CHAPTER 10

AUXILIARY MACHINERY AND EQUIPMENT

Ships depend on the reliability of auxiliary systems. Proper maintenance and operation of auxiliary systems will enhance the performance of main propulsion machinery. As a Fireman, you will gain a thorough knowledge of main propulsion auxiliary machinery and systems. In this chapter, we will discuss the operation of refrigeration and air-conditioning equipment, air compressors, dehydrators, distilling plants, and purifiers. Other auxiliary machinery includes the steering gear, the anchor windlass and capstan, cranes, elevators, winches, and galley and laundry equipment.

REFRIGERATION

Most Navy refrigeration systems use R-12 as a refrigerant: Chemically, R-12 dichlorodifluoromethane (CC 1425F425). R-12 has such a low boiling point that it cannot exist as a liquid unless it is confined in a container under pressure. The cycle of operation and the main components of R- 12 systems are basically the same as those in other refrigeration and air-conditioning plants.

FUNDAMENTALS OF REFRIGERATION

Refrigeration is a general term. It describes the process of removing heat from spaces, objects, or materials and maintaining them at a temperature below that 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 artificial way of lowering the temperature. Mechanical refrigeration is a mechanical system or apparatus that transfers heat from one substance to another.

It is easy to understand refrigeration if you know the relationships among temperature, pressure, and volume, and how pressure affects liquids and gases. Refer back to chapter 2 for a review.

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 Btus. Therefore, the number of Btus 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 Btus in 24 hours. On an hourly basis, the refrigeration ton is 12,000 Btus per hour (288,000 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.

MECHANICAL REFRIGERATION SYSTEMS

Various types of refrigerating systems are used for naval shipboard refrigeration and air conditioning. The one usually used for refrigeration purposes is the vapor compression cycle with reciprocating compressors.

Figure 10-1 shows a general idea of this type of 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, you need to understand (1) why the refrigerant changes from liquid to vapor, (2) why it changes from vapor to liquid, and (3) what happens in terms of heat because of these changes of state. In this section, the refrigerant is traced through its entire cycle, beginning with the thermostatic expansion valve (TXV).

Liquid refrigerant enters the TXV that separates the high side of the system and the low side of the system. This valve regulates the amount of refrigerant that enters the cooling coil. Because of the pressure differential as the refrigerant passes through the TXV, some of the refrigerant flashes to a vapor.

From the TXV, 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

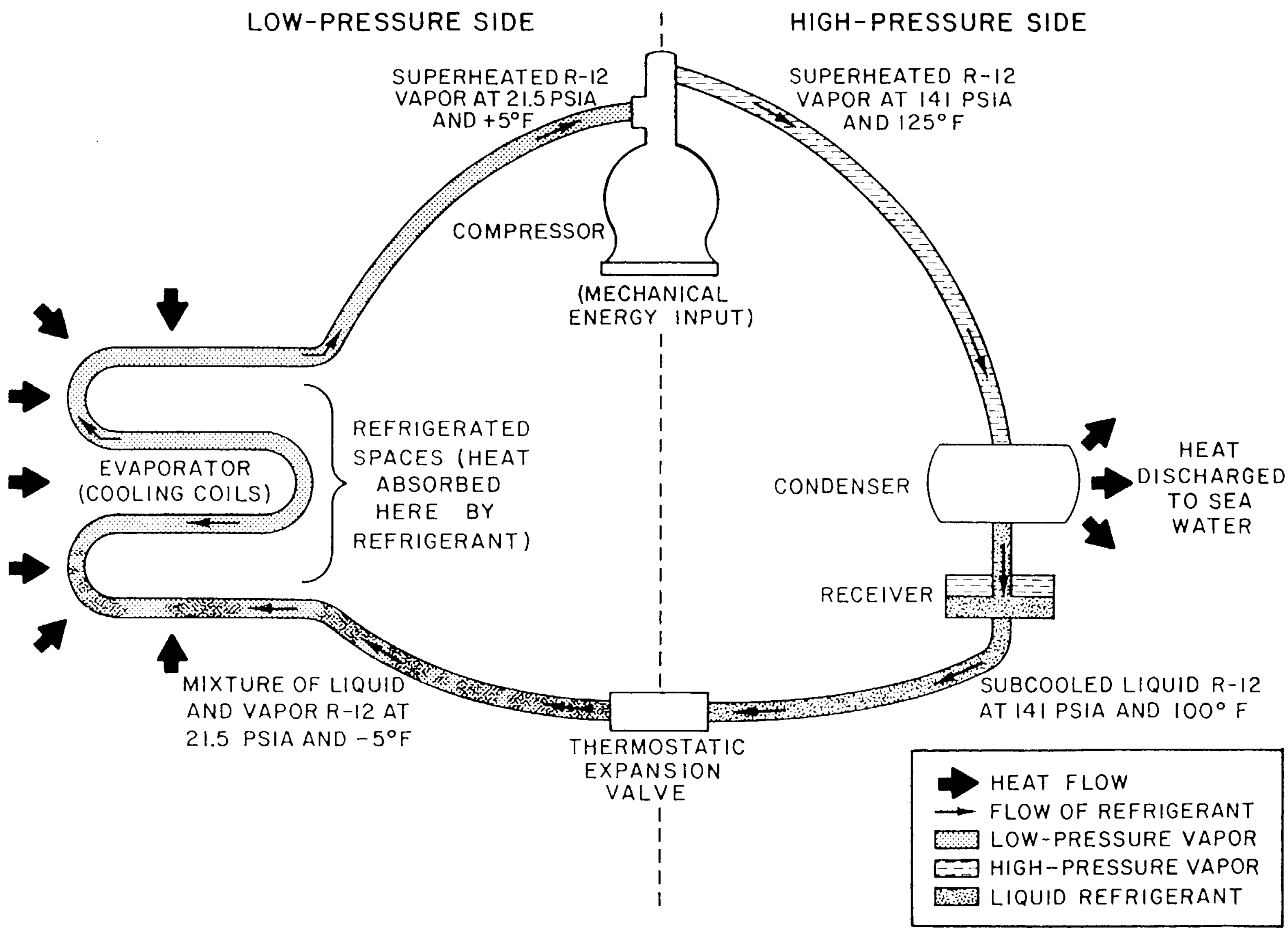


Figure 10-1.–Schematic representation of the refrigeration cycle.

and vaporizes, it picks up latent heat of vaporization from the space being cooled. The refrigerant continues to absorb latent heat of vaporization until all the liquid has been vaporized. By the time the refrigerant leaves the cooling coil, it has not only absorbed this latent heat of vaporization. It 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. The remainder of the cycle is used to dispose of this heat and convert the refrigerant back into a liquid state so that it can again vaporize in the evaporator and absorb the heat again.

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. The condenser may be air or watercooled. 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 TXV and the cycle begins again.

This type of refrigeration system has two pressure sides. The LOW-PRESSURE SIDE extends from the TXV 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 TXV. Figure 10-2 shows most of the components on the high-pressure side of an R- 12 system as it is installed aboard ship.

MAIN PARTS OF THE R-12 SYSTEM

The main parts of an R- 12 refrigeration system are shown diagrammatically in figure 10-3. The six primary components of the system include the

1. TXV,

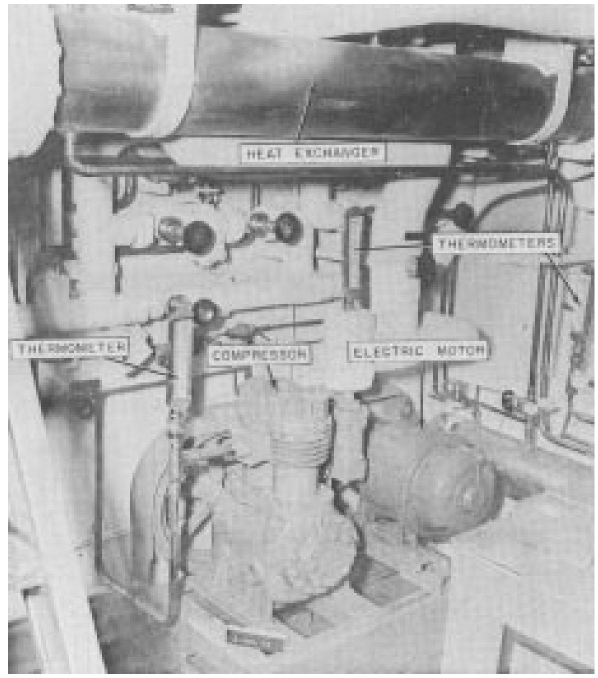
2. evaporator,

3. capacity control system,

4. compressor,

5. condenser, and

6. receiver.



47.92

Figure 10-2.-High-pressure side of an R-12 installation aboard ship.

Additional equipment required to complete the plant includes piping, pressure gauges, thermometers, various types of control switches and control valves, strainer, relief valves, sight-flow indicators, dehydrators, and charging connections.

In this chapter, 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 10-3, however, a refrigeration system usually has more than one evaporator, and it may include an additional compressor and condenser units.

Thermostatic Expansion Valve (TXV)

Earlier, you learned that the TXV regulates the amount of refrigerant to the cooling coil. The amount of refrigerant needed in the coil depends, of course, on the temperature of the space being cooled.

The thermal control bulb, which controls the opening and closing of the TXV, is clamped to the cooling coil near the outlet. The substance in the thermal bulb varies, depending on the refrigerant used. The expansion and contraction (because of temperature change) transmit a pressure to the diaphragm. This causes the diaphragm to be moved downward, opening

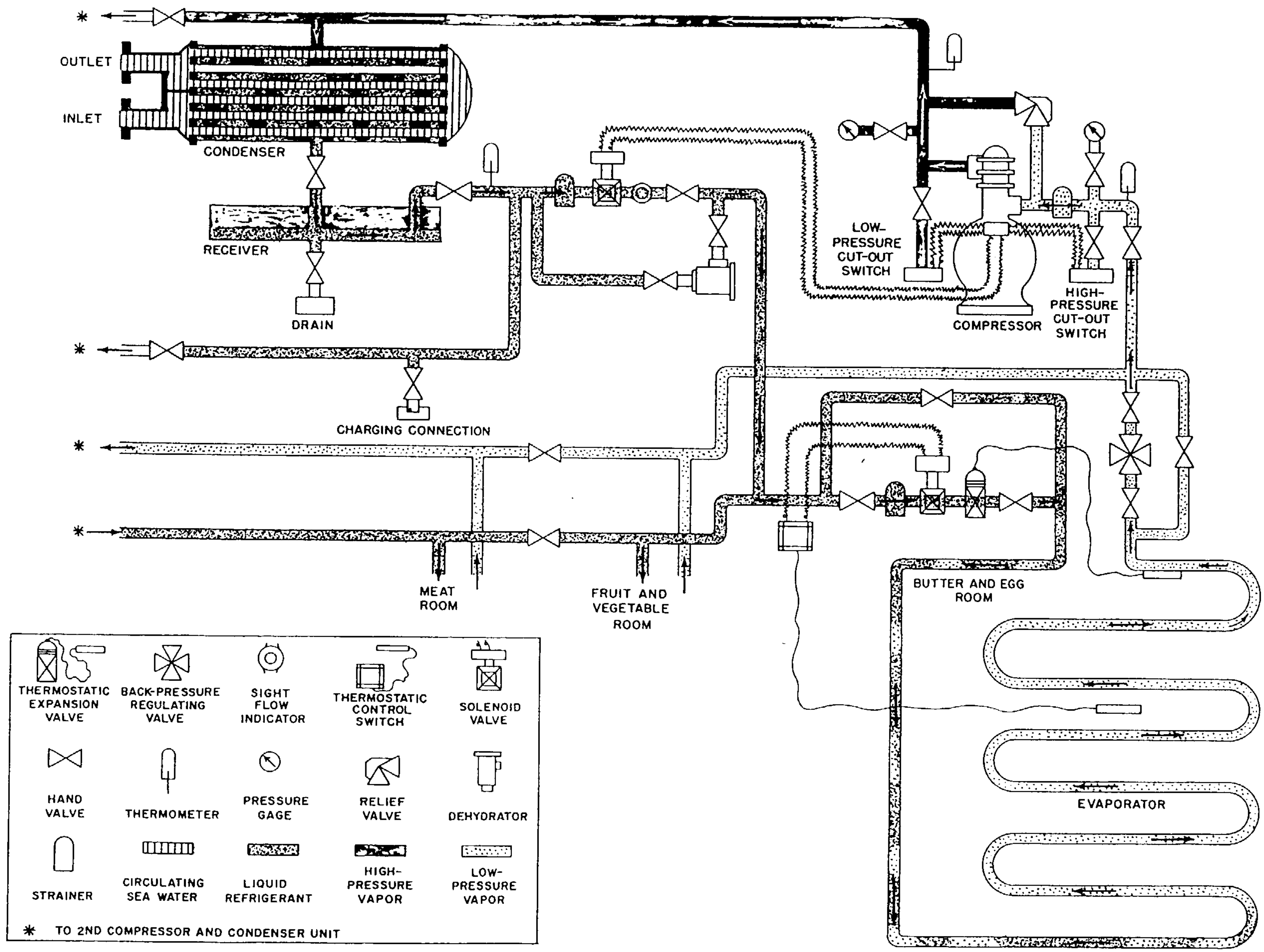


Figure 10-3.–Diagram of an R-12 refrigeration system.

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 TXV.

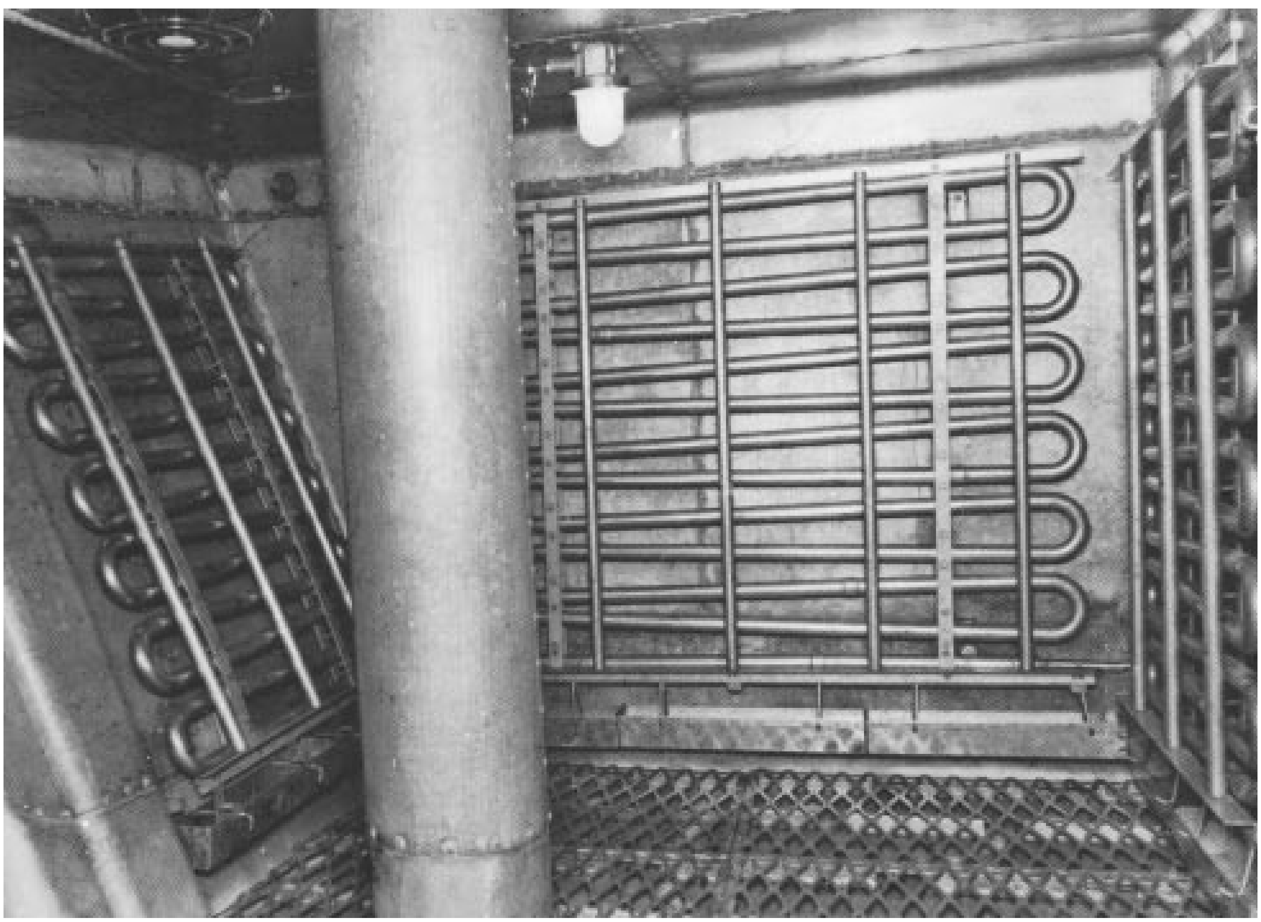
Evaporator

The evaporator consists of a coil of copper, aluminum, or aluminum alloy tubing installed in the space to be refrigerated. Figure 10-4 shows some of this tubing. As mentioned before, the liquid R-12 enters the tubing at a reduced pressure and, therefore, with a lower boiling point. 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. This, in turn, is controlled by the spring adjustment of the TXV. A temperature range of 4° to 12°F of superheat is considered desirable. It increases the efficiency of the plant and evaporates all of the liquid. This prevents liquid carry-over 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



47.93

Figure 10-4.-Evaporator tubing.

temperature of the available cooling medium, the only way to make the vapor condense is to compress it.

When we raise the pressure, we also raise the temperature. Therefore, we have raised its condensing temperature, which allows us to use seawater as a cooling medium 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 and low-pressure sides 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 10-5 shows a motor-driven, single-acting, two-cylinder, reciprocating compressor, such as those commonly used in naval refrigeration plants.

Compressors used in R-12 systems may be lubricated either by splash lubrication or by pressure 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 lubrications systems.

Capacity Control System

Most compressors are equipped with an oil-pressure-operated automatic capacity control system. This system unloads or cuts cylinders out of operation following decreases in the refrigerant 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.

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

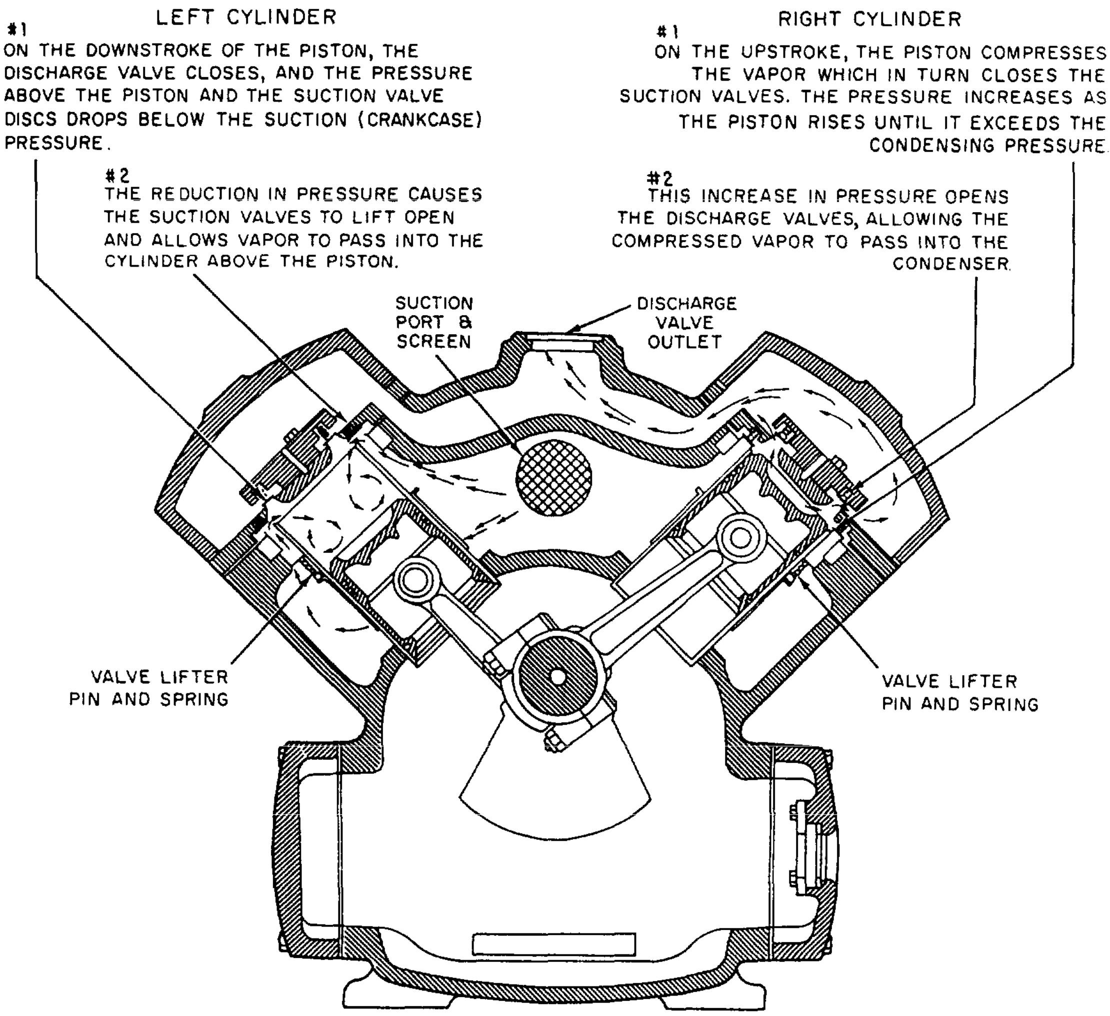


Figure 10-5.-Reciprocating compressor.

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 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. This will prevent stopping the compressor before all solenoid valves are closed.

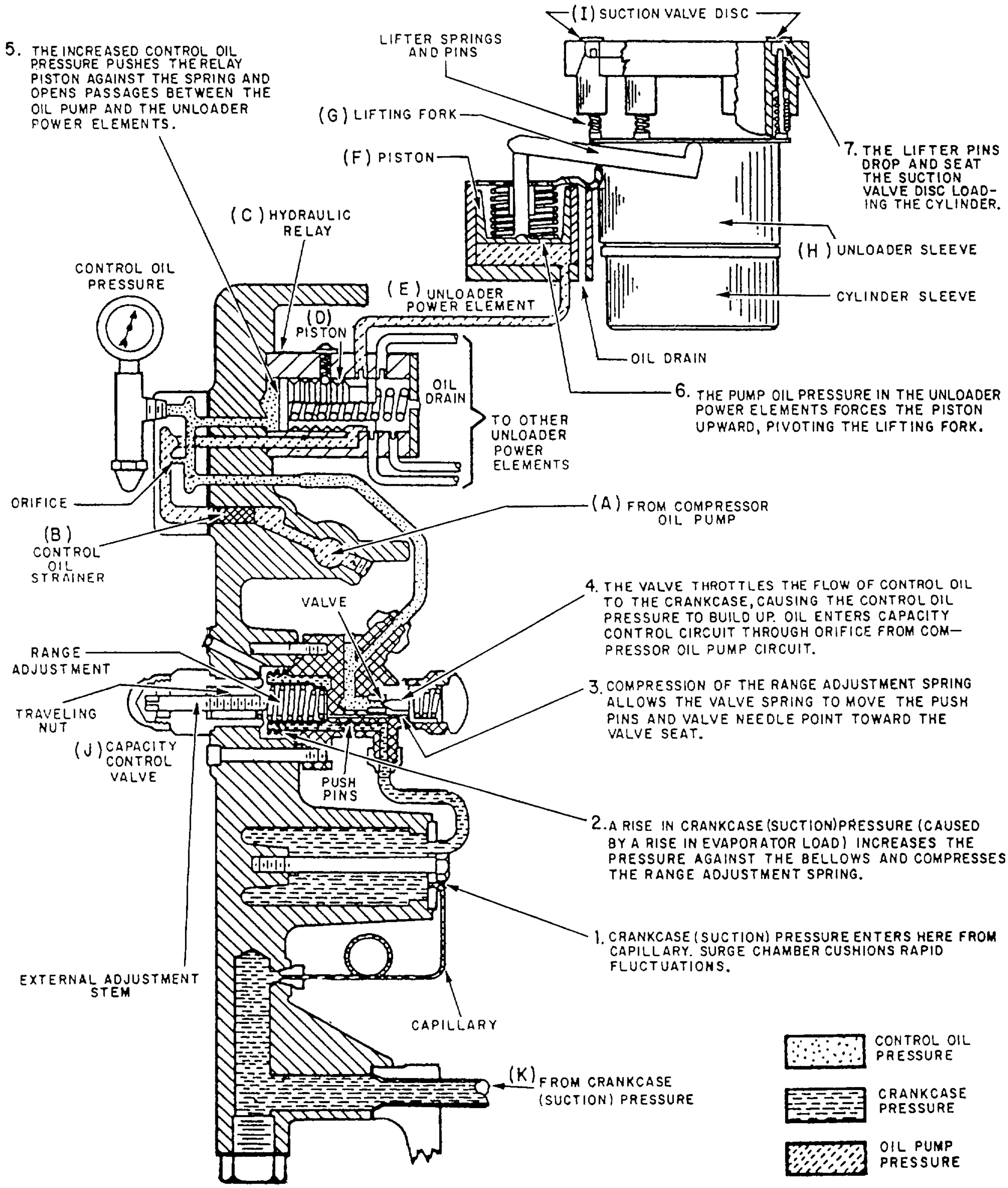


Figure 10-6.-Capacity control system.

Several designs of capacity control systems are in use. One of the most common is shown in figure 10-6. The capacity control system consists of a power element and its link for each controlled cylinder, a step control hydraulic relay, and a capacity control valve.

The system's 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 10-6, and refer to them as you read the next two paragraphs.

(A) Compressor oil pump pressure tap-off

(B) Control oil strainer

(C) Hydraulic relay

(D) Hydraulic relay piston

(E) Unloader power element

(M) Unloader power element piston

(G) Lifting fork

(H) Unloader sleeve

(O) 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). There 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 (1) to seat. The system is governed by suction pressure, which actuates the capacity control valve (J). This 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. There is a resulting decrease in control oil pressure within the hydraulic relay. This decrease allows the piston to be moved by spring action. This action 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, this process is reversed, and the controlled cylinders will load in succession. The loading process is detailed in steps 1 through 7 in figure 10-6.

Condenser

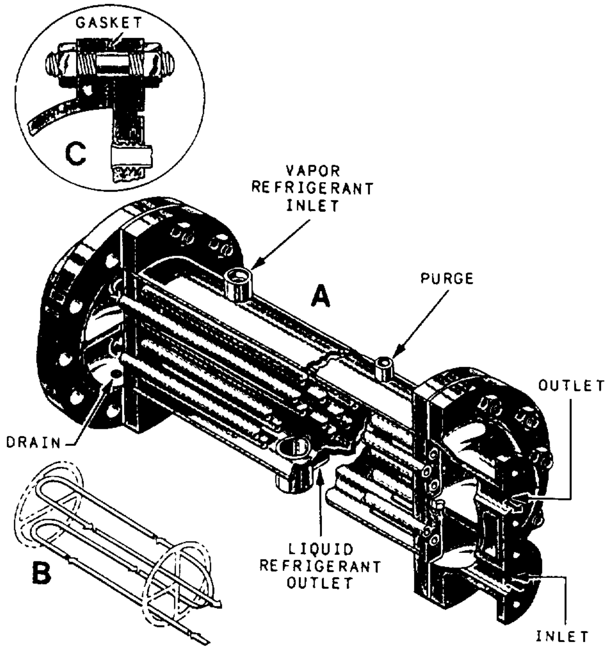
The compressor discharges the high-pressure, high-temperature refrigerant vapor to the condenser, where it flows around the tubes through which seawater is being pumped. As the vapor gives up its superheat (sensible heat) to the seawater, the temperature of the vapor drops to the condensing point. The refrigerant, now in liquid form, is subcooled slightly below its condensing point. This is done 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 10-7. Circulating water is obtained through a branch connection from the fire main or by means of an individual pump taking suction from the sea. The purge connection (fig. 10-7) 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.

Receiver

The receiver (fig. 10-8) acts as a temporary storage space and surge tank for the liquid refrigerant. The receiver also serves as a vapor seal to keep vapor out of the liquid line to the expansion valve. Receivers are constructed for either horizontal or vertical installation.



A. Cutaway view
B. Water-flow diagram
C. Arrangement of heat joint

Figure 10-7.-Water-cooled condenser for an R-12 refrigeration system.

ACCESSORIES

In addition to the five main components of a refrigeration system, a number of controls and accessories are required. The most important of these are described briefly in the following paragraphs.

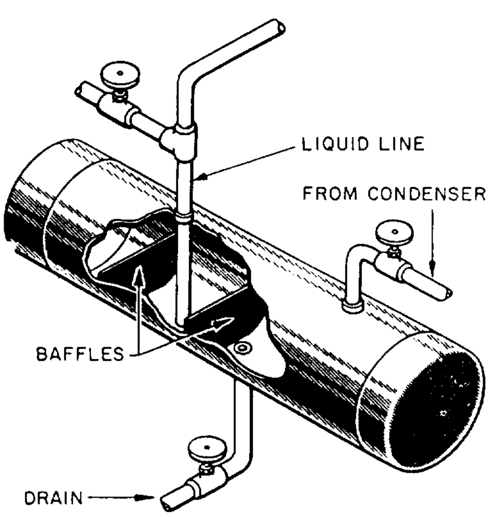


Figure 10-8.-Receiver.

Dehydrator

A dehydrator, or dryer, containing silica gel or activated alumina, is placed in the liquid refrigerant line between the receiver and the TXV. 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 10-9.

Moisture Indicator

A moisture indicator is located either in the liquid refrigerant line or built into the dehydrator. The moisture indicator contains a chemically treated element that changes color when there is an increase of moisture in the refrigerant. The color change is reversible and changes 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 10-10 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 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

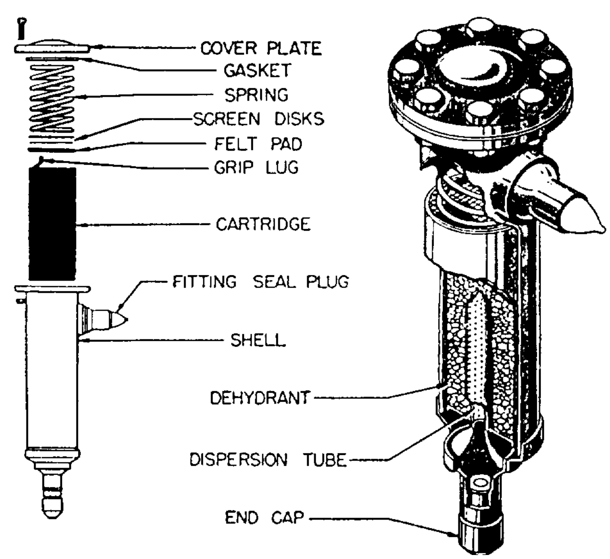
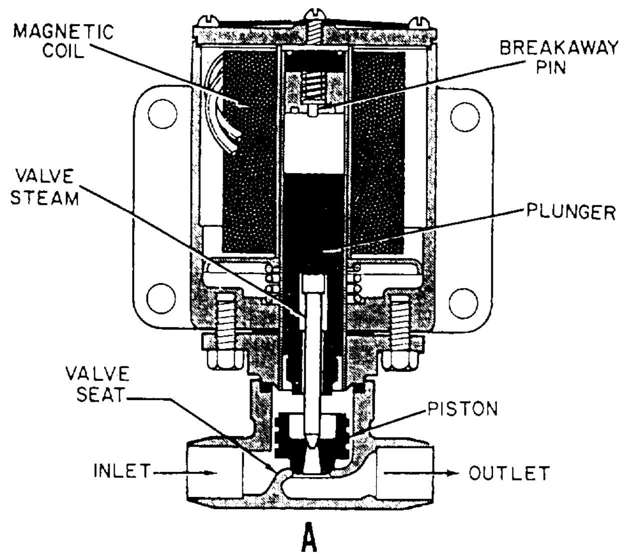


Figure 10-9.-Refrigeration dehydrator.



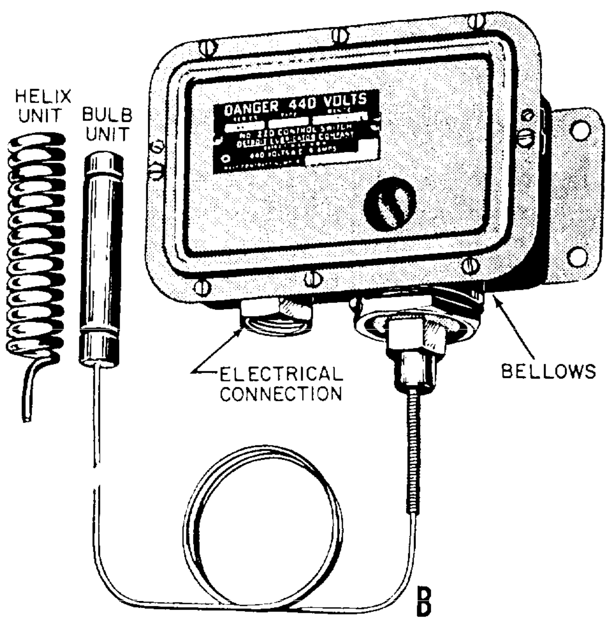


Figure 10-10.-Solenoid valve and thermostatic control switch.

open. This action closes the solenoid valve and shuts off all flow of liquid refrigerant to the TXV. 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 TXV.

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 TXV 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 and 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. This 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

In some ships, several refrigerated spaces of varying temperatures are maintained by one compressor. In these cases, 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

- on water coolers,
- on units where high humidity is required (such as fruit and vegetable stow 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 the EPR valve) is shown in figure 10-11. The tension of the spring above the diaphragm is adjusted so 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 is also known as a *suction pressure control switch*. This switch is the control that causes the compressor to go on or off as required for normal operation of the refrigeration plant.

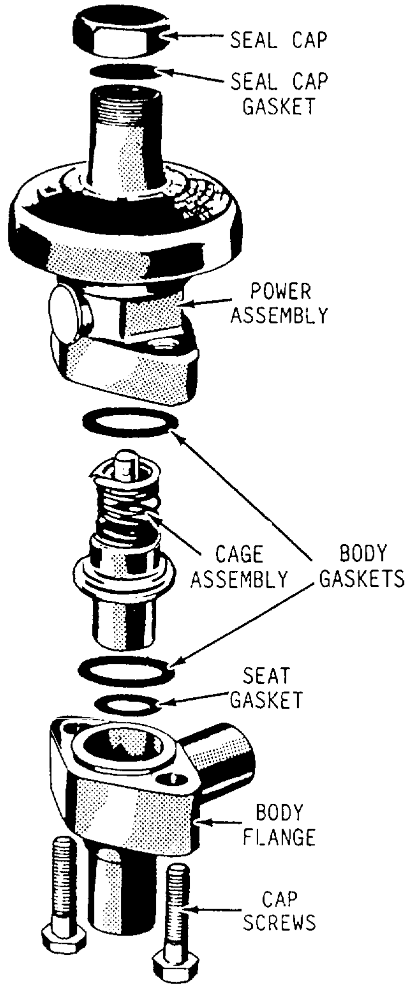


Figure 10-11.-Exploded view of a typical evaporator pressure regulating valve.

It 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, the flow of refrigerant to the evaporators is stopped. This action causes the pressure of the vapor in the compressor suction line to drop quickly. When the suction pressure has dropped to the desired pressure, the low-pressure cutout switch stops the compressor motor. When the temperature in the refrigerated spaces rises enough to operate one or more of the solenoid valves, refrigerant is again admitted to the cooling coils. This causes the compressor suction pressure to buildup again. At the desired pressure, the low-pressure cutout switch closes, starting the compressor, and the cycle is repeated again.

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, while the high-pressure cutout switch is made to OPEN when the discharge pressure is too high. As you already have learned, the low-pressure cutout switch is the compressor control for the normal operation of the plant. On the other hand, the high-pressure cutout switch is a safety device only. **It does not have control of the compressor under normal conditions.**

Water Failure Switch

A water failure switch stops the compressor if there is a circulating water supply failure. The water failure switch is a pressure-actuated switch. Its operation is similar to the low- and high-pressure cutout switches previously described. If the water failure cutout switch fails to function, the refrigerant pressure in the condenser quickly builds up to the point that the high-pressure switch stops the compressor.

Strainer

Because of the solvent action of R-12, any particles of grit, scale, dirt, or metal that the system may contain are circulated through the refrigerant lines. To avoid damaging the compressor from foreign matter, a strainer is installed in the compressor suction connection.

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) that transmits motion to the valve stem.

The primary function of the water regulating valve is to maintain a constant refrigerant condensing pressure. Basically, the following two variable conditions exist:

1. The amount of refrigerant to be condensed
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.

Pressure Gauges and Thermometers

A number of pressure gauges and thermometers are used in refrigeration systems. Figure 10-12 shows a compound R-12 gauge. The temperature markings on this gauge show the boiling point (or condensing point) of the refrigerant at each pressure; the gauge 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 gauge 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.

CHARACTERISTICS OF REFRIGERANTS

Pure R-12 (CC 1425F425) is colorless. It is odorless in concentrations of less than 20 percent by volume in air. In higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of -21°F at atmospheric pressure. At ordinary temperatures under a pressure of approximately 70 psig to 75 psig, R-12 is a

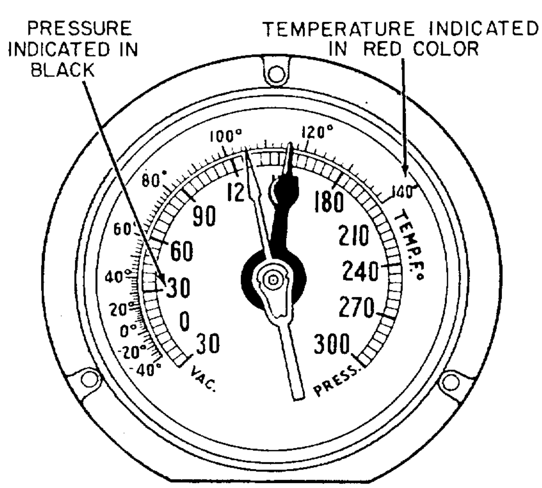


Figure 10-12.-Compound R-12 pressure gauge.

liquid. Because 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-22 (CHC1F425) and R-11 (CC1435F) are colorless, nonexplosive, nonpoisonous refrigerants with many properties similar to those of R-12. Because of the similarities between R-22, R-11, and R-12, only R-12 is discussed.

Mixtures of R-12 vapor and air, in all proportions, will not irritate your eyes, nose, throat, or lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous. However, if R-12 concentration becomes excessive, it can cause you to become unconscious or cause death because of lack of oxygen to the brain.

R-12 is nonflammable and nonexplosive in either a liquid or vapor state. R-12 will not corrode the metals commonly used in refrigerating systems.

R-12 is a stable compound capable of undergoing the physical changes required of it in refrigeration service without decomposing. 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.

HALOCARBONS

HaloCarbons are organic chemical compounds containing hydrogen and one or more atoms of carbon, fluorine, bromine, chlorine, or iodine. These elements may be present in various combinations in the compound.

WARNING

Refrigerants are halocarbons. Personnel working with refrigerants may be injured or killed if proper precautions are not taken.

You may be more familiar with the brand names of halocarbons, such as Freon(s) (refrigerants), Gentron, Gension D., Frigen, AFFF, or Carbon Tetrachloride. You will work with these compounds regularly aboard ship. Because you use them frequently, you gain a false sense of security that makes you forget their potential for danger. Halocarbons are especially dangerous when used in high concentration in confined or poorly ventilated spaces.

PERSONAL SAFETY PRECAUTIONS

R-12 is a powerful freezing agent. Even a very small amount can freeze the delicate tissues of the eye, causing permanent damage. All personnel must wear goggles when working in spaces were they maybe exposed to a refrigerant, particularly in its liquid form. If refrigerant does get into someone's eyes, get that person **IMMEDIATE** medical treatment to avoid permanent damage. In the meantime, put drops of clean olive oil, mineral oil, or other nonirritating oil in the eyes. Make sure that the person does not rub his/her 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.

Know, understand, and use these safety precautions, and you can safely operate and maintain refrigeration plants.

HANDLING OF REFRIGERANT CYLINDERS (BOTTLES)

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:

NOTE: Before handling refrigerant bottles, read OPNAVINST 5100.19.

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 you handle cylinders. A crane maybe used if a safe cradle or platform is provided to hold the cylinders.

3. Keep the caps provided for valve protection on cylinders except when the cylinders are being used.

4. When refrigerant is discharged from a cylinder, weigh the cylinder immediately. Record the weight of the refrigerant remaining in the cylinder.

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 is empty, close the cylinder valve immediately to prevent the entrance of air, moisture, or dirt. Also, replace the valve protection cap.

8. NEVER use cylinders for other than their intended purpose. Do NOT use them as rollers and supports.

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 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 gauges 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 percent 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, protect them against extremes of weather. NEVER store a cylinder in an area where the temperature will be 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.

AIR CONDITIONING

Air conditioning is a field of engineering that deals with the design, construction, and operation of equipment used to establish and maintain desirable indoor air conditions. It is used to maintain the environment of an enclosure at any required temperature, humidity, and purity. Simply stated, air conditioning involves the cooling, heating, dehumidifying, ventilating, and purifying of air.

One of the chief purposes of air conditioning aboard ship is to keep the crew comfortable, alert, and physically fit. None of us can long maintain a high level of efficiency under adverse environmental conditions. We have to maintain a variety of compartments at a prescribed temperature with proper circulation. These compartments must have the proper moisture content, the correct proportion of oxygen, and an acceptable level of air contamination (dust, airborne dirt, etc.). We also have to provide mechanical cooling or ventilation in ammunition spaces to prevent deterioration of ammunition components. We have to provide them in gas storage spaces to prevent excessive pressure buildup in containers and contamination in the space caused by gas leaks. Finally, we must provide cooling and ventilation in electrical/electronic equipment spaces. his is done to maintain the ambient temperature and humidity, as specified for the equipment.

To properly air-condition a space, the humidity, heat of the air, temperature, body heat balance, the effect of air motion, and the sensation of comfort is considered.

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 (dry-bulb) thermometer,

Air always contains some water vapor. Any water vapor in the air contains the LATENT HEAT OF VAPORIZATION. (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, you must consider two different temperatures-the dry-bulb and wet-bulb temperature.

Measurement of Temperatures

The **DRY-BULB TEMPERATURE** is the temperature of sensible heat of the air, as measured by an ordinary thermometer. In air conditioning, such a thermometer is known as a *dry-bulb thermometer* because its sensing bulb is dry.

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 and which is then wet with distilled water. The water in the sleeve or wick is evaporated by a current of air at high velocity (see next paragraph). This evaporation withdraws heat from the thermometer bulb, lowering the temperature by several degrees. The difference between the dry-bulb and the wet-bulb temperatures is called the *wet-bulb depression*. when the wet-bulb temperature is the same as the dry-bulb, the air is said to be 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 and a short chain attached. This allows the thermometers to be whirled in the air, providing a high-velocity air current to promote evaporation. Such a device is known as a SLING PSYCHROMETER (fig. 10- 13). When using the sling psychrometer, whirl it rapidly-at least four times per second. Observe the wet-bulb 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. 10- 14) are provided with a small motor-driven fan and dry-cell batteries. Motorized psychrometer are generally preferred and are gradually replacing sling psychrometer.

Relationships Between Temperatures

You should clearly understand the definite relationships of the three temperatures-dry-bulb, wet-bulb, and dew-point.

When air contains some moisture but is not saturated, the dewpoint temperature is lower than the dry-bulb temperature; the wet-bulb temperature lies between them. As the amount of moisture in the air increases, the difference between the dry-bulb temperature and the wet-bulb temperature becomes less.

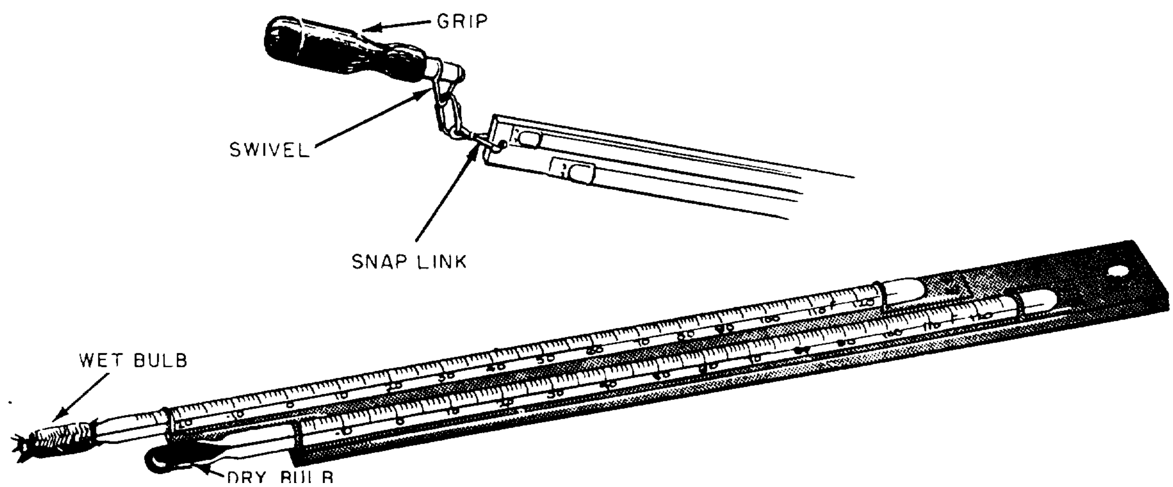
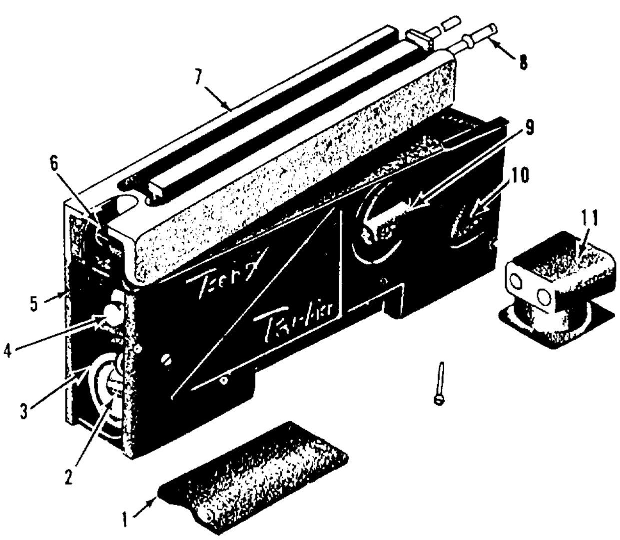


Figure 10-13.-A standard sling Psychrometer.



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

Figure 10-14.-Exposed view of motorized psychrometer.

When the air is saturated, all three temperatures are the same.

By using both the wet-bulb and the dry-bulb temperature readings, you can find the relative humidity and the dew-point temperature on a psychometric chart (fig, 10-15).

DEW-POINT TEMPERATURE.– The wet-bulb temperature lines are angled across the chart (see fig. 10-15). The dew-point temperature lines are straight across the chart (indicated by the arrows for wet bulb and dew point). Find where the wet-bulb and dry-bulb lines cross, interpolate the relative humidity from the nearest humidity lines to the temperature-line crossing point. Then, to find the dew point, follow the straight dew-point line closest to the intersection across to the right of the chart and read the dew-point temperature. For example, find the wet-bulb temperature of 70°F. Next, trace the line angling down to the right to the dry-bulb temperature of 95°F. Finally, to find the dew-point temperature, follow the dew-point temperature lines nearest the intersection straight across to the right of the chart. The dew-point line falls about one-third of the way between the 55°F mark and the 60° mark. You can see that the dew-point temperature is about 57°F.

RELATIVE HUMIDITY.– To find the relative humidity (see fig. 10- 15), first 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 percent. However, the intersecting line is below 30 percent and higher than 20 percent. You can see that the relative humidity is about 28 percent.

BODY HEAT BALANCE

Ordinarily, the body remains at a fairly constant temperature of 98.6°F. It is important to maintain this body temperature. Since there is a continuous heat gain from internal body processes, there must be a continuous loss to maintain body heat balance. Excess heat must be absorbed by the surrounding air or lost by radiation. As the temperature and humidity of the

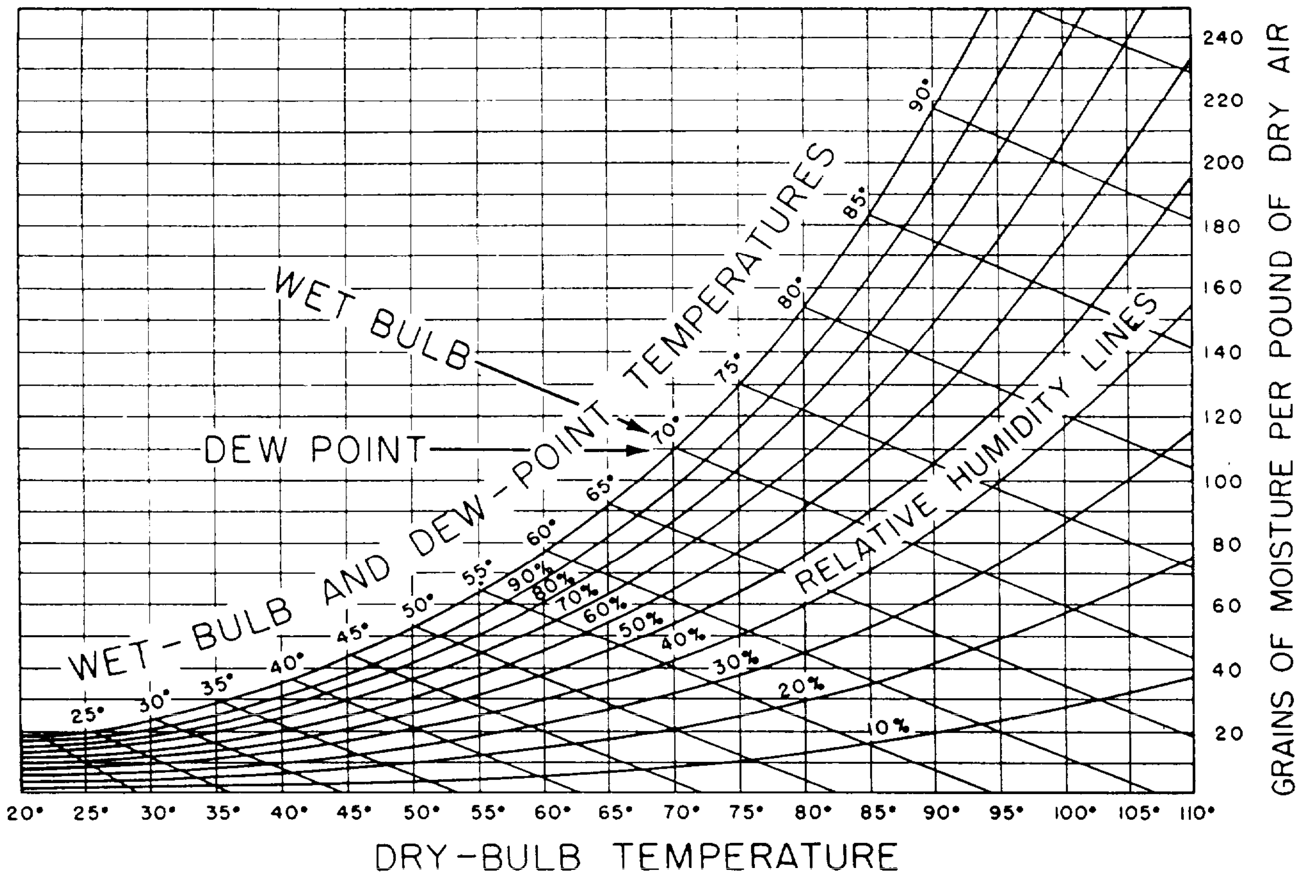


Figure 10-15.-Simplified psychometric chart.

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 that 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 by radiation, by convection, by conduction, and as a by-product of physiological processes that take place within the body.

The heat gain by radiation comes from our surroundings. However, heat always travels from areas of higher temperature to areas of lower temperature. Therefore, 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. Some sources of indoor heat radiation are heating devices, operating machinery, and hot steam piping.

The heat gain by convection comes only from currents of heated air. 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 comes in contact.

Most body heat comes from within the body itself. Heat is produced continuously inside the body by the oxidation of foodstuffs and other chemical processes, friction and tension within the muscle tissues, and other causes.

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 radiation, convection, and conduction. Latent heat is given off in the breath and by evaporation of perspiration.

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 its relative humidity. This means the body is surrounded by an envelope of moist air that 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 continuously being removed and replaced by the ambient air. This movement increases 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, the rate of heat loss makes the body feel cool and the sensation of a draft is felt.

SENSATION OF COMFORT

From what you have just learned, you know that three factors are closely interrelated in their effects upon the comfort and health of personnel aboard ship. These factors are temperature, humidity, and air motion. In fact, a given combination of temperature, humidity, and air motion produces the same feeling of warmth or coolness as a higher or lower temperature along 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 psychometric chart when the dry-bulb temperatures and air velocity are known.

The combinations of temperature, relative humidity, and air motion of a particularly effective temperature may produce the same feeling of warmth or coolness. However, they are NOT all equally comfortable. Relative humidity below 15 percent produces a parched condition of the mucous membranes of the mouth, nose, and lungs, and increases susceptibility to disease germs. Relative humidity above 70 percent causes an accumulation of moisture in clothing. For best health conditions, you need a relative humidity ranging from 40 percent to 50 percent for cold weather and from 50 percent to 60 percent for warm weather. An overall range from 30 percent to 70 percent is acceptable.

VENTILATION EQUIPMENT

Proper circulation is the basis for all ventilating and air-conditioning systems and related processes. Therefore, we must 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.

In Navy ships, the fans used with supply and exhaust systems are divided into two general classes-axial flow and centrifugal.

Most fans induct 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. Because the motors of these fans are outside the air stream, they cannot ignite the explosive gases. The drive motors for centrifugal fans are less subject to overheating to a lesser degree than are motors of vane-axial fans.

VANE-AXIAL FANS

Vane-axial fans (fig. 10-16) 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 flow of air in the duct from the fan blades across the motor. The motor will overheat if it is allowed to operate while the supply air to the fan is shut off.

TUBE-AXIAL FANS

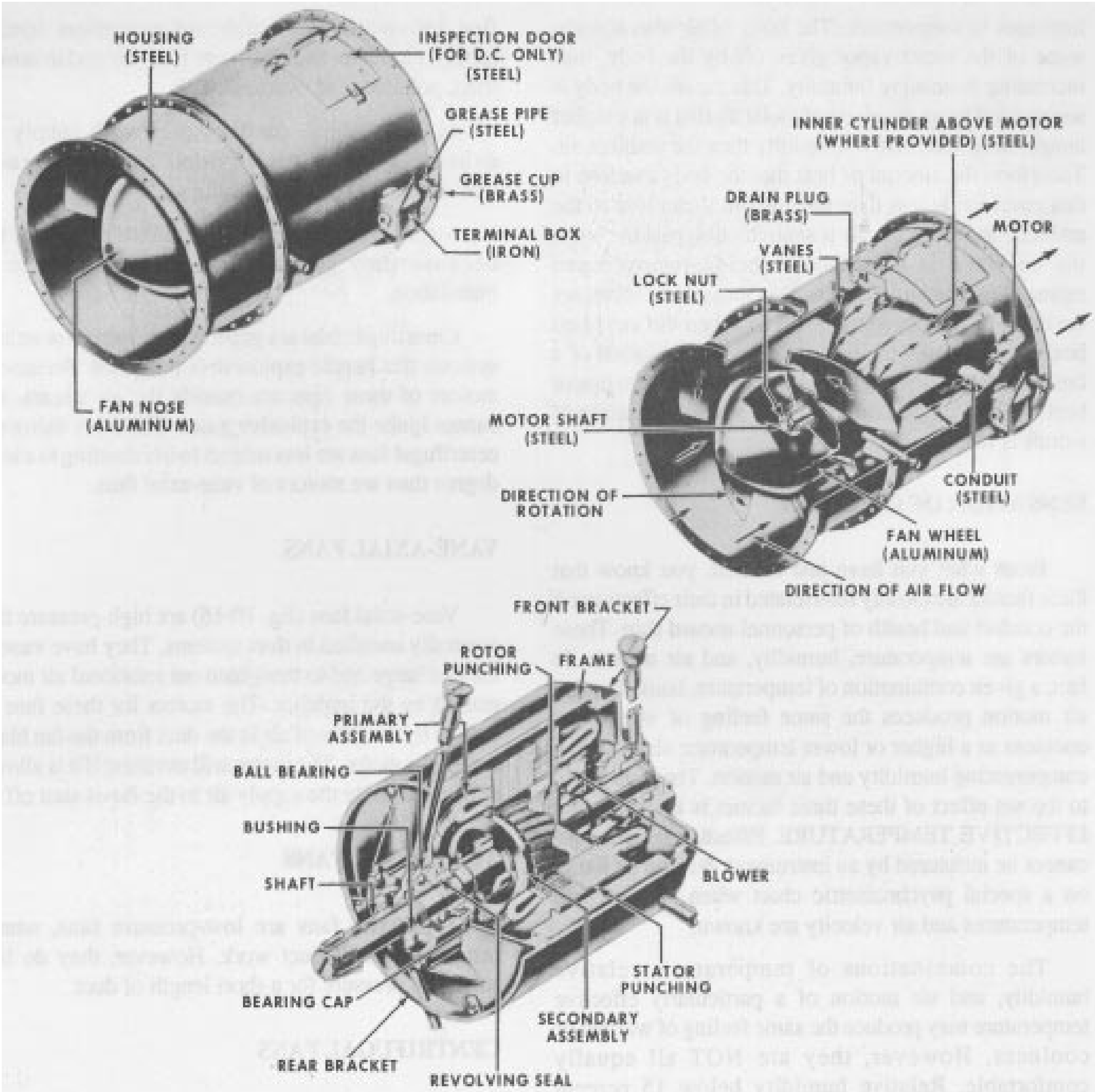
Tube-axial fans are low-pressure fans, usually installed without duct work. However, they do have sufficient pressure for a short length of duct.

CENTRIFUGAL FANS

Centrifugal fans (fig. 10-17, view A) are used primarily to exhaust explosive or hot gases. However, they may be used in lieu of axial-flow fans if they work 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 (fig. 10-17, view B) with flexible air hoses are used aboard ship for ventilating holds and cofferdams. They are also used in unventilated spaces to clear out stale air or gases before personnel enter and for emergency cooling of machinery.



47.106

Figure 10-16.-Vane-axia1 fan: A. Exterior view. B. Cutaway view. C. Cutaway view of the fan motor.

Most portable fans are of the axial-flow type, driven by electric, explosionproof motors. On ships carrying gasoline, a few air turbine-driven centrifugal fans are normally provided. You can place greater confidence in the explosionproof characteristics of these fans.

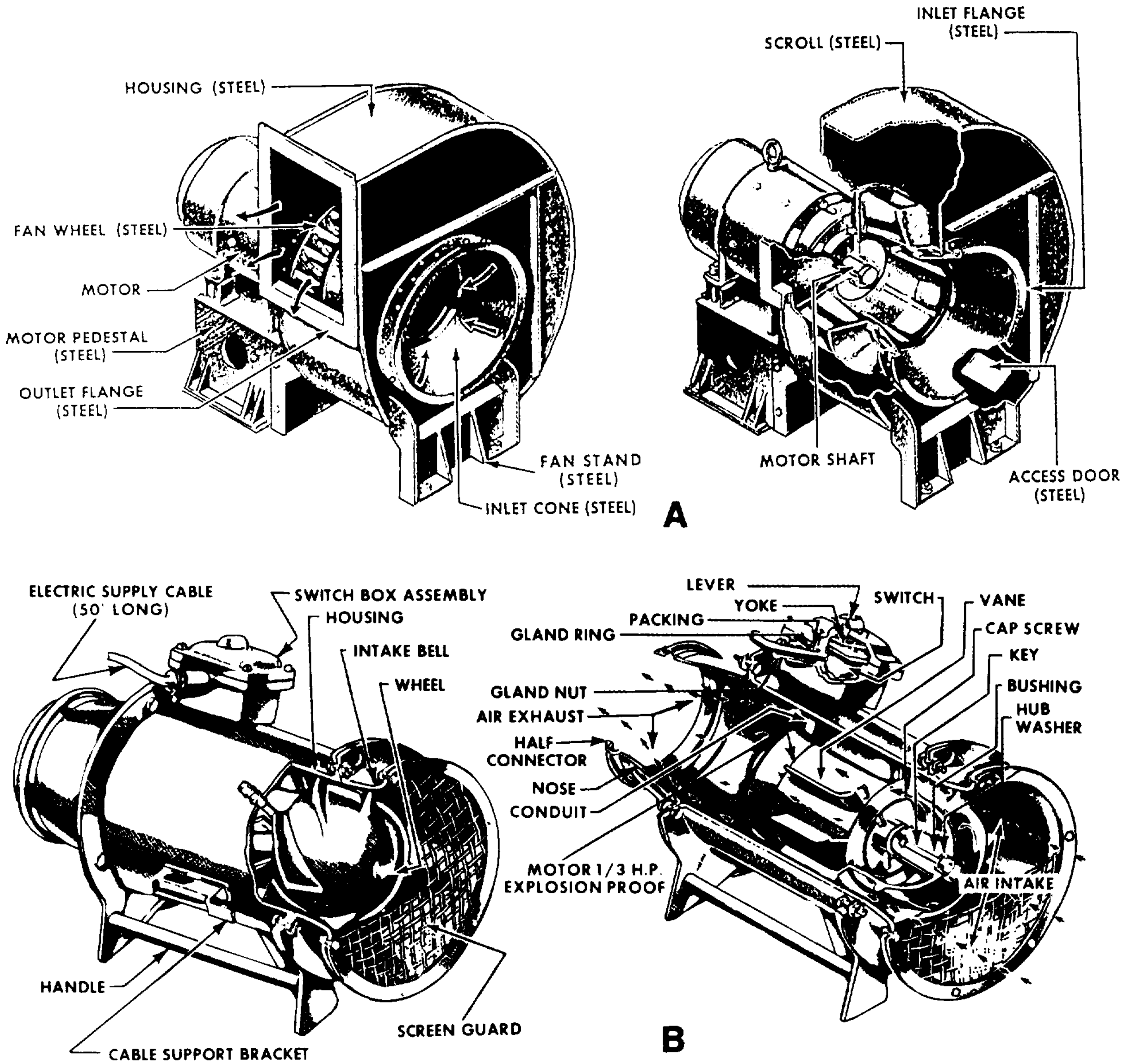
CAUTION

Never use a dc-driven fan to exhaust air that contains explosive vapor.

EXHAUSTS

Many local exhausts are used to remove heat and odors. Machinery spaces, laundries, and galleys are some of the shipboard spaces where local exhausts are used.

Most exhausts used on Navy ships are mechanical (contain an exhaust fan), although natural exhausts are sometimes used in ship's structures and on small craft.



47.107

Figure 10-17.-Miscellaneous ventilation fans: A. Centrifugal fan. B. Portable axial fan.

MECHANICAL COOLING EQUIPMENT

Almost all working and living spaces on newer ships are air conditioned. The equipment used on these ships was carefully tested to see which types would best dehumidify and cool ship compartments. Two basic types of equipment have been found most effective and are now in general use. They are chilled water circulating systems and self-contained air conditioners.

CHILLED WATER CIRCULATING SYSTEMS

TWO basic types of chilled water air-conditioning systems are now in use. They are a vapor compression unit and a lithium bromide absorption unit. In the vapor compression unit, the primary refrigerant cools the secondary refrigerant (chilled water) that is used to cool the spaces. This type uses the vapor compression cycle and R-11 or R-114 as the primary refrigerant. The type of primary refrigerant depends on the size and type of compressor. The lithium bromide unit 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. However, lithium bromide plants are used in submarines because they require no compression, which means a quieter operation.

Vapor Compression Units

The vapor compression chilled water circulating system differs from a refrigerant circulating (direct expansion) air-conditioning system. In vapor compression chilled water circulating systems, the air is conditioned by using a secondary refrigerant (chilled water) that is circulated to the various cooling coils. Heat from the air-conditioned space is absorbed by the circulating chilled water. Heat is then removed from the water by the primary refrigerant system in the water chiller. In large ton vapor compression 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. 10-18) is basically the same as other refrigeration plants except for the method of compression. The refrigerant gas is pressurized in the centrifugal turbocompressor. This then 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. **(NOTE:** In some R-11 units, an orifice is installed instead of a float valve.) This allows 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. Then, the vaporized refrigerant reenters the suction side of the compressor to start the cycle again.

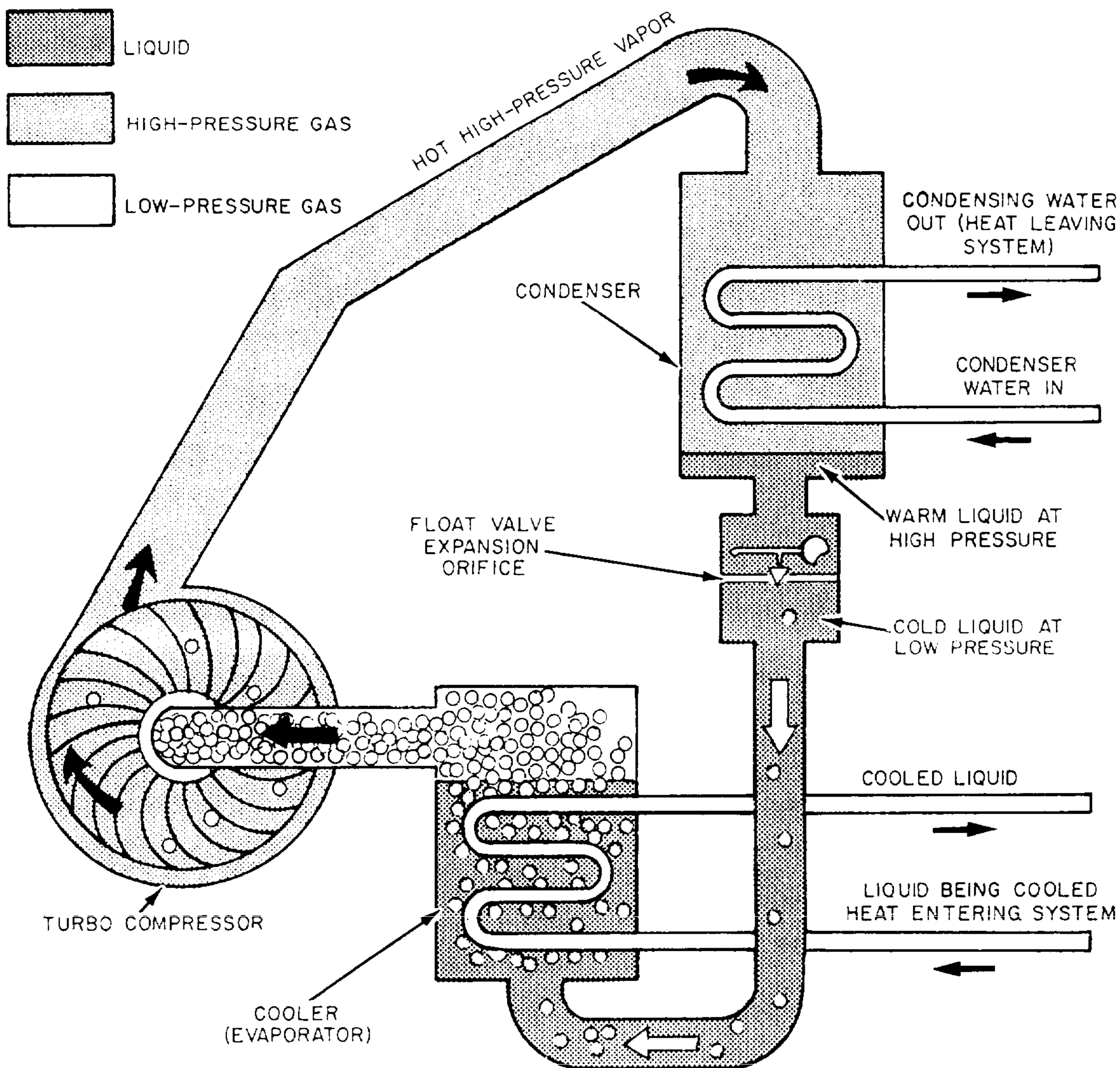


Figure 10-18.-Vapor compressor (centrifugal) unit.

The load on the air-conditioning plant is determined by the desired chilled water temperature. The compressor load is changed by either an increased or decreased demand of the chilled water temperature. Upon demand, the load is changed by the use of adjustable prerotation vanes. The vanes are located on the suction side of the compressor. The vanes act as dampers to 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 10-19 shows a centrifugal compressor with the inlet piping removed. Note that the prerotation vanes are in the fully open position. The 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 vanes.

In some plants, the electric motor used In some plants, the electric motoerrive the compressor is hermetically sealed and is cooled by a flow of refrigerant through it. The compressor is lubricated by a force-feed lubrication system. This system 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 condition develops. Some of these conditions are high condenser pressure, low compressor lube oil pressure, seawater loss to the condenser, loss of chilled water, low refrigerant temperature, low chilled water temperature, and high discharge temperature.

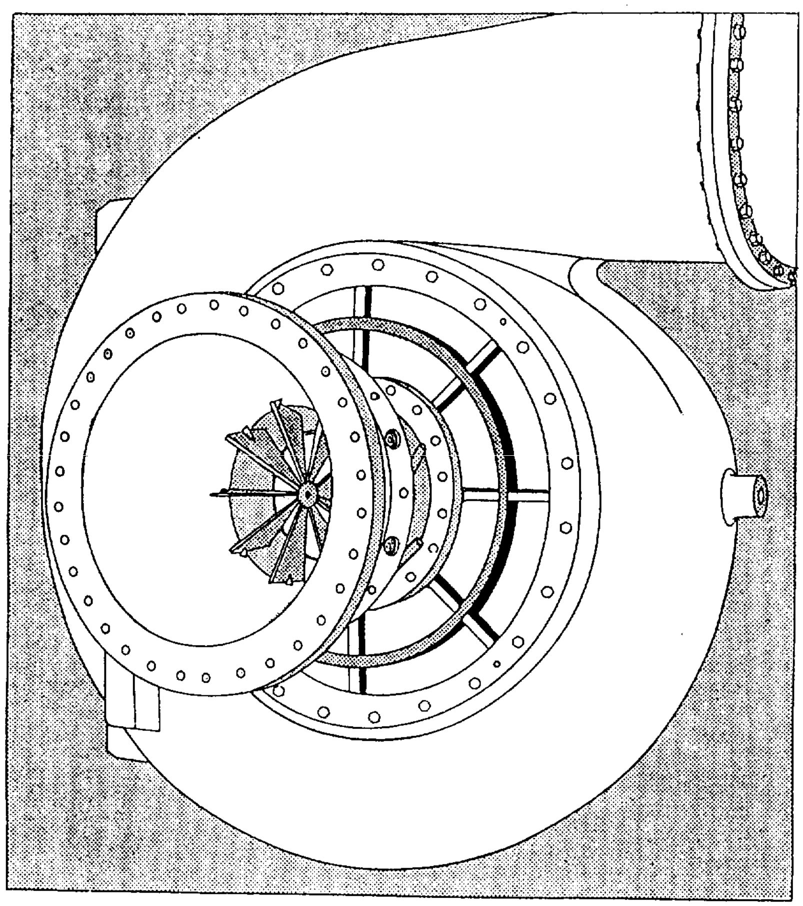


Figure 10-19.-Suction end of a centrifugal compressor showing prerotation vanes.

An oil heater keeps the oil warm in the oil sump of the compressor during plant shutdown. If the oil is not kept heated, it absorbs large amounts of refrigerant. This results 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 10-20 shows a centrifugal compressor air-conditioning unit. This particular plant has a 150-ton capacity and uses R-114 as the refrigerant. The gauges and controls for the plant are on the other side of the unit.

Lithium Bromide Absorption Unit

Water is used as a refrigerant in the lithium bromide absorption cycle. The absorption system differs from the compression-type refrigeration machines. 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.

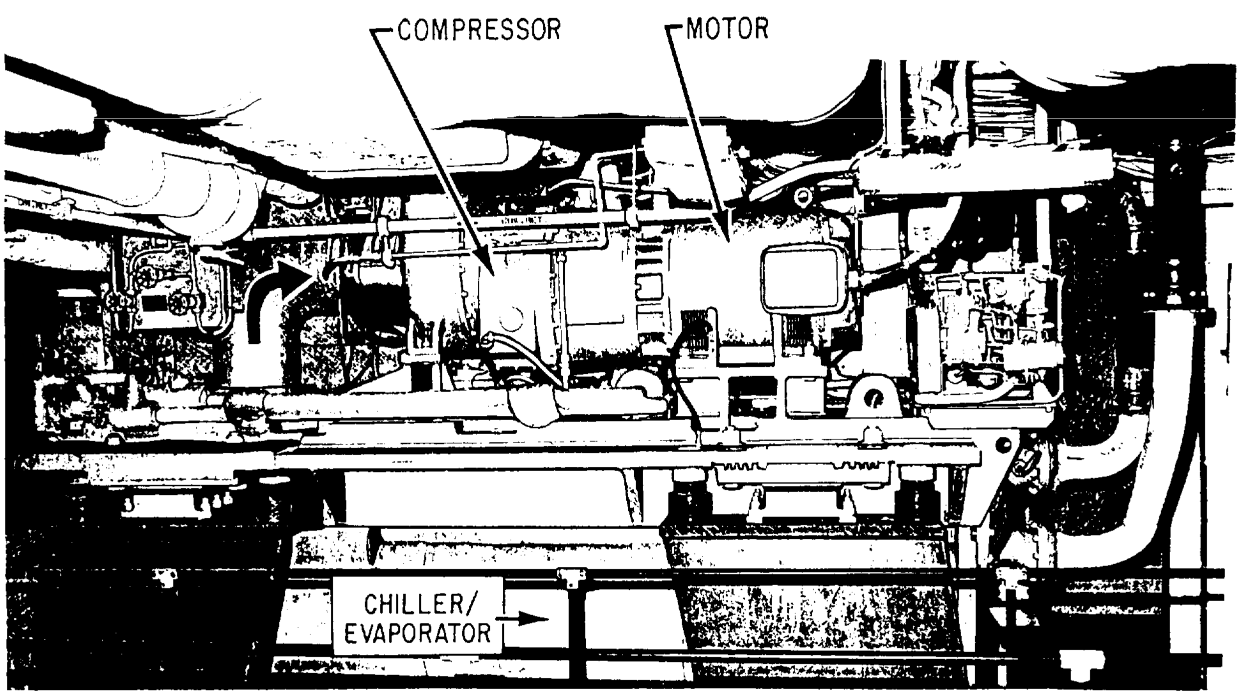
The following are the two principles that form the basis for the lithium bromide absorption refrigeration cycle:

1. Lithium bromide has the ability to absorb large quantities of water vapor.

2. When under a high vacuum, water boils (vaporizes) at a low temperature and, in doing so, absorbs heat.

To understand the lithium bromide absorption cycle, follow along on figure 10-21 during as you read the following explanation. Notice that the EVAPORATOR and ABSORBER sections 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 boils 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 88the chilled water tubes through a spray header. This causes the water 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 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



47.217

Figure 10-20.-R-114 centrifugal air-conditioning plant.

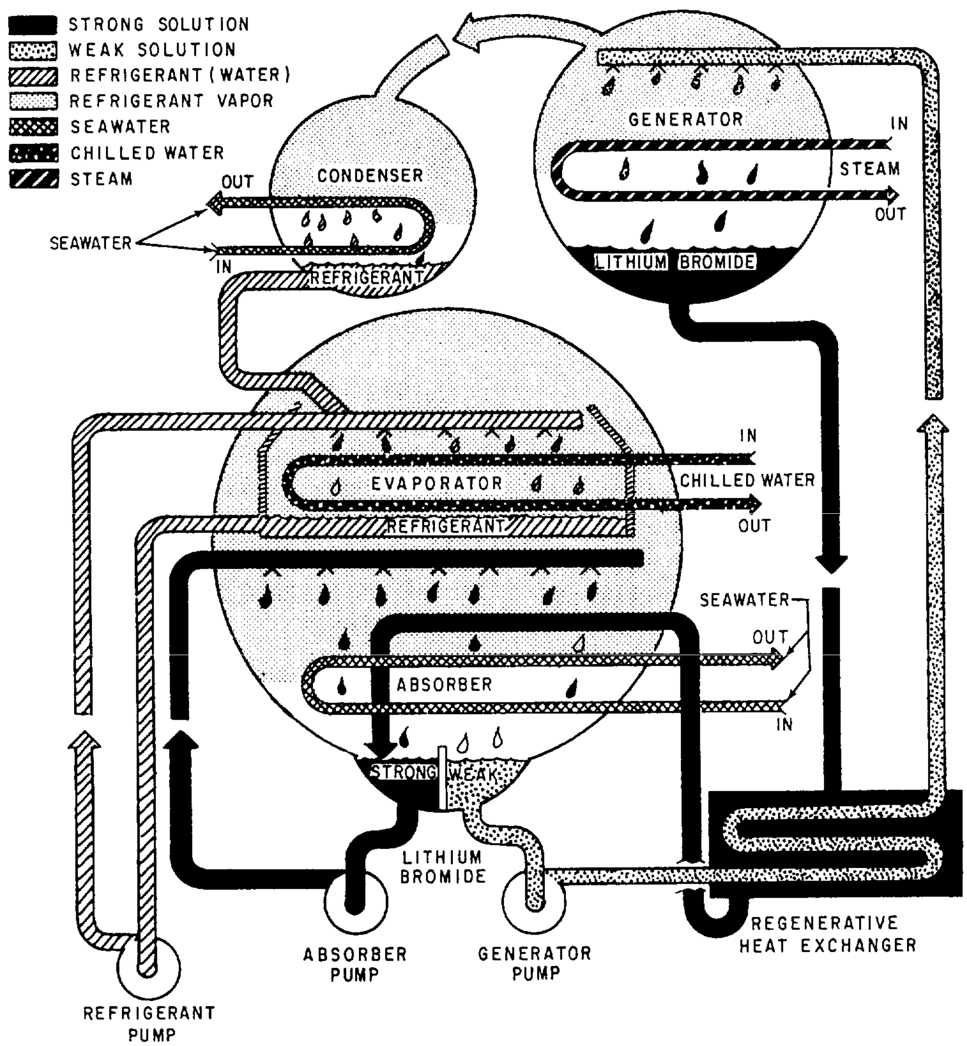


Figure 10-21.-Basic absorption cycle.

known as a WEAK solution. Here, in the generator section of the plant, the weak solution is rejuvenated for reuse as a STRONG solution. 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 that heat the solution and drive the water vapor out of the 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 a 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; the strong solution must be cooled to absorb water vapor. The regenerative heat exchanger aids in this process by cooling the strong solution and preheating the weak solution in the cycle.

Seawater (condensing) flow is provided through the absorber section. It cools the strong solution returning from the generator and removes 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. Therefore, the two pumps are referred to cumulatively as the absorber/generator pump.

A purge system (not shown) consists of a pump, an eductor, and a purge tank. The system 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 important to the proper operation of the plant.

Fan-Coil Assemblies

Fan-coil assemblies (fig. 10-22) use chilled water to air-condition spaces. These assemblies are known as spot coolers. The chilled water is piped through the cooling coils of the units, and a fan forces air over the coils. 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. 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 collects and evaporates, leaving impurities that can rapidly cause the tray to corrode.

SELF-CONTAINED AIR CONDITIONERS

Ships without central air conditioning may use self-contained air-conditioning units. Naval Sea Systems Command (NAVSEASYSCOM) approval is required. 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.

These units use nonaccessible hermetically sealed compressors (motor and compressor are contained in a welded steel shell). For this reason, shipboard maintenance of the motor-compressor unit is impractical. The thermal expansion valve used in these units is preset and nonadjustable. However, a thermostat and fan speed control are normally provided for comfort adjustment.

AIR COMPRESSORS

The air compressor is the heart of any compressed air system. It takes in atmospheric air, compresses it to the desired pressure, and moves it into supply lines or into storage tanks for later use. Air compressors come in different designs and configurations and have different methods of compression. Some of the most common types used on gas turbine ships are discussed in this chapter.

Before describing the various types of air compressors, you need to know about the composition of air and some of the things air may contain. This discussion should help you understand why air compressors have special features that prevent water, dirt, and oil vapor from getting into compressed air piping systems.

Air is mostly composed of nitrogen and oxygen. At atmospheric pressure (within the range of temperatures for the earth's atmosphere), air is in a gaseous form. The

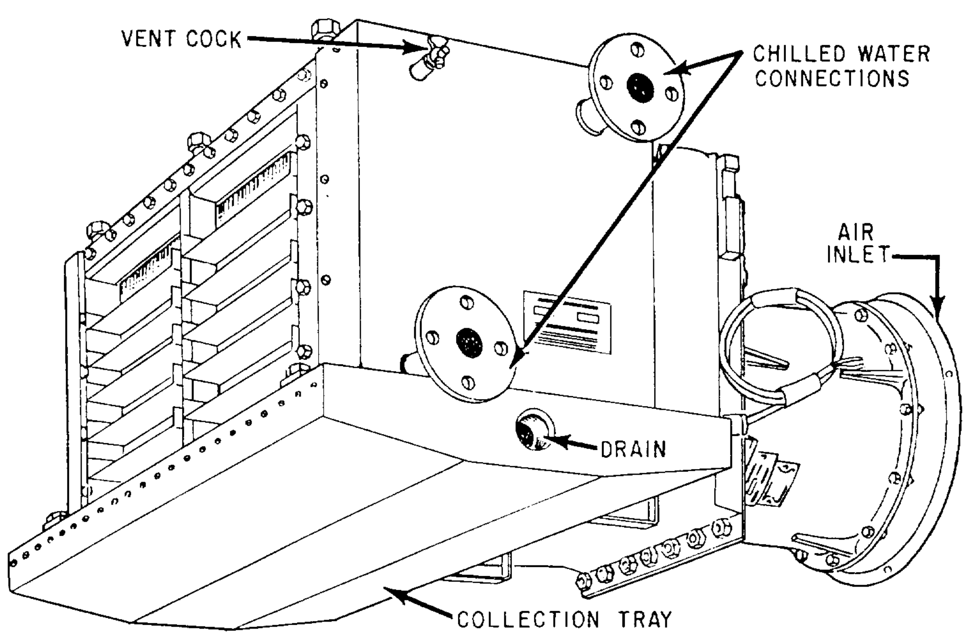


Figure 10-22.-Fan-coil assembly.

earth's atmosphere also contains varying amounts of water. Depending on weather conditions, water will appear in a variety of forms, such as rain (liquid water), snow crystals, ice (solid water), and vapor. Vapor is composed of tiny drops of water that are light enough to stay airborne. Clouds are an example of the existence of water vapor.

Since air is a gas, it expands when heated. Consequently, heating air causes a given amount of air2routed through to expand, take up more space (volume), and hold more water vapor. When a given amount of air at a given temperature and pressure is no longer able to soak up water vapor, the air is saturated, and the humidity is 100 percent.

When air cools, its density increases; however, its volume and ability to hold water decrease, When temperature and pressure conditions cause the air to cool and to reach the dew point, any water vapor in the air condenses into a liquid state (water). In other words, one method of drying air out is to cool it until it reaches the dew point.

Besides nitrogen, oxygen, and water vapor, air contains particles of dust and dirt that are so tiny and lightweight that they remain suspended in the air. You may wonder how the composition of air directly affects the work of an air compressor. Although one cubic foot of air will not hold a tremendous amount of water or dirt, you should realize that air compressors have capacities that are rated in hundreds of standard cubic feet per minute (cfm). This is a very high rate of flow. When a high flow rate of dirty, moisture-laden air is allowed to enter and pass through an air compressor, the result is rapid wear of the seals and load-bearing parts, internal corrosion (rust), and early failure of the unit. The reliability and useful life of any air compressor is extended by the installation of filters. Filters remove most of the dirt and dust from the air before it enters the equipment. On the other hand, most of the water vapor in the air at the intake passes directly through the filter material and is compressed with the air. When air is compressed, it becomes very hot. As you know, hot air is capable of holding great amounts of water. The water is removed as the compressed air is routed through the coolers. The coolers remove the heat from the airstream and cause some of the water vapor to condense into liquid (condensate). The condensate must be periodically drained from the compressor.

Although the coolers will remove some of the water from the air, simple cooling between the stages of compression (intercooling) and cooling of the airstream after it leaves the compressor (aftercooling) will not make the air dry. When clean dry air suitable for pneumatic control and other shipboard systems are required air from the compressor is routed through air-drying units. Many air-drying units are capable of removing enough water vapor from the airstream to cause the dew point to be as low as -60°F. Some of the more common devices used to remove water vapor from the airstream, such as dehydrators, are discussed later in this chapter.

CLASSIFICATION OF AIR COMPRESSORS

An air compressor may be classified according to pressure (low, medium, or high), type of compressing element, and whether the discharged air is oil free.

Because of our increasing need for oil-free air aboard ship, the oil-free air compressor is gradually replacing most of the standard low-pressure and high-pressure air compressors. For this reason, most of this discussion is focused on the features of oil-free air compressors.

The *Naval Ships' Technical Manual (NSTM)*, chapter 551, lists compressors in three classifications:

1. Low-pressure air compressors (LPACs), which have a discharge pressure of 150 psi or less

2. Medium-pressure compressors, which have a discharge pressure of 151 psi to 1,000 psi

3. High-pressure air compressors (HPACs), which have a discharge pressure above 1,000 psi

Low-Pressure or Ship's Service Air Compressors

The two types of LPACs that are used on naval ships are the screw type and the reciprocating type.

SCREW TYPE.– The helical-screw type of compressor is a relatively new design of oil-free air compressor. This low-pressure air compressor is a single-stage, positive-displacement, axial-flow, helical-screw type of compressor. It is often referred to as a screw-type compressor. Figure 10-23 shows the general arrangement of the LPAC unit.

In the screw-type LPAC, compression is caused by the meshing of two helical rotors (a male and a female rotor, as shown in fig. 10-24) located on parallel shafts and enclosed in a casing. Air inlet and outlet ports are located on opposite sides of the casing. Atmospheric air is drawn into the compressor through the filter-silencer. The air passes through the air cylinder-operated unloader (butterfly) valve and into the

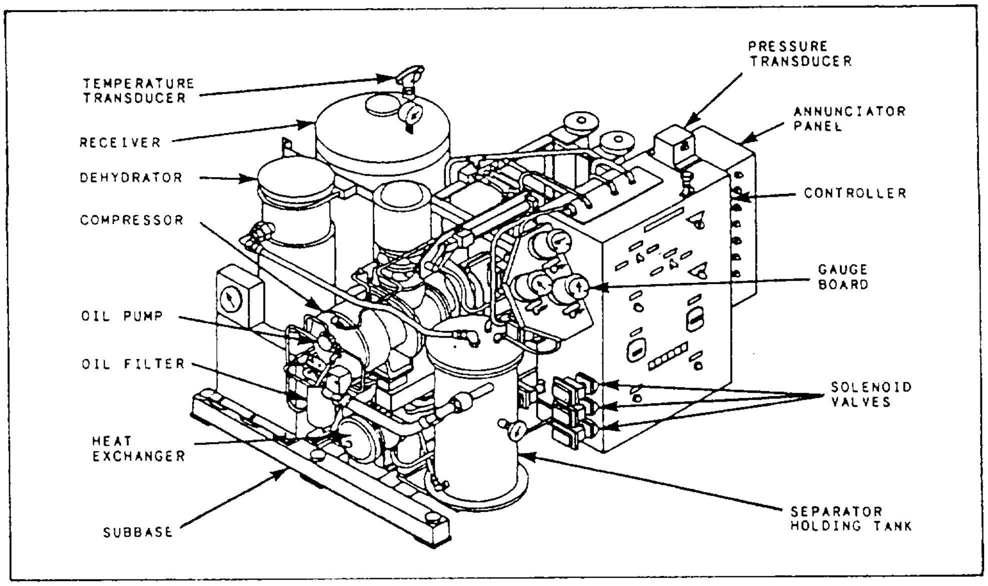


Figure 10-23.-LPAC unit (screw type.)

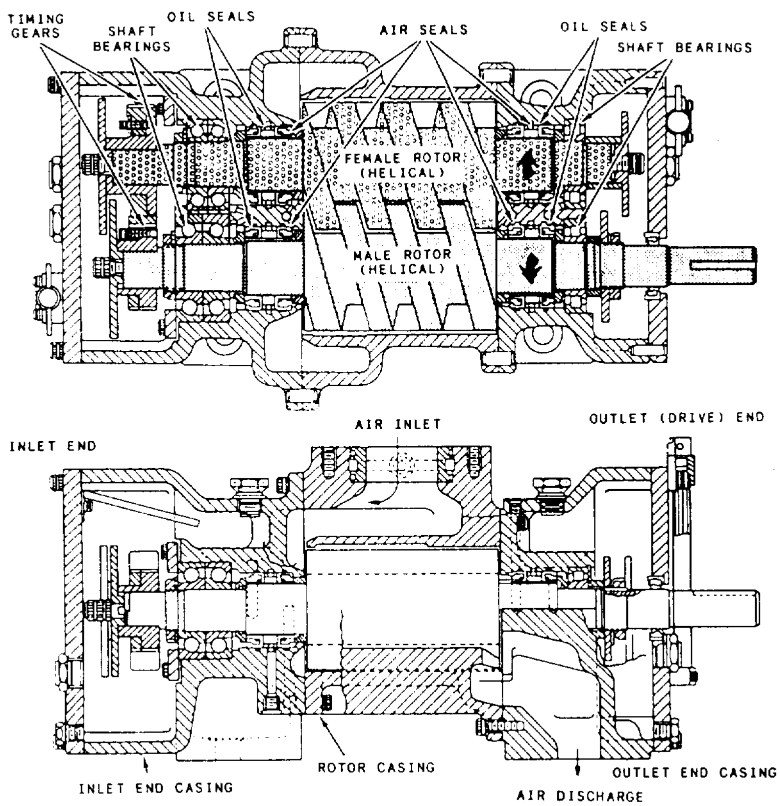


Figure 10-24.-LPAC, compressor section.

inlet part of the compressor when the valve is in the open (load) position. Fresh water is injected into the airstream as it passes through the inlet port of the compressor casing. The injected fresh water serves two purposes:

1. It reduces the air discharge temperature caused by compression.
2. It seals the running clearances to minimize air leak.

Most of the injected water is entrained into the airstream as it moves through the compressor.

The compression cycle starts as the rotors unmesh at the inlet port. As rotation continues, air is drawn into the cavity between the male rotor lobes and into the grooves of the female rotor. The air is trapped in these grooves, or pockets, and follows the rotative direction of each rotor. As soon as the inlet port is closed, the compression cycle begins as the air is directed to the opposite (discharge) end of the compressor. The rotors mesh, and the normal free volume is reduced. The reduction in volume (compression) continues with a resulting increase in pressure, until the closing pocket reaches the discharge port.

The entrained water is removed from the discharged air by a combined separator and water holding tank. The water in the tank passes through a seawater-cooled heat exchanger. The cooled water then recirculates to the compressor for reinfection.

During rotation and throughout the meshing cycle, the timing gears maintain the correct clearances between the rotors. Since no contact occurs between the rotor lobes and grooves, between the rotor lobes and casing, or between the rotor faces and end walls, no internal oil lubrication is required. This design allows the compressor to discharge oil-free air.

For gear and bearing lubrication, lube oil from a force-feed system is supplied to each end of the compressor. Mechanical seals serve to keep the oil isolated from the compression chamber.

RECIPROCATING TYPE.– All reciprocating air compressors are similar to each other in design and operation. The following discussion describes the basic components and principles of operation of a low-pressure reciprocating air compressor.

The LPAC is a vertical, two-stage single-acting compressor that is belt-driven by an electrical motor. Two first-stage cylinders and one second-stage cylinder are arranged in-line in individual blocks mounted to the crankcase (frame) with a distance piece (frame extension). The crankcase is mounted on a subbase that supports the motor, moisture separators, and a rack assembly. The intercooler, aftercooler, freshwater heat exchanger, and freshwater pump are mounted on the rack assembly. The subbase serves as the oil sump. Figure 10-25 shows the general arrangement of the reciprocating-type compressor.

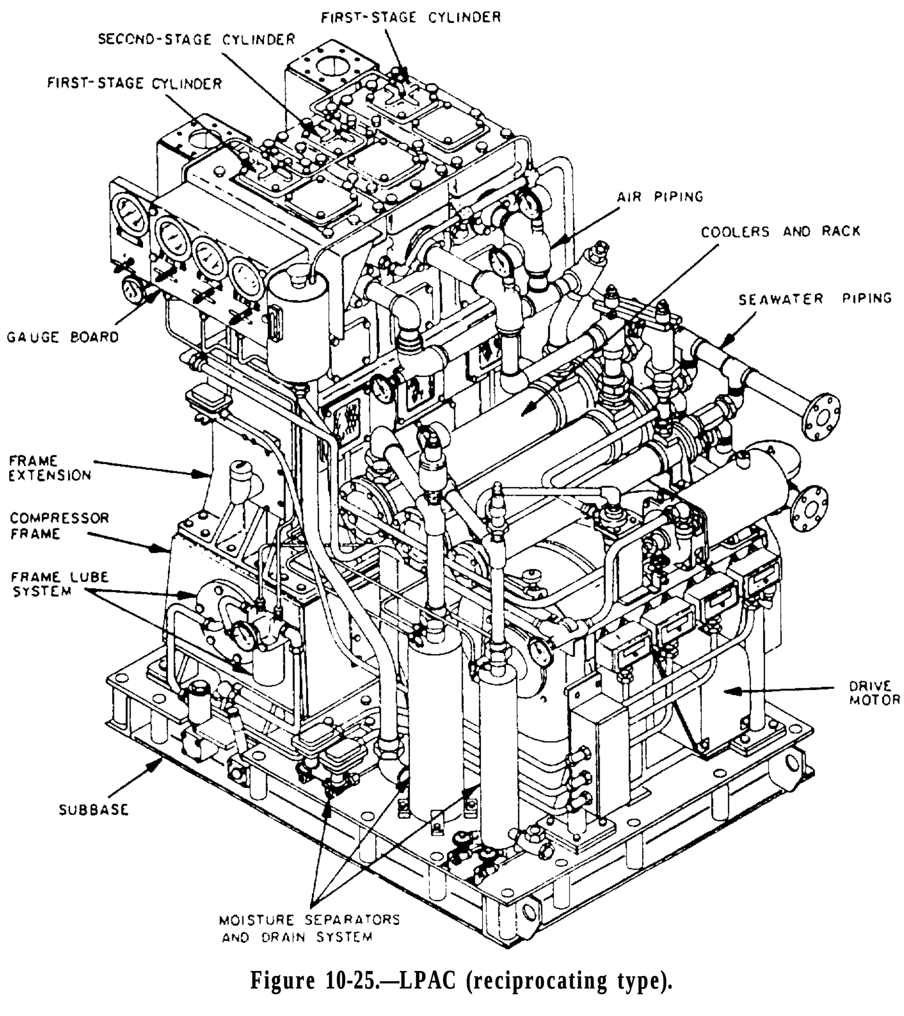


Figure 10-25.—LPAC (reciprocating type).

The compressor is of the crosshead design. Figure 10-26 shows cross-sectional views of the LPAC. The frame extension houses the crossheads and crosshead guides and is open to the atmosphere. It separates the cylinders, which are not oil lubricated, from the crankcase. Oil wiper assemblies (seals) are located in the frame extension to scrape lubricating oil off the piston rods when the compressor is in operation. Oil deflector plates are attached to the piston rods to prevent any oil that creeps through the scrapers from entering the cylinders. Oil that is scraped from the piston rods drains back to the sump. Air leak along the piston rods is prevented by full floating packing assemblies bolted to the underside of the cylinder blocks.

During operation, ambient air is drawn into the first-stage cylinders through the inlet filter silencers and inlet valves during the downstroke. When the piston reaches the bottom of its stroke, the inlet valve closes and traps the air in the cylinder. When the piston moves upward, the trapped air is compressed and forced out of the first-stage cylinders, through the first-stage cooler and the first-stage moisture separator. When the second-stage piston starts its downstroke, the air is drawn into the second-stage cylinder. Then, it is further

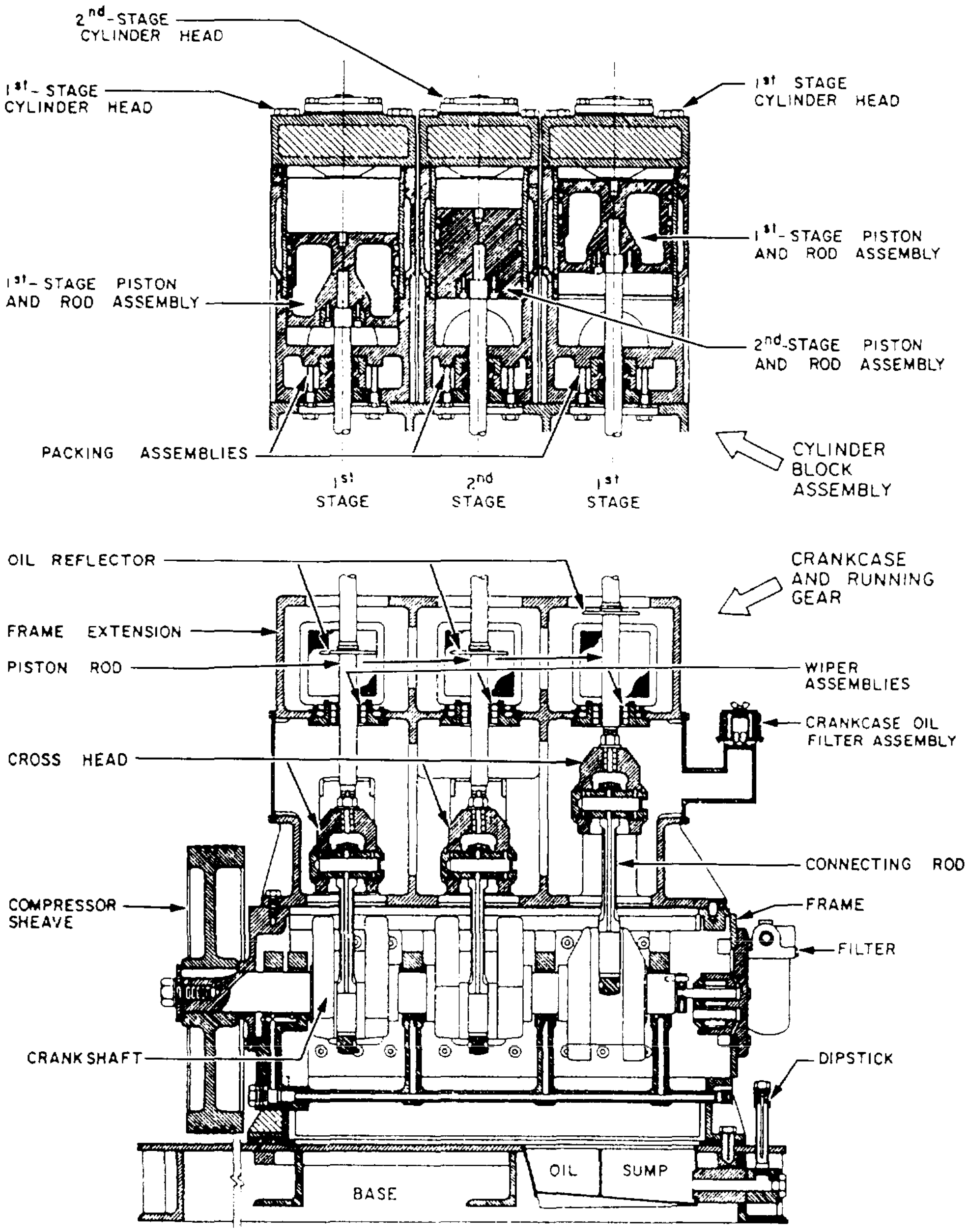


Figure 10-26.—LPAC, cross-sectional views (reciprocating type.)

compressed, followed by a cooling and moisture removal process similar to the first stage.

High-Pressure Air Compressors

The HPAC is a vertical, five-stage, reciprocating air compressor. It is driven by being directly connected to an electrical motor. Refer to figures 10-27 and 10-28 as we describe the compressor.

The subbase supports the compressor assembly, the electric drive motor, and the coolers and rack assembly. The crankcase is bolted directly to the subbase and is made up of the frame and frame extension. The frame houses the crankshaft and oil pump. The frame extension is open to the atmosphere and isolates the conventionally lubricated frame from the oil-free cylinders. The crosshead guides are machined in the frame extension. A uniblock casting contains the first three-stage cylinders and is mounted on the frame extension (fig. 10-28). The cylinders are arranged in line. The first stage is in the center, the second stage is at the motor end, and the third stage is outboard. The fourth stage is mounted above the second stage, and the fifth stage is above the third stage. The fourth- and fifth-stage pistons are tandem mounted to the second- and third-stage pistons, respectively.

During operation, ambient air is drawn into the first-stage cylinder through the inlet falter and inlet valves. The first stage is double acting, and air is drawn into the lower cylinder area as the piston is moving upward. At the same time, air in the upper cylinder is being compressed and forced out the upper discharge valve. As the piston moves downward, air is drawn into the upper cylinder; likewise, air in the lower cylinder is being compressed and forced out the lower discharge valve. Compressed air leaves the first-stage discharge valves and flows through the first-stage intercooler, and into the first-stage moisture separator.

The first-stage separator has a small tank mounted on the side of the compressor frame below the gauge panel and a holding tank mounted below the cooler rack. The separators for the remaining stages handle smaller volumes of air due to compression; as a result, the separators and holding chambers are smaller and are integrated into one tank. Condensate is removed from the air as it collides with the internal tank baffles and collects in the holding chamber.

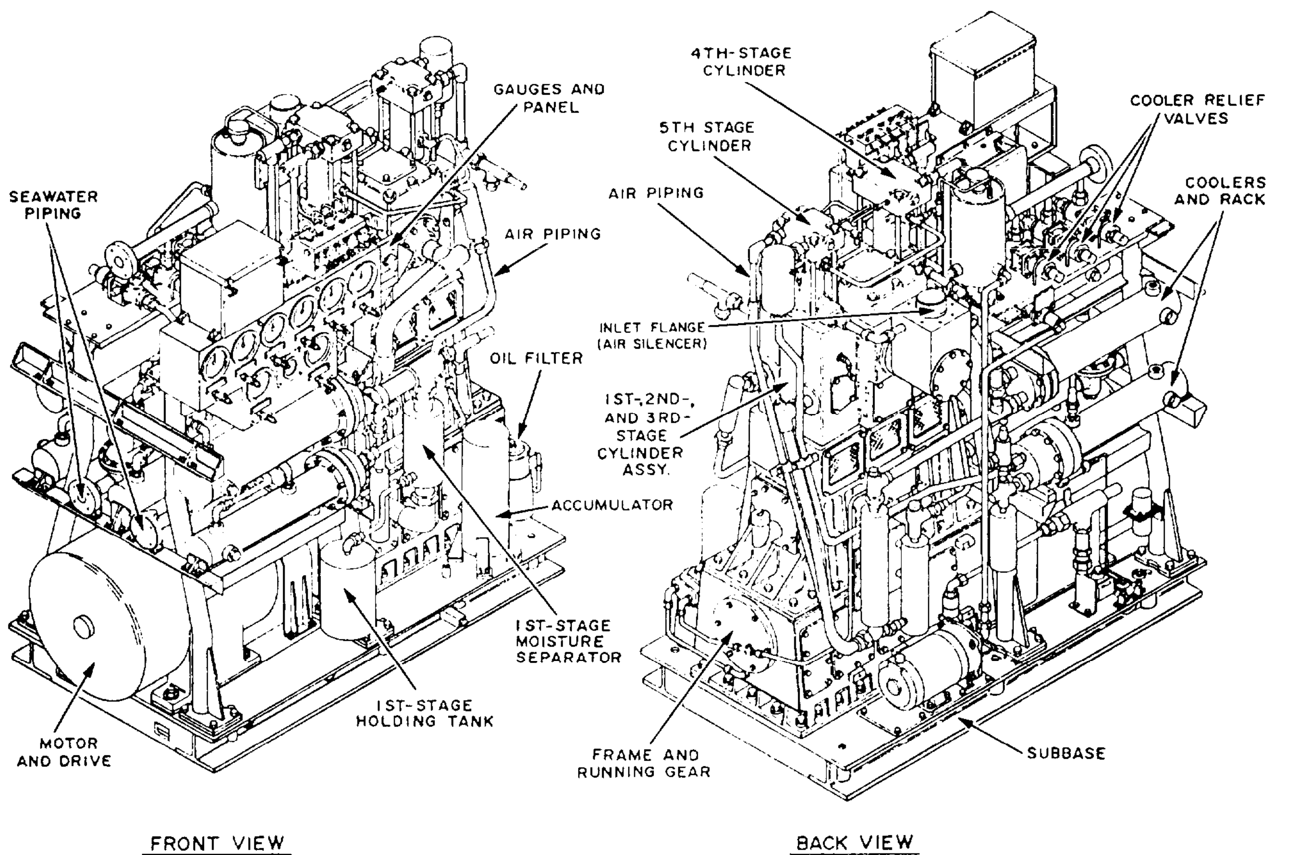


Figure 10-27.—HPAC.

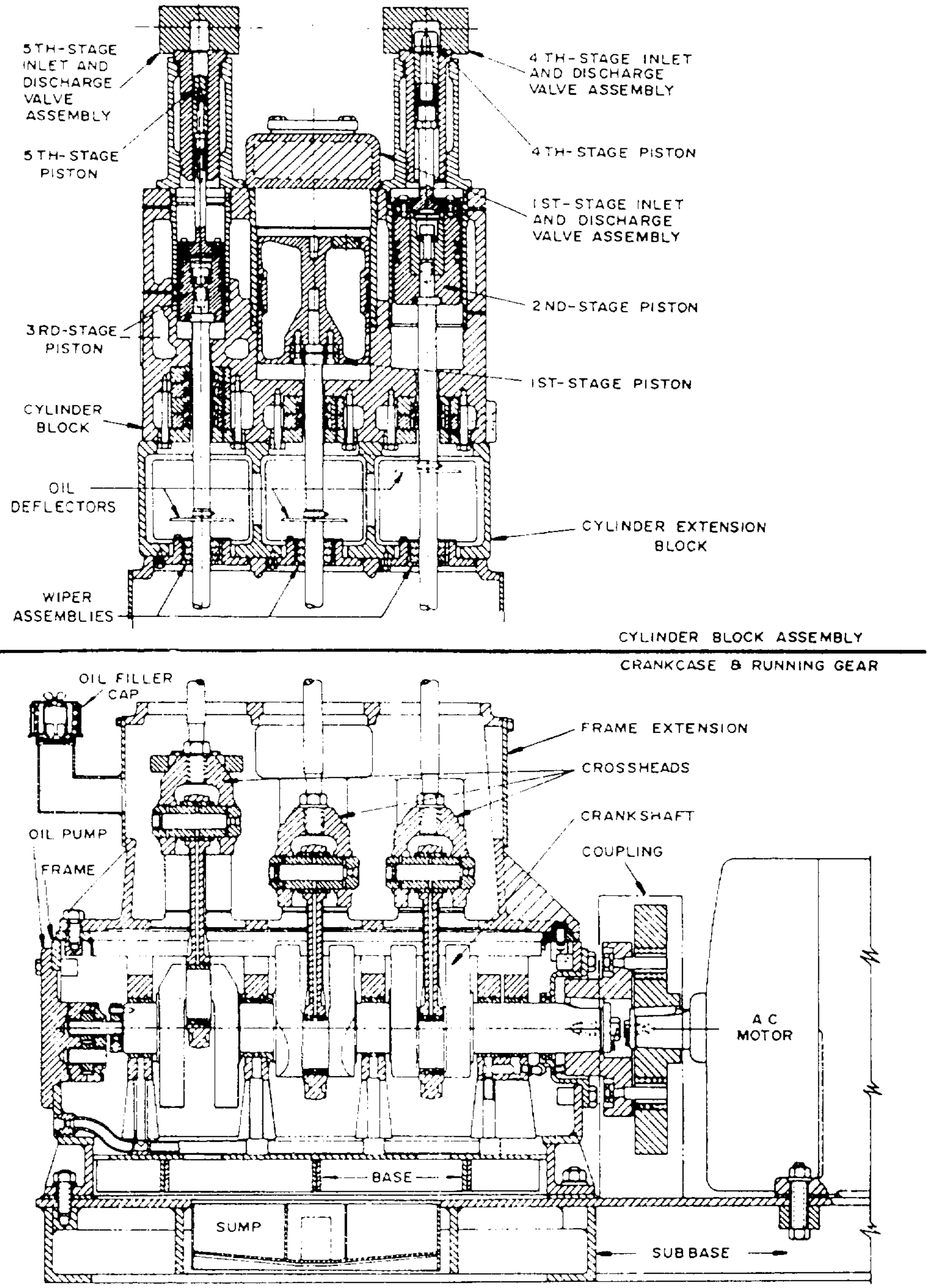


Figure 10-28.—HPAC, cross-sectional views.

Air from the first-stage separator is drawn into the single-acting, second-stage cylinder on tile upward stroke of the piston. As the piston travels downward, the air is compressed and forced out the discharge valve. The second-stage discharge air passes through the second-stage intercooler into the second separator.

The third stage draws air from the second separator and compresses it in the same manner as in the second stage. Third-stage air enters a pulsation bottle before passing through the third-interstage cooler. Pulsation bottles are used after the third and fifth compression stages to minimize the shock effect of inlet and discharge pulses as well as pressure changes due to condensate draining.

After passing through the third-interstage cooler and moisture separator, the air is drawn into the fourth-stage cylinder on the downstroke of the piston. As the piston travels upward, the air is compressed and forced out the discharge valve. Then it passes through the fourth-stage intercooler and moisture separator.

Air is drawn into the fifth-stage cylinder on the piston downstroke and is compressed and discharged on the upstroke. The discharge air passes through the fifth-stage pulsation bottle, the aftercooler, the moisture separator, a back-pressure valve, and a check valve before entering the ships' HP piping.

SAFETY PRECAUTIONS

Many hazards are associated with pressurized air, particularly air under high pressure. Dangerous 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, and so forth). When the ignition temperature is reached, a violent explosion will occur as these impurities ignite. Ignition temperatures may also result from other causes. Some are rapid pressurization of a low-pressure dead-end portion of the piping system, malfunctioning of compressor aftercoolers, and leaky or dirty valves.

Air compressor accidents have also been caused by improper maintenance procedures. These accidents can happen when you disconnect parts under pressure, replace parts with units designed for lower pressures, and install stop valves or check valves in improper locations. Improper operating procedures have resulted in air compressor accidents with serious injury to personnel and damage to equipment.

You must take every possible step to minimize the hazards inherent in the process of compression and in the use of compressed air. Strictly follow all safety precautions outlined in the manufacturer's technical manuals and in the NSTM, chapter 551. Some of these hazards and precautions are as follows:

1. Explosions can be caused by dust-laden air or by oil vapor in the compressor or receiver if abnormally high temperatures exist. Leaky or dirty valves, excessive pressurization rates, or faulty cooling systems may cause these high temperatures.

2. NEVER use distillate fuel 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 being discharged from any stage exceeds the maximum temperature specified.

4. NEVER leave the compressor station after starting the compressor unless you are sure that the control and unloading devices are operating properly.

5. Before working on a compressor, make sure the compressor is secured. Make sure that it cannot start automatically or accidentally. Completely blow down the compressor, and then secure all valves (including the control or unloading valves) between the compressor and the receiver. Follow the appropriate tag-out procedures for the compressor control valves and the isolation valves. When the gauges are in place, leave the pressure gauge cutout valves open at all times.

6. Before disconnecting any part of an air system, be sure the part is not under pressure. Always leave the pressure gauge cutout valves open to the sections to which they are attached.

7. Avoid rapid operation of manual valves. The heat of compression caused by a sudden flow of high-pressure air into an empty line or vessel can cause an explosion if oil or other impurities are present. Slowly crack open the valves until flow is noted, and keep the valves in this position until pressure on both sides has equalized. **Keep the rate of pressure rise under 200 psi per second.**

DEHYDRATORS

The removal of moisture from compressed air is an important feature of compressed air systems. As you have learned, some moisture is removed by the intercoolers and aftercoolers. Air flasks and receivers are provided with low-point drains so any collected moisture may drain periodically. However, many shipboard uses for compressed air require air with an even smaller moisture content than is obtained through these methods. Water vapor in air lines can create other potentially hazardous problems. Water vapor can cause control valves and controls to freeze. These conditions can occur when air at very high pressure is throttled to a low-pressure area at a high-flow rate. The venturi effect of the throttled air produces very low temperatures that cause any moisture in the air to freeze into ice. Under these conditions, a valve (especially an automatic valve) may become very difficult or impossible to operate. Also, moisture in any air system can cause serious water hammering (a banging sound) within the system. For these reasons, air dehydrators or dryers are used to remove most of the water vapor from compressed air.

The Navy uses two basic types of air dehydrators and a combination of the two. These air dehydrators are classified as follows:

1. Type I-refrigeration
2. Type II–heater, desiccant
3. Type III-refrigeration, desiccant

Each of these types meets the specified requirements for the quality of the compressed air used in pneumatic control systems or for clean, dry air used for shipboard electronic systems. Usually, specific requirements involve operating pressure, flow rate, dew point, and purity (percent of aerosols and size of particles). We will briefly discuss each of the types of air dehydrators.

REFRIGERATION AIR DEHYDRATOR (TYPE I)

Refrigeration is one method of removing moisture from compressed air. The dehydrator shown in figure 10-29 is a REFRIGERATION DEHYDRATOR or REFRIGERATED AIR DRYER. This unit removes water vapor entrained in the stream of compressed air by condensing the water into a liquid that is heavier than air. Air flowing from the separator/holding tank first passes through the air-to-air heat exchanger, where some of the heat of compression is removed from the airstream. The air then moves through the evaporator section of the dehydrator, where the air is chilled by circulating refrigerant. In this unit, the airstream is cooled to a temperature that is below the dew point. This will cause the water vapor in the air to condense so the condensate drain system can remove it. After leaving the evaporator section, the dehydrated air moves upward through the cold air side of the air-to-air heat exchanger.

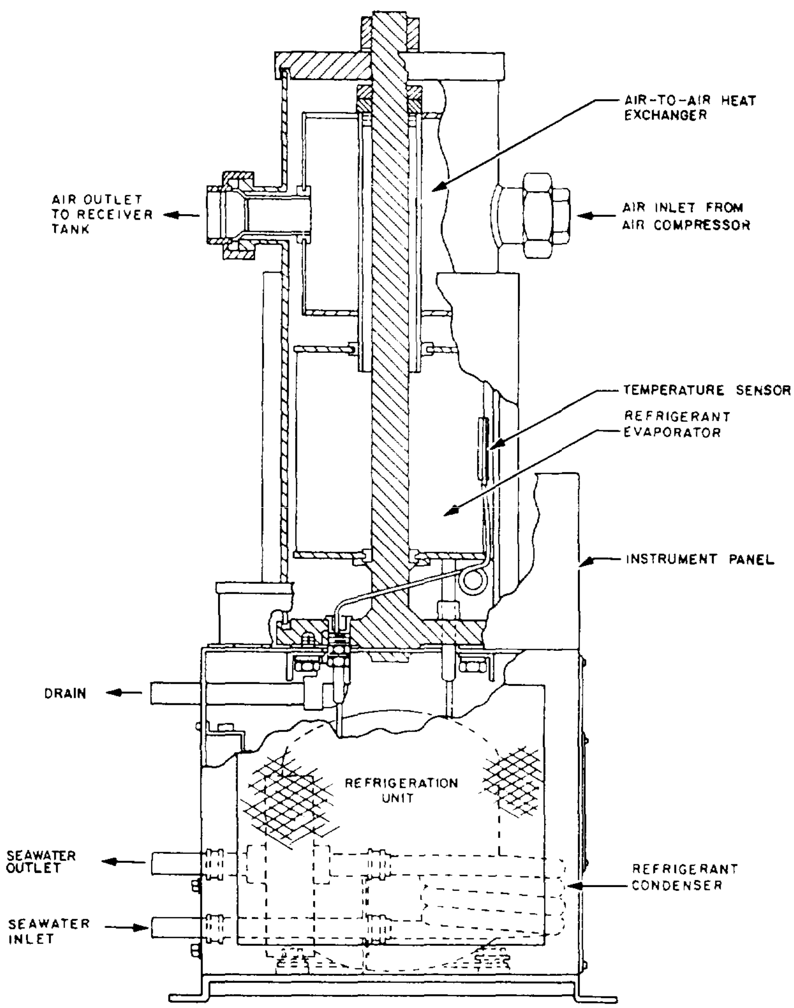


Figure 10-29.—Dehydrator (type I).

In the air-to-air heat exchanger, the dehydrated air is raised in temperature by the warm air entering the dehydrator. Heating the air serves to reduce thermal shock as the air enters the system. The exiting dry air flows into the receiver for availability to the ship's air system.

DESICCANT AIR DEHYDRATOR (TYPE II)

The desiccant is a drying unit. More practically, desiccant is a substance with a high capacity to remove (adsorb) water or moisture. It also has a high capacity to give off that moisture so the desiccant can be reused. DESICCANT-TYPE DEHYDRATORS (fig. 10-30) are basically composed of cylindrical flasks filled with desiccant.

Compressed air system dehydrators use a pair of desiccant towers. One tower is in service dehydrating the compressed air, while the other is being reactivated. A desiccant tower is normally reactivated when dry, heated air is routed through the tower in the direction opposite to that of the normal dehydration airflow. The hot air evaporates the collected moisture and carries it out of the tower to the atmosphere. The air for the purge cycle is heated by electrical heaters. When the reactivating tower completes the reactivation cycle, it is placed in service to dehydrate air, and the other tower is reactivated.

REFRIGERATION AND DESICCANT AIR DEHYDRATOR (TYPE III)

Some installations may use a combination of refrigeration and desiccant for moisture removal. Hot, wet air from the compressor first enters a refrigeration section, where low temperature removes heat from the airstream and condenses water vapor from the air. Then,

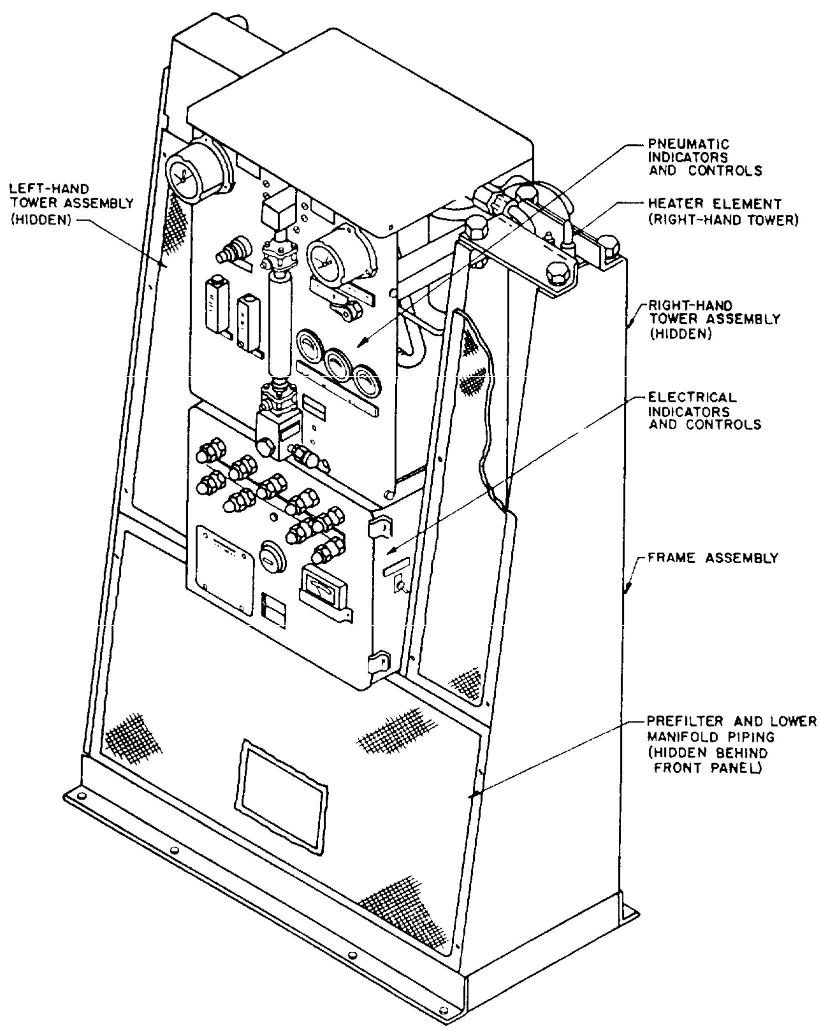


Figure 10-30.—Dehydrator (type II).

the cold, partially-dried air flows into a desiccant section, where the desiccant absorbs additional moisture from the air.

DISTILLING PLANTS

Distilling plants are used to supply fresh water and boiler feedwater. Distillers use either steam, hot water, or electrical energy to boil seawater.

The majority of Navy ships have steam-heated distilling plants. There are three types of steam-heated distilling plants–submerged tube, flash, and vapor compression. Of these types, the submerged-tube heat recovery and flash are the most widely used.

Heat recovery units are used in vessels with engine propulsion or auxiliary engines. Two variations of the heat recovery types are used; both use the heat from engine cooling systems for evaporization of seawater.

In one model of a heat recovery plant, the heat of the diesel engine jacket water is transferred to the seawater in a heat exchanger. The heated seawater is then flashed to freshwater vapor as in the flash-type distilling unit. In the second variation, the hot diesel engine jacket water is circulated through a tube bundle that is submerged in seawater. The seawater is boiled in a chamber that is under vacuum as in the submerged tube distilling unit.

Refer to figure 10-31, which shows a simplified flow diagram for a 12,000 gpd (gallons per day), Model S500ST, submerged-tube recovery unit. In this recovery unit, jacket water from the ship's main propulsion diesels is fed to a tube bundle. The tube is submerged in the seawater that will be evaporated. The jacket water imparts its heat to the seawater surrounding the tubes, which induces seawater evaporation. The vapor created by the evaporating seawater is drawn through vapor separators to the distillate condensing tube bundle. The temperature of evaporation is maintained below the normal 212°F boiling point by a feedwater-operated air eductor. The eductor mechanically evacuates air and gases entrained in the vapor formed in the evaporating process and creates an internal shell pressure as low as 2 1/2 psia.

The flash-type distilling plant (fig. 10-32) has preheater that heat seawater to a high temperature. Then, the seawater is admitted to a vacuum chamber where some of it flashes to vapor. The remaining seawater is directed to another vacuum chamber maintained at an even lower vacuum. Here, more seawater flashes to vapor. At this point, the remaining

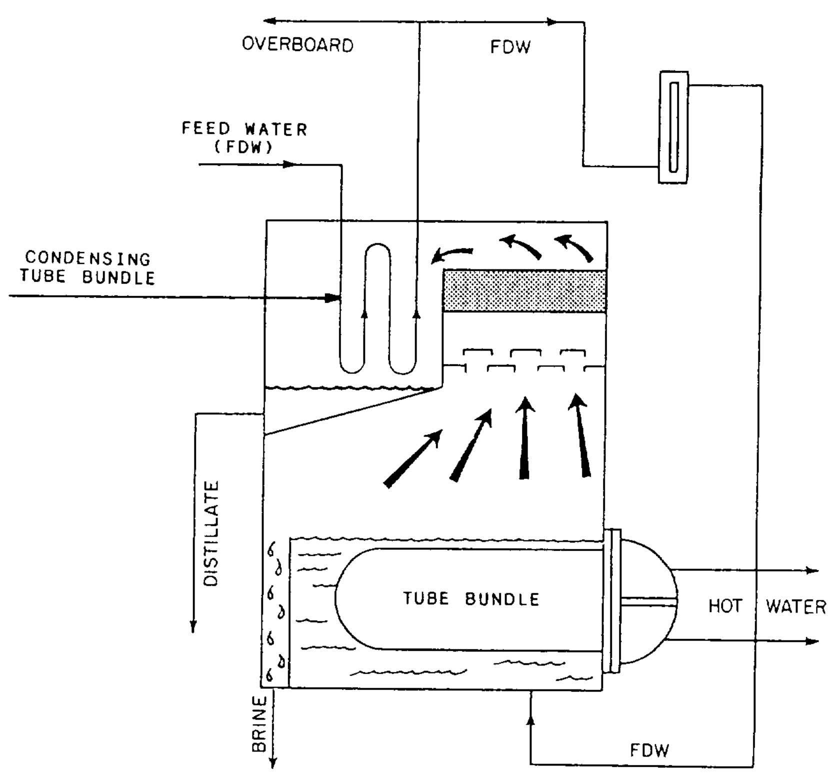


Figure 10-31.—Simplified flow diagram-heat recovery unit.

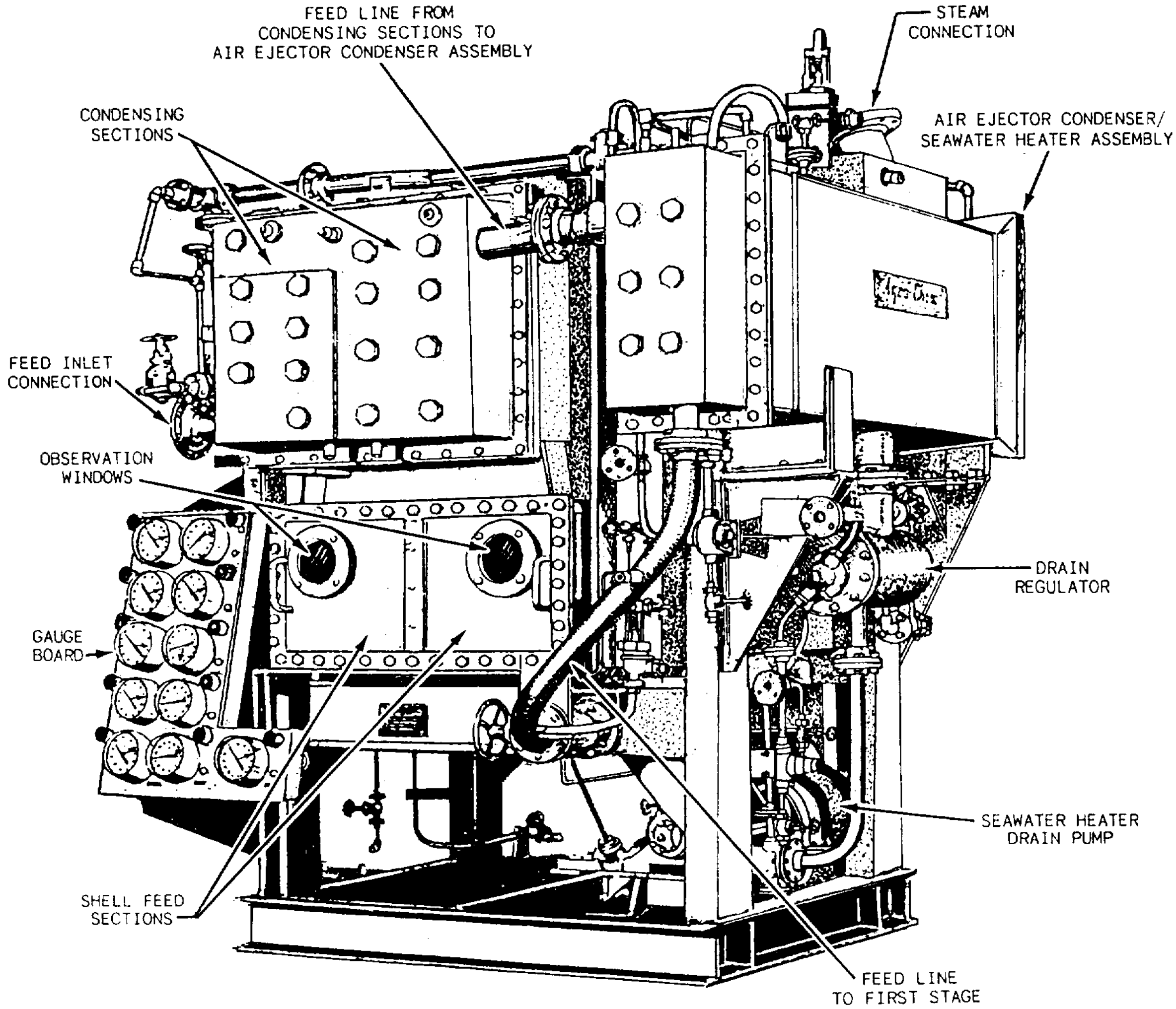


Figure 10-32.—Two-stage flash-type evaporator.

seawater is pumped overboard. Some flash-type distilling plants have as many as five flash chambers through which the seawater passes before being pumped overboard. The vapor is condensed and routed to the ship's freshwater tanks.

Distilling plants range in capacity from 2,000 to 100,000 gpd. The size depends on shipboard needs and space available. Some ships have only one distilling unit, while others have two or more.

PURIFIERS

When you operate and maintain a purifier, you should refer to the detailed instructions that come with each purifier. These manufacturers' technical manuals contain information on the construction, operation, and maintenance of the specific purifier. You need to follow these instructions carefully. This section of the TRAMAN contains a discussion and general information on the methods of purification and the principles of operation of centrifugal purifiers. Centrifugal purifiers are used to purify both lube oil and fuel. However, we will discuss lube oil only since the principles are the same for both.

A purifier may remove both water and sediment, or it may remove sediment only. When water is involved in the purification process, the purifier is usually called a SEPARATOR. When the principal contaminant is dirt or sediment, the purifier is used as a CLARIFIER. Purifiers are generally used as separators for the purification of fuel. When used for purification of a lube oil, a purifier may be used as either a separator or a clarifier. Whether a purifier is used as a separator or a clarifier depends on the water content of the oil that is being purified.

The following general information will help you understand the purification process, the purposes and principles of purifier operation, and the basic types of centrifugal purifiers used by the Navy.

PURIFIER OPERATION

Centrifugal force is the fundamental operating principle used in the purification of fluid. Centrifugal force is that force exerted on a body or substance by rotation. Centrifugal force impels the body or substance out ward from the axis of rotation.

Essentially, a centrifugal purifier is a container rotated at high speed. As it rotates, contaminated lube oil is forced through, and rotates with, the container. Only materials that are in the lube oil are separated by centrifugal force. For example, water is separated from lube oil because water and lube oil are immiscible, which means they are incapable of being mixed. Also, there must be a difference in the specific gravities of the materials before they can be separated by centrifugal force. You cannot use a centrifugal purifier to separate JP-5 or naval distillate from lube oil because it **is** capable of being mixed; likewise, you cannot remove salt from seawater by centrifugal force.

When a mixture of lube oil, water, and sediment stands undisturbed, gravity tends to form an upper layer of lube oil, an intermediate layer of water, and a lower layer of sediment. The layers form because of the specific gravities of the materials in the mixture. If the lube oil, water, and sediment are placed in a container that is revolving rapidly around a vertical axis, the effect of gravity is negligible in comparison with that of the centrifugal force. Since centrifugal force acts at right angles to the axis of rotation of the container, the sediment with its greater specific gravity assumes the outermost position, forming a layer on the inner surface of the container. Water, being heavier than lube oil, forms an intermediate layer between the layer of sediment and the lube oil, which forms the innermost layer. The separated water is discharged as waste, and

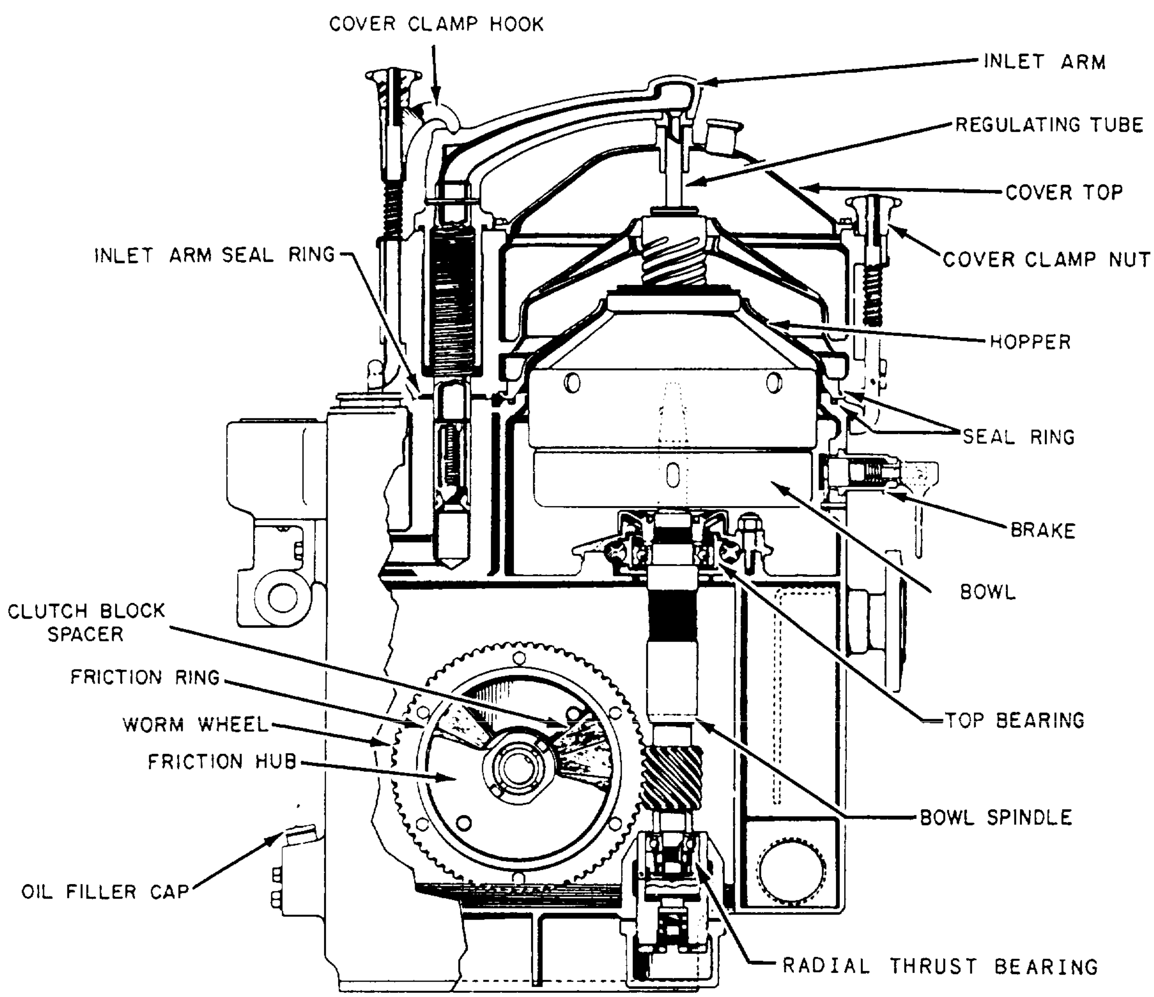


Figure 10-33.—Disc-type centrifugal purifier.

the lube oil is discharged to the sump. The solids remain in the rotating unit.

Other factors that affect separation by centrifugal force include the size of the particles, the viscosity of the fluids, and the length of time the materials are subjected to centrifugal force. Generally, the greater the difference in specific gravity between the substances to be separated and the lower the viscosity of the lube oil, the greater the rate of separation.

PURIFIER TYPES

Two basic types of purifiers are used in Navy installations, and both types use centrifugal force. There are principal differences in the equipment design and operating speed of the rotating elements of the two machines. In one type, the rotating element is a bowl-like container that encases a stack of discs. This is the disc-type DeLaval purifier, which has a bowl operating speed of about 7,200 rpm. In the other type, the rotating element is a hollow cylinder. This machine is the tubular-type Sharples purifier, which has an operating speed of 15,000 rpm.

Disc-Type Purifier

Figure 10-33 shows a cutaway view of a disc-type centrifugal purifier. The bowl is mounted on the upper end of the vertical bowl spindle, and driven by 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. Figure 10-34 shows the parts of a disc-type bowl. The flow of fluid through the bowl and additional parts are shown in figure 10-35. Contaminated fluid enters the top of the revolving bowl through the regulating tube. The fluid then passes down the inside of the tubular shaft, out the bottom, and up into the stack of discs. As the dirty fluid flows up through the distribution holes in the discs, the high centrifugal force exerted by the revolving bowl causes the dirt, sludge, and water to move outward. The purified fluid is forced inward and upward, discharging from the neck of the top disc. 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 fluid.) The discs divide the space within the bowl into many separate narrow passages or spaces. The liquid confined within each pass is restricted so that it flows only along that pass. This arrangement minimizes agitation of the liquid passing through the bowl. It also forms shallow settling distances between the discs.

Any water separated from the fluid, along with some dirt and sludge, is discharged through the discharge ring at the top of the bowl. However, most of the dirt and sludge remains in the bowl and collects in a more or less uniform layer on the inside vertical surface of the bowl shell.

Tubular-Type Purifier

A cutaway view of a tubular-type centrifugal purifier is shown in figure 10-36. This type of purifier consists of a bowl or hollow rotor that rotates at high speeds. The bowl has an opening in the bottom to allow the dirty fluid to enter. It also has two sets of openings

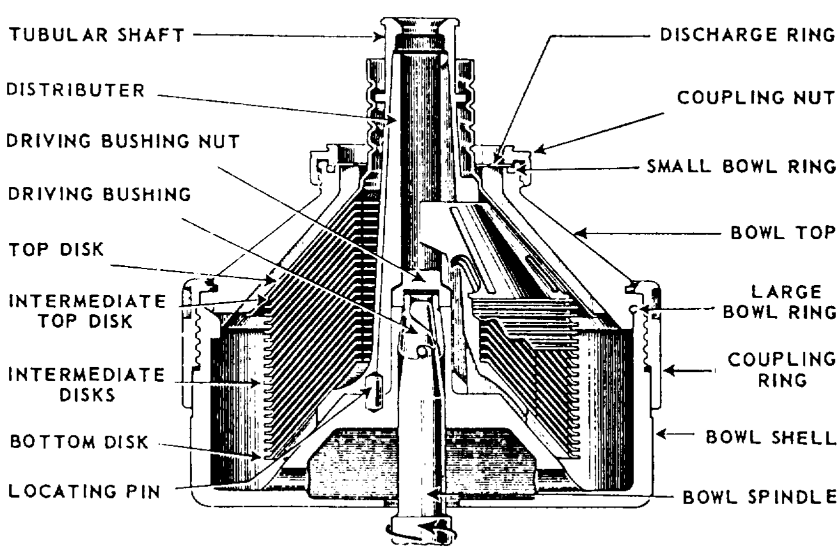


Figure 10-34.—Parts of a disc-type purifier bowl.

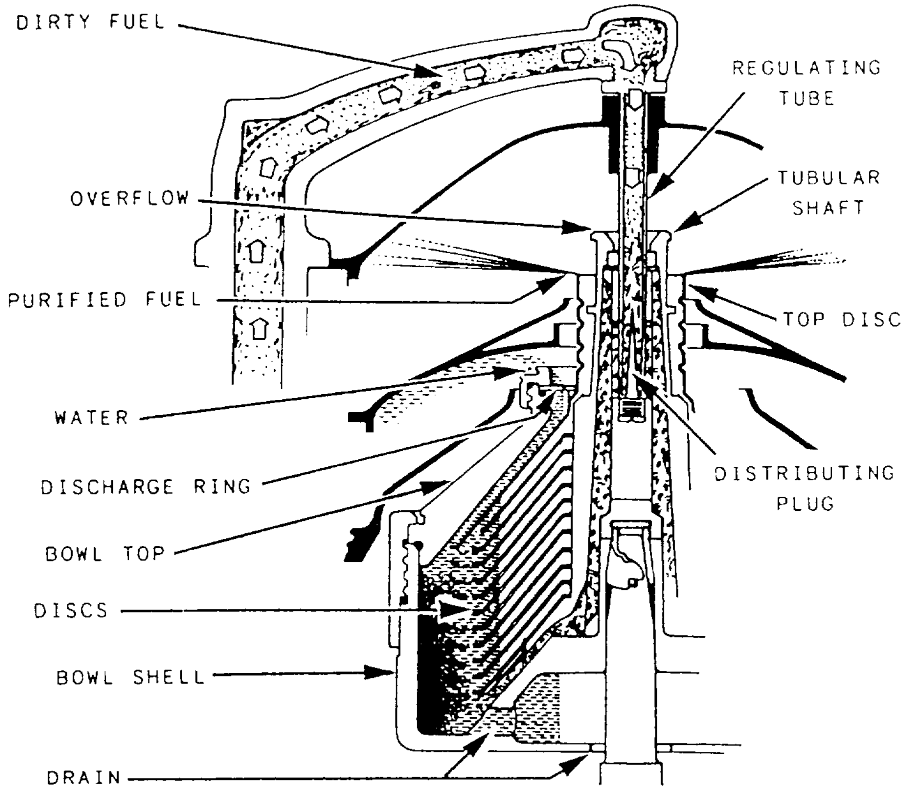


Figure 10-35.—Path of contaminated oil through a disc-type purifier bowl (Delaval).

at the top to allow the fluid and water to discharge. The bowl of the purifier is connected by a coupling unit to a spindle. The spindle 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 restrains movement of the bottom of the bowl, but it also allows the bowl enough movement to center itself during operation. Inside the bowl is a device with three flat plates that are equally spaced radially. This device is commonly referred to as the THREE-WING DEVICE, or just the 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.

After priming the bowl with water, separation is basically the same as it is in the disc-type purifier. Centrifugal force causes clean fluid to assume the innermost position (lowest specific gravity), and the higher density water and dirt are forced outward towards the sides of the bowl. Fluid and water are discharged from separate openings at the top of the bowl. The location of the fluid-water interface within the bowl is determined by the size of a metal ring called a RING DAM or by the setting of a discharge screw. The ring dam or discharge screw is also located at the top of the bowl. Any solid contamination separated from the liquid remains inside the bowl all around the inner surface.

GENERAL NOTES ON PURIFIER OPERATIONS

For maximum efficiency, you should operate purifiers at the maximum designed speed and rated capacity. Since reduction gear oils are usually contaminated with water condensation, the purifier bowls should be operated as separators and not as clarifiers.

When a purifier is operated as a separator, you should **prime the bowl** with fresh water **before** any oil is admitted into the purifier. The water seals the bowl and creates an initial equilibrium of liquid layers. If the bowl is not primed, the oil is lost through the water discharge port.

There are many factors that influence the time required for purification and the output of a purifier, such as the

1. viscosity of the oil,

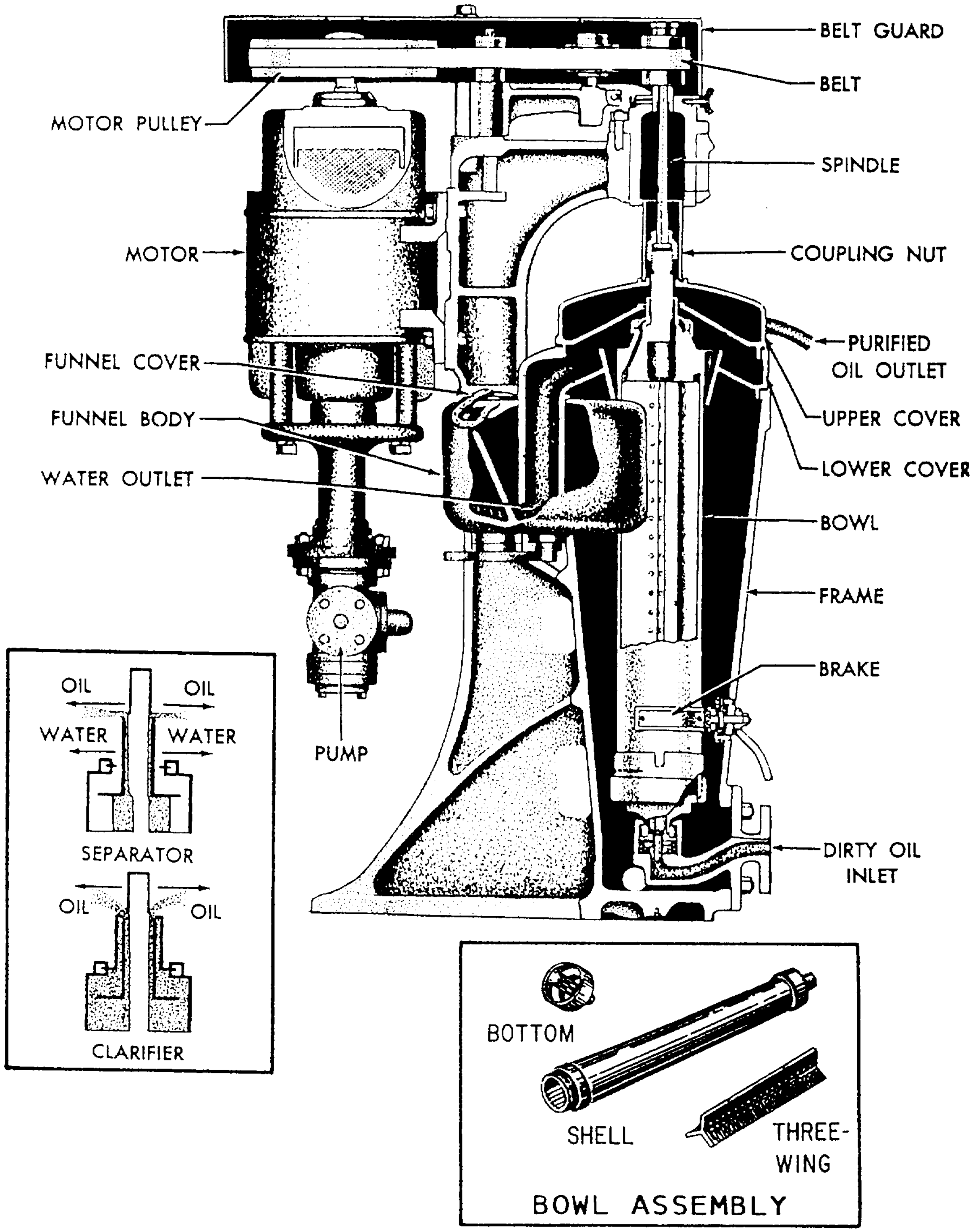


Figure 10-36.-Tubular-type centrifugal purifier.

2. pressure applied to the oil,
3. size of the sediment particles,
4. difference in the specific gravity of the oil,
5. substances that contaminate the oil, and
6. tendency of the oil to emulsify.

The viscosity of the oil will determine the length of time required to purify the oil. The more viscous the oil, the longer the time will be to purify it to a given degree of purity. Heating decreases the viscosity of the oil, and this is one of the most effective methods to make purification easier.

Even though certain oils may be satisfactorily purified at operating temperatures, a greater degree of purification generally results if the oil is heated to a higher temperature. To do 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 ships maybe heated to specified temperatures without adverse effects. However, prolonged heating at higher temperatures is not recommended because of the tendency of such oils to oxidize. Oxidation results in rapid deterioration. Generally, heat oil to produce a viscosity of approximately 90 seconds Saybolt universal (90 SSU).

You should NEVER increase the pressure above normal to force a high-viscosity oil through the purifier. Instead, decrease the viscosity by heating the oil. Using excess pressure to force oil through the purifier results in less efficient purification. On the other hand, reducing the pressure at which the oil is forced into the purifier increases the length of time the oil is under the influence of centrifugal force and results in improved purification.

To make sure that the oil discharged from a purifier is free of water, dirt, and sludge, you need to use the proper size discharge ring (ring dam). The size of the discharge ring depends on the specific gravity of the oil being purified. All discharge rings have the same outside diameter; but, they have inside diameters of different sizes.

The information in this TRAMAN on purifiers is general, and it applies to both types of purifiers. Before you operate a specific purifier, refer to the specific operating procedures contained in the instructions that come with the unit.

ELECTROHYDRAULIC DRIVE MACHINERY

Hydraulic units drive or control steering gears, windlasses, winches, capstans, airplane cranes, ammunition hoists, and distant control valves. In this part of the chapter, you will learn about some of the hydraulic units that will concern you.

The electrohydraulic type of drive operates several different kinds of machinery better than other types of drives. Here are some of the advantages of electrohydraulic machinery.

- Tubing, which can readily transmit fluids around corners, conducts the liquid which transmits the force. Tubing requires very little space.
- The machinery operates at variable speeds.
- Operating speed can be closely controlled from minimum to maximum limits.
- The controls can be shifted from no load to full load rapidly without damage to machinery.

ELECTROHYDRAULIC SPEED GEAR

An electrohydraulic speed gear is frequently used in electrohydraulic applications. Different variations of the basic design are used for specific applications, but the operating principles remain the same. Basically, the unit consists of an electric motor-driven hydraulic pump (A-end) and a hydraulic motor (B-end).

The B-end (fig. 10-37) is already on stroke and is rotated by the hydraulic force of the oil acting on the pistons. Movement of the pistons' A-end is controlled by a tilt box (also called a swash plate) in which the socket ring is mounted, as shown in part A of figure 10-37.

The length of piston movement, one way or the other, is controlled by movement of the tilt box 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. However, with the tilt box in a neutral or vertical position, there is no reciprocating motion of the pistons. Therefore, no oil is pumped to the B-end. Any movement of the tilt box, no matter how slight, causes pumping action to start. This causes immediate action in the B-end because force is transmitted by the hydraulic fluid.

When you need reciprocating motion, 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 is controlled locally (as on the anchor windlass) or remotely (as on the steering gear).

ELECTROHYDRAULIC STEERING GEAR

The steering gear transmits power from the steering engine to the rudder stock. The steering gear frequently includes the driving engine and the transmitting mechanism.

Many different designs of steering gear are in use, and they all operate on the same principle. One type of

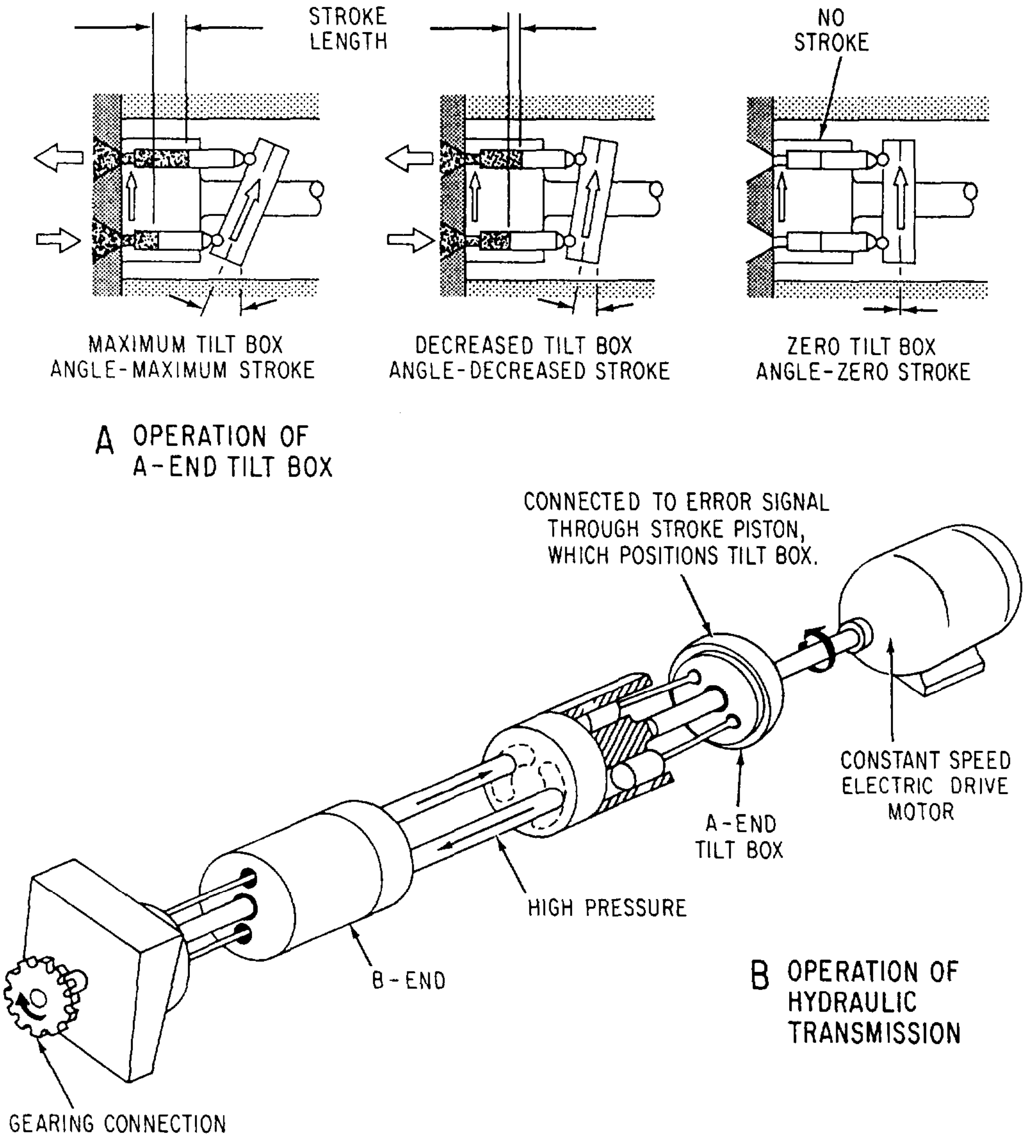


Figure 10-37.—Electrohydraulic speed gear.

electrohydraulic steering gear is shown in figure 10-38. It consists essentially of a ram unit and a power unit.

Ram Unit

The ram unit (view A) is mounted athwartship and consists of a single ram 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 moves, 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 (view B) consists of two independent pumping systems. Two systems are used for reliability. One pump can be operated 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 are driven by a single electric motor through a flexible coupling. Each system also includes a transfer valve with operating gear, relief valves, a differential control box, and trick wheels. The whole unit is mounted on a bedplate that serves as the top of an oil reservoir. Steering power is taken from either of the two independent pumping systems.

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 link (not shown) are connected to the two transfer valves so that

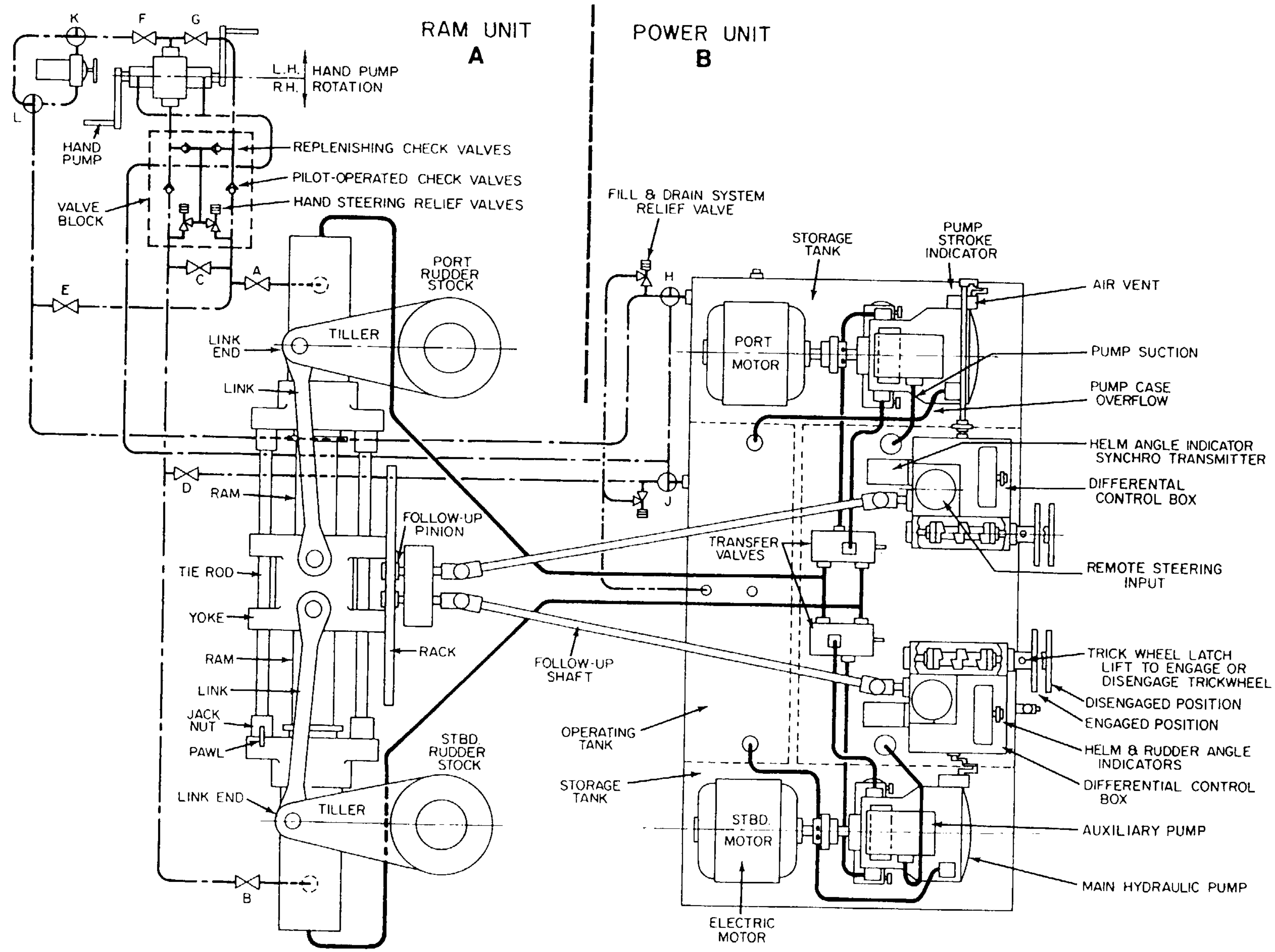


Figure 10-38.–Electrohydraulic steering gear. A. Ram unit. B. Power unit.

both valves are operated together. This allows rapid shifting from the on-service pumping unit to the standby unit; it prevents lining up both pumps to the ram at the same time. The hand lever is usually located between the trick wheels. It has three positions marked **P, N,** and **S. P** denotes the port pump is connected to the ram; **N** denotes neutral (neither pump connected to the ram); and **S** denotes the starboard pump is connected to the ram. Also, the hand lever is usually connected to motor switches. This lets the operator connect the selected pump to the ram and start the pump drive motor in one quick operation. In most ships this valve is electrically controlled by the motor controller and by pressure switches.

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 no oil is being moved within the main system. The auxiliary pump provides control oil and supercharge flows for the system.

To understand the operation of the pump, let's assume that a steering order signal comes into the differential control box. It can come 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.

NOTE: Remember that direction of fluid and flow may be in either direction in a hydraulic speed gear. It depends 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. 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 moves, 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 follow-up pinion gear. The pinions drive follow-up shafts that feed into the differential box. This feedback or servo system tells the differential control box when the steering operation is complete. As the ordered rudder angle is approached, the differential control box begins realigning the tilt box of the main hydraulic pump. By the time the desired rudder angle is reached, the tilt box is at zero stroke. This means that the ordered signal (from the pilot house or trick wheel) and the actual signal (from the follow-up shafts) are the same. If either of these change, the differential control box reacts accordingly; the main hydraulic unit pumps oil to one end or the other of the ram.

The trick wheels provide local-hydraulic control of the steering system of the remote steering system fails. A hand pump and associated service lines are also provided for local-manual operation of the ram if both hydraulic pump units fail.

Operation and Maintenance

The Machinist's Mate watch stander usually operates the steering equipment only in 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 requires that you clean, inspect, and lubricate the mechanical parts and maintain the hydraulic oil at the proper level and purity. The Planned Maintenance System (PMS) lists the individual requirements for the equipment. The electricians maintain the electrical portion of the steering system, including the control system.

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. However, if you use a three-way plug cock-type valve, either pump may drive either of the two wildcats. The hydraulic motors drive the wildcat shafts with a multiple-spur gearing and a locking head. The locking head allows you to disconnect the wildcat shaft and permits free operation of the wildcat, as when dropping anchor.

Each windlass pump is controlled either from the weather deck or locally. The controls are handwheels on shafting that lead to the pump control. The hydraulic system requires your attention. Make sure the hydraulic system is always serviced with the specified type of clean oil.

Normally, you will maintain three types of anchor windlasses–the electric, electrohydraulic, and hand-driven windlasses. Hand-driven windlasses are used only on small ships where the anchor gear can be handled without excessive effort by operating personnel.

The major work on a hand windlass is to properly adjust the link, friction shoes, locking head, and brake and to keep them in satisfactory operating condition at all times. In an electrohydraulic windlass, your principal concern is the hydraulic system.

A windlass is used intermittently and for short periods of time. However, it must handle the required load under severe conditions. This means that you must maintain and adjust the machinery when it is not in use. This practice will prevent deterioration and ensure dependable use.

Windlass brakes must be kept in satisfactory condition if they are to function properly. Wear and compression of brake linings increases the clearance between the brake drum and band after a windlass has been in operation. Inspect brake linings and clearances frequently. Make adjustments according to the manufacturer's instructions.

You should follow the lubrication instructions furnished by the manufacturer. If a windlass has been idle for some time, lubricate it. This protects finished surfaces from corrosion and prevents seizure of moving parts.

The hydraulic transmissions of electrohydraulic windlasses and other auxiliaries are manufactured with close tolerances between moving and stationary parts. Keep dirt and other abrasive material out of the system. When the system is replenished or refilled, use only clean oil. Strain it as it is poured into the tank. If a hydraulic transmission is disassembled, clean it thoroughly before reassembly. Before installing piping or valves, clean their interiors to remove any scale, dirt, preservatives, or other foreign matter.

WINCHES

Winches are used to heave in on mooring lines, to hoist boats, as top lifts on jumbo booms of large auxiliary ships, and to handle cargo. Power for operating shipboard winches is usually furnished by electricity and, on some older ships, by steam. Sometimes delicate control and high acceleration without jerking are required, such as for handling aircraft. Electrohydraulic winches are usually installed for this purpose. Most auxiliary ships are equipped with either electrohydraulic or electric winches.

Cargo Winches

Some of the most common winches used for general cargo handling are the double-drum, double-gypsy, and the single-drum, single-gypsy units. Four-drum, two-gypsy machines are generally used for minesweeping..

Electrohydraulic Winches

Electrohydraulic winches (fig. 10-39) are always drum type. The drive equipment is like most hydraulic systems. A constant-speed electric motor drives the A-end (variable-speed 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..

Normally, winches have one horizontally mounted drum and one or two gypsy heads. If only one gypsy is required, it is 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.

Electric Winches

An electrically driven winch is shown in figure 10-40. This winch is a single-drum, single-gypsy type. The electric motor drives the unit through a set of reduction gears. A clutch engages or disengages the drum from the drum shaft. Additional features include an electric brake and a speed control switch.

CAPSTANS

The terms capstan and winch should not be confused. A winch has a horizontal shaft and a capstan has a vertical shaft. The type of 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 are usually of the reversible type. They develop the same speed and power in either direction. Capstans driven by ac motors run at either full, one-half, or one-third speed. Capstans driven by dc motors usually have from three to five speeds in either direction of rotation.

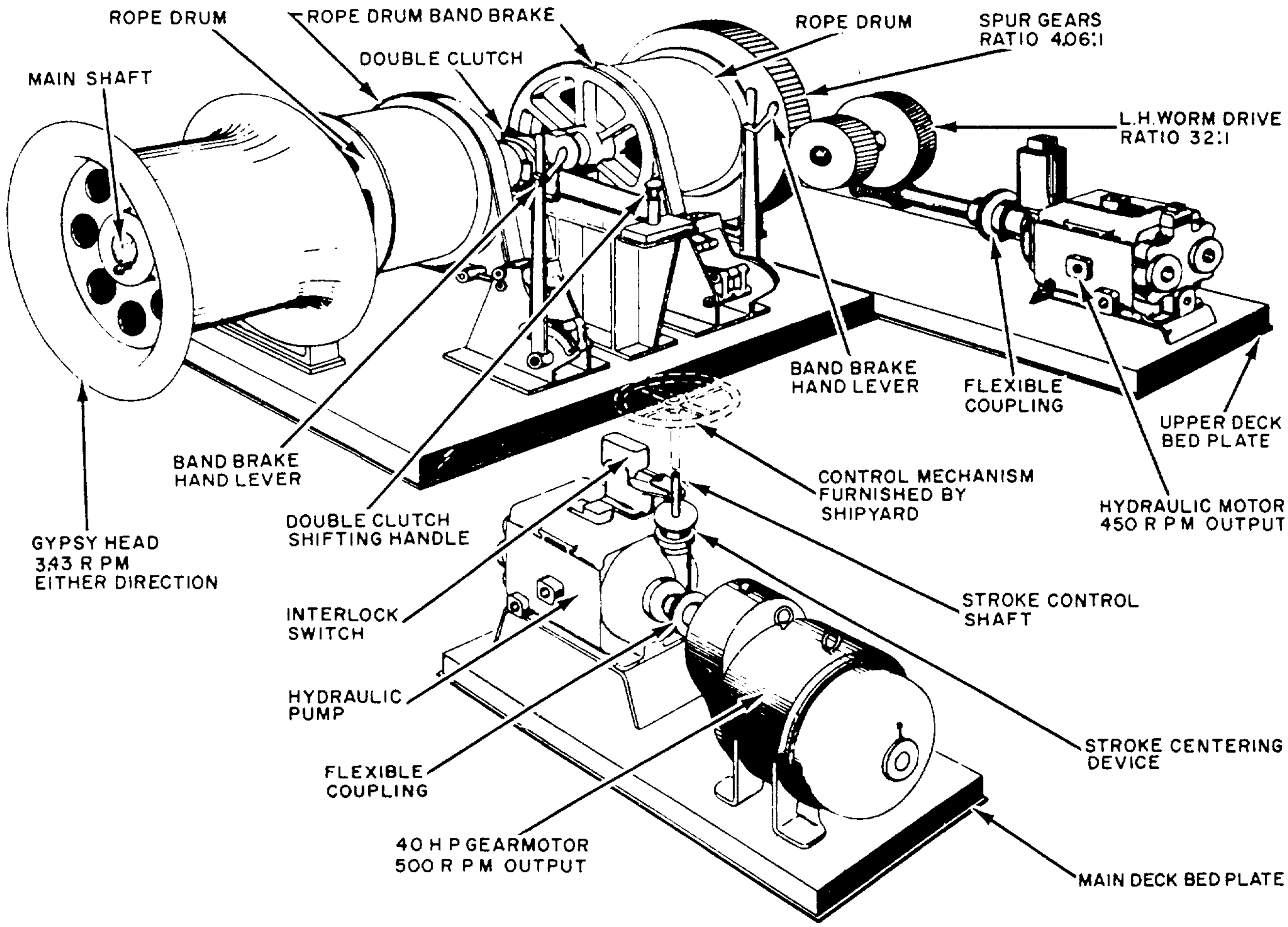


Figure 10-39.—Electrohydraulic winch units.

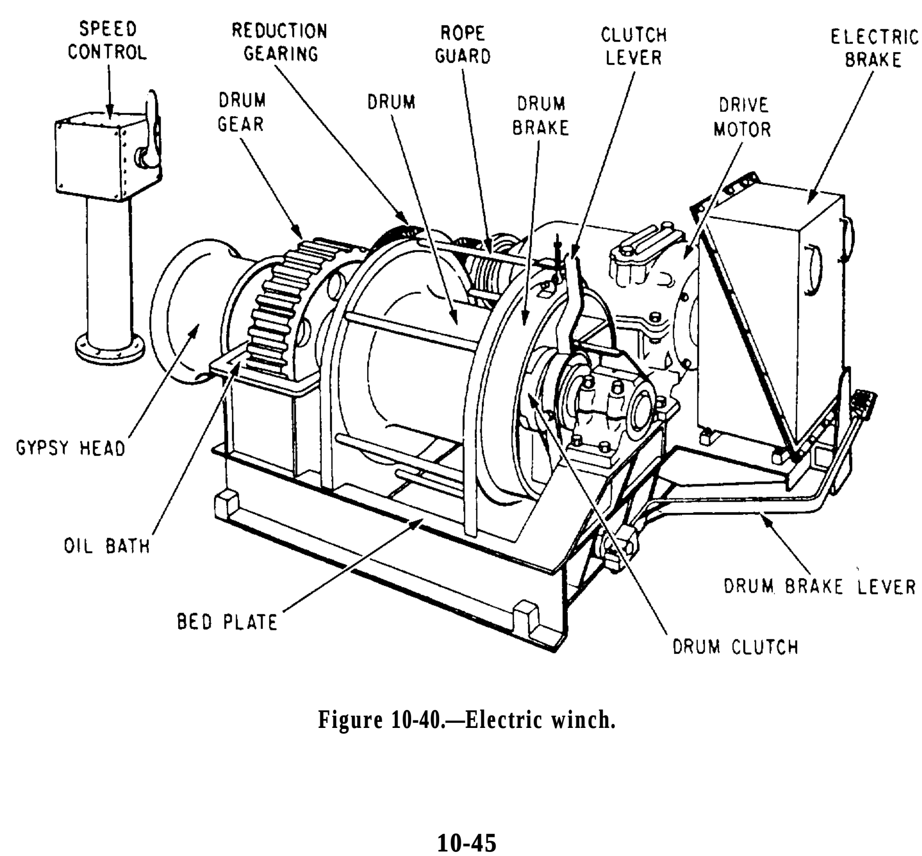


Figure 10-40.—Electric winch.

Maintenance of Winches and Capstans

You will maintain the winch or capstan similarly. Where band brakes are used on the drums, inspect the friction linings regularly and replace them when necessary. Take steps to prevent oil or grease from accumulating on the brake drums. Check the operation of brake-actuating mechanisms, latches, and pawls periodically.

Inspect winch drums driven by friction clutches frequently for deterioration in the friction material. Check also to see if oil and grease are preventing proper operation. Lubricate the sliding parts of positive clutches properly. Check the locking device on the shifting gear to see if it will hold under load.

CRANES

Cranes are designed to meet the following criteria:

1. Hoist, lower, top, and rotate a rated load at the specified speed and against a specified list of the ship.

2. Handle 150 percent of rated load at no specified speed.

3. Withstand a static, suspended load of 200 percent of rated load without dam or distortion to any part of the crane or structure.

The types of cranes installed on ships vary according to the equipment handled.

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. Some of the components of cranes include booms, king post bearings, sheaves and ropes, machinery platforms, rotating gear and pinions, and drums.

Booms

A boom, used as a mechanical shipboard appliance, is a structural unit used to lift, transfer, or support heavy weights. A boom is used with other structures or structural members that support it, and various ropes and pulleys, called blocks, which control it.

King Post Bearings

Bearings on stationary king posts take both vertical load and horizontal strain at the collar, located at the top of the king post. On rotating king posts, bearings take both vertical and horizontal loads at the base and 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 according to recommendations by NAVSEASYSCOM. This command sets 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 carry 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 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 hoisting system uses single or multiple part lines as required. The topping system uses 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. They may also be rotated by an electric motor and hydraulic variable-speed gear connected to reduction gearing.

Some electrohydraulic cranes have automatic slack line take-up equipment. This consists of an electric torque motor geared to the drum. These cranes are used to lift 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. The pump strokes are controlled through operating handwheels. START, STOP, and EMERGENCY RUN pushbuttons at the operator's station control the electric motors. Interlocks 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. They drive the drums of the hoisting and topping units or the rotating machinery.

Reduction gears are located 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 has an electric brake on the hydraulic motor output shaft. This brake is interlocked with the hydraulic pump control. It will set when the hydraulic control is on neutral or when electric power is lost. A centering device is used to find and retain the neutral position of the hydraulic pump.

Relief valves protect the hydraulic system. These valves are set according to the requirements of chapter 556 of the NSTM.

Cranes usually have a rapid slack take-up device consisting of an electric torque motor. This motor is connected to the hoist drum through reduction gearing. This device works in conjunction with the pressure stroke control on the hydraulic pump. It provides fast acceleration of the hook in the hoisting direction under light hook conditions. Thus, slack in the cable is prevented when hoisting is started.

Some cranes have a light-hook paying-out device mounted on the end of the boom. It pays out the heisting 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. 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 unclamps the sheaves. Alimit switch opens and automatically de-energizes the paying-out device.

Maintain cranes according to the PMS requirements or the manufactured instructions. Keep the oil in the replenishing tanks at the prescribed levels. Keep the system clean and free of air. Check the limit stop and other mechanical safety devices regularly for proper operation. When cranes are not in use, secure them in their stowed positions. Secure all electric power to the controllers.

ELECTROHYDRAULIC ELEVATORS

Some of the hydraulic equipment that you maintain is found in electrohydraulic elevator installations. Modern carriers use elevators of this type. The elevators described in this chapter are now in service in some of the ships of the CV class. These ships are equipped with four, deck-edge airplane elevators having a maximum lift 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 for the elevators consists of the following components:

1. A horizontal plunger-type hydraulic engine
2. Multiple variable-delivery parallel piston-type pumps
3. Two high-pressure tanks
4. One low-pressure tank
5. A sump tank system
6. Two constant-delivery vane-type pumps (sump pumps)
7. An oil storage tank
8. A piping system and valves
9. A 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 kept at 97 percent purity.

The hydraulic engine has 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, move the valve off center to allow high-pressure oil to enter the cylinder. High-pressure oil entering the cylinder moves the ram. The ram works through a system of cables and sheaves to move 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. These pumps 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, move the control valve in the opposite direction. This lets oil in the cylinder flow into the exhaust tank. As the platform descends, oil is discharged to the low-pressure tank (exhaust tank). The original oil levels and pressures, except for leaks, are reestablished. The lowering speed is controlled by the control valve and the cushioning effect of the pressure in the exhaust tank. Leak is drained to the sump tanks. It is then 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

The following list contains some of the major safety features incorporated into modem deck-edge elevators:

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 have serrated safety shoes. If all the hoisting cable should break on one side, the shoes will wedge the platform between the guide rails. This will stop the platform with minimum damage.

3. A main pump may have a pressure-actuated switch to stop the pump motors when the discharge pressure is excessive. They may also have to relieve the pressure when the pressure switch fails to operate.

4. The sump pump system has enough capacity to return the unloaded platform from the hangar deck to the flight deck.

5. The oil filter system maybe used continuously while the engine is running. This allows part of the oil to be cleaned with each operation of the elevater.

ELECTROMECHANICAL ELEVATORS

Electromechanical elevators are used for freight, bombs, and stores. In this type of elevator, the platform is raised and lowered by one or more wire ropes that pass over pulleys and wind or unwind on hoisting drums. Hoisting drums are driven through a reduction gear unit by an electric motor. An electric brake stops and holds the platform. The motor has two speeds, full speed and low, or one-sixth, speed. Control arrangements allow the elevator to start and run on high speed. Low speed is used for automatic deceleration as the elevator approaches the selected level. The platform travels on two or four guides. Hand-operated or power-operated lock bars, equipped with electrical interlocks, hold the platform in position.

LUBRICATING SYSTEMS

Most equipment is provided with a lubricating system that supplies oil under pressure to the bearings. The system consists of a sump or reservoir for storing the oil, an oil pump, a strainer, a cooler, temperature and pressure gauges, and the necessary piping to carry the oil to the bearings and back to the sump. The location and arrangement of these parts vary with each piece of equipment. This system allows the lube-oil system to perform the following functions:

- Supply lubrication to the bearings
- Cool the bearings
- Flush any wear products from the bearings

The lube-oil pump is generally a gear-type pump. A definite pressure is maintained in the oil feed lines. A pressure relief valve allows excess oil to recirculate to the suction side of the pump.

Quite often, dual strainers are connected in the line so that the system can operate on one strainer while the other one is being cleaned. The tube-in-shell type of cooler is generally used with seawater circulating through the tubes and the oil flowing around them. The temperature of the oil is controlled by adjusting the valve that regulates the amount of seawater flowing through the tubes.

Oil must be supplied to the bearings at the prescribed pressure and within certain temperature limits. A pressure gauge installed in the feed line and a thermometer installed in the return line indicate oil system functioning. Thermometers are often installed in the bearings to serve as a warning against overheating. If there is a decided drop in oil pressure, shut down the equipment immediately. You should investigate even a moderate rise in the oil temperature. An oil-level float gauge indicates the amount of oil in the sump. Some bearings do not require a lot of cooling or flushing of wear products, so they are grease lubricated (like automobile steering joints). These bearings are usually fitted with a zerk fitting (grease fitting), but some may have grease cups installed.

FUNCTIONS OF LUBRICATION

Lubrication reduces friction between moving parts by substituting fluid friction for sliding friction. Most lubricants are oils or greases; but other units, such as water, can be used for lubrication. When a rotating journal is set in motion, a wedge of oil is formed. This wedge (layer of oil) supports the rotor and substitutes fluid friction for sliding friction. The views shown in figure 10-41 represent a rotor (journal) rotating in a solid sleeve-type bearing. The clearances are exaggerated in the drawing so you can see the formation of the oil film. The shaded portion represents the clearance filled with oil. While the journal is stopped, the oil is squeezed from between the rotor and the bearing, As the rotor starts to turn, oil adhering to the rotor surfaces is carried into the area between the rotor and the bearing. This oil increases the thickness of the oil film, tending to raise and support the rotor. Thus, sliding friction has been replaced by fluid friction.

LUBRICATING OILS AND GREASES

Many different kinds of lubricating materials are in use, each of them filling the requirements of a particular set of conditions. Animal and vegetable oils and even water have good lubricating qualities, but they cannot withstand high temperatures. Mineral oils, similar to the oils used in an automobile engine, are the best type of lubricant for modern machinery operating at high speeds and high temperatures.

Mineral lubricating oils are derived from crude oil in the same process that produces gasoline, kerosene, and fuel oil. They vary according to the type of crude oil and the refining methods used. The same type of oil is usually made in several grades or weights. These grades correspond to the different weights of oil for an automobile, varying from light to heavy.

Oils used in the Navy are divided into nine classes, or series, depending on their use. Each type of oil has a symbol number that indicates its class and viscosity. For example, symbol 2190 oil is a number 2 class of oil with a viscosity of 190 SSU. The viscosity number represents the time in seconds that is required for 60 cubic centimeters (cc) of oil, at a temperature of 130°F, to flow through a standard size opening in a Saybolt viscosimeter (fig. 10-42).

A 2190TEP oil is used for all propulsion turbines and reduction gears. The letters **TEP** indicate that the oil contains additive materials that increase its ability to displace water from steel and inhibit oxidation.

Internal combustion engines (gasoline and diesel) use symbol 9110, 9170, 9250, or 9500 lubricating oils.

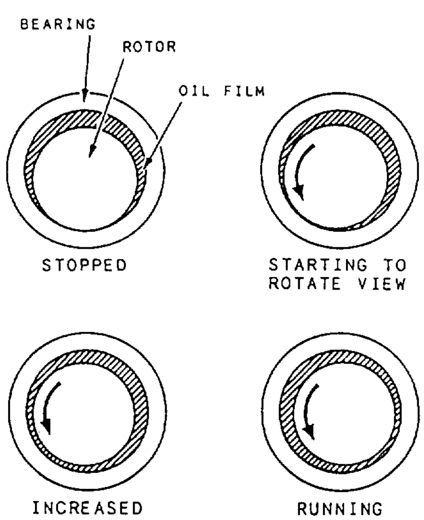


Figure 10-41.—Rotating journals in sleeve-type bearings.

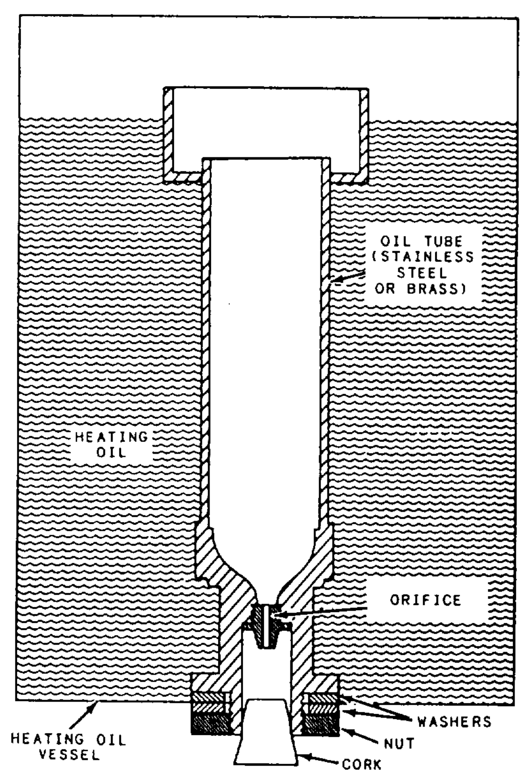


Figure 10-42.—Viscosimeter tube.

These oils have been developed for lubrication of high-speed, high-output diesel engines.

Grease lubrication is used in locations where the retention of lube oil would be difficult. Some of these locations include throttle links, pump bearings, small boat steering links, laundry equipment, etc. Grease is graded according to its intended use and the additives it may contain. Always be sure that you are using the specified lubricant for the individual machinery part, unit, or system you are responsible for operating or maintaining.

The manufacturer's technical manual for each unit of machinery is the basic reference for the correct lube oil, if no lubrication chart (based on manufacturer's instructions) is available. In addition, the table of recommended oils can be found in NSTM, chapter 262.

GALLEY AND LAUNDRY EQUIPMENT

The Navy uses a variety of galley and laundry equipment. The type of equipment depends on the size of the ship, the availability of steam, and other factors. You will need the equipment manufacturer's technical manual for each different piece of gear aboard. Schedule and perform preventive maintenance according to the 3-M systems.

GALLEY EQUIPMENT

In the following paragraphs, we will discuss some of the types of galley equipment with which you will deal.

Steam-Jacketed Kettles

Steam-jacketed kettles (fig. 10-43) come in sizes from 5 to 80 gallons. The kettles are made of corrosion-resisting steel. They operate at a maximum steam pressure of 45 psi. A relief valve in the steam line leading to the kettles is set to lift at 45 psi. Maintenance on these units is normally limited to the steam lines and valves associated with the kettles.

Other steam-operated cooking equipment includes steamers (fig. 10-44) and steam tables (fig. 10-45). Steamers use steam at a pressure of 5 to 7 psi; steam tables use steam at a pressure of 40 psi or less.

Dishwashing Equipment

Dishwashing machines used in the Navy are classified as one-, two-, or three-tank machines. The three-tank machine is a fully automatic, continuous

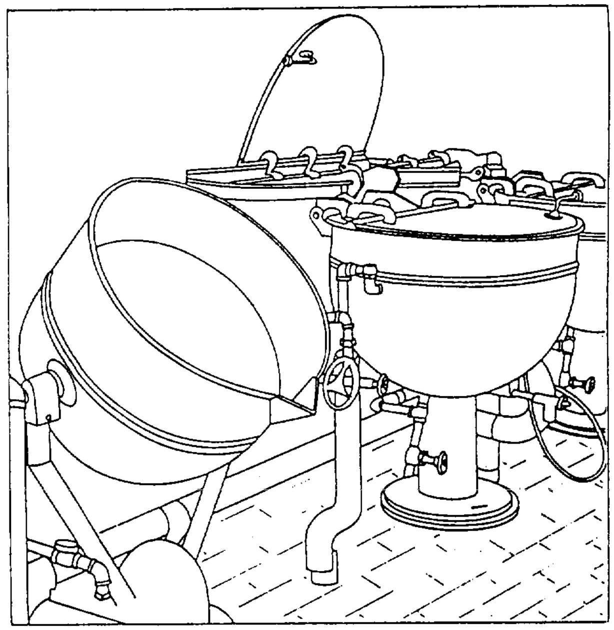


Figure 10-43.—Steam-jacketed kettles

racking machine. It scrapes, brushes, and provides two rinses. It is used at large activities.

Bacteria in these tanks must be controlled at a satisfactory level. This is done by controlling the temperature of the water. The temperature ranges will vary in one-, two- and three-tank machines.

SINGLE TANK.– Single-tank machines (fig. 10-46) are used on small ships, where larger models are not feasible.

The temperature of the washwater must be at least 140°F and no greater than 160°F. Lower temperatures will not control bacteria and higher temperatures are not efficient at removing some foods. These temperatures are controlled by a thermostat. The washing time is 40 seconds in the automatic machines.

For rinsing, hot water is sprayed on the dishes from an external source. It is controlled by an adjustable automatic steam-mixing valve that maintains the rinse water between 180°F and 195°F. To conserve fresh water, 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.

DOUBLE TANK.– Double-tank machines (fig. 10-47) are available in several capacities. They are used when more than 150 persons are to be served at one

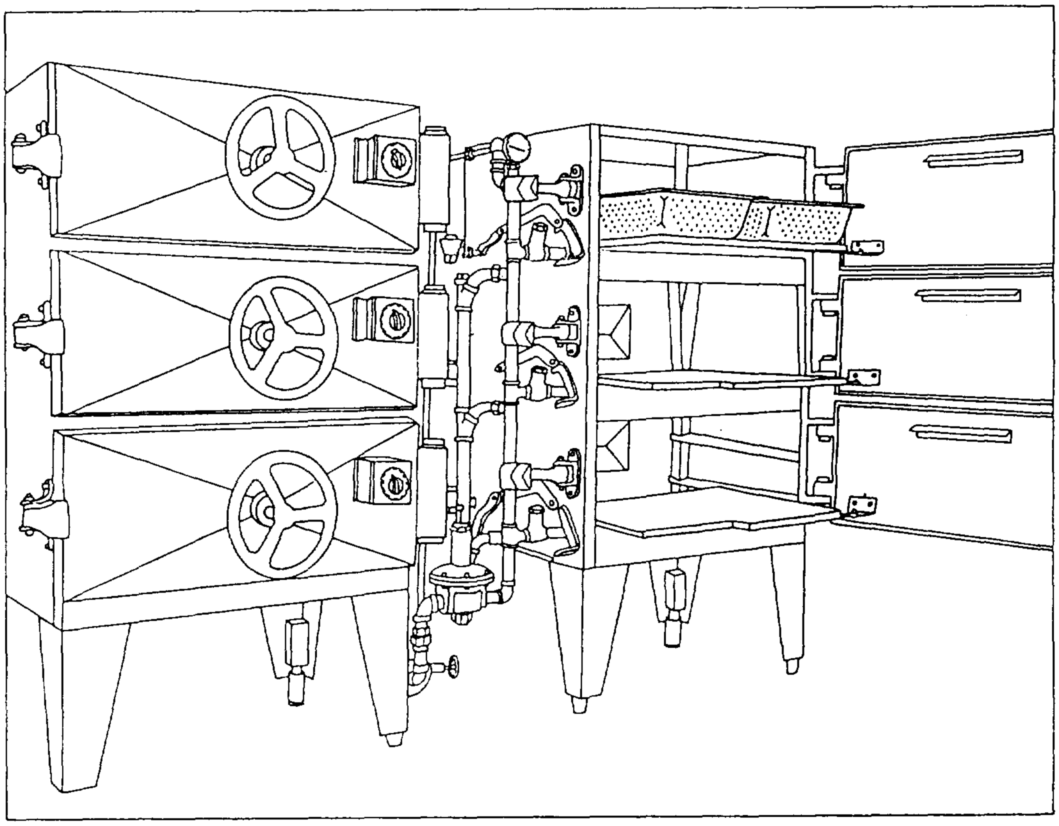


Figure 10-44.—Steamer.

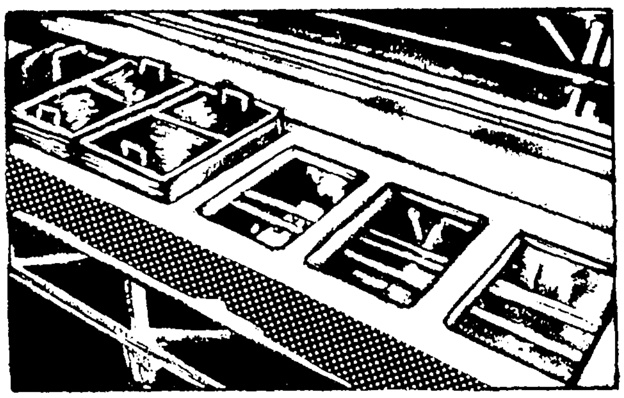


Figure 10-45.—Steam table.

meal. These machines have separate wash and rinse tanks. They also have a final rinse of hot water that 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 that maintains temperature between 180°F and 195°F. double-tank machines are also equipped with a thermostatically operated switch in the rinse tank. This switch prevents operation of the machine if the temperature of the rinse water falls below 180°F. The racks pass through the machine automatically on conveyor chains. Utensils should be exposed to the machine sprays for not less than 40 seconds (20-second wash, 20-second rinse).

Descaling Dishwashers

You should prevent the accumulation of scale deposits in dishwashing machines for at least two reasons. First, excessive scale deposit on the inside of pipes and pumps will clog them. This will 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 following supply list:

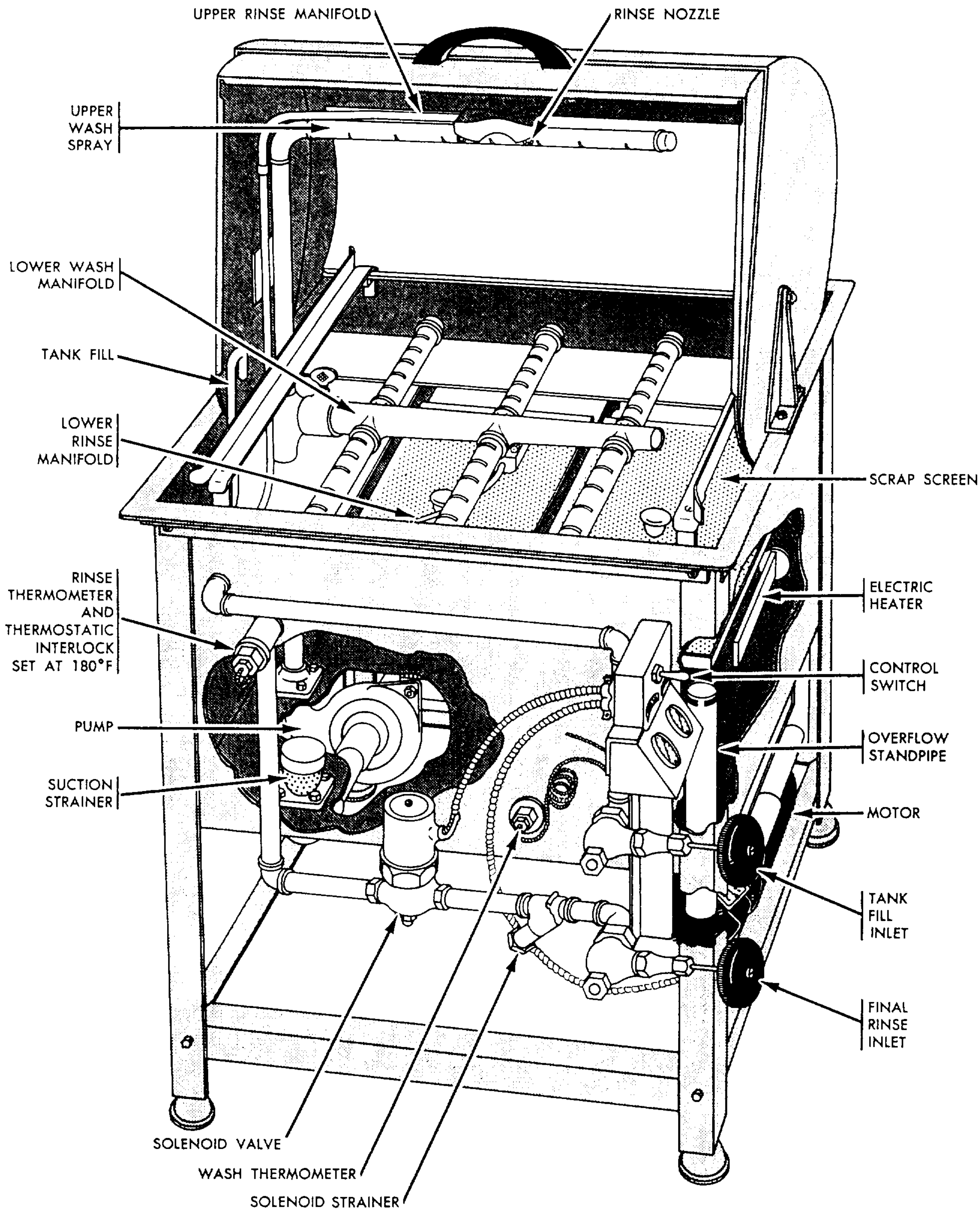


Figure 10-46.—Typical semiautomatic single-tank dishwashing machine.

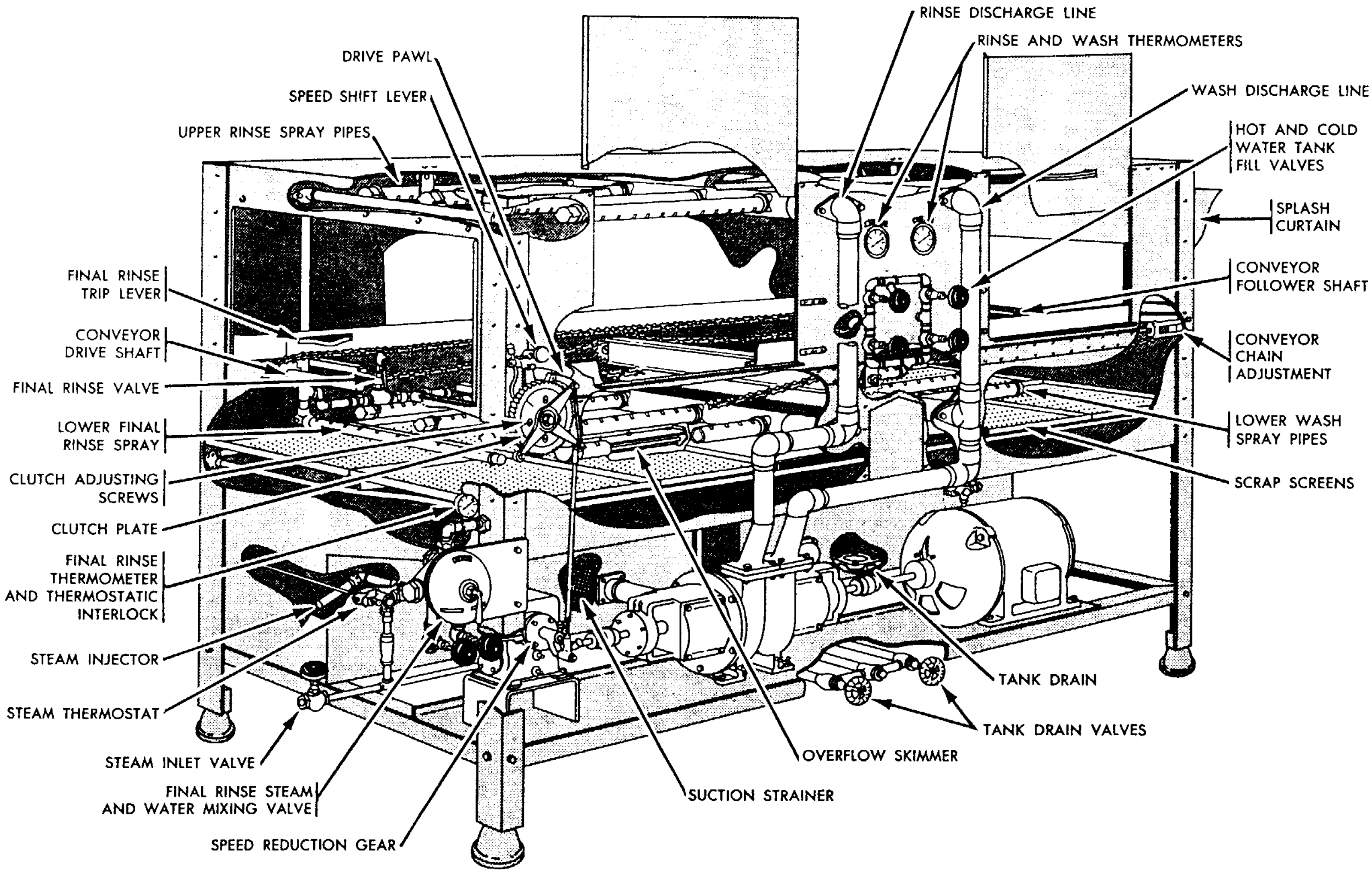


Figure 10-47.--Typical automatic double-tank dishwashing machine.

9G6810-00-264-6722	Orthophosphoric acid 85 percent technical, 7-pound bottle
9Q7930-00-282-9699	Detergent, general-purpose, 1-gallon can
9Q7930-00-985-6911	Detergent, general-purpose, 5-gallon pail

You should know the capacity of the dishwashing machine tanks. Measure (in inches) the inside dimensions of each tank and apply the following formula: length X width X depth (to water line) 231 = capacity in gallons. Steps and key points in descaling the machine:

Steps and key points in descaling the machine.

1. Fill the tanks halfway to the overflow level with hot, clean water. If tanks do not have 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 percent plus 1/2 fluid ounce detergent, general purpose. Use this measure for each gallon capacity of the tank when it is filled to the overflow level.
3. Complete filling the tanks. Fill to the overflow level.
4. Put scrap screens, spray pipes, and splash curtains in place. Remove scale deposits on all attachments.
5. Turn on the 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. Repeat the entire method at such intervals as may be required for operation of the dishwashing machine.

LAUNDRY EQUIPMENT

Equipment used to clean, dry, and press clothing includes washers, extractors, dryers, dry-cleaning machines, and various types of presses. Most of the maintenance on 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 and have caused shipboard fires and damage to equipment, clothing, and personnel. Pay special attention to these safety devices during preventive and corrective maintenance. Pay extra special attention to those devices designed to protect operator personnel.

SUMMARY

This chapter covered refrigeration equipment, cooling systems, air compressors, purifiers, and lubrication, electrohydraulic drive machinery, and weight-handling equipment. It also covered galley equipment, including steam kettles and dishwashers. Laundry equipment was covered briefly since most of your work is limited to inspection and lubrication.

Think back over these broad areas. If you feel that you do not have a general understanding of your rate as it relates to a specific type of equipment, go back now and review that section.