Identify the various safety precautions applicable to some of the gases used in the Navy. Textbook pages 357 through 366.

15-32. Which of the following violates the safety rules for handling acetylene gas?

1. Storing acetylene in an oxygen cylinder
2. Discharging acetylene into a hose line at a pressure of 20 psi
3. Replacing an acetylene regulator with an oxygen regulator
4. All of the above

15-33. What should you use to test an acetylene cylinder for leaks?

1. Soapy water
2. Oil
3. A low flame
4. Dry ice

15-34. If an acetylene cylinder catches on fire, which of the following should be used to extinguish the blaze?

1. Carbon dioxide
2. Purple K
3. Foam
4. Water

15-35. CO_2 is one of the chief fire extinguishing agents in use today mainly because it

1. is heavier than air
2. mixes readily with oxygen
3. can be condensed into a colorless liquid and stored in this state
4. will neither support combustion nor form explosive mixtures

15-36. Where aboard ship is an excessive amount of carbon dioxide most likely to collect?

1. In high, ventilated areas
2. In high, unventilated areas
3. In low, ventilated areas
4. In low, unventilated areas

15-37. Before entering a shipboard compartment containing hazardous amounts of carbon dioxide, you should be equipped with which of the following?

1. An independent supply of nitrogen
2. An independent supply of oxygen
3. A breathing mask
4. Both 2 and 3 above

15-38. If it is necessary to immerse chlorine cylinders in water to increase discharge, which of the following temperatures is below the upper limit for the water?

1. 100° C
2. 130° C
3. 100° F
4. 130° F

15-39. When a chlorine cylinder is to be immersed in water, the maximum amount of bottle surface area that should be submerged is

1. 10%
2. 20%
3. 50%
4. 80%

15-40. Approximately what percentage of air is made of oxygen?

1. 10%
2. 15%
3. 21%
4. 26%

15-41. Although an important use of oxygen is to sustain life, it has another use aboard ship when combined with another gas. With which gas is the oxygen combined and for what purpose?

1. Acetylene for welding
2. Nitrogen for heat treatment of metals
3. Acetylene for pressure operating equipment
4. Nitrogen for preservation of packing

15-42. Although oxygen itself is nonflammable, it becomes highly explosive when mixed with either hydrogen or grease.

15-43. Which of the following statements pertains to nitrogen gas?

1. It can be safely used for inert-gas shielded metal arc welding because, at high temperatures, it will not combine with other substances
2. It is explosive when exposed to open flame while it is under high pressure
3. It is safe for use in pressure-operated mechanisms because it does not support combustion and is nonflammable
4. It is poisonous and becomes an asphyxiant when mixed with oxygen

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15-44. Nitrogen will support life.

15-45. Nitrogen, if heated, will generate oxygen.

15-46. When using compressed gas from a gas cylinder, you always release the gas through a pressure regulator.

15-47. When using industrial gas from a gas cylinder you should always open the valves all the way except when using

1. argon
2. acetylene
3. nitrogen
4. oxygen

15-48. You are charging a recoil mechanism with nitrogen. After opening the valve of the nitrogen cylinder, you notice a slight leak in the pressure regulator. Inspection indicates that the leakage can probably be stopped by tightening an adjusting nut. What action should you take?

1. Tighten the adjusting nut
2. Close gas cylinder valve and then tighten adjusting nut
3. Close gas cylinder valve, release pressure from regulator, and then tighten adjusting nut
4. Open gas cylinder valve all the way and then slowly tighten adjusting nut until leakage stops

15-49. Which of the following is a safety precaution that must be observed in handling gas cylinders?

1. Store ammonia cylinders upright
2. Construct fire-resistant partitions between flammable and nonflammable gas cylinders
3. Do not immerse gas cylinders to promote more rapid discharge
4. Do not mark empty gas cylinders

Learning Objective: Recognize some of the gas cylinders used by the Navy and identify their markings. Textbook pages 360 through 362.

15-50. If each of the following gases is contained in a cylinder designed for that particular gas, which will be easiest to identify by sight if the cylinders are unmarked?

1. Acetylene
2. Argon
3. Helium
4. Oxygen

15-51. After being exposed to high temperature, metal in the safety device of a gas cylinder melts and opens a vent through which the gas escapes. The cylinder is most likely equipped with which of the following?

1. A fusible plug
2. An unbacked safety device
3. A backed safety device
4. Either 2 or 3 above

15-52. Which of the following cylinders has a frangible disk?

1. Argon
2. Refrigerant 12
3. Sulfur dioxide
4. Oxygen

15-53. Gas cylinders used by the Army and Air Force may be used in an emergency.

15-54. Which of the following colored cylinders contain toxic or poisonous materials?

1. Yellow
2. Brown
3. Blue
4. Gray

15-55. Which of the following cylinders contains fire protection materials?

1. Yellow
2. Blue
3. Green
4. Red

15-56. In addition to the standard markings, a Navy-owned gas cylinder is further identified by

1. a four-digit serial number
2. A four-digit serial number followed by the letters USN
3. a serial number preceded by the letters US and followed by the letter N
4. an indented serial number preceded and followed by the letters USN

15-57. What should you remember about the letter, in the serial number of a Navy-owned gas cylinder, that identifies the gas?

1. It is the first letter of the gas name
2. It is one of the letters contained in the gas symbol
3. It has no consistent connection with the spelling of the gas name or symbol
4. It precedes a number that reflects the number of letters in the gas name

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Learning Objective: Specify the basic principle on which liquid oxygen and nitrogen is produced. Textbook pages 363 and 364.

15-58. Large amounts of oxygen for industrial purposes are usually prepared by the process of

1. electrolysis
2. chemical decomposition of unstable compounds
3. catalysis
4. distillation

15-59. When both are in the liquid state, how is nitrogen removed from oxygen?

1. By boiling
2. By cooling
3. By pressurizing
4. By a combination of 2 and 3 above

15-60. In the process of liquefying air, heat is removed from the air by

1. raising its temperature
2. raising its pressure
3. reducing its temperature and then suddenly increasing its pressure
4. reducing its temperature and then suddenly reducing its pressure

15-61. Which of the gases found in the air at sea level must be removed before the air is liquefied?

1. Argon
2. Carbon dioxide
3. Neon
4. Nitrogen

15-62. Refer to textbook figure 15-2. Air passing through the high-pressure side of the heat exchanger is cooled by

1. the air passing through the low-pressure side
2. water pumped through the heat exchanger
3. action of the compressor
4. condensate from the flash tank

15-63. In a high-pressure liquid air plant, the yield of liquid oxygen will be increased to what percentage by the use of the mechanical refrigeration?

1. 9%
2. 12%
3. 17%
4. 21%

15-64. Refer to textbook figure 15-3. After the nitrogen is separated from the oxygen in the oxygen plant, the nitrogen is

1. discharged to the atmosphere
2. discharged to the compressor
3. collected in nitrogen bottles
4. collected in the heat exchanger

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