Overview, Installation and Maintenance of Pumps, Valves and Piping

Course No: M07-004
Credit: 7 PDH

Elie Tawil, P.E., LEED AP

CED
engineering.com
PDH FOR THE PROFESSIONAL

CHAPTER 9

PUMPS, VALVES, AND PIPING

As a Fireman, you must know the basic operating principles of various types of pumps and supporting components, such as the different types of valves and piping used aboard ships. Some of the primary uses of pumps are as follows:

- To supply feedwater to boilers

- To deliver fuel oil to oil-fired boilers

- To circulate coolants and lubricants in internal combustion engines

- To supply chemical feed in water purification systems

- To lift water from cells and distribute it throughout a system

- To discharge sewage into setting tanks or mains

- To pressurize and move liquids through a distribution system

With the knowledge gained in this chapter, you should be able to describe pumps, valves, and piping systems in terms of their construction, function, and operation. The information in this chapter, as it is throughout the book, is of a broad and general nature. You should refer to the appropriate manufacturer's technical manuals and/or ship's plans, information books, and plant or valve manuals for specific problems with individual equipment. By studying this material, you should be able to relate to the specific equipment found on your ship.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Recognize the principles of pump operation.

2. Identify the different types of pumps.

3. Identify an eductor.

4. Identify basic types and functions of valves.

5. Identify the types of steam traps.

6. Identify the different types of strainers.

7. Recognize the different types of filters.

8. Identify tubing and associated fittings.

9. Identify piping, associated fittings, and flange shielding.

10. Identify the types of packing and gasket material.

PUMPS

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

A pump is a device that uses an external source of power to force fluid to move from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source, such as a gasoline or electric motor, into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then used to do work, for example, to raise liquid from one level to another, as when water is raised from a well; to transport liquid through a pipe, as when oil is moved through an oil pipeline; to move liquid against some resistance, as when water is pumped to a boiler under pressure; or to force liquid through a hydraulic system against resistance. Every pump has a POWER END, whether it is a combustion engine or some type of electric motor. Each pump also has a FLUID END, where the fluid enters (suctions) and leaves (discharges) the pump.

When a pump delivers energy to a liquid, it usually causes an increase in pressure, which is generally referred to as HEAD. There are four types of heads:

- Net positive suction head (NPSH)
- Suction head
- Discharge head
- Total head

Net Positive Suction Head (NPSH)

NPSH is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. An example is a feed booster pump with a deaerating feed tank operating at saturated conditions. The NPSH on this pump equals the pressure resulting from the height of the water above the booster pump suction.

Suction Head

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

Discharge Head

The discharge head is the pressure of liquid leaving the pump and/or the level of liquid with respect to the level of the pump on the discharge side.

Total Head

The total head is the net difference between the suction head and the discharge head.

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

It is not practical or necessary to mention all of the various locations where pumps are found aboard ship. You will learn their location and operation as you perform your duties. The pumps with which you are primarily concerned are used for such purposes as providing fuel oil to the prime mover, circulating lubricating (lube) oil to the bearings and gears of the main reduction gear (MRG), supplying seawater for the coolers in engineering spaces, pumping out the bilges, and transferring fuel oil to various storage and service tanks.

Classification of Pumps

Pumps aboard ships outnumber all other auxiliary machinery units. They include such types as centrifugal, rotary, and jet pumps. In the following section we discuss these different pumps and their application to the engineering plant.

Centrifugal Pumps

When a body or a liquid is made to revolve or whirl around a point, a force is created that impels the body or fluid to move outward from the center of rotation. This phenomenon is called centrifugal force. It is from this force that the centrifugal pump got its name. The fire pump and seawater service pump are two examples of this type of pump.

A basic centrifugal pump has an impeller keyed to a drive shaft, which is rotated by an electric motor. The drive shaft is fitted inside a casing, which has a suction inlet and a discharge outlet. *Figure 9-1* shows the arrangement of components in a centrifugal pump.
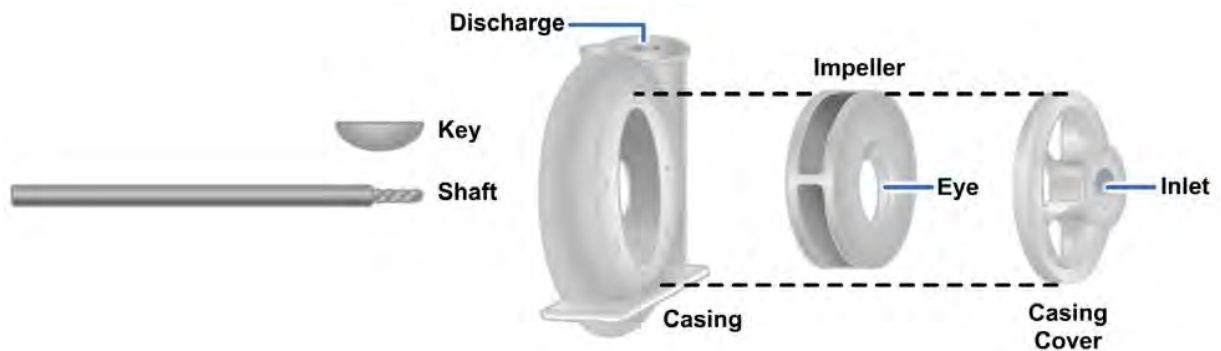

Figure 9-1 — Centrifugal pump.

Types of Centrifugal Pumps

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

Volute Pump

In the volute pump (*Figure 9-2, views A and B*), the impeller discharges into a volute (a gradually widening spiral channel in the pump casing). As the liquid passes through the volute and into the
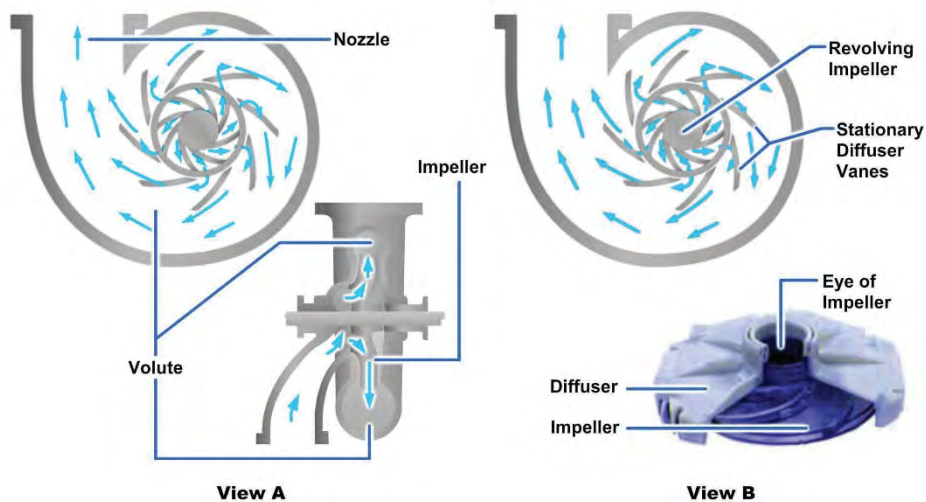

Figure 9-2 — Volute pump.

discharge nozzle, a great part of its kinetic energy (velocity head) is converted into potential energy (pressure head).

Diffuser Pump

In the diffuser pump, the liquid leaving the impeller is first slowed down by the stationary diffuser vanes that surround the impeller. The liquid is then forced through gradually widening passages in the diffuser ring and into the volute (casing). Since both the diffuser vanes and the volute reduce the velocity of the liquid, there is an almost complete conversion of kinetic energy to potential energy.

Centrifugal Pump Classification

Centrifugal pumps may be classified in several ways. For example, they may be either single-stage or multistage. A single-stage pump has only one impeller; a multistage pump has two or more impellers housed together in one casing. In a multistage pump, each impeller usually acts separately, discharging to the suction of the next stage impeller.

Centrifugal pumps are also classified as horizontal or vertical, depending on the position of the pump shaft.

One method of increasing the discharge pressure of centrifugal pumps is by providing additional impellers. Impellers used in centrifugal pumps may be classified as single-suction or double-suction, depending on the way in which liquid enters the eye of the impeller. *Figure 9-3* shows single-suction and double-suction arrangements of centrifugal pump impellers. The single-suction impeller (view A) allows liquid to enter the eye from one side only; the double-suction impeller (view B) allows liquid to enter the eye from both sides. The double-suction arrangement has the advantage of balancing the end thrust in one direction with the end thrust in the other direction.

Impellers are also classified as closed or open. A closed impeller has side walls that extend from the eye to the outer edge of the vane tips; an open impeller does not have side walls. Most centrifugal pumps used in the Navy have closed impellers.

Figure 9-3 — Centrifugal pump impellers. A. Single-suction. B. Double-suction.

Construction

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

Since an impeller rotates at high speed, it must be carefully machined to minimize friction. An impeller must be balanced to avoid vibration. A close radial clearance must be maintained between the outer hub of the impeller and that part of the pump casing in which the hub rotates. The purpose of this is to minimize leakage from the discharge side of the pump casing to the suction side.
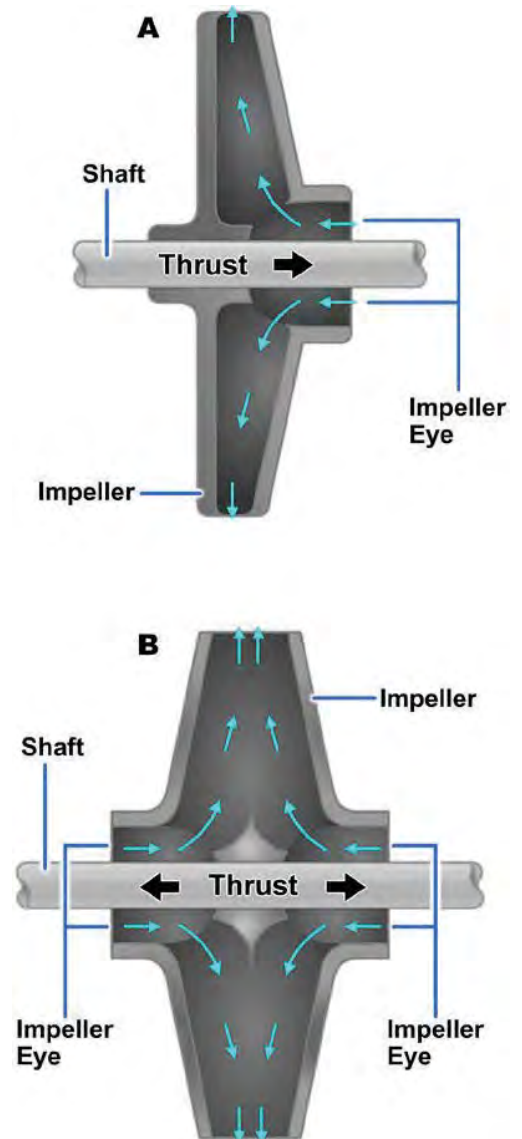
Because of the high rotational speed of the impeller and the necessarily close clearance, the rubbing surfaces of both the impeller hub and the casing at that point are subject to stress, causing rapid wear. To eliminate the need for replacing an entire impeller and pump casing solely because of wear in this location, most centrifugal pumps are designed with replaceable wearing rings. One ring is attached to each outer hub of the impeller. This ring is called the impeller wearing ring. The other ring, which is stationary and attached to the casing, is called the casing wearing ring (*Figure 9-4*).

In most centrifugal pumps, the shaft is fitted with a replaceable sleeve (*Figure 9-5*). These sleeves protect the shaft from becoming grooved. A shaft that is in direct contact with the packing will become grooved because of its rotation in the packing. It is much cheaper to replace the shaft sleeves than to replace the pump shaft. The shaft sleeves are also used to position the impeller axially on the pump shaft.
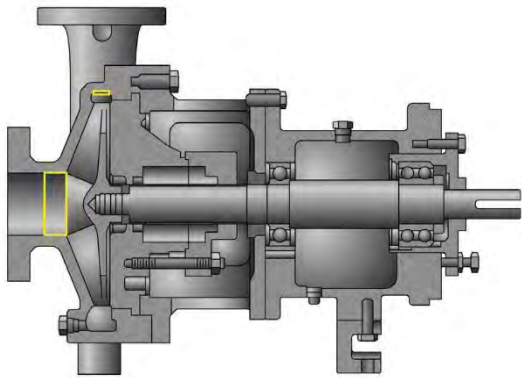
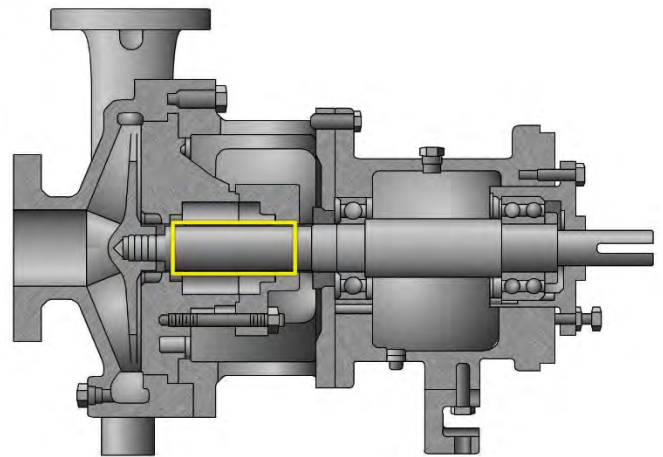**Figure 9-4 — Two-stage main feed pump with a casing wearing ring.**

Figure 9-5 — Shaft sleeve.

Stuffing Box

The stuffing box (*Figure 9-6*) is a chamber in the packing gland used to seal the shaft where it passes through the pump casing. Packing rings are placed inside of the stuffing box, and a gland is used to compress the packing down the shaft. Piping that supplies sealing liquid to the stuffing box is called seal piping (liquid seal). Seal piping is installed to cool the shaft and the packing, to lubricate the packing, and to seal the joint between the shaft and the packing against air leakage. The sealing liquid either comes from the discharge side of the pump (internally sealed) or from an external source (externally sealed).

Seal piping leads liquid from the discharge side of the pump or from an external source to the lantern ring. The lantern ring is a perforated hollow ring located near the center of the stuffing box. The web of the ring is perforated so that water can flow in either direction along the shaft to distribute liquid uniformly around the shaft to provide lubrication and cooling.

Figure 9-6 — Stuffing box.

Recirculating lines are installed on some centrifugal pumps to prevent them from overheating and becoming vapor bound when the discharge is entirely shut off.
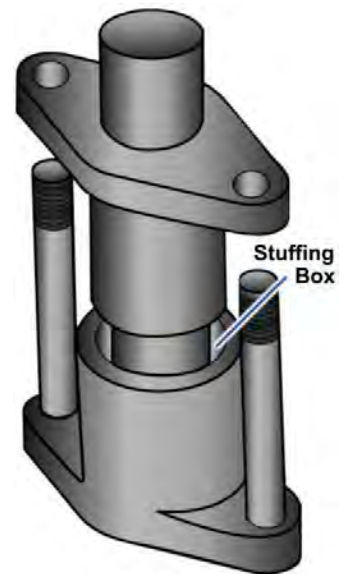
A water flinger is fitted on the shaft outboard of the stuffing box glands to prevent leakage from the stuffing box following along the shaft and entering the bearing housings. The flingers must fit tightly on the shaft. If the flingers are fitted on the shaft sleeves instead of on the shaft, ensure that no water leaks under the sleeves.

Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings. Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, sonar, radar, and other electronic cooling systems). They not only conserve the fluid being pumped but also improve system operation.

Operation

Liquid enters the rotating impeller on the suction side of the casing and enters the eye of the impeller (*Figure 9-2*). Liquid is thrown out through the opening around the edge of the impeller and against the side of the casing by centrifugal force. When liquid is thrown out to the edge of the casing, a region of low pressure (below atmospheric) is created around the center of the impeller; more liquid moves into the eye to replace the liquid that was thrown out. Liquid moves into the center of the impeller with a high velocity (speed). Therefore, liquid in the center of the impeller has a low pressure, but it is moving at a high velocity.

Liquid moving between the blades of the impeller spreads out, which causes the liquid to slow down. (Its velocity decreases.) At the same time, as the liquid moves closer to the edge of the casing, the pressure of the liquid increases. This change (from low pressure and high velocity at the center to high pressure and low velocity at the edge) is caused by the shape of the opening between the impeller blades. This space has the shape of a diffuser, a device that causes the velocity-pressure relationship of any fluid that moves through it to change.

A centrifugal pump is considered to be a nonpositive-displacement pump because the volume of liquid discharged from the pump changes whenever the pressure head changes. The pressure head is the combined effect of liquid weight, fluid friction, and obstruction to flow. In a centrifugal pump, the force of the discharge pressure of the pump must be able to overcome the force of the pressure head; otherwise, the pump could not deliver any liquid to a piping system. The pressure head and the discharge pressure of a centrifugal pump oppose each other. When the pressure head increases, the discharge pressure of the pump must also increase.

Since no energy can be lost, when the discharge pressure of the pump increases, the velocity of flow must decrease. On the other hand, when the pressure head decreases, the volume of liquid discharged from the pump increases. As a general rule, a centrifugal pump is usually located below the liquid being pumped. (This discussion assumes a constant impeller speed.)

Figure 9-7 shows that when the pump discharge is blocked, nothing happens because the impeller is hollow. A tremendous buildup in pressure cannot occur because the
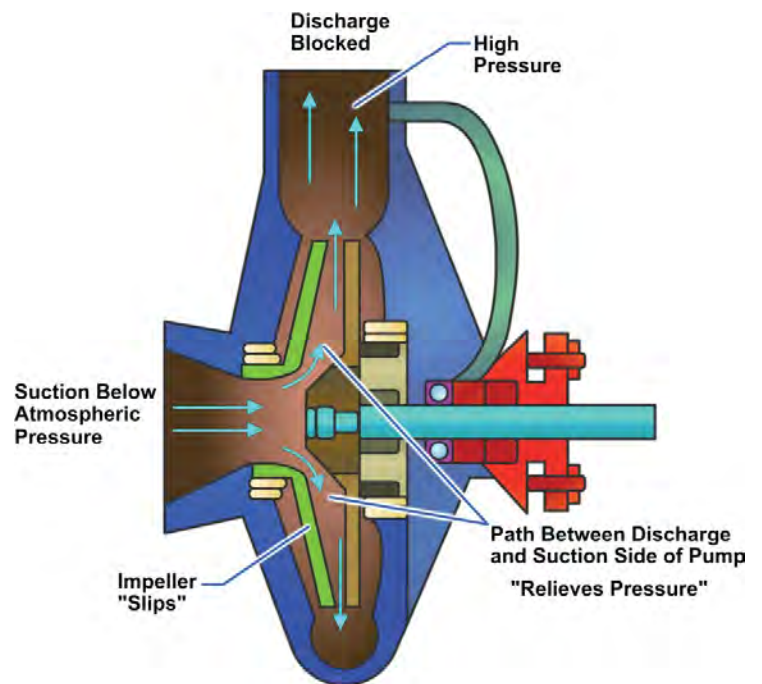

Figure 9-7 — Nonpositive-displacement pump.

passages in the impeller (between the discharge and suction side of the pump) act like a built-in relief valve. When the discharge pressure and pressure head are equal (as in this case), the impeller is allowed to rotate (slip) through the liquid in the casing.

> **NOTE**
>
> Centrifugal pumps used for intermittent service may have to run for long periods of time against a blocked discharge. Friction between the impeller and the liquid raises the temperature of the liquid in the casing and causes the pump to overheat. To prevent this, a small line is connected between the discharge and the suction piping of the pump.

When a centrifugal pump is started, the vent line must be opened to release entrained air. The open passage through the impeller of a centrifugal pump also causes another problem. It is possible for liquid to flow backwards (reverse flow) through the pump. A reverse flow, from the discharge back to the suction, can happen when the pressure head overcomes the discharge pressure of the pump. A reverse flow can also occur when the pump is not running and another pump is delivering liquid to the same piping system. To prevent a reverse flow of liquid through a centrifugal pump, a check valve is usually installed in the discharge line.

> **NOTE**
>
> Instead of two separate valves, some installations use a globe stop-check valve.

With a check valve in the discharge line, whenever the pressure above the disk rises above the pressure below it, the check valve shuts. This prevents liquid from flowing backwards through the pump.

Maintenance

You must observe the operation and safety precautions pertaining to pumps by following the engineering operational procedure (EOP) subsystem of the engineering operational sequencing system (EOSS)—if your ship has EOSS. If not, use the Naval Ships' Technical Manual (NSTM) and/or the instructions posted on or near each individual pump. You must follow the manufacturer's technical manual or maintenance requirement cards (MRCs) for planned maintenance system (PMS) related work for all maintenance work. The MRCs list in detail what you have to do for each individual maintenance requirement.

Mechanical Seals

One type of mechanical seal is shown in *Figure 9-8*. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason or whenever leakage causes undesirable effects on equipment or surrounding spaces.
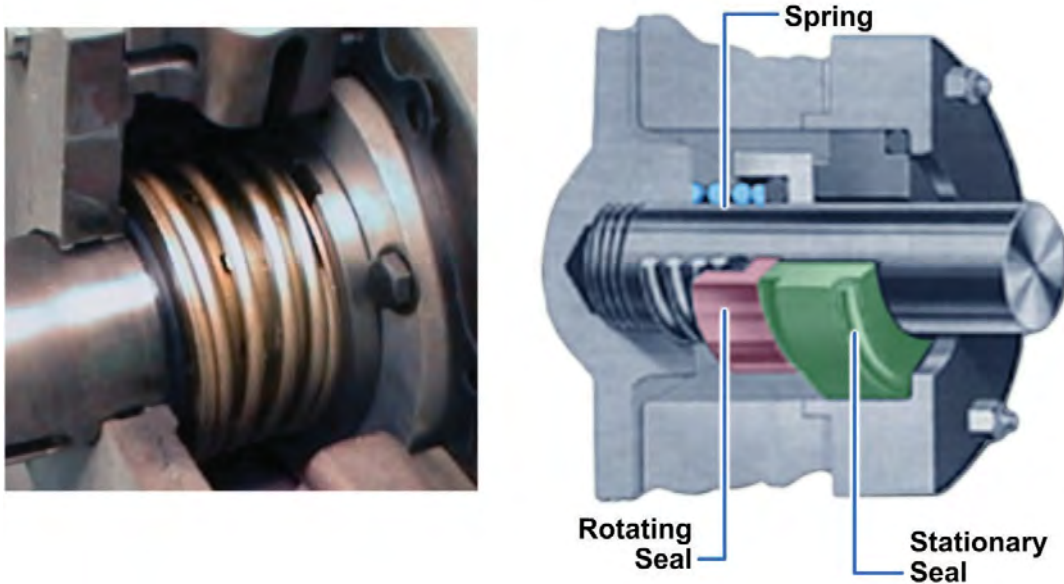
MECHANICAL SEALS

Figure 9-8 — Mechanical seal.

You should observe the following precautions when performing maintenance on mechanical seals:

- Do not touch new seals on the sealing face because body acid and grease can cause the seal face to prematurely pit and fail

- Replace mechanical seals when the seal is removed for any reason, when the leakage rate exceeds 5 drops per minute, or when leakage causes undesirable effects on equipment or surrounding spaces

- Position mechanical shaft seals on the shaft by stub or step sleeves. Shaft sleeves are chamfered (beveled) on outboard ends to provide ease of mechanical seal mounting

- Do not position mechanical shaft seals by using setscrews

Fire pumps and all seawater pumps installed in surface ships are being provided with mechanical shaft seals with cyclone separators. These separators use centrifugal force to prevent abrasive material (such as sand in the seawater) from passing between the sealing surfaces of the mechanical seal. There is an opening at each end of the separator. The opening at the top is for "clean" water, which is directed though tubing to the mechanical seals in the pump. The high velocity "dirty" water is directed through the bottom of the separator, back to the inlet piping for the pump. The glands are designed to incorporate two or more rings of packing if the mechanical shaft seal fails.

Repacking

Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use.

To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, you are not using the right size.

Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure. Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off. This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Renewing Shaft Sleeves

In some pumps (usually large pumps), the shaft sleeve is pressed onto the shaft tightly by a hydraulic press. In this case, the old sleeve must be machined off with a lathe before a new one can be installed. You must disassemble the pump and take the sleeve to a machine shop, a repair shop, or a naval shipyard to have this done. On other pumps (usually small pumps), the shaft sleeve may have a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On these pumps, new sleeves can be installed by removing the water end casing, impeller, and old shaft sleeves. New sleeves are carried as repair parts; they can also be made in the machine shop.

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

Renewing Wearing Rings

The clearance between the impeller and the casing wearing ring must be maintained as directed by the manufacturer. When clearances exceed the specified amount, the casing wearing ring must be replaced. On most ships, this job can be done by the ship's force, but it requires the complete disassembly of the pump. All necessary information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is specified by PMS or can be found in the manufacturer's technical manual. Failure to replace the casing wearing ring when the allowable clearance is exceeded results in a decrease of pump capacity and efficiency. If a pump has to be disassembled because of some internal trouble, the wearing ring should be checked for clearance. Measure the outside diameter of the impeller hub with an outside micrometer and the inside diameter of the casing wearing ring with an inside micrometer; the difference between the two diameters is the actual wearing ring diametric clearance. By checking the actual wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the ring before reassembling the pump. The applicable MRCs are a readily available source of information on proper clearances.

Wearing rings for most small pumps are carried aboard ship as part of the ship's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, spare rotors are carried aboard ship. The new rotor can be installed and the old rotor sent to

a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, bearings, and shaft sleeve.

Operating Troubles

You will be responsible for the maintenance of centrifugal pumps. The following is a description of some of the problems you will have to deal with and the probable causes:

TROUBLE	CAUSE
Does not deliver any liquid	Insufficient priming
	Insufficient speed of the pump
	Excessive discharge pressure (such as a partially closed valve or some other obstruction in the discharge line)
	Excessive suction lift
	Clogged impeller passages
	Wrong direction of rotation
	Clogged suction screen (if used)
	Ruptured suction line
	Loss of suction pressure
Insufficient capacity	Air leakage into the suction line
	Insufficient speed of the pump
	Excessive suction lift
	Clogged impeller passages
	Excessive discharge pressure
	Mechanical defects (such as worn wearing rings, impellers, stuffing box packing, or sleeves)
Does not develop enough discharge pressure	Insufficient speed of the pump
	Air or gas in the liquid being pumped
	Mechanical defects (such as worn wearing rings, impellers, or sleeves and leaking mechanical seals)
Works for a while and then fails to deliver liquid	Air leakage into the suction line
	Air leakage in the stuffing boxes
	Clogged water seal passages
	Insufficient liquid on the suction side
	Excessive heat in the liquid being pumped
Takes too much power and the motor overheats	Operation of the pump at excess capacity and insufficient discharge pressure
	Misalignment
	Bent shaft
	Excessively tight stuffing box packing
	Worn wearing rings
	Other mechanical defects
Vibration	Misalignment
	Bent shaft
	Clogged, eroded, or otherwise unbalanced impeller
	Lack of rigidity in the foundation

Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure.

Rotary Pumps

Another type of pump you find aboard ship is the rotary pump. A number of types are included in this classification, among which are the gear pump, the screw pump, and the moving vane pump. Unlike the centrifugal pump, which we have discussed, the rotary pump is a positive-displacement pump. This means that for each revolution of the pump, a fixed volume of fluid is moved regardless of the resistance against which the pump is pushing. As you can see, any blockage in the system could quickly cause damage to the pump or a rupture of the system. You, as a pump operator, must always be sure that the system is properly aligned so a complete flow path exists for fluid flow. Also, because of their positive-displacement feature, rotary pumps require a relief valve to protect the pump and piping system. The relief valve lifts at a preset pressure and returns the system liquid either to the suction side of the pump or back to the supply tank or sump.

Rotary pumps are also different from centrifugal pumps in that they are essentially self-priming. As we saw in our discussion of centrifugal pumps, the pump is located below the liquid being pumped; gravity creates a static pressure head, which keeps the pump primed. A rotary pump operates within limits with the pump located above the source of supply.

Rotary pumps are useful for pumping oil and other heavy viscous liquids. In the engine room, rotary pumps are used for handling lube oil and fuel oil and are suitable for handling liquids over a wide range of viscosities.

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

Types of Rotary Pumps

There are several types of positive-displacement rotary pumps, including the simple gear, herringbone gear, helical gear, and vane, lobe, and screw types. Classification of rotary pumps is generally based on the types of rotating element. The main features of gear, screw, and sliding vane pumps will be discussed briefly in the following paragraphs.

Gear Pumps

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

Figure 9-9 shows a gear pump located above the tank. The tank must be vented to allow air into the tank to provide atmospheric pressure on the surface of the liquid. To lower the pressure on the suction side of the pump, the clearances between the pump parts must be close enough to pump air. When the pump starts, the air is pumped through the discharge side of the pump and creates the low- pressure area on the suction side, which allows the atmospheric pressure to force the liquid up the

pipe to the pump. To operate properly, the piping leading to the pump must have no leaks or it will draw in air and can lose its prime.

One example of the use of a gear pump is in the LM2500 engine fuel pump. However, gear pumps are not used extensively on gas turbine ships.
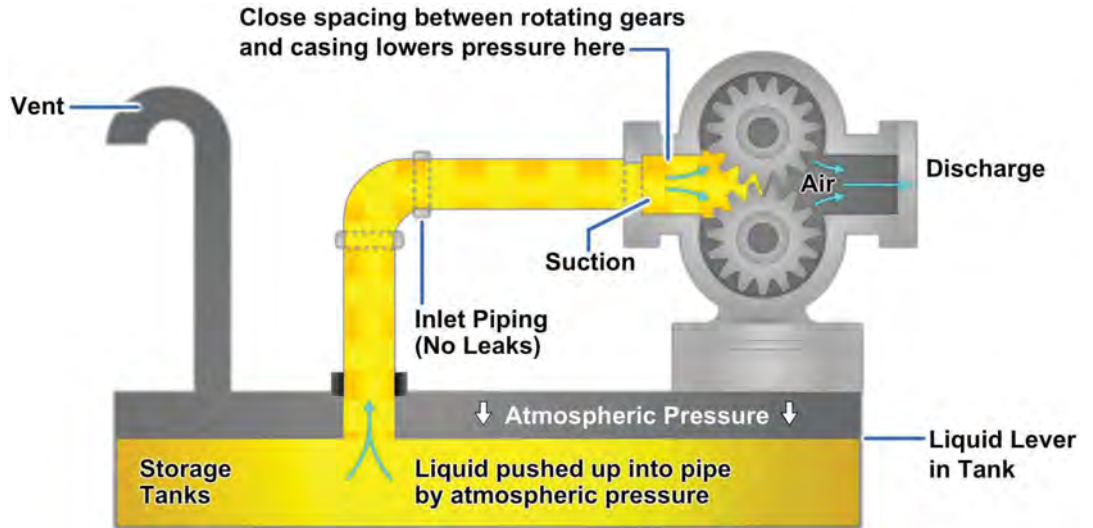

Figure 9-9 — Gear pump located above the tank.

Screw Pumps

Several different types of screw pumps exist. The differences between the various types are the number of intermeshing screws and the pitch of the screws. *Figure 9-10* shows a double-screw, low-pitch pump. Screw pumps are used aboard ship to pump fuel and lube oil and to supply pressure to the hydraulic system. In the double-screw pump, one rotor is driven by the drive shaft and the other by a set of timing gears. In the triple-screw pump, a central rotor meshes with two idler rotors.

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

Most screw pumps are now equipped with mechanical seals. If the mechanical seal fails, the stuffing box has the capability of accepting two rings of conventional packing for emergency use.
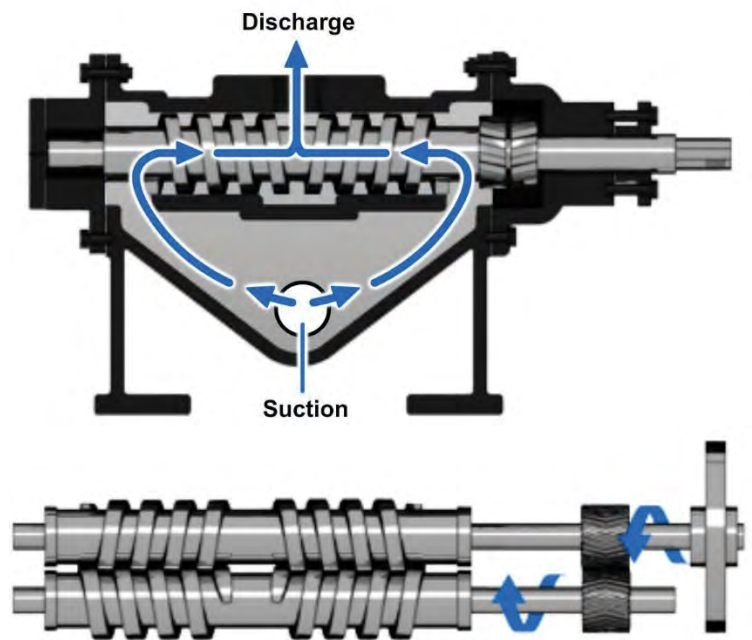
Figure 9-10 — Double-screw, low-pitch pump.

Sliding Vane Pumps

The sliding-vane pump (*Figure 9-11*) has a cylindrically bored housing with a suction inlet on one side and a discharge outlet on the other side. A rotor (smaller in diameter than the cylinder) is driven about an axis that is placed above the center line of the cylinder to provide minimum clearance between the rotor and cylinder at the top and maximum clearance at the bottom.

The rotor carries vanes (which move in and out as the rotor rotates) to maintain sealed spaces between the rotor and the cylinder wall. The vanes trap liquid on the suction side and carry it to the discharge side, where contraction of the space expels liquid through the discharge line. The vanes slide on slots in the rotor. Vane pumps are used for lube oil service and transfer, tank stripping, bilge, aircraft fueling and defueling and, in general, for handling lighter viscous liquids.
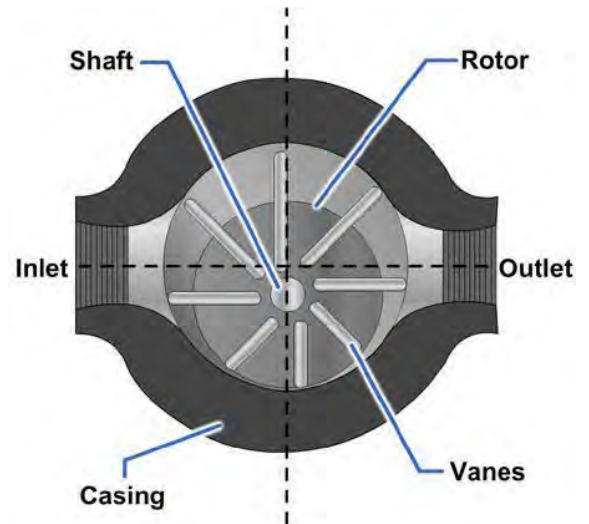
Figure 9-11 — Sliding vane pump.

Jet Pumps

The pumps discussed so far in this chapter have had a variety of moving parts. One type of pump you find in the engine room is the jet pump, usually called an eductor. *Figure 9-12* shows an eductor, which has no moving parts. These pumps are used for pumping large quantities of water overboard in such applications as pumping bilges and dewatering compartments. As an engineer, you will think of eductors as part of the main and secondary drainage system; you will also become familiar with them as part of the ship's damage control equipment.

Eductors use a high-velocity jet of seawater to lower the pressure in the chamber around the converging nozzle. Seawater is supplied to the converging nozzle at a relatively low velocity and exits the nozzle at a high velocity. As the seawater leaves the nozzle and passes through the chamber, air becomes entrained in the jet stream and is pumped out of the chamber. Pressure in the chamber decreases, allowing atmospheric pressure to push the surrounding water into the chamber and mix with the jet stream. The diverging nozzle allows the velocity of the fluid to decrease and the pressure to increase; the discharge pressure is then established.
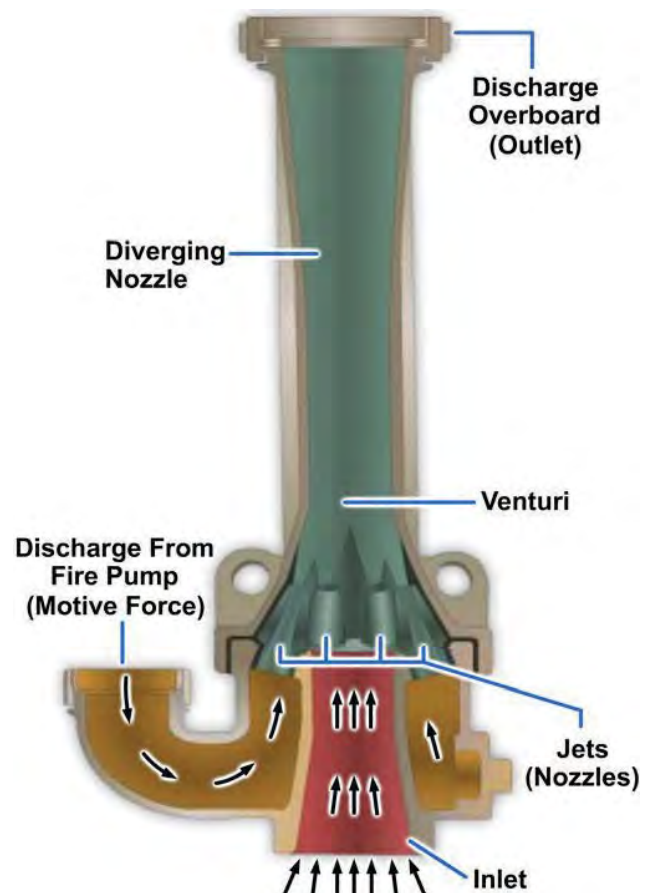

Figure 9-12 — Portable eductor.

Figure 9-13 is an example of a typical shipboard eductor system. A simple jet pump consists of a jet supply line, a jet or nozzle, a suction line, a suction chamber, a diffuser, and a discharge line. In a jet pump, pumping action is created as a fluid (water, steam, or air) passes at a high pressure and velocity through a nozzle and into a chamber that has an inlet and outlet opening.

The operating principle of a jet pump is as follows: Upon starting up, the rapidly moving jet fluid pushes on and gives sufficient motion to the air (or whatever substance may be in the suction chamber) to carry it out through the discharge line. Displacement of the air from the suction chamber creates a partial vacuum within the suction chamber, causing fluid to flow through the suction line. The fluid entering the chamber from the suction line is picked up by the high-velocity fluid, thus providing continuous pumping action.
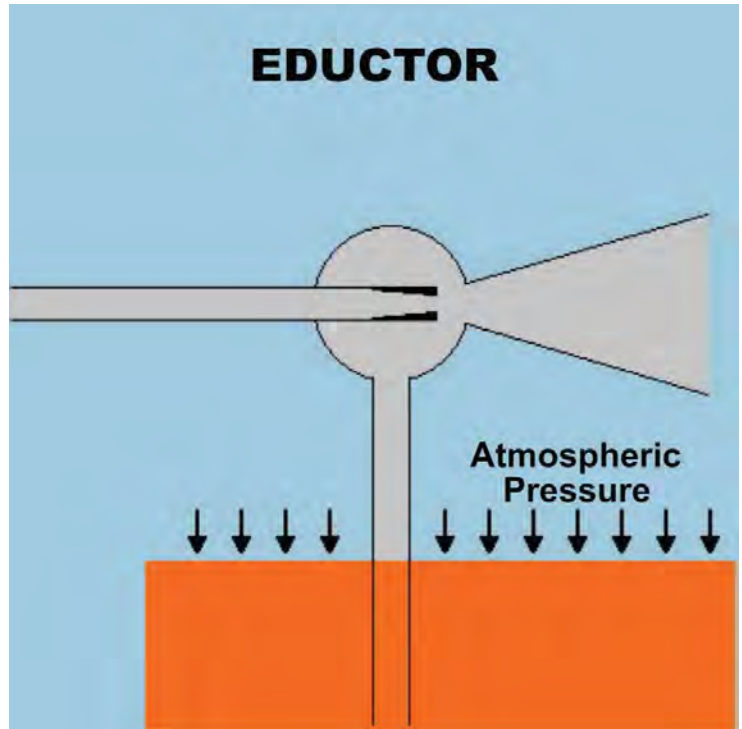
Figure 9-13 — Simple jet pump.

ALIGNMENT OF SHAFT AND COUPLING

When you install or assemble pumps driven by electric motors, make sure the unit is aligned properly. If the shaft is misaligned, you must realign the unit to prevent shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Always check the shaft alignment with all the piping in place.

Some driving units are connected to the pump by a flexible coupling. A flexible coupling (*Figure 9-14*) is intended to take care of only a slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. If the misalignment is excessive, the coupling parts are subjected to severe punishment, necessitating frequent replacement of pins, bushings, and bearings. It is absolutely necessary to have the rotating shafts of the driver and driven units in proper alignment.

Figure 9-14 — Flexible couplings.

You should check the shaft alignment when the pump is opened for repair or maintenance, or if a noticeable vibration occurs. You must realign the unit if the shafts are out of line or inclined at an angle to each other. Whenever practicable, check the alignment with all piping in place and with the adjacent tanks and piping filled.

When the driving unit is connected to the pump by a flange coupling, the shafting may require frequent realignment, which may be indicated by high temperatures, noises, and worn bearings or bushings.

Wedges, or shims, are sometimes placed under the bases of both the driven and driving units (*Figure 9-15, view A*) for ease in alignment when the machinery is installed. When the wedges or other packing have been adjusted so the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks are fastened, the units are securely bolted to the foundation, and the coupling flanges are bolted together.

The faces of the coupling flanges should be checked at 90-degree intervals. This method is shown in *Figure 9-15, view B*. Find the distances between the faces at point a, point b (on the opposite side), point c, and point d (opposite point c). This action will show whether the coupling faces are parallel to each other. If they are not parallel to each other, adjust the driving unit or the pump with shims until the couplings check true. While measuring the distances, you must keep the outside diameters of the coupling flanges in line. To do this, place the scale across the two flanges, as shown in *Figure 9-15, view C*. If the flanges do not line up, raise or lower one of the units with shims, or shift them sideways.

The procedure for using a thickness gauge to check alignments is similar to that for a scale. When the outside diameters of the coupling flanges are not the same, use a scale on the surface of the larger flange, and then use a thickness gauge between the surface of the smaller flange and the edge of the scale. When the space is narrow, check the distance between the coupling flanges with a thickness gauge, as shown in *Figure 9-15, view D*. Check wider spaces with a piece of square key stock and a thickness gauge.
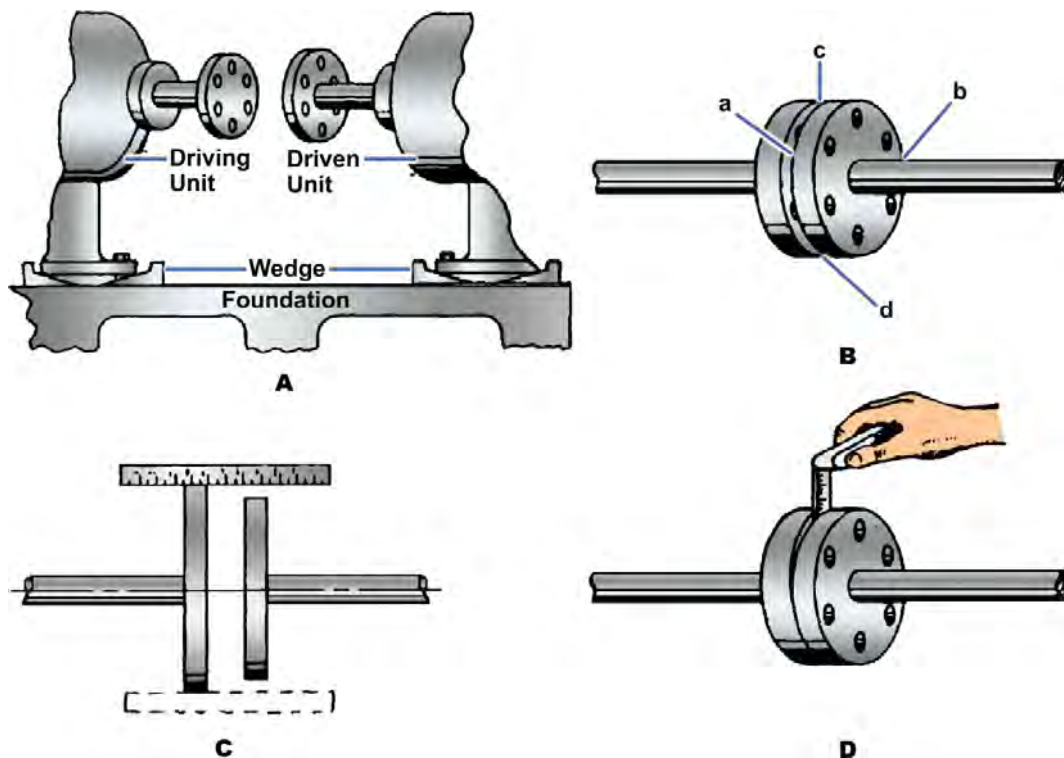
Figure 9-15 — Coupling alignment.

CONSTANT-PRESSURE PUMP GOVERNORS

A governor is a feedback device that is used to provide automatic control of speed, pressure, or temperature. A constant-pressure pump governor maintains a constant discharge pressure, regardless of pump capacity or output. Most constant-pressure pump governors used in the Navy control steam-driven pumps, both rotary and centrifugal types.

The constant-pressure pump governor (sometimes referred to as pressure-regulating) consists essentially of an automatic throttling valve installed in the steam supply line to the pump's driving unit. A pipeline connects the governor to the pump's discharge line. Variations in discharge pressure, or in pressure differential, actuate the governor, causing it to regulate the pump speed by varying the flow of steam to the driving unit.

A constant-pressure pump governor for a lubricating oil service pump is shown in *Figure 9-16*. The governors used on fuel oil service pumps and on main feed pumps are of the same type. The size of the upper diaphragm and the amount of spring tension vary on governors used for different services.
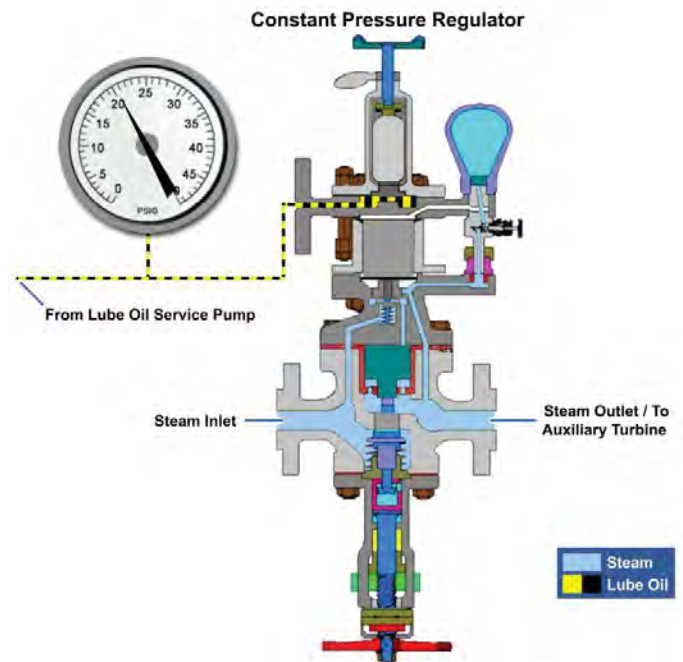
Figure 9-16 — Constant-pressure governor for main feed pump.

VALVES

A valve is any device used to control fluids in a closed system. In this section we will discuss valve construction and the most common types of valves you will use in the day-to-day operation and maintenance of the various shipboard engineering systems. Valves are typed or classified according to their use in a system.

Every piping system must have some means to control the amount and direction of the flow of a liquid or a gas through the lines. This is accomplished by the use of valves, which can be opened or closed as required. All valves can be grouped in two general classifications: (1) manually operated valves and (2) automatic valves.

Manually operated valves include all valves that are adjusted by hand. Automatic valves include check valves, thermostatic valves, and pressure-regulating valves. This section contains general information only. You should refer to the appropriate Naval Sea Systems Command (NAVSEA) valve manuals if you should require more specific information.

Valve Construction

Valves are usually made of bronze, brass, cast or malleable iron, or steel. Steel valves are either cast or forged and are made of either plain steel or alloy steel. Alloy steel valves are used in high- pressure, high-temperature systems; the disks and seats (internal sealing surfaces) of these valves are usually surfaced with a chromium cobalt alloy known as Stellite, which is extremely hard.

Brass and bronze valves are never used in systems where temperatures exceed 550 °F. Steel valves are used for all services above 550 °F and in lower temperature systems where internal or external

conditions of high pressure, vibration, or shock would be too severe for valves made of brass or bronze. Bronze valves are used almost exclusively in systems that carry saltwater. The seats and disks of these valves are usually made of Monel, a metal that has excellent corrosion- and erosion- resistant qualities.

Most submarine seawater valves are made of an alloy of 70 percent copper to 30 percent nickel (70/30).

Valve Types

Although many different types of valves are used to control the flow of fluids, the basic valve types can be divided into two general groups: stop valves and check valves.

Besides the basic types of valves, many special valves, which cannot really be classified as either stop valves or check valves, are found in the engineering spaces. Many of these valves serve to control the pressure of fluids and are known as pressure-control valves. Other valves are identified by names that indicate their general function, such as thermostatic recirculating valves. The following sections deal first with the basic types of stop valves and check valves, then with some of the more complicated special valves.

Stop Valves

Stop valves are used to shut off or, in some cases, partially shut off the flow of fluid. Stop valves are controlled by the movement of the valve stem.
Stop valves can be divided into four general categories: globe, gate, butterfly, and ball valves. Plug valves and needle valves may also be considered stop valves.

Globe Valves

Globe valves are probably the most common valves in existence. The globe valve derives its name from the globular shape of the valve body. However, positive identification of a globe valve must be made internally because other valve types may have globular appearing bodies. Globe valve inlet and outlet openings are arranged in several ways to suit varying requirements of flow. *Figure 9- 17* shows the common types of globe valve bodies: straight-flow, angle-flow, and cross-flow. A cutaway view of a straight-flow globe valve is shown in *Figure 9-18*.
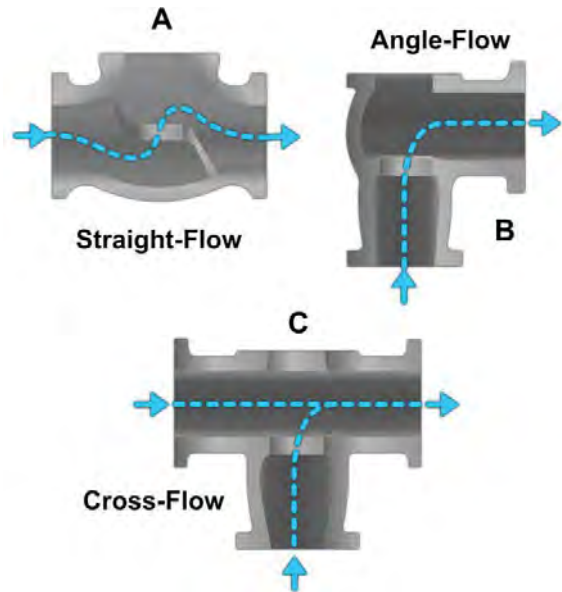
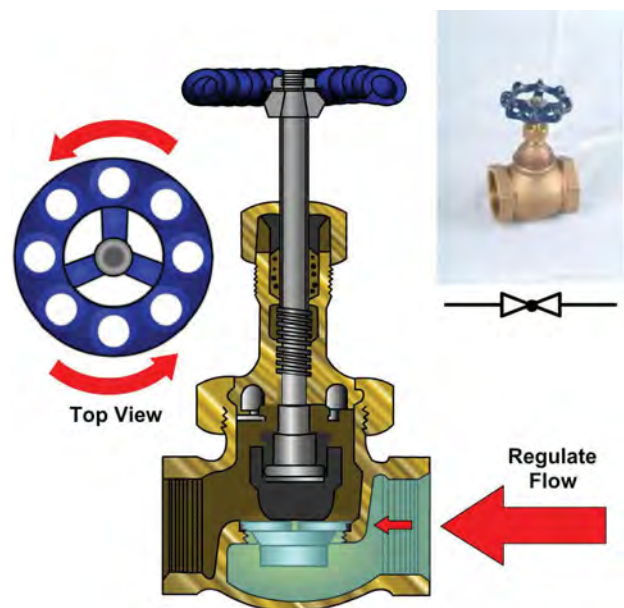**Figure 9-17 — Types of globe valve bodies.**

Figure 9-18 — Cutaway view of a straight-flow globe valve.

Gate Valves

Gate valves are used when a straight-line flow of fluid and minimum restriction is desired. Gate valves are so named because the part that either stops or allows flow through the valve acts somewhat like the opening or closing of a gate and is called, appropriately, the gate. The gate is usually wedge shaped. When the valve is wide open, the gate is fully drawn up into the valve, leaving an opening for flow through the valve the same size as the pipe in which the valve is installed. Therefore, there is   little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes since the control of flow would be difficult due to valve design and since the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.

Gate valves are classified as either rising-stem or nonrising-stem valves (*Figure 9-19*). On the nonrising-stem gate valve, the stem is threaded on the lower end into the gate. As the handwheel on the stem is rotated, the gate travels up or down the stem on the threads, while the stem remains vertically stationary.

This type of valve almost always has a pointer-type indicator threaded onto the upper end of the stem to indicate valve position. In the design of the rising-stem valve, the stem is attached to the gate. The gate and stem rise and sink together as the valve is operated.

Figure 9-19 — Gate stop valve (nonrising-stem).

Gate valves used in steam systems have flexible gates. The reason for using a flexible gate is to prevent binding of the gate within the valve when the valve is in the closed position. When steam lines are heated, they will expand, causing   some distortion of valve bodies. If a solid gate fits snugly between the seat of a valve in a cold steam system, when   the system is heated and pipes elongate, the seats will compress against the gate, wedging the gate between them and clamping the valve shut. This problem is overcome by use of a flexible gate (two circular plates attached to each other with a flexible hub in the middle). This design allows the gate to flex as the valve seat compresses it, thereby preventing clamping.

Butterfly Valves

The butterfly valve, one type of which is shown in *Figure 9- 20*, may be used in a variety of systems aboard ship. These valves can be used effectively in freshwater, saltwater, JP-5, F-76 (naval distillate), lube oil, and chill water systems aboard ship. The butterfly valve is light in weight, relatively small, relatively quick-acting, provides positive shut-off, and can be used for throttling.
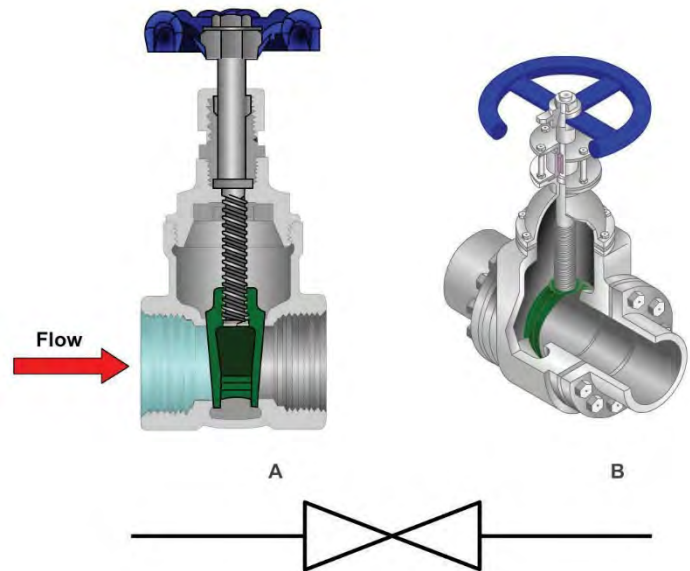

Figure 9-20 — Butterfly valve.

The butterfly valve has a body, a resilient seat, a butterfly disk, a stem, packing, a notched positioning plate, and a handle. The resilient seat is under compression when it is mounted in the valve body, thus making a seal around the periphery of the disk and both upper and lower points where the stem passes through the seat. Packing is provided to form a positive seal around the stem for added protection in case the seal formed by the seat should become damaged. To close or open a butterfly valve, turn the handle only one quarter turn to rotate the disk 90 degrees. Some larger butterfly valves may have a handwheel that operates through a gearing arrangement to operate the valve. This method is used especially where space limitation prevents use of a long handle.

A newer, high-performance butterfly valve is shown in *Figure 9-21*. This improved design has higher pressure capabilities and allows for a full range of throttling positions not offered in the older design of butterfly valve shown in *Figure 9-20*. The newer design of butterfly valve has been introduced into the fleet and is gradually replacing the older design.

Unlike the older style of butterfly valve, the new style has a removable retaining ring that holds the seat in place. To change the seat, all you must do is remove the retaining ring, remove the old seat, place a new seat into its groove, and reinstall the retainer ring.

Butterfly valves are relatively easy to maintain. The resilient seat is held in place by mechanical means, and neither bonding nor cementing is necessary. Because the seat is replaceable, the valve seat does not require lapping, grinding, or machine work.

Figure 9-21 — Cutaway view of a high-performance butterfly valve.

Ball Valves

Ball valves, as the name implies, are stop valves that use a ball to stop or start the flow of fluid. The ball (*Figure 9-22*) performs the same function as the disk in the globe valve. When the valve handle is operated to open the valve, the ball rotates to a point where the hole through the ball is in line with the valve body inlet and outlet. When the valve is shut, which requires only a 90-degree rotation of the handwheel for most valves, the ball is rotated so the hole is perpendicular to the flow openings of the valve body, and flow is stopped.

Most ball valves are of the quick-acting type (requiring only a 90-degree turn to operate the valve either completely open or closed), but many are planetary gear operated. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. The gearing does, however, increase the operating

Figure 9-22 — Ball valve.

time for the valve. Some ball valves contain a swing check located within the ball to give the valve a check valve feature. Ball valves are normally found in the following systems aboard ship: seawater, sanitary, trim and drain, air, hydraulic, and oil transfer.
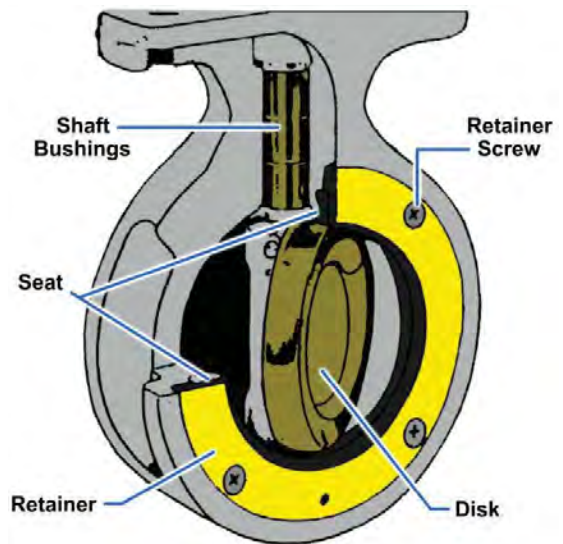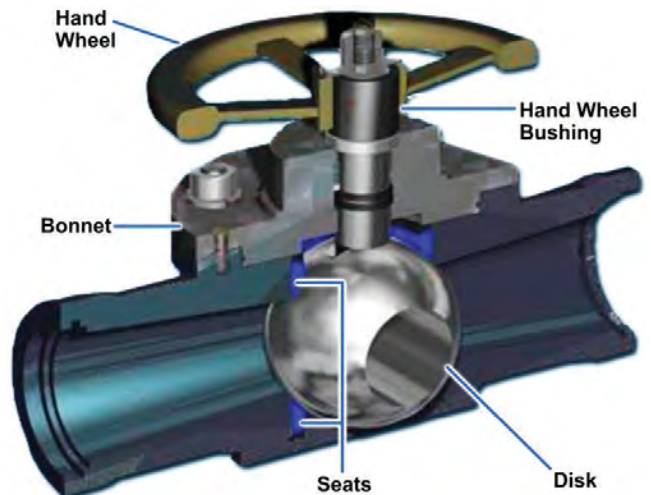
Check Valves

Check valves permit liquids to flow through a line in one direction only; for example, they are used in drain lines where it is important that there is no backflow. Considerable care must be taken to see that valves are installed properly. Most of them have an arrow, or the word "inlet," cast on the valve body to indicate direction of flow. If not, you must check closely to make sure the flow of the liquid in the system operates the valve in the proper manner.

The port in a check valve may be closed by a disk, a ball, or a plunger. The valve opens automatically when the pressure on the inlet side is greater than that on the outlet side. They are made with threaded, flanged, or union faces, with screwed or bolted caps, and for specific pressure ranges.

The disk of a swing-check valve (*Figure 9-23*) is raised as soon as the pressure in the line below the disk is of sufficient force. While the disk is raised, continuous flow takes place. If for any reason the flow is reversed or if back pressure builds up, this opposing pressure forces the disk to seat, which, in turn, stops the flow. Swing-check valves are used in horizontal lines and have a small amount of resistance to flow.

The operation of a lift-check valve (*Figure 9-24)* is basically the same as that of the swing-check valve. The difference is the valve disk moves in an up and down direction instead of through an arc. Lift-check valves are used in lines where reversal of flow and pressures are changing frequently. This valve does not chatter or slam as the swing check valve does, but it does cause some restriction of flow.

Figure 9-23 — Swing-check valve.

Stop-Check Valve

As we have seen, most valves can be classified as being either stop valves or check valves. Some valves, however, function either as stop valves or as check valves—depending on the position of the valve stem. These valves are known as stop-check valves.

The cross section of two stop-check valves is shown in *Figure 9-25*. As you can see, this type of valve looks much like a lift-check valve. The valve stem is long enough so when it is screwed all the way down, it holds the disk firmly against the seat, thereby preventing the flow of any fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can then be opened by pressure on the inlet side. In this position, the valve acts as a check valve and allows the flow of fluid in one
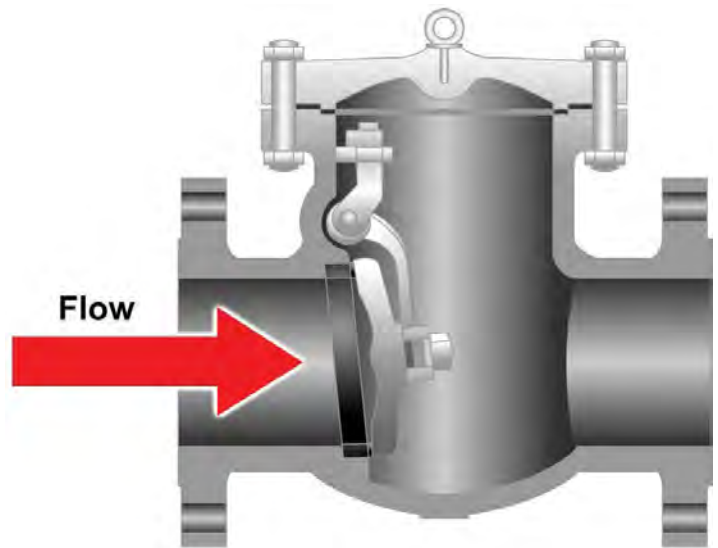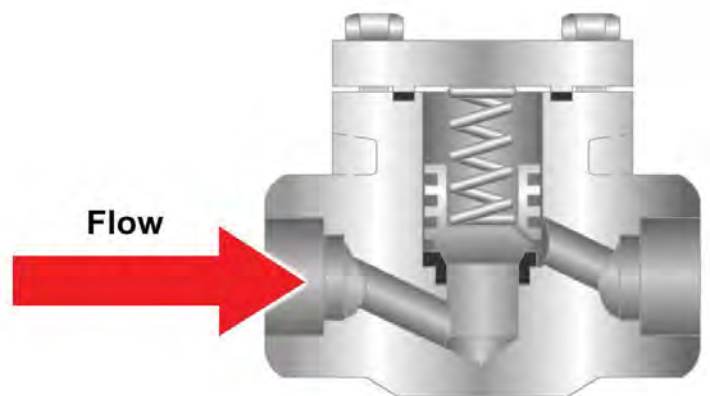

Figure 9-24 — Lift-check valve.

direction only. The amount of fluid allowed to pass through is regulated by the opening. The opening is adjusted by the stem.

Special-Purpose Valves

There are many types of automatic pressure-control valves. Some of them merely provide an escape for pressures exceeding the normal pressure; some provide only for the reduction of pressure; and some provide for the regulation of pressure.

Relief Valves

Relief valves are automatic valves used on system lines and equipment to prevent overpressurization. Most relief valves simply lift (open) at a preset pressure and reset (shut) when the pressure drops only slightly below the lifting pressure. *Figure 9-26* shows a relief valve of this type. System pressure simply acts under the valve disk at the inlet of the valve. When system pressure exceeds the force exerted by the valve spring, the valve disk lifts off its seat, allowing some of the system fluid to escape through the valve outlet until system pressure is reduced to just below the relief set point of the valve. The spring then reseats the valve. An operating lever is provided to allow manual cycling of the relief valve or to gag it open for certain tests. Virtually all relief valves are provided with some type of device to allow manual cycling.

Other types of relief valves are the high-pressure air safety relief valve and the bleed air surge relief valve. Both of these types of valves are designed to open completely at a specified lift pressure and to remain open until a specific reset pressure is reached—at which time they shut. Many different designs of these valves are used, but the same result is achieved.

Spring-Loaded Reducing Valves

One type of spring-loaded reducing valve is shown in *Figure 9-27*. These valves are used in a wide variety of applications. Low-pressure air reducers, auxiliary machinery cooling-water reducing stations, and some reduced-steam system reducers are of this type. The spring-loaded pressure-
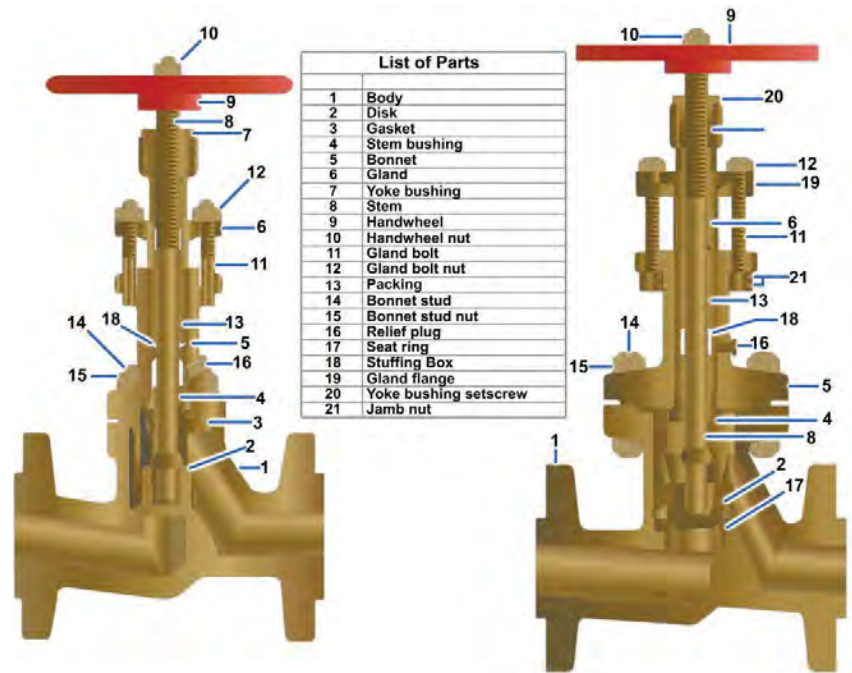
List of Parts	
1	Body
2	Disk
3	Gasket
4	Stem bushing
5	Bonnet
6	Gland
7	Yoke bushing
8	Stem
9	Handwheel
10	Handwheel nut
11	Gland bolt
12	Gland bolt nut
13	Packing
14	Bonnet stud
15	Bonnet stud nut
16	Relief plug
17	Seat ring
18	Stuffing Box
19	Gland flange
20	Yoke bushing setscrew
21	Jamb nut

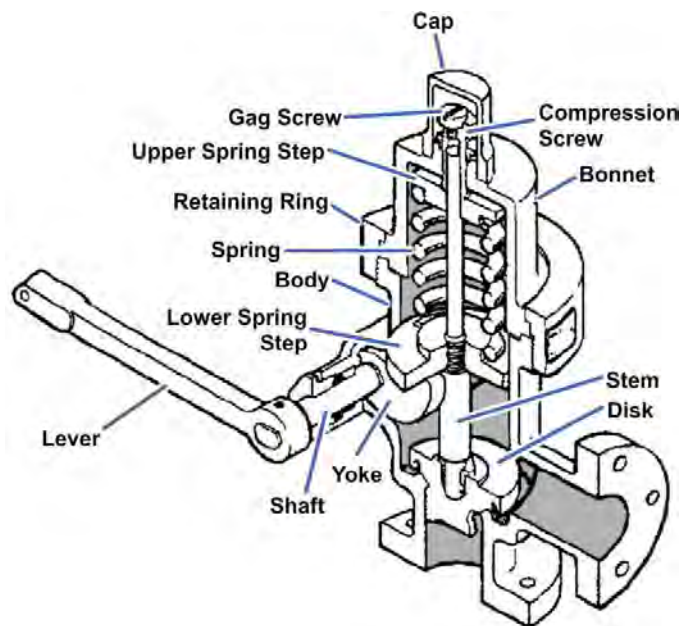**Figure 9-25 — Stop-check valve.**

Figure 9-26 — Typical relief valve.

reducing valve is commonly used in pneumatic systems. It is often referred to as a pressure regulator. The valve simply uses spring pressure against a diaphragm to open the valve. On the bottom of the diaphragm, the outlet pressure (the pressure in the reduced-pressure system) of the valve forces the disk upward to shut the valve. When the outlet pressure drops below the set point of the valve, spring pressure overcomes the outlet pressure and forces the valve stem downward, opening the valve. As outlet pressure increases, approaching the desired value, the pressure under the diaphragm begins to overcome spring pressure. This forces the valve stem upward, shutting the valve.

Downstream pressure can be adjusted by removing the valve cap and turning the adjusting screw, which varies the spring pressure against the diaphragm. This particular spring-loaded valve will fail in the open position in the case of a diaphragm rupture.
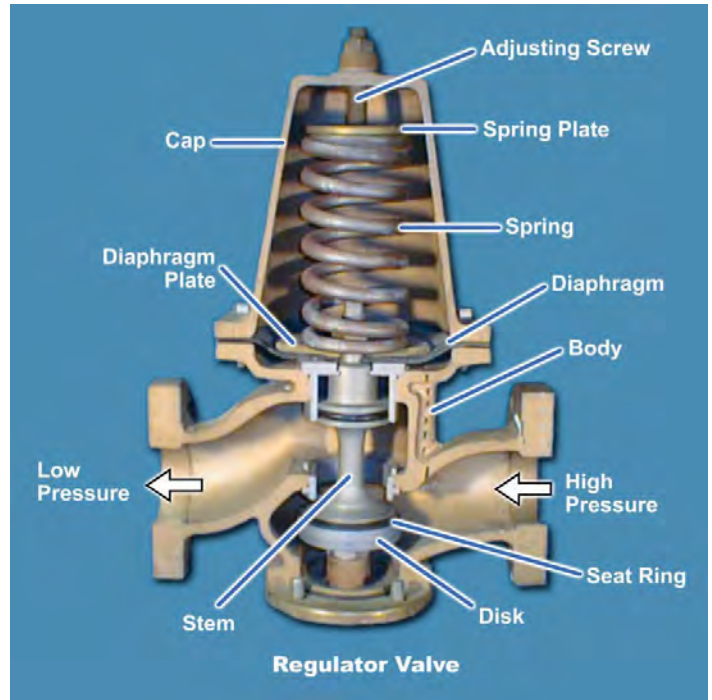
Figure 9-27 — Spring-loaded pressure-reducing valve.

Remote-Operating Valves

Remote-operating gear is installed to provide a means of operating certain valves from distant stations. Remote-operating gear may be mechanical, hydraulic, pneumatic, or electric.

Some remote-operating gear for valves is used in the normal operation of valves. For example, the main drain system manual valves are opened and closed by a reach rod or a series of reach rods and gears. Reach rods may be used to operate engine-room valves in instances where the valves are difficult to reach from the operating stations.

Other remote-operating gear is installed as emergency equipment. Some of the main drain and almost all of the secondary drain system valves are equipped with remote-operating gears. You can operate these valves locally, or in an emergency, you can operate them from remote stations.

Remote-operating gear also includes a valve position indicator to show whether the valve is open or closed.

Pressure-Reducing Valves

Pressure-reducing valves are automatic valves that provide a steady pressure into a system that is at a lower pressure than the supply system. Reducing valves of one type or another are found, for example, in firemain, seawater, and other systems. A reducing valve can normally be set for any desired downstream pressure within the design limits of the valve. Once the valve is set, the reduced pressure will be maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the reduced pressure desired) and regardless of the amount of reduced pressure fluid that is used.

Various designs of pressure-reducing valves are in use. Two of the types most commonly found on gas turbine ships are the spring-loaded reducing valve (already discussed) and the air-pilot-operated diaphragm reducing valve.

Air-Pilot-Operated Diaphragm Control Valves

Air-pilot-operated diaphragm control valves are used extensively on naval ships. The valves and pilots are available in several designs to meet different requirements. They may be used to reduce pressure, to increase pressure, to serve as unloading valves, or to provide continuous regulation of pressure. Valves and pilots of very similar design can also be used for other services, such as liquid-level control and temperature control.

The air-operated control pilot may be either direct acting or reverse acting. A direct-acting, air-operated control pilot is shown in *Figure 9-28*. In this type of pilot, the controlled pressure—that is, the pressure from the discharge side of the diaphragm control valve—acts on top of a diaphragm in the control pilot. This pressure is balanced by the pressure exerted by the pilot adjusting spring. If the controlled pressure increases and overcomes the pressure exerted by the pilot adjusting spring, the pilot valve stem is forced downward. This action causes the pilot valve to open, thereby increasing the amount of operating air pressure going from the pilot to the diaphragm control valve. A reverse-acting pilot has a lever that reverses the pilot action. In a reverse-acting pilot, therefore, an increase in controlled pressure produces a decrease in operating air pressure.

External Control Pilot
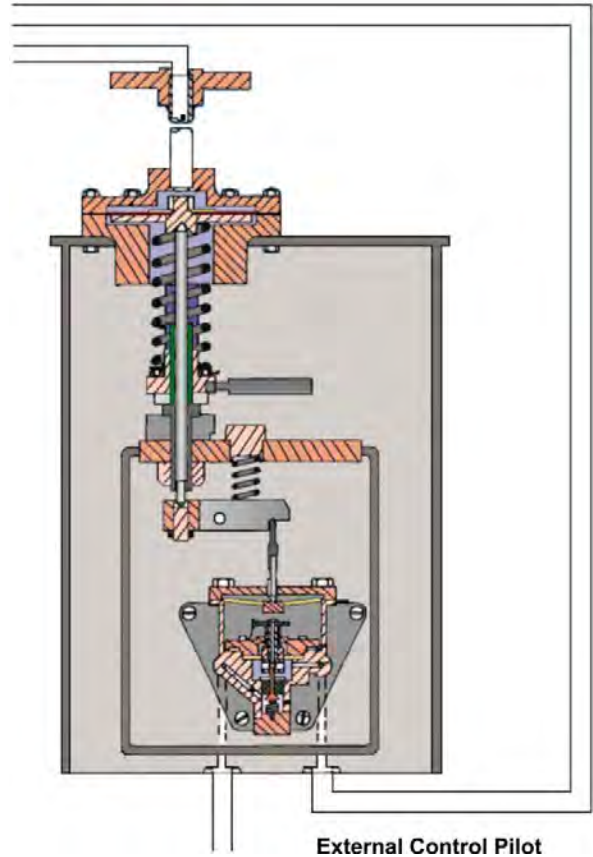
Figure 9-28 — Air-operated control pilot.

In the diaphragm control valve, operating air from the pilot acts on the valve diaphragm. The superstructure, which contains the diaphragm, is direct acting in some valves and reverse acting in others. If the superstructure is direct-acting, the operating air pressure from the control pilot is applied to the top of the valve diaphragm. If the superstructure is reverse-acting, the operating air pressure from the pilot is applied to the underside of the valve diaphragm.

A very simple type of direct-acting diaphragm control valve is shown in *Figure 9-29*. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. The valve in *Figure 9-29, view A*, is a downward-seating valve. Any increase in operating air pressure pushes the valve stem downward. This tends to close the valve.

Now look at *Figure 9-29, view B*; this is also a direct-acting valve. The operating air pressure from the control pilot is applied to the top of the valve diaphragm. But the valve is more complicated than the one shown in *Figure 9-29, view A*. The valve in *Figure 9-29, view B*, is an upward-seating valve rather than a downward-seating valve. Therefore, any increase in operating air pressure from the control pilot tends to open this valve rather than to close it.

As you have seen, the air-operated control pilot may be either direct acting or reverse acting. The superstructure of the diaphragm control valve may be either direct acting or reverse acting. And, the diaphragm control valve may be either upward seating or downward seating. These three factors, as well as the purpose of the installation, determine how the diaphragm control valve and its air-operated control pilot are installed in relation to each other.
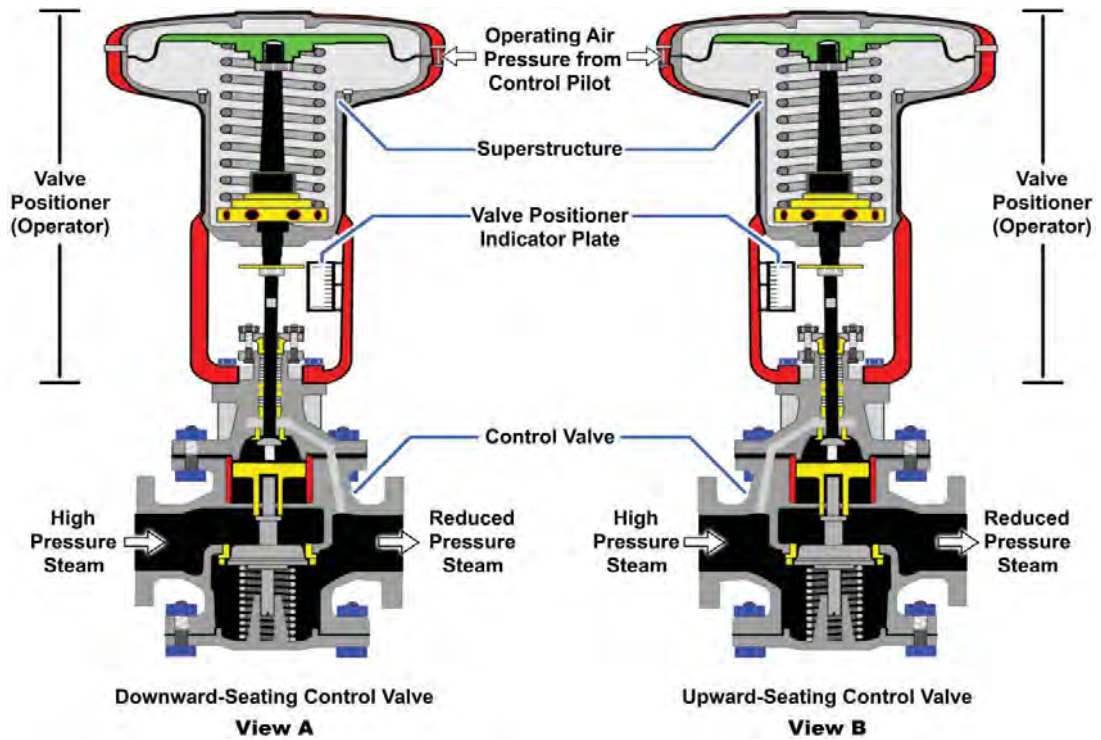
Figure 9-29 — Diaphragm control valves.

To see how these factors are related, let us consider an installation: A diaphragm control valve and its air-operated control pilot are used to supply reduced steam pressure (*Figure 9-30*). We will assume that the service requirements indicate the need for a direct-acting, upward-seating, diaphragm control valve. Can you figure out which kind of a control pilot— direct-acting or reverse-acting— should be used in this installation?
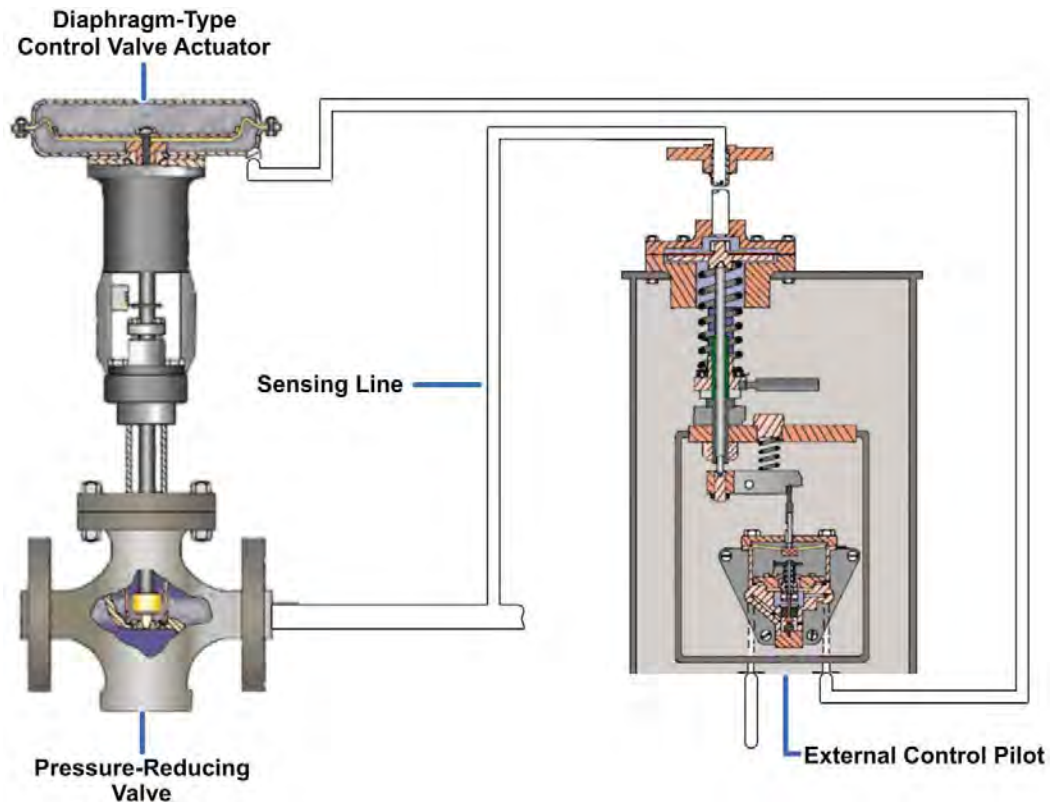

Figure 9-30 — Arrangement of control pilot and diagram control valve for supplying reduced steam pressure.

Let us try it first with a direct-acting control pilot. The controlled pressure (discharge pressure from the diaphragm control valve) increases. When that happens, increased pressure is applied to the diaphragm of the direct-acting control pilot. The valve stem is pushed downward and the valve in the control pilot is opened. This sends an increased amount of operating air pressure from the control pilot to the top of the diaphragm control valve. The increased operating air pressure acting on the diaphragm of the valve pushes the stem downward. Since this is an upward-seating valve, this action opens the diaphragm control valve still wider. Obviously, this will not work—for this application, an increase in controlled pressure must result in a decrease in operating air pressure. Therefore, we made a mistake in choosing the direct-acting control pilot. For this particular pressure-reducing application, we should choose a reverse-acting control pilot.

You will probably not need to decide which type of control pilot and diaphragm control valve are needed in any particular installation. But you must know how and why they are selected so that you will not make mistakes in repairing or replacing these units.

Priority Valves

In systems with two or more circuits, it is sometimes necessary to have some means of supplying all available fluid to one particular circuit in case of a pressure drop in the system. A priority valve is often incorporated in the system to ensure a supply of fluid to the critical/vital circuit. The components of the system are arranged so the fluid to operate each circuit, except the one critical/vital circuit, must flow through the priority valve. A priority valve may also be used within a subsystem containing two or more actuating units to ensure a supply of fluid to one of the actuating units. In this case, the priority valve is incorporated in the subsystem in such a location that the fluid to each actuating unit, except the critical/vital unit, must flow through the valve.

Figure 9-31 shows one type of priority valve. *Figure 9-31, view A*, shows the valve in the priority-flow position; that is, the fluid must flow through the valve in the direction shown by the arrows to get to the noncritical/vital circuits or actuating units. With no fluid pressure in the valve, spring tension forces the piston against the stop and the poppet seats against the hole in the center of the piston. As fluid pressure increases, the spring compresses and the piston moves to the right. The poppet follows the piston, sealing the hole in the center of the piston until the preset pressure is reached. (The preset pressure depends upon the requirements of the system and is set by the manufacturer.) Assume that the critical/vital circuit or actuating unit requires 1,500 pounds per square inch (psi). When the pressure in the valve reaches 1,500 psi, the poppet reaches the end of its travel. As the pressure increases, the piston continues to move to the right, which unseats the poppet and allows flow

A. Priority Flow

B. Free Flow

Figure 9-31 — Priority valve.

through the valve, as shown in *Figure 9-31, view A*. If the pressure drops below 1,500 psi, the compressed spring forces the piston to the left, the poppet seats, and flow through the valve stops.

Figure 9-31, view B, shows the priority valve in the free-flow position. The flow of fluid moves the poppet to the left, the poppet spring compresses, and the poppet unseats. This allows free flow of fluid through the valve.
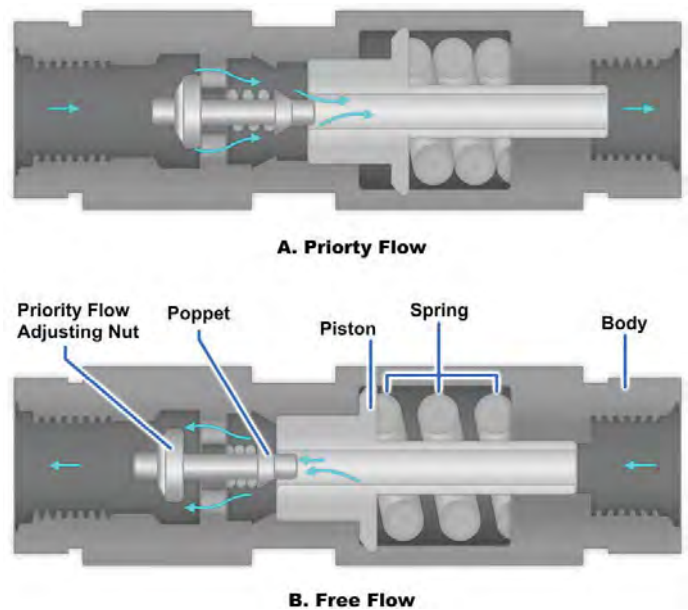
Valve Manifolds

Sometimes suction must be taken from one of many sources and discharged to another unit or units of either the same or another group. A valve manifold is used for this type of operation. An example of such a manifold (*Figure 9-32*) is the fuel oil filling and transfer system where provision must be made for the transfer of oil from any tank to any other tank, to the service system, or to another ship. If, for example, the purpose is to transfer oil from tank No. 1 to tank No. 4, the discharge valve for tank No. 4 and the suction valve from tank No. 1 are opened, and all other valves are closed. Fuel oil can now flow from tank No. 1, through the suction line, through the pump, through the discharge valve, and into tank No. 4. The manifold suction valves are often of the stop-check type to prevent draining of pumps when they are stopped.
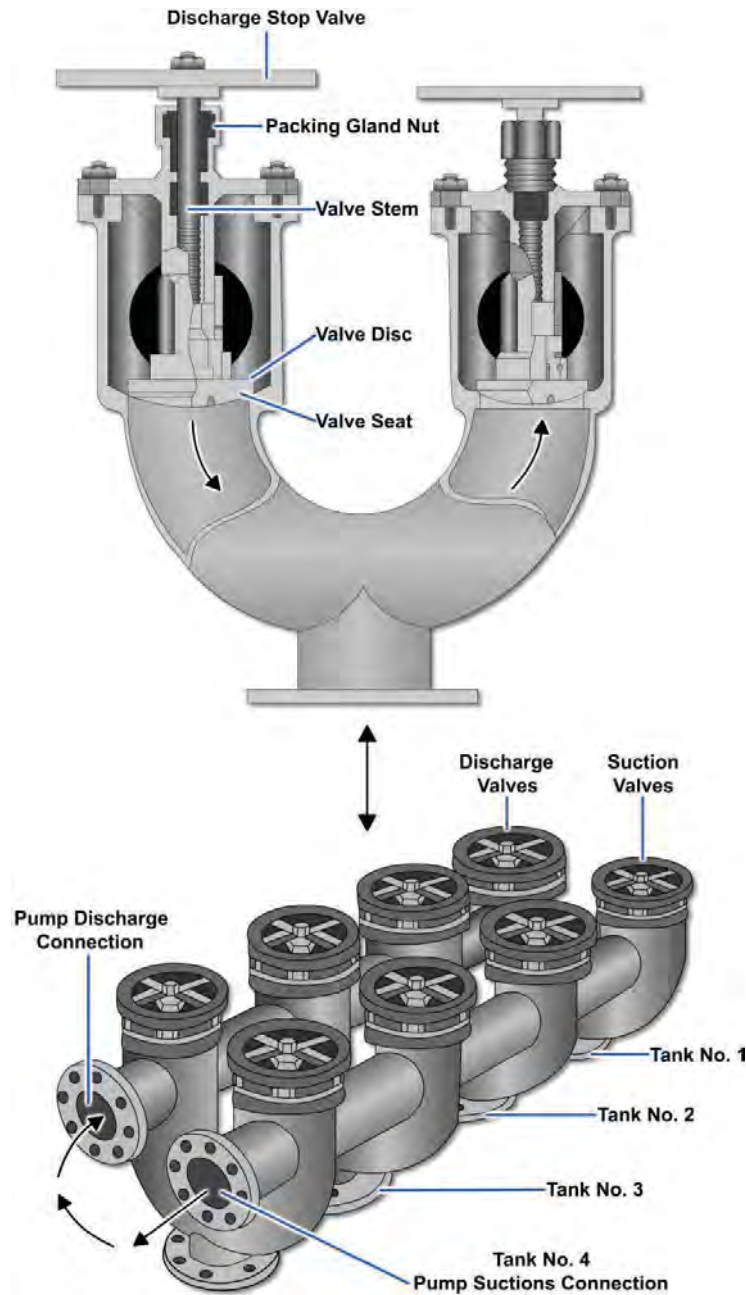
Figure 9-32 — Valve manifold showing cutaway view of the valves and typical combination of suction and discharge valves.

Valve Handwheel Identification and Color Coding

Valves are identified by markings inscribed on the rims of the handwheels, by a circular label plate secured by the handwheel nut, or by label plates attached to the ship's structure or to the adjacent piping.

Piping system valve handwheels and operating levers are marked for training and casualty control purposes with a standardized color code. Color code identification is in conformance with the color scheme of *Table 9-1*. Implementation of this color scheme provides uniformity among all naval surface ships and shore-based training facilities.

Table 9-1 — Valve Handwheel Color Code

FLUID	VALVE HANDWHEEL & OPERATING LEVER	
STEAM	WHITE	
POTABLE-WATER	DARK BLUE	
NITROGEN	LIGHT GRAY	
HP AIR	DARK GRAY	
LP AIR	TAN	
OXYGEN	LIGHT GREEN	
SALTWATER	DARK GREEN	
JP-5	PURPLE	
FUEL OIL	YELLOW	
LUBE OIL	STRIPPED YELLOW/BLACK	
FIRE PLUGS	RED	
FOAM DISCHARGE	STRIPED RED/GREEN	
GASOLINE	YELLOW	
FEEDWATER	LIGHT BLUE	
HYDRAULIC	ORANGE	
HYDROGEN	CHARTREUSE	
HELIUM	BUFF	
HELIUM/OXYGEN	STRIPED BUFF/GREEN	
SEWAGE	GOLD	

Maintenance

Preventive maintenance is the best way to extend the life of valves and fittings. Always refer to the applicable PMS procedures and the Navy Standard Valve Technical Manual. When making repairs on more sophisticated valve types, use the available manufacturer's technical manuals. As soon as you observe a leak, determine the cause, and then apply the proper corrective maintenance. Maintenance may be as simple as tightening a packing nut or gland. A leaking flange joint may need only to have the bolts tightened or to have a new gasket or O-ring inserted. Dirt and scale, if allowed to collect, will cause leakage. Loose hangers permit sections of a line to sag, and the weight of the pipe and the fluid in these sagging sections may strain joints to the point of leakage.

Whenever you are going to install a valve, be sure you know the function the valve is going to perform— that is, whether it must start flow, stop flow, regulate flow, regulate pressure, or prevent backflow. Inspect the valve body for the information that is stamped upon it by the manufacturer: type of system (oil, water, and gas), operating pressure, direction of flow, and other information.

You should also know the operating characteristics of the valve, the metal from which it is made, and the type of end connection with which it is fitted. Operating characteristics and the material are factors that affect the length and kind of service that a valve will give; end connections indicate whether or not a particular valve is suited to the installation.

When you install valves, ensure they are readily accessible and allow enough headroom for full operation. Install valves with stems pointing upward if possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). If the valve is installed with the stem pointing downward, sediment will collect in the bonnet and score the stem. Also, in a line that is subject to freezing temperatures, liquid that is trapped in the valve bonnet may freeze and rupture it.

Since you can install a globe valve with pressure either above the disk or below the disk (depending on which method will be best for the operation, protection, maintenance, and repair of the machinery served by the system), you should use caution. The question of what would happen if the disk became detached from the stem is a major consideration in determining whether pressure should be above the disk or below it. If you are required to install a globe valve, be SURE to check the blueprints for the system to see which way the valve must be installed. Very serious casualties can result if a valve is installed with pressure above the disk when it should be below the disk, or below the disk when it should be above.

Valves that have been in constant service for a long time will eventually require gland tightening, repacking, or a complete overhaul of all parts. If you know that a valve is not doing the job for which it was intended, dismantle the valve and inspect all parts. You must repair or replace all defective parts.

The repair of globe valves (other than routine renewal of packing) is limited to refinishing the seat and/or disk surface. When doing this work, you should observe the following precautions:

When refinishing the valve seat, do not remove more material than is necessary. You can finish valves that do not have replaceable valve seats only a limited number of times.

Before doing any repair to the seat and disk of a globe valve, check the valve disk to make certain it is secured rigidly to and is square on the valve stem. Also, check to be sure that the stem is straight. If the stem is not straight, the valve disk cannot seat properly.

Spotting-In Valves

The method used to visually determine whether the seat and the disk of a valve make good contact with each other is called spotting-in. To spot-in a valve seat, first apply a thin coating of Prussian blue evenly over the entire machined face surface of the disk. Then, insert the disk into the valve and

rotate it one-quarter turn, using light downward pressure. The Prussian blue will adhere to the valve seat at those points where the disk makes contact. *Figure 9-33* shows the appearance of a correct seat when it is spotted-in. It also shows the appearance of various kinds of imperfect seats.

After you have noted the condition of the seat surface, wipe all the Prussian blue off the disk face surface. Apply a thin, even coat of Prussian blue to the contact face of the seat, place the disk on the valve seat again, and rotate the disk one-quarter turn. Examine the resulting blue ring on the valve disk. The ring should be unbroken and of uniform width. If the blue ring is broken in any way, the disk is not a proper fit.

Grinding-In Valves

The manual process used to remove small irregularities by grinding together the contact

Figure 9-33 — Examples of spotted-in valve seats.

surfaces of the seat and disk is called grinding-in. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a light coating of grinding compound to the face of the disk. Then, insert the disk into the valve and rotate the disk back and forth about one-quarter turn; shift the disk- seat relationship from time to time so the disk will be moved gradually, in increments, through several rotations. During the grinding process, the grinding compound will gradually be displaced from between the seat and disk surfaces; therefore, you must stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When you are satisfied that the irregularities have been removed, spot-in the disk to the seat in the manner previously described.

Grinding-in is also used to follow up all machining work on valve seats or disks. When the valve seat and disk are first spotted-in after they have been machined, the seat contact will be very narrow and will be located close to the bore. Grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering about one-third of the seating surface.

Be careful to avoid overgrinding a valve seat or disk. Overgrinding will produce a groove in the seating surface of the disk; it will also round off the straight, angular surface of the disk. Machining is the only process by which overgrinding can be corrected.

Lapping Valves

When a valve seat contains irregularities that are slightly larger than can be satisfactorily removed by grinding-in, remove the irregularities by lapping. Use a cast-iron tool of exactly the same size and shape as the valve disk to true the valve seat surface. A lapping tool is shown in *Figure 9-34*.

Observe the following operating instructions when you use a lapping tool:

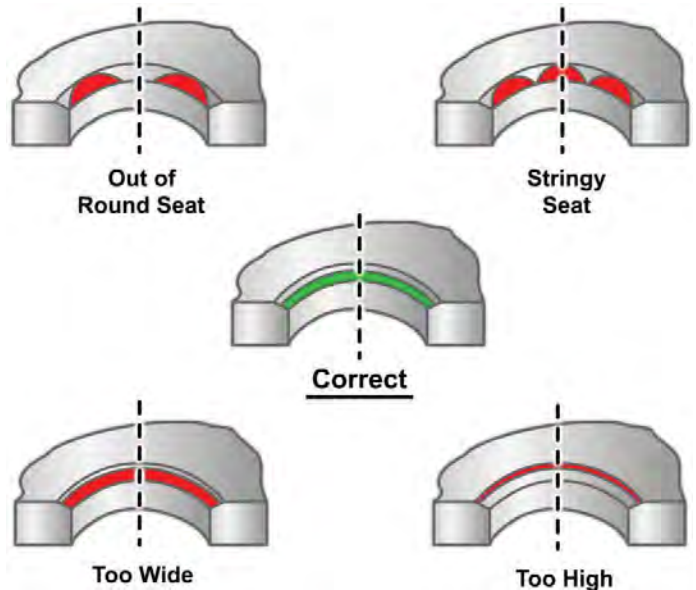- Do not bear down heavily on the handle of the lapping tool

- Do not bear sideways on the handle of the lapping tool

- Rotate the lapping tool so that the lap will gradually and uniformly cover the entire seat

- Keep a check on the working surface of the lapping tool. If a groove develops, have the tool refaced

- Always use clean compound for lapping

- Replace the compound frequently

- Spread the compound evenly and lightly

- Do not lap more than is necessary to produce a smooth, even seat

- Always use a fine grinding compound to finish the lapping job

- Upon completion of the lapping job, spot-in and grind-in the disk to the seat

Use only approved abrasive compounds to recondition valve seats and disks. Compounds for lapping and grinding valve disks and seats come in various grades. Use a course grade compound when you find extensive corrosion or deep cuts on the disks and seats. Use a compound of medium grade to follow up the coarse grade and to start the reconditioning process on valves that are not too severely damaged. Use a fine grade compound when the reconditioning process nears completion. Use a microscopic-fine grade for finish lapping and for all grinding-in.

Lapping Tool

Figure 9-34 — Lapping tool.

Refacing Valves

Badly scored valve seats must be refaced in a lathe, with a power grinder, or with a valve reseating machine. However, the lathe, rather than the reseating machine, should be used for refacing all valve disks and all hard-surfaced valve seats. Work that must be done on a lathe or with a power grinder should be turned over to shop personnel.

Repacking Valves

If the stem and packing of a valve are in good condition, you can normally stop packing gland leaks by tightening up on the packing. You must be careful, however, to avoid excessive thread engagement of the packing gland studs (if used) and to avoid tightening old, hardened packing, which will cause the valve to seize. Subsequent operation of such a valve may score or bend the stem.

Coils, rings, and corrugated ribbon are the common forms of packing used in valves. The form of packing to be used in repacking a particular valve will depend on the valve size, application, and type. Packing materials will be discussed in more detail later in this chapter.

Steam Traps

Steam traps are installed in steam lines to drain condensate from the lines without allowing the escape of steam. There are many different designs of steam traps; some are suitable for high-pressure use and others for low-pressure use.

Types of Steam Traps

Some types of steam traps that are used in the Navy are the mechanical steam traps, bimetallic steam traps, and orifice-type steam traps.

Mechanical Steam Traps

Mechanical steam traps may be of the ball-float or bucket type.

Ball-Float Trap

In a ball-float steam trap (*Figure 9-35*), the valve of the trap is connected to the float in such a way that the valve opens when the float rises. When the trap is in operation, the steam and any water that may be mixed with it flow into the float chamber. As the water level rises, the float lifts, thereby lifting the valve plug and opening the valve. The condensate drains out and the float moves down to a lower position, closing the valve. The condensate that passes out of the trap returns to the feed system.
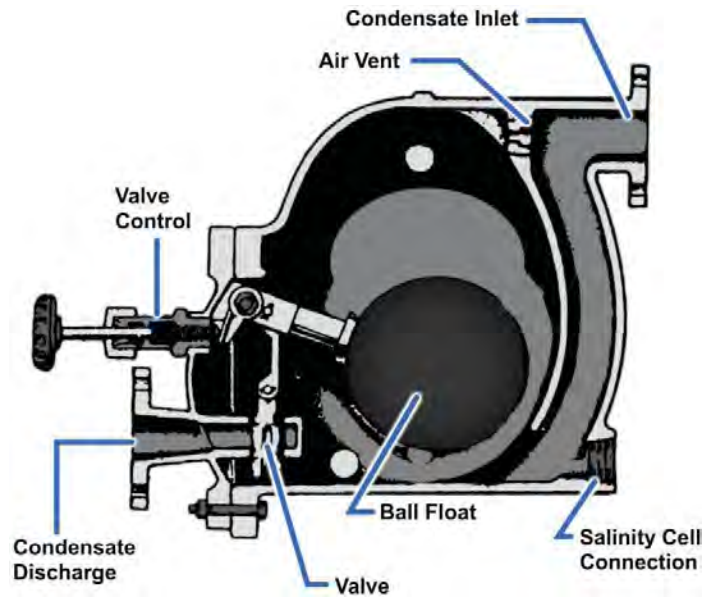
Bucket-Type Trap

In a bucket-type steam trap (*Figure 9-36*) the bucket floats when condensate enters the trap body. The valve is connected to the bucket in such a way that the valve closes as the bucket rises. As condensate continues to flow into the trap body, the valve remains closed until the bucket is full. When the bucket is full, it sinks, opening the valve. The valve remains open until enough condensate has passed out to allow the bucket to float, thus closing the valve.

Thermostatic Steam Traps

There are several types of thermostatic steam traps. In general, these traps are more compact and have fewer moving parts than most mechanical steam traps. The operation of a bellows-type thermostatic trap is controlled by expansion of the vapor of a volatile liquid enclosed in a bellows-type element. Steam enters the trap body and heats the volatile liquid in the sealed bellows, thus causing expansion of the bellows.

The valve is attached to the bellows in such a way that the valve closes when the bellows expands. The valve remains closed, trapping steam in the trap body. As the steam cools and condenses, the bellows cools and contracts, thereby opening the valve and allowing the condensate to drain.

The impulse and bimetallic steam traps are two examples of those that use the thermostatic principle.
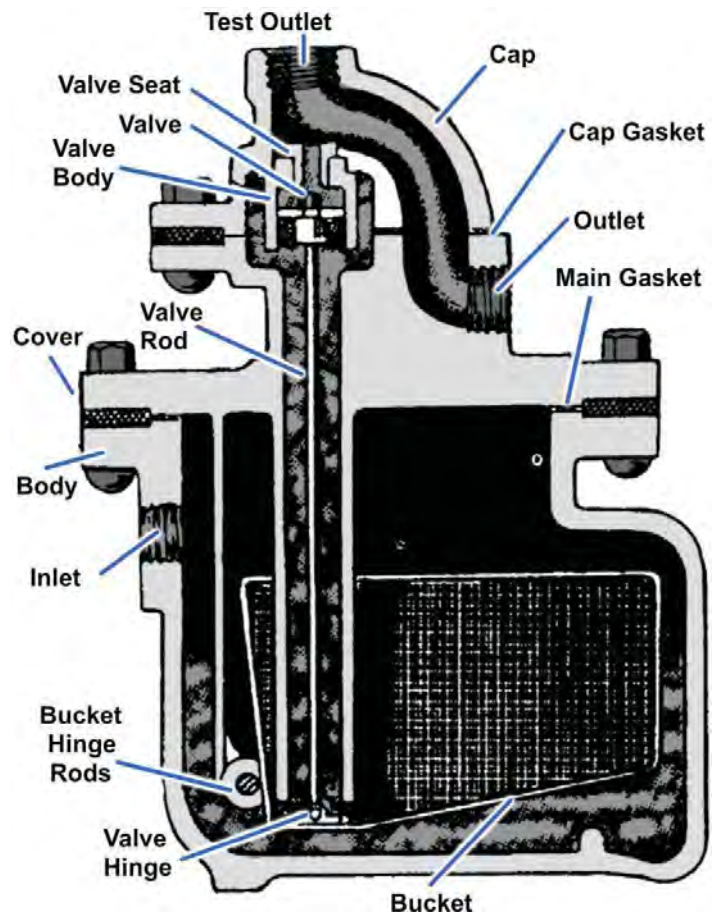

Figure 9-35 — Ball-float steam trap.

Figure 9-36 — Bucket-type steam trap.

Impulse Steam Traps

Impulse steam traps of the type shown in *Figure 9-37* are commonly used in steam drain collecting systems aboard ship. Steam and condensate pass through a strainer before entering the trap. A circular baffle keeps the entering steam and condensate from impinging on the cylinder or on the disk.

The impulse trap operates on the principle that hot water under pressure tends to flash into steam when the pressure is reduced. So that you understand how this principle is used, let us consider the arrangement of the parts shown in *Figure 9-37* and see what happens to the flow of condensate under various conditions.
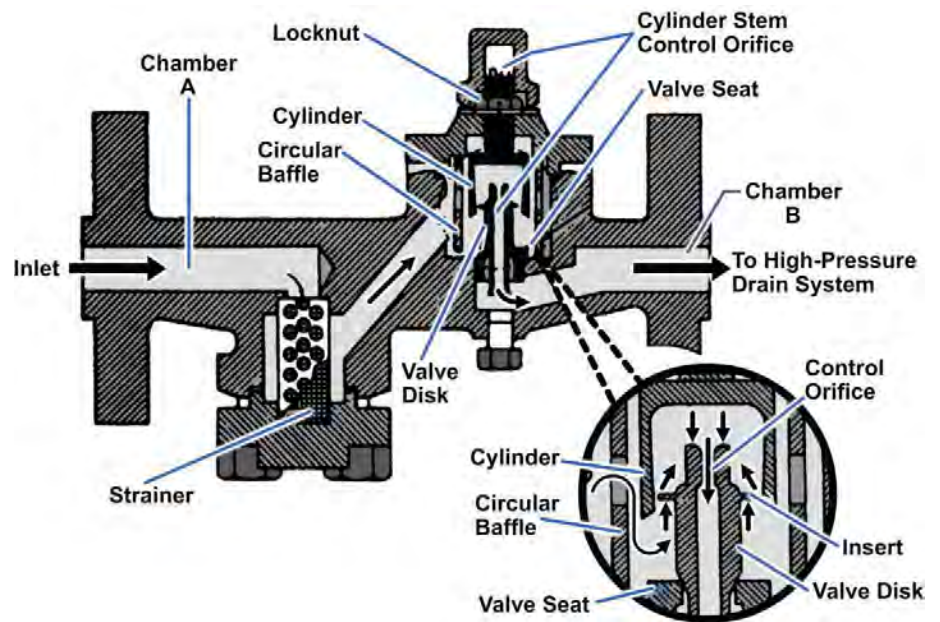

Figure 9-37 — Impulse steam trap.

The only moving part in the steam trap is the disk, which is rather unusual in design. Near the top of the disk is an insert that acts as a piston. As you can see in the figure, the working surface above the insert is larger than the working surface below the insert. The importance of having this larger effective area above the insert is brought out later in this discussion.

A control orifice runs through the disk from top to bottom and is considerably smaller at the top than at the bottom. The bottom part of the disk extends through and beyond the orifice in the seat. The upper part of the disk (including the insert) is inside a cylinder. The cylinder tapers inward, so the amount of clearance between the insert and the cylinder varies according to the position of the valve. When the valve is open, the clearance is greater than when the valve is closed.

When the trap is first cut in (put in service), pressure from the inlet (chamber A) acts against the underside of the insert and lifts the disk off the valve seat. Condensate is thus allowed to pass out through the orifice in the seat. At the same time, a small amount of condensate (control flow) flows up past the insert and into chamber B. The control flow discharges through the control orifice, into the outlet side of the trap. The pressure in chamber B remains lower than the pressure in chamber A.

As the line warms up, the temperature of the condensate flowing through the trap increases. The reverse taper of the cylinder varies the amount of flow around the insert. This variation continues until a balanced position is reached in which the total force exerted above the insert is equal to the total force exerted below the insert. It is important to note that there is still a pressure difference between chamber A and chamber B. The force is equalized because the effective area above the insert is larger than the effective area below the insert. The difference in working area is such that the valve maintains an open, balanced position when the pressure in chamber B is 86 percent of the pressure in chamber A.

As the temperature of the condensate approaches its boiling point, some of the control flow going to chamber B flashes into steam as it enters the low-pressure area. The steam has a much larger volume than the water from which it is generated. Therefore, pressure is built up in the space above

the insert (chamber B). The pressure in this space becomes greater than 86 percent of the inlet pressure. At that time, the force exerted on the top of the insert pushes the entire disk downward and closes the valve.

With the valve closed, the only flow through the trap is past the insert and through the control orifice. When the temperature of the condensate entering the trap drops slightly, condensate enters chamber B without flashing into steam. Pressure in chamber B is thus reduced to the point that the valve opens and allows condensate to flow through the orifice in the valve seat. Thus, the entire cycle is repeated.

With a normal condensate load, the valve opens and closes at frequent intervals. A small amount of condensate discharges at each opening. With a heavy condensate load, the valve remains wide open and allows a heavy, continuous discharge of condensate.

Bimetallic Steam Traps

These traps are used in many ships to drain condensate from main steam lines, auxiliary steam lines, and other steam components. The main working parts of this steam trap are a segmented bimetallic element and a ball-type check valve (*Figure 9-38*).

The bimetallic element consists of several bimetallic strips fastened together in a segmented fashion. One end of the bimetallic element is fastened rigidly to a part of the valve body. The other end, which is free to move, is fastened to the top of the stem of the ball- type check valve.

Figure 9-38 — Bimetallic steam trap.

Line pressure acting on the check valve tends to keep the valve open. When steam enters the trap body, the bimetallic element expands unequally because of the different response to temperature of the two metals. The bimetallic element deflects upward at its free end. This motion moves the valve stem upward and closes the valve. As the steam cools and condenses, the bimetallic element moves downward toward the horizontal position.

This movement opens the valve and allows some condensate to flow out through the valve. As the flow of condensate begins, it creates an unbalance of line pressure across the valve. Since the line pressure is greater on the upper side of the ball of the check valve, the valve now opens wide and allows a full capacity flow of condensate.

Orifice-Type Steam Traps

Figure 9-39 shows the assembly of an orifice-type steam trap. Constant-flow drain orifices may be used in systems of 150 psi and above where condensate load and pressure remain near constant.
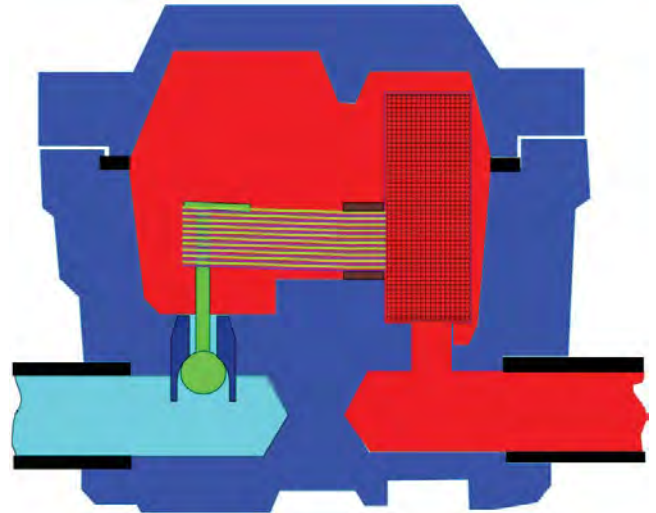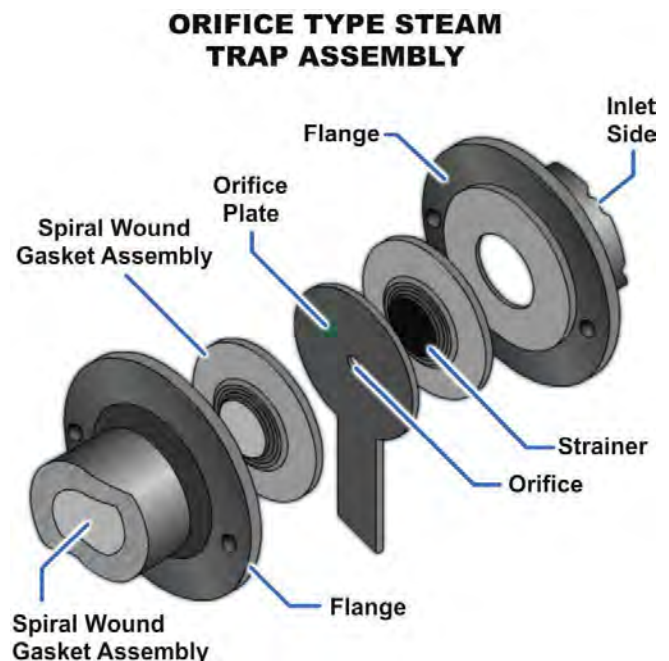

Figure 9-39 — Orifice-type steam trap.

The constant-flow drain orifice operates on a thermodynamic principle; the variable density of condensate helps its operation. Density changes with temperature. As the temperature of the condensate decreases, the density of the condensate increases, as does the flow of the condensate through the orifice. The reverse is also true. As the temperature of the condensate increases, the density of the condensate decreases, as does the flow of the condensate through the orifice.

Because of the difference in densities between the steam and the condensate, the condensate will flow through the orifice at a faster rate.

Other operating aspects of the orifice are size, pressure, and condensate load.

By calculating the condensate flow based on the condensing rate of the equipment and by knowing the pressure of the system, you can select an orifice of the proper size. Flow rate through the orifice is expressed in pounds per hour (lb/hr).

The advantages of the orifice-type trap over other types warrant its use in all systems of 150 psi and above.

Maintenance

A strainer is installed just ahead of each steam trap. The strainer must be kept clean and in good condition to keep scale and other foreign matter from getting into the trap. Scale and sediment can clog the working parts of a steam trap and seriously interfere with the working of the trap.

Steam traps that are not operating properly can cause problems in systems and machinery. One way to check on the operation of a steam trap is to listen to it. If the trap is leaking, you will probably be able to hear it blowing through. Another way to check the operation of steam traps is to check the pressure in the drain system. A leaking steam trap causes an unusual increase in pressure in the drain system. When observing this condition, you can locate the defective trap by cutting out (isolating from the system) traps, one at a time, until the pressure in the drain system returns to normal.

You should disassemble, clean, and inspect defective steam traps. After determining the cause of the trouble, repair or replace parts as required. In some steam traps, you can replace the main working parts as a unit; in others, you may have to grind in a seating surface, replace a disk, or perform other repairs. You should reseat defective trap discharge valves. Always install new gaskets when reassembling steam traps.

FILTERS AND STRAINERS

A variety of strainers and filters are used in Navy installations. According to Navy terminology, all metal-edge and wire-mesh devices are classed as strainers. Devices that have replaceable, absorbent cartridges are called filters. Filters remove smaller particles than strainers do. The location and number of strainers and filters will vary, depending on the type of installation.

Strainers

Lubricating oil strainers may be either simplex or duplex. A duplex strainer is two strainer elements in one assembly. A manual valve directs the flow of oil through either of the elements. When duplex strainers are used, one element can be bypassed, and the element can be removed and cleaned without disturbing the flow of oil through the other element to the engine.

Every approved lubricating oil strainer has a built-in, spring-loaded or differential area, pressure-relief valve. The valve must be sufficiently large to bypass all of the oil around a clogged strainer to maintain an uninterrupted flow of oil to the engine.

Simplex Strainer

Metal-edge strainers consist of a strainer element surrounded by a case that serves as a sump to collect foreign material and water. The element has an edge-wound metal ribbon or a series (stack) of edge-type disks. Most strainers have devices for manually rotating the strainer element against metallic scrapers, which remove the material caught by the element. Strainers usually have vents for releasing air from the system. An edge-wound metal ribbon strainer is shown in *Figure 9-40*.

Duplex Strainer

A duplex strainer of the edge-disk type is shown in *Figure 9-41*. The strainer consists of two sections, each of which contains two strainer elements. A control valve between the two sections secures one section while the other remains in operation. The secured section acts as a standby unit; it may be opened for cleaning and inspection without interrupting the straining operation.

Wire-Mesh (Screen) Strainer

Strainers installed on the suction or intake side of the pressure pumps are generally of the wire mesh (screen) type and are referred to as coarse strainers. Some screen-type strainers are located in the oil pan or sump.
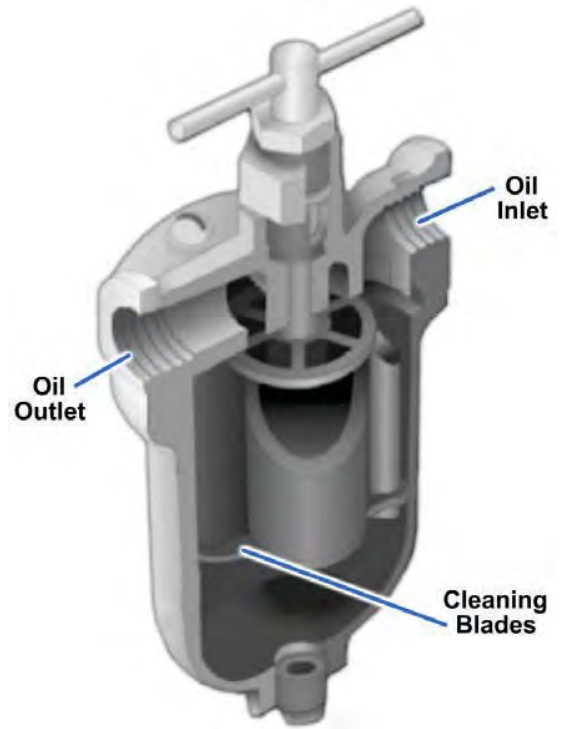

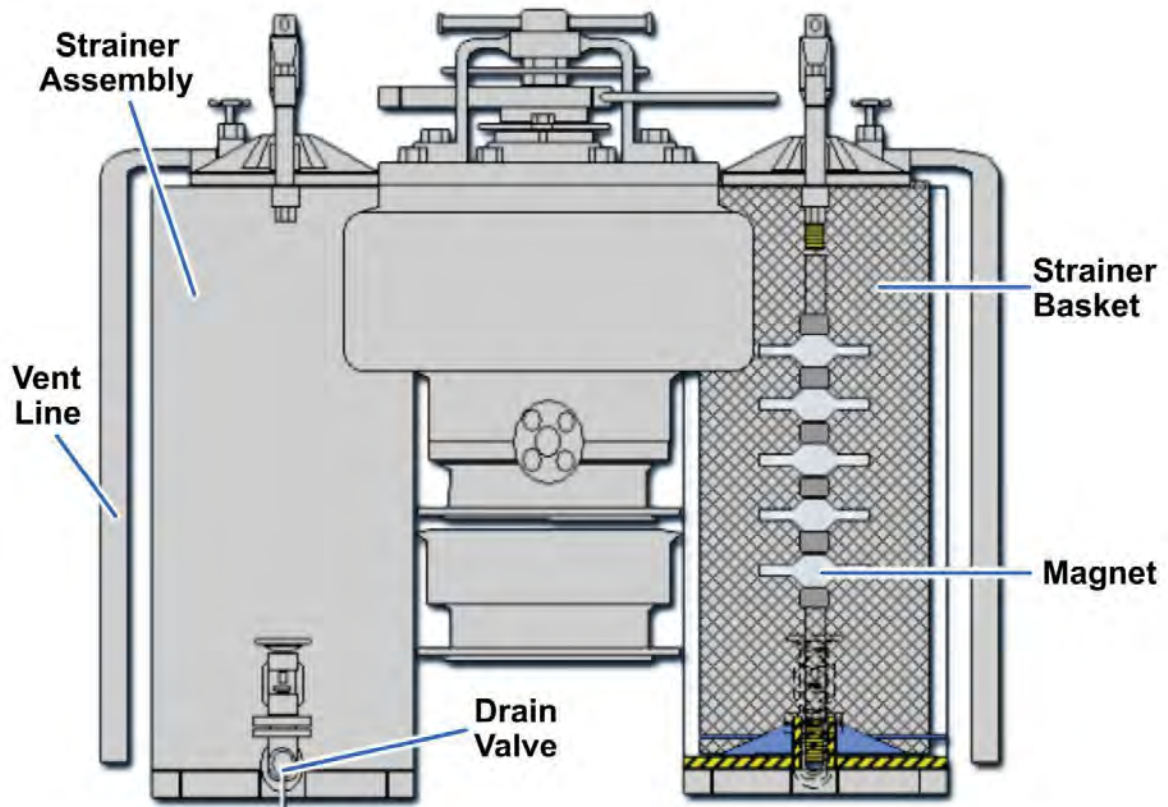**Figure 9-40 — Edge-wound metal ribbon lube oil strainer.**

Figure 9-41 — Edge-disk lube oil strainer.

Filters

In filters approved by the Navy, the absorbent material is composed of such substances as cellulose, cotton yarn, and paper disks. Filters may be located directly in the pressure-lubricating oil system, or they may be installed as bypass filters. When installed in the pressure system, a filter must contain a built- in, spring-loaded, pressure-relief valve. The valve must be large enough to bypass all oil to the engine in case the filter element becomes restricted. A bypass filter has an orifice plate in the line to the filter. This component controls the amount of oil removed from the lubricating oil pressure system. (The amount of oil that flows through a bypass filter is only a small percentage of the oil that flows through the pressure system.) The oil from a bypass filter is returned to the sump tank. Examples of some of the filters with which you will come into contact are shown in *Figure 9-42.*

There are three general areas in a system for locating a filter: the inlet line, the pressure line, or a return line. Both filters and strainers are available for inlet lines. Filters are normally used in other lines. *Figure 9-43* shows a typical pressure line and return line filter arrangement in a hydraulic system.

Pressure Line Filters

A number of filters are designed for installation right in the pressure line (*Figure 9-43*) and can trap much smaller particles than inlet line filters. Such a filter might be used where system components, such as valves, are less dirt-tolerant than the pump. The filter thus would trap this fine contamination from the fluid as it leaves the pump. Pressure line filters must be able to withstand the operating pressure of the system.

Return Line Filters

Return line filters (*Figure 9-43*) also can trap very small particles before the fluid returns to the reservoir/tank. They are particularly useful in systems that do not have large reservoirs/tanks to allow contaminants to settle out of the fluid. A return line filter is usually necessary in a system with a high-performance pump, which has very close clearances and usually cannot be sufficiently protected by an inlet line filter.
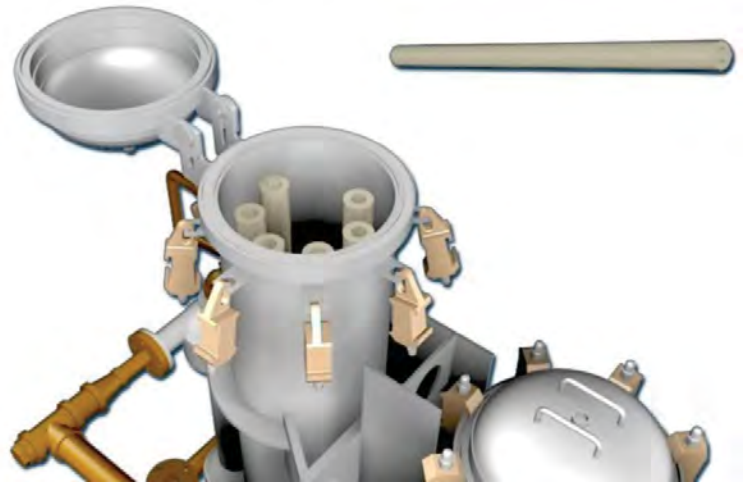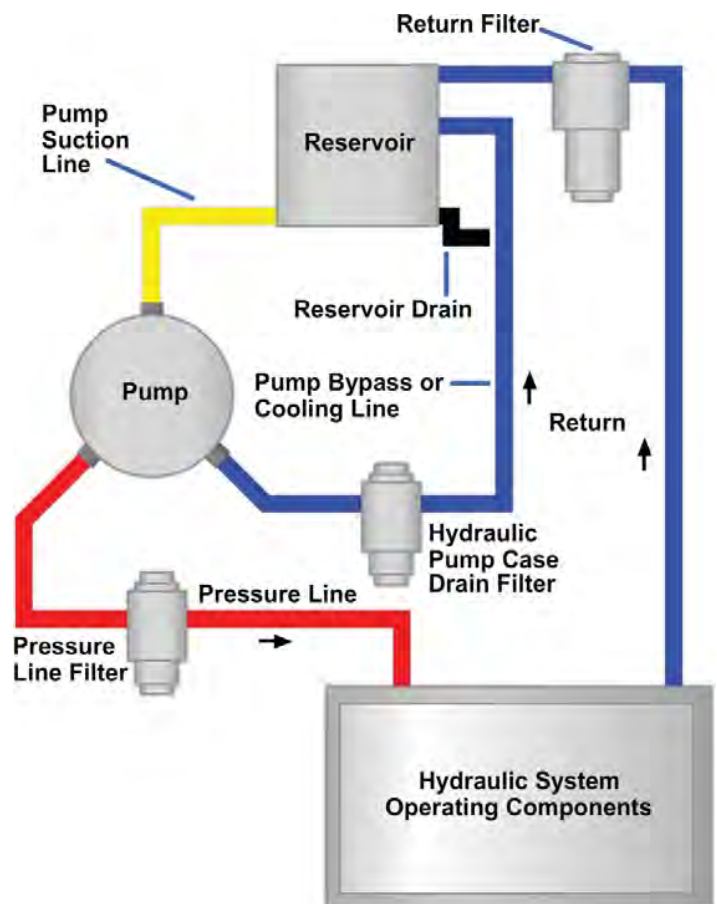

Figure 9-42 — Tank-type lube oil filter.

hydraulic system.

Fuel Filters

The fuel filter operates by passing fuel through a porous element that removes particles large enough to cause problems in the system (*Figure 9-44*). Particles are often measured in microns. A micron is one millionth of a meter. Some filters serve as sediment bowls. These types of filters separate water and larger particles from the fuel. After separation, the water and particles settle to the bottom of the bowl, where they can be removed through a drain plug.

Filter/Strainer Materials

The materials used in filters and strainers are classified as mechanical, absorbent, or adsorbent.

Filter elements can be made of ceramic, treated paper, sintered bronze, or metal screen (*Figure 9-45*). Some filter elements are made of laminated disks that are spaced 0.0003 inch apart. Foreign matter is blocked out as the fuel passes between the disks.

Most strainer material is of the mechanical type, which operates by trapping particles between closely woven metal screens and/or disks, and metal baskets. The mechanical type of material is used mostly where the particles removed from the medium are of a relatively coarse nature.

Absorbent filters are used for most minute particle filtration in fluid systems. They are made of a wide range of porous materials, including paper, wood pulp, cotton, yarn, and cellulose. Paper filters are usually resin-impregnated for strength.

Adsorbent (or active) filters, such as charcoal and fuller's earth, are used mostly in gaseous or vaporous systems. This type of filter material should not be used in hydraulic systems since they remove essential additives from the hydraulic fluid.

Construction of Filter Elements

Filter elements are constructed in various ways.

Surface-type filter elements are made of closely woven fabric or treated paper with pores to allow fluid to flow through. Very accurate control of the pore size is a feature of the surface-type elements.
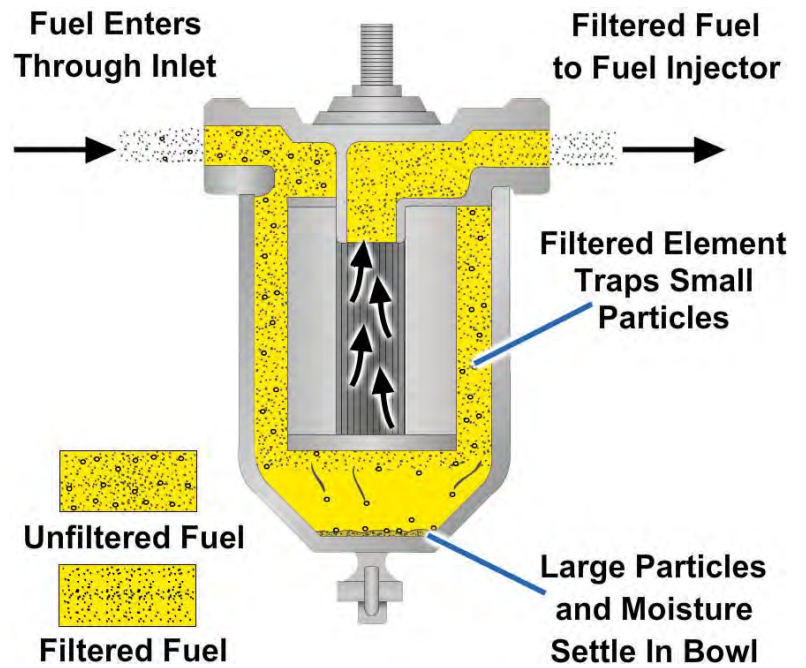

Figure 9-44 — Fuel filter operation.

Figure 9-45 — Filter elements.

A depth-type filter element is composed of layers of a fabric or fibers, which provide many tortuous paths for the fluid to flow through. The pores or passages vary in size, and the degree of filtration depends on the flow rate. Increases in flow rate tend to dislodge trapped particles. This filter is limited to low-flow, low pressure-drop conditions.

An edge-type filter element separates particles from fluids passing between finely spaced plates. The filter shown in *Figure 9-45* features stationary cleaner blades that scrape out the collected contaminants when the handle is twisted to turn the element.

Types of Filters

In this section we will discuss the various filters (full flow, proportional flow, and indicator) that you will most frequently find installed in equipment.

Full-Flow Filters

The term "full-flow" applied to a filter means that all the flow into the filter inlet port passes through the filtering element. In most full-flow filters, however, there is a bypass valve preset to open at a given pressure drop and divert flow past the filter element. This prevents a dirty element from restricting   flow excessively. *Figure 9-46* shows a full-flow filter. Flow, as shown, is out-to-in; that is, from around the element, through it to its center. The bypass opens when total flow can no longer pass through   the contaminated element without raising the system pressure. The element is replaceable after removing a single bolt.
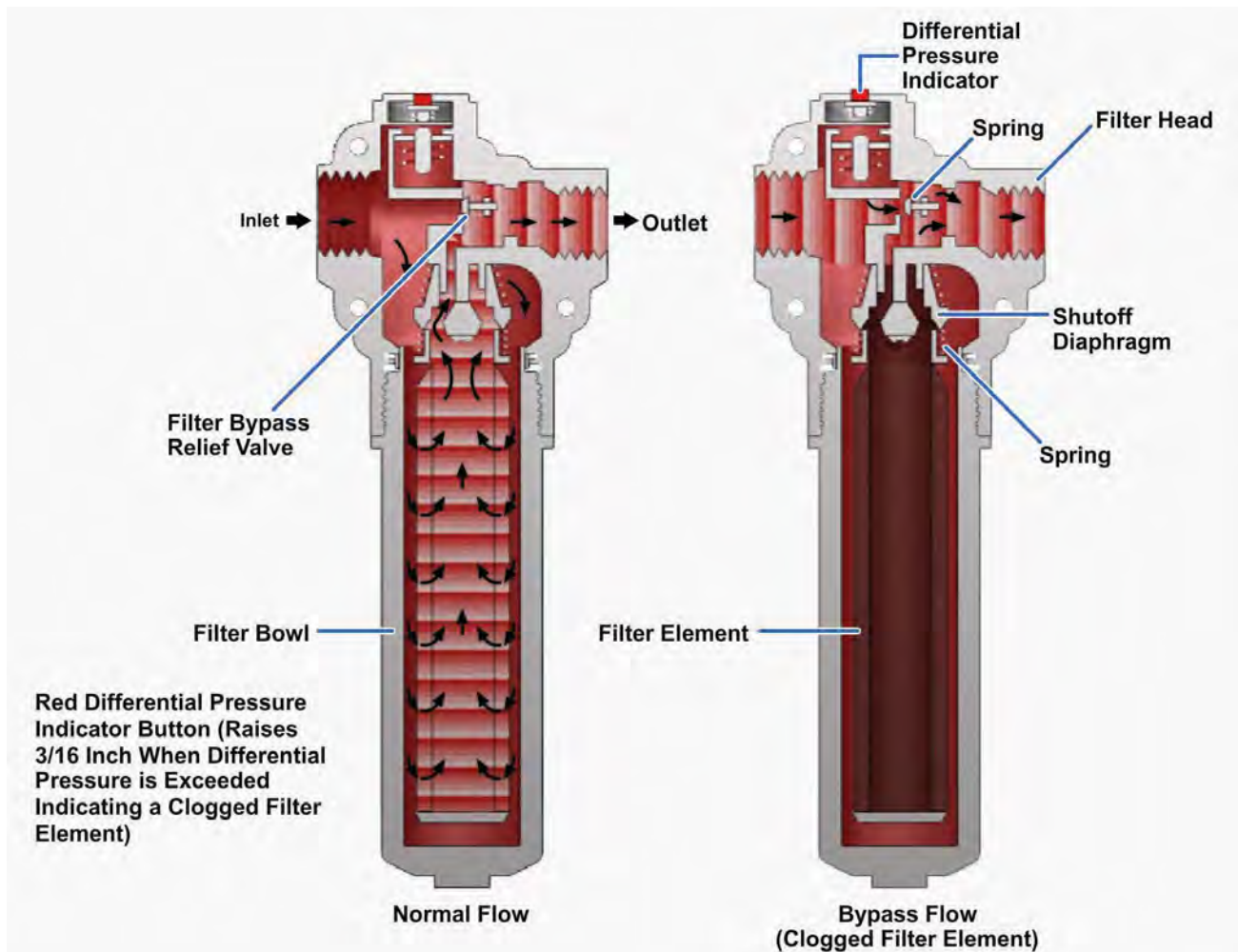

Figure 9-46 — Hydraulic filter assembly incorporating differential pressure.

Proportional-Flow Filters

A proportional-flow filter (*Figure 9-47*) may use the venturi effect to filter a portion of the fluid flow. The fluid can flow in either direction. As it passes through the filter body, a venturi throat causes an increase in velocity and a decrease in pressure.

The pressure difference forces some of the fluid through the element to rejoin the main stream at the venturi. The amount of fluid filtered is proportional to the flow velocity. Hence, the name proportional-flow filter.
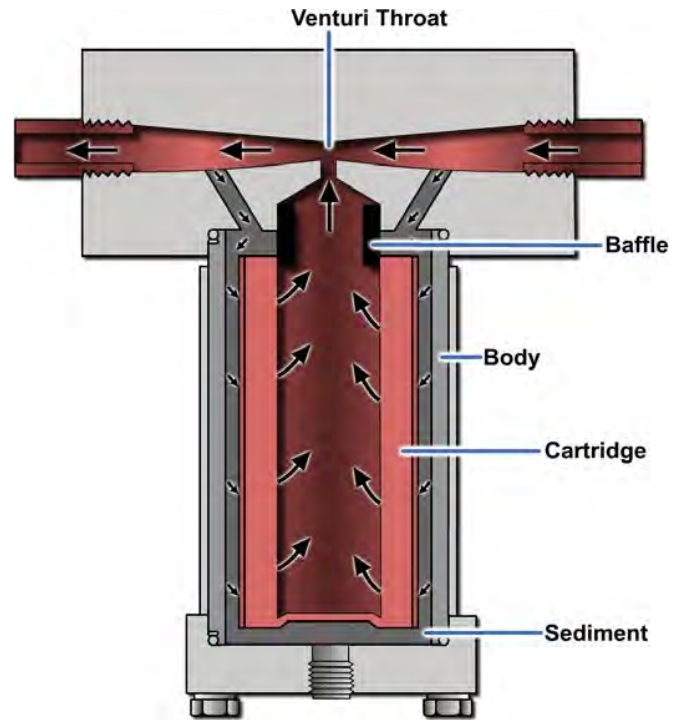
Indicating Filters

Indicating filters are designed to signal the operator when the element needs cleaning. There are various types of indicators, such as color-coded, flag, pop-up, and swing arm. *Figure 9-48* shows a color-coded indicating filter. The element is designed so it begins to move as the pressure increases due to dirt accumulation. One end is linked to an indicator that shows the operator just how clean or dirty the element is. Another feature of this type of filter is the ease and speed with which the element can be removed and replaced. Most filters of this kind are designed for inlet line installation.

Filter/Separator

The filter/separator is a two-stage unit consisting of a coalescer stage and a separator stage within a single housing. Each stage is made up of replaceable elements, the number of which is determined by such considerations as the capacity of the elements in gallons per minute (gpm) and the elements' dirt retaining properties. Coalescer elements filter solids from the fluid and cause small particles of undissolved water to combine (coalesce) into larger drops of water that, because of their weight, will settle in the filter/separator sump. Separator elements are provided to remove any remaining free water that has not coalesced. Water that accumulates in the filter/separator sump is removed through a drain line, either automatically or manually.
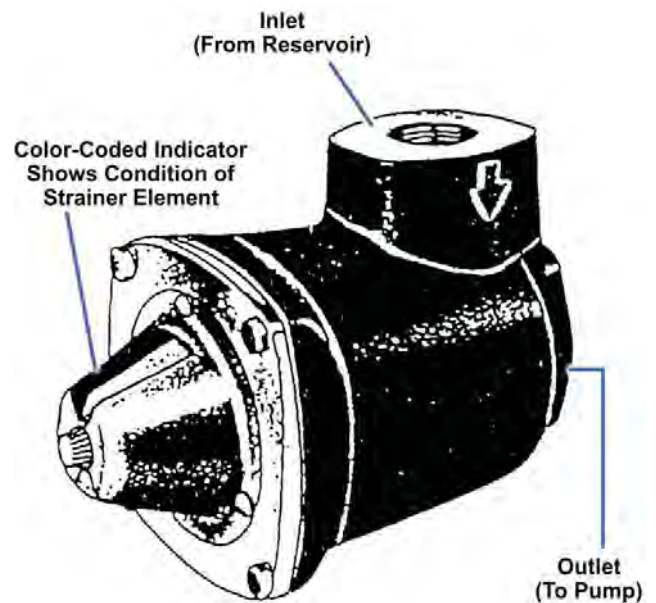

Figure 9-47 — Proportional-flow filter.

Figure 9-48 — Color-coded indicating filter.

In-Line or Cone Filter

In-line or cone filters have conical-shaped fine mesh screen or perforated metal sheet that is inserted into the system pipe and secured by a set of flanges. Its system application determines whether it is

considered a filter or strainer. It is most commonly used in seawater systems, where it is considered a strainer. This type of filter is prohibited in fuel systems.

Maintenance

Proper operation of filters, strainers, and filter separators is essential for satisfactory gas turbine and diesel engine performance. Besides clogging the systems with foreign matter, continued operation with unfiltered fluids results in accelerated pump wear and system degradation.

PIPING

The control and application of fluid power would be impossible without a suitable means of conveying the fluid from the power source to the point of application. Fluid lines used for this purpose are called piping. They must be designed and installed with the same care applicable to other components of the system. To obtain this desired result, attention must be given to the various types, materials, and sizes of lines available for the fluid power system. The different types of lines and their application to fluid power systems are described in the first part of this section. The last part of this section is devoted to the various connectors applicable to the different types of fluid lines.

Identification of Piping

The three types of lines used in fluid power systems are tubing (semi rigid), pipe (rigid), and hose (flexible). A number of factors are considered when the type of line is selected for a particular system. These factors include the type of fluid, the required system pressure, and the location of the system. For example, heavy pipe might be used for a large stationary system, but comparatively lightweight steel tubing is used in the automotive brake system. Flexible hose is required in installations where units must be free to move relative to each other.

The choice between pipe and tubing depends on system pressure and flow. The advantages of tubing include easier bending and flaring, fewer fittings, better appearance, better reusability, and less leakage. However, pipe is cheaper and will handle large volumes under high pressures. Pipe is also used where straight-line hookups are required and for more permanent installations.

Piping Materials

The pipe and tubing used in fluid systems today are commonly made from steel, copper, brass, aluminum, and stainless steel. The hose assemblies are constructed of rubber or Teflon®. Each of these materials has its own distinct advantages or disadvantages, depending upon its application.

Steel piping and tubing are relatively inexpensive, have a high tensile strength, are suitable for bending and flanging, and are very adaptable to high pressures and temperatures. Their chief disadvantage is a comparatively low resistance to corrosion.

Copper and brass piping and tubing have a high resistance to corrosion and are easily drawn or bent. Pipe or tubing made from these materials is unsuitable for systems with high temperatures, stress, or vibration because they have a tendency to harden and break.

Aluminum has many characteristics and qualities required for fluid systems. It has a high resistance to corrosion, is lightweight, is easily drawn or bent, and (when combined with certain alloys) will withstand high pressures and temperatures.

Plastic tubing lines are made from a variety of materials; nylon is the most suitable for use in low-pressure hydraulic applications ONLY.

Stainless steel piping or tubing is relatively lightweight and is used in a system that will be exposed to abrasion, high pressure, and intense heat. Its main disadvantage is high cost.

FLEXIBLE HOSE ASSEMBLIES

The flexible hose assembly is a specific type of flexible device that uses reinforced rubber hose and metal end fittings. Hose assemblies are used to connect moving parts with stationary parts and in locations subject to severe vibration. Hose assemblies are heavier than aluminum-alloy tubing and deteriorate more rapidly.

Flexible hose is used in fluid power systems where there is a need for flexibility, such as connection to units that move while in operation or to units attached to a hinged portion of the equipment. It is used to absorb motions between resiliently mounted machinery and fixed or resiliently mounted piping systems. The motions to be considered may be of either relatively large size due to high- impact shock or of smaller size due to the vibratory forces of rotating machinery. The configuration selected must contain enough hose to accommodate shock and vibratory motions without stressing the hose assembly or machinery to an unacceptable degree.

Flexible hose is provided in four pressure ranges. Low-pressure hose is used in a low-pressure system and for the exhaust lines of high-pressure systems. Medium-pressure hose is used in   systems with pressures up to 1,200 psi; high-pressure hose is used with pressures up to 3,000 psi; and extra high-pressure hose is used in systems with pressures up to 5,000 psi. High- and extra high- pressure hoses normally come as complete assemblies with factory-installed end fittings. Medium- and low-pressure hose are available in bulk and are usually fabricated locally. Hose assemblies are made up of hose and hose fittings. A hose consists of multiple layers of various materials to include aluminum, carbon steel, and corrosion-resistant steel (CRES).

Rubber hose is designed for specific fluid, temperature, and pressure ranges and is provided in various specifications. Flexible hydraulic hose is composed of three basic parts. An example of a flexible hose is shown in *Figure 9-49*.

The inner tube is a synthetic rubber layer that is oil-resistant. It must be smooth, flexible, and able to resist heat and corrosion.

The reinforcement layers vary with the type of hose. These layers (or plies) are constructed of natural or synthetic fibers, braided wire, or a combination of these. The strength of this layer depends upon the pressure requirement of the system.

The outer cover protects the reinforcement layers. A special rubber is most commonly used for the outer layer because it resists abrasion and exposure to weather, oil, and dirt.

Figure 9-49 — Flexible rubber hose construction.

Hose Identification

It is important that the proper hose to be used is clearly identified by various recognizable hose markings.

Hose built to military specification (MILSPEC) requirements have the number of the specification and, where applicable, the class of hose, the quarter and year of manufacture, and the manufacturer's trademark. This information is molded or otherwise permanently repeated periodically on the hose

cover (sometimes referred to as the "lay line marking"). Other information permanently marked on the hose cover is the manufacturer's code and the date of manufacture. For interpretations of commercial lay line markings, refer to the appropriate manufacturer's catalog or manual.

Synthetic Rubber

Synthetic rubber hose (if rubber-covered) is identified by the indicator stripe and markings that are stenciled along the length of the hose. The indicator stripe (also called the lay line because of its use in determining the straightness or lie of a hose) is a series of dots or dashes. The markings (letters and numerals) contain the MILSPEC, hose size, cure date, and manufacturer's federal supply code number. This information is repeated at intervals of 9 inches. Refer to *Figure 9-50*.
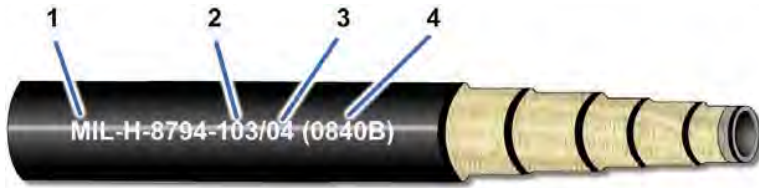
1. Military specification of hose
2. Size indicated by a dash (-) No. or fraction of an inch for MIL-DTL-6000 hose
3. Cure date for age control
4. Manufacturer's Federal Supply Code No.

Manufacturer	ACME
Manufacturer's code	0840B
Part No. with dash (size) No.	AB123-10
Lot No.	16160
Operating pressure	3000 PSI
Military specification	MIL-H-83298

Wire Braid Covered PTFE Hose Label

Figure 9-50 — Synthetic rubber hose identification.

Size is indicated by a dash followed by a number (referred to as a dash number). The dash number does not denote the inside or outside diameter of the hose. It refers to the equivalent outside diameter of rigid tube size in sixteenths (1/16) of an inch. A dash 8 (-8) mates to a number 8 rigid tube, which has an outside diameter of one-half inch (8/16). The inside of the hose will not be one-half inch, but slightly smaller to allow for tube thickness. The cure date is provided for age control. It is indicated by the quarter of the year and year. The year is divided into four quarters.

1st quarter — January, February, March 2rd

quarter — April, May, June

3rd quarter — July, August, September

4th quarter — October, November, December

The cure date is also marked on bulk hose containers in accordance with Military Standard 129 (MIL-STD-129).

Synthetic rubber hose (if wire-braid covered) is identified by bands wrapped around the hose at the ends and at intervals along the length of the hose. Each band is marked with the same information (*Figure 9-50*).

Teflon® Hose

Teflon® hose is identified by metal bands or pliable plastic bands at the ends and at 3-foot intervals. These bands contain the hose MILSPEC number, size indicated by a dash (-) and a number, operating pressure, and the manufacturer's federal supply code number. Refer to *Figure 9-50*.

Fitting Identification

Hose fittings are designed and constructed in accordance with MILSPEC and military standard drawings for particular hose configurations and operating pressures.

Fittings designated by a military standard drawing number have a particular dash number to indicate size. The fitting dash number does not designate a size in the same manner as a hose dash number. The fitting dash number corresponds to the dash number of the hose so that both will match at the critical dimensions to form a hose assembly.

Materials used in the construction of fittings vary according to the application. Materials include aluminum, carbon steel, and corrosion-resistant steel. Fittings that qualify under one military document may be produced by several manufacturers. Two methods or styles are used to secure the hose fitting to the hose. They are the reusable and swage or crimp style.

Reusable Style

The preferred reusable style has modified internal threads in the socket to grip the hose properly. The fitting can be disassembled from a hose assembly and reused on another hose, provided it passes an inspection for defects. Reusable style fittings are authorized replacement fittings for replacement hose assemblies.

Swage or Crimp Style

Some hose assembly manufacturers use a swage or crimp style. This style requires the socket to be permanently deformed by an electric- or hydraulic-powered machine. The deformed socket and related hardware are to be scrapped.

Flexible hose connectors are designed to be either permanent or reusable and are made of forged steel. There are various types of end fittings for both the piping connection side and the hose connection side of hose fittings (*Figure 9-51*).
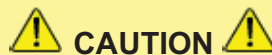
> ⚠️ **CAUTION** ⚠️
>
> If hoses and fittings are matched incorrectly, the results can be pinhole leaks, ruptures, heat buildups, pressure drops, cavitations, and other failures.
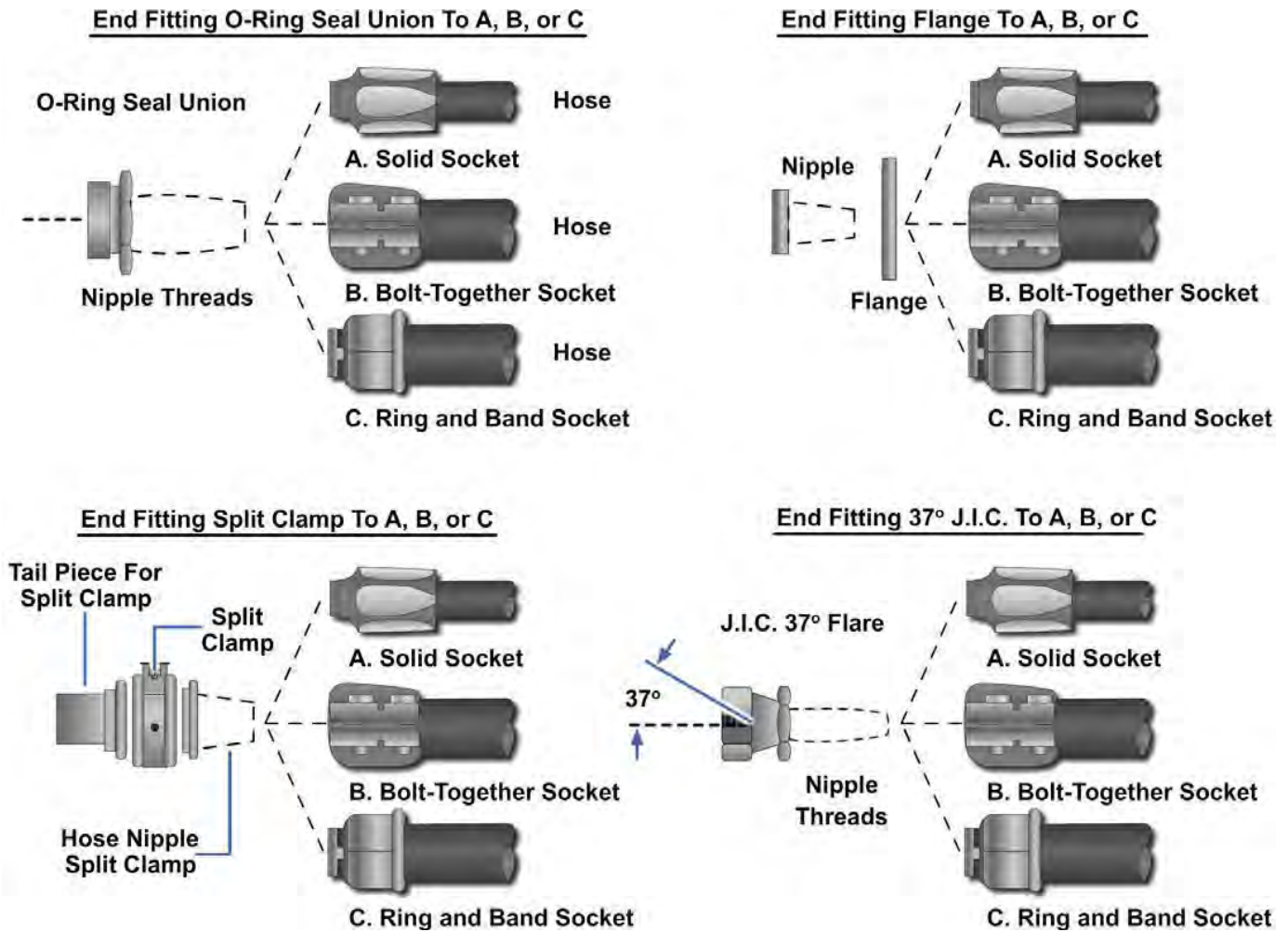
End Fitting O-Ring Seal Union To A, B, or C

O-Ring Seal Union

Hose

A. Solid Socket

Nipple Threads

Hose

B. Bolt-Together Socket

Hose

C. Ring and Band Socket

End Fitting Flange To A, B, or C

Nipple

Hose

A. Solid Socket

B. Bolt-Together Socket

Flange

C. Ring and Band Socket

End Fitting Split Clamp To A, B, or C

Tail Piece For Split Clamp

Split Clamp

A. Solid Socket

B. Bolt-Together Socket

Hose Nipple Split Clamp

C. Ring and Band Socket

End Fitting 37° J.I.C. To A, B, or C

J.I.C. 37° Flare

37°

A. Solid Socket

Nipple Threads

B. Bolt-Together Socket

C. Ring and Band Socket

Figure 9-51 — Flexible hose connectors.

Hose Assembly Identification

All hose assemblies are identified by tags, bands, or tapes. Some identifications are permanently marked while others are removable. Removable tags, bands, or tapes should not be installed on hose assemblies located inside fuel and oil tanks or in areas of an aircraft where tags, bands, or tapes could be drawn into the engine intake. Hose assemblies are either commercially manufactured or locally fabricated.

Commercially manufactured Teflon® hose assemblies are identified by a permanently marked and attached band on the assembly. The band contains the assembly manufacturer's name or trademark, hose manufacturer's federal supply code number, hose assembly part number, operating pressure in psi, pressure test (PT) symbol, and the date of hose assembly manufacture (in month and year).

Hose assemblies manufactured by depot and intermediate maintenance activities are identified with hose assembly identification tags or labels. The hose assembly identification tag is a metal tag that contains the basic hose assembly and part number, date of fabrication (in quarter and year), operating pressure (in psi), and organizational code of the activity fabricating the hose assembly.
Figure 9-52 shows where this information is located. All marking of the tag is to be done prior to its attachment to the hose assembly.

The hose assembly identification tag should be installed by wrapping the band snugly around the hose, inserting the tab through the slot and pulling it tight; crimping the tab after bending the tab back; and finally, cutting away the excess tab after crimping. A length of not less than one-half inch must remain between the tag and the end fitting after proof pressure testing has been performed.

Labels should be used (*Figure 9-53*) to identify hose assemblies located in areas where a tag may be drawn into an engine intake or where hose assemblies are covered with heat-shrinkable tubing. The label should be placed 1 inch from the socket and a 2 1/2-inch piece of clear, heat- shrinkable tubing, MIL-PRF-46846, Type V, applied over the label and hose.

Approved Flexible Hose Configurations

The arrangements (or configurations) determined to give the best noise attenuation characteristics and to accommodate the motions of resiliently mounted equipment are shown in *Figures 9-54 and 9-55*. The 90° "L" configuration (dogleg) is the preferred configuration; however, where space and piping arrangement prohibit the use of the "L" configuration, a 180° or "U" configuration may be used. The 90° "L" and 180° "U" configurations are shown as sketches A and B of *Figure 9-54*.
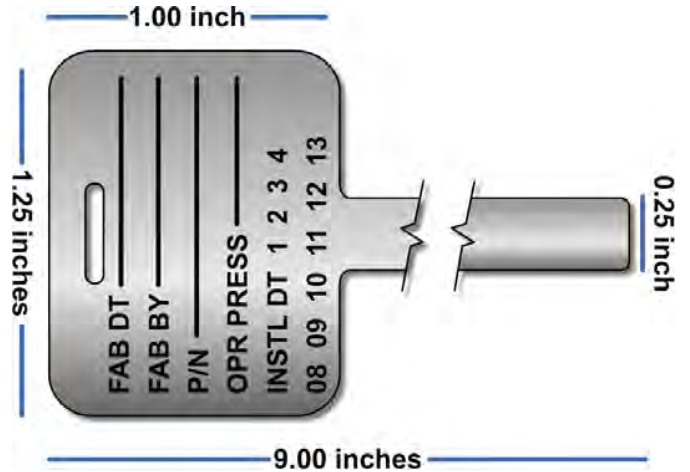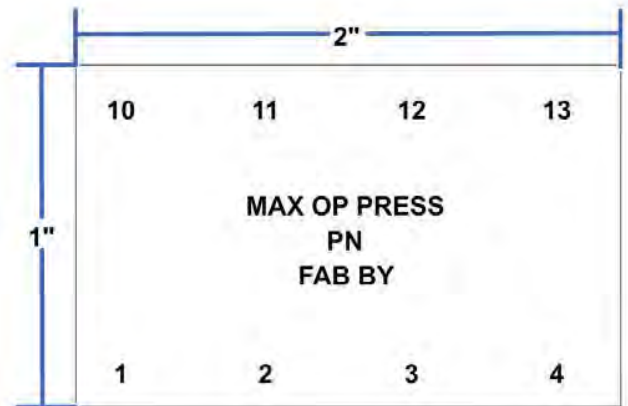
Figure 9-52 — Hose assembly identification tags.

(Material: White Polyester Film Per MIL-38477)

Figure 9-53 — Hose assembly labels.

A configuration that uses a single length of hose bent to about 90° is approved where the hose does not bend below its specified minimum bending radius when the equipment moves to the maximum limits allowed by its mounts (*Figure 9- 55, view A*). The straight single hose configuration and the 180° single hose bend (*Figure 9-55, view B)* are also approved for use where the hose size is less than 1 inch inside diameter (ID).
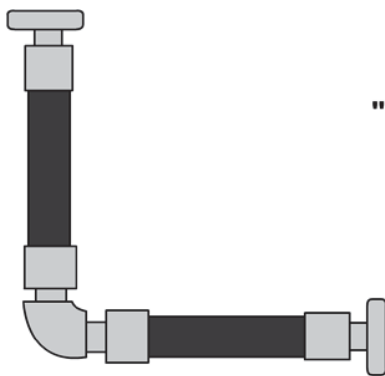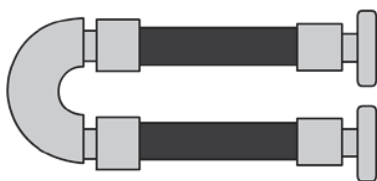
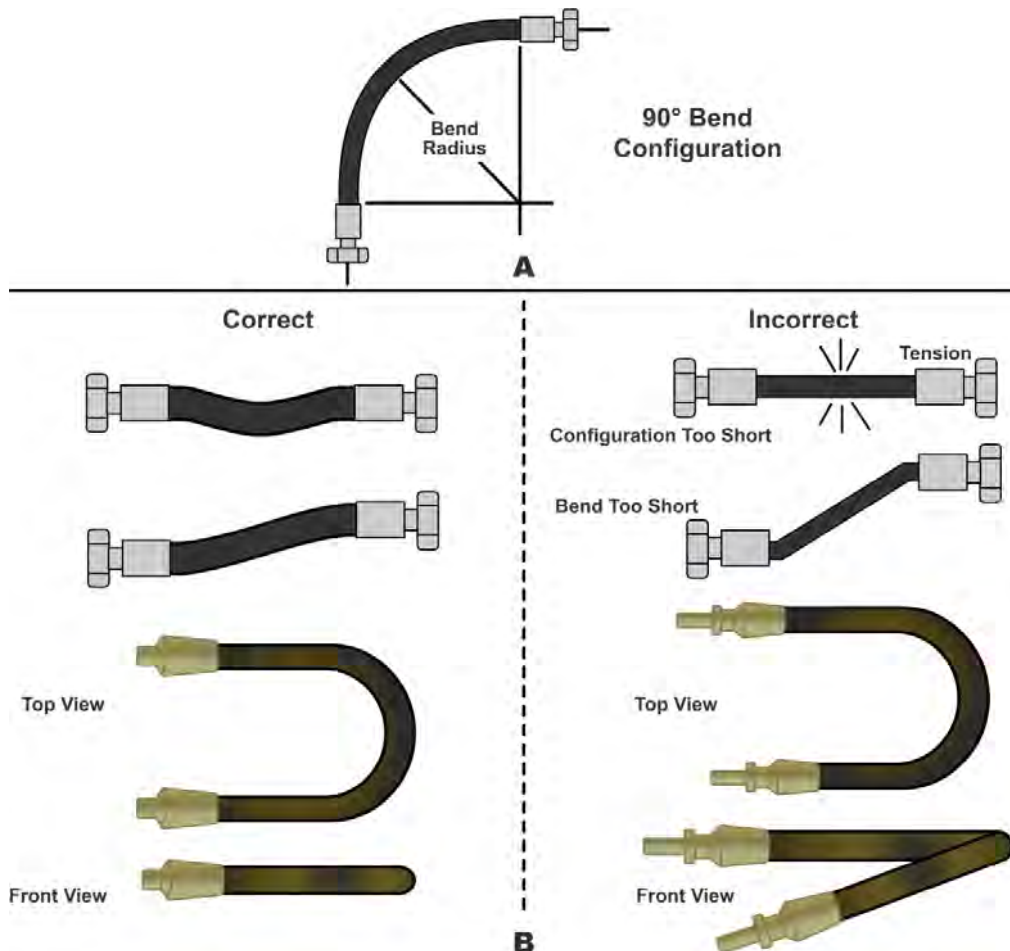**Figure 9-54 — Types of flexible hose installations and fittings.**

Figure 9-55 — Other approved single hose length configurations.

Inspection of Hose and Fittings Prior to Make-Up

The basic inspection methods for hose and fittings are listed as follows:

1. Ensure that the hose and couplings are the correct ones for the intended use.

> **NOTE**
>
> Synthetic rubber hose, bulk or assembly, shall have a shelf life not to exceed 10 years (40 quarters) from the cure date.
>
> Hoses and hose assemblies made from Teflon® (PTFE) do not have shelf life limitations.

2. Inspect for signs that the hose has been twisted. Use the hose lay line for a guide to determine whether or not any twist is present. <u>If twisted, reject</u>.

3. Inspect for signs that the hose has been kinked or bent beyond its minimum bend radius. <u>If suspect, reject</u>.

4. Inspect for signs of loose inner liner. If found, cut the hose to see if this condition exists throughout the entire length. <u>If suspect, reject</u>.

5. Visually check the inner liner and outer rubber cover of the hose for breaks, hairline cuts, or severe abrasions. <u>If any suspect areas are found, reject</u>.

6. Inspect the fittings for defects, such as cracked nipples and damaged threads. <u>If suspect, or if defects are found, reject</u>.

Visual Inspection

After assembling the hose and fittings, visually inspect the entire configuration to ensure the following:

1. The hose inner liner and outer cover is intact and contains no cuts or harmful abrasions.

2. The hose has not been twisted (check the lay line).

3. The circumferential chalk line on the hose next to the coupling has been drawn before the hydrostatic test.

4. The internal spring (if installed) is evenly spaced and flat against the inner liner. Ensure a gap exists between one of the end fittings and the end of the spring.

Flexible hose must NOT be twisted on installation since this reduces the life of the hose considerably and may cause fittings to loosen as well. You can determine whether or not a hose is twisted by looking at the lay line that runs along the length of the hose. This lay line should not tend to spiral around the hose.

Hose should be installed so that it will be subjected to a minimum of flexing during operation. Support clamps are not necessary with short installations, but with hoses of considerable length (48 inches, for example); clamps should be placed not more than 24 inches apart. Closer supports are desirable and, in some cases, needed.

Hose must NEVER be stretched tight between two fittings. About 5 to 8 percent of the total length must be allowed as slack to provide freedom of movement under pressure. When flexible hose is under pressure, it contracts in length and expands in diameter. Examples of correct and incorrect installations of flexible hose are shown in *Figure 9-56*.
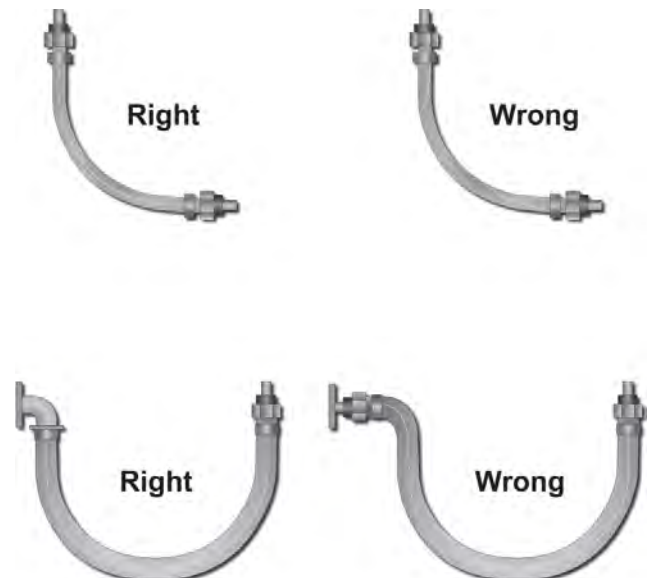

Figure 9-56 — Correct and incorrect installation of flexible hose.

Hydrostatic Test

Upon completion of visual inspection, hydrostatically shop test the hose assembly with freshwater. When you test pressure, hold for not more than 5 minutes nor less than 60 seconds. When test pressure is reached, visually inspect the hose assembly for the following defects:

1. Leaks or signs of weakness.

2. Twisting of the hose (this indicates that some twist existed before pressure was applied).

3. Slippage of the hose out of the coupling (a circumferential chalk line can help determine this).

If any of these defects occur, <u>reject the assembly</u>.

> ⚠️ **CAUTION** ⚠️
>
> Do not confuse hose elongation under pressure with coupling slippage. If the chalk line returns to near its original position, no slippage has occurred and the assembly is satisfactory. If there is any doubt, perform a second test. If doubt persists after the second test, reject the assembly.

Air Test

Hose assemblies intended for gas or air service must also be tested with air or nitrogen at 100 psi and the assembly immersed in water. Random bubbles may appear over the hose and in the fitting area when the assembly is first pressurized. Do not construe this as a defect. However, if the bubbles persist in forming at a steady rate at any particular point on the hose, reject the assembly.

Installation of Flexible Hose Assemblies

After completion of tests, proceed as follows:

1. Install as soon as possible.

2. Do not leave the hose assembly around on decks or on docks where they can be subjected to any form of abuse.

3. Make up hose assemblies as late as possible during the availability schedule to minimize the chances of damage while the ship is being overhauled.

4. Install plastic dust caps, plugs, or tape ends to protect threaded areas until the hose assembly is installed.

When installing flexible base connections, observe the following requirements:

1. Ensure each leg of hose is free of twist between end fittings.

2. Ensure the fixed piping near the flexible configuration is properly supported so that it does not vibrate from the resiliently mounted equipment.

3. Ensure the configurations are clear of all surrounding structures and remain so when resiliently mounted equipment moves through its maximum excursion under shock.

4. Locate flexible connections as close as possible to the sound-mounted unit.

5. Support the free elbow of the configuration with an approved pipe hanger so as not to sag or otherwise unduly stress or distort the configuration.

6. Do not appreciably change the alignment of the hose configuration between the unpressurized and pressurized conditions. If you do, you could cause misalignment or improper support at   the fixed end.

7. Leave the configuration in a condition where one end can hang down unsupported during installation or dismantling of piping. Otherwise, you can damage the hose wire reinforcement.

Periodic Inspection by Ship's Force

No less than once a quarter, preferably about once a month, visually inspect all flexible piping connections to determine whether any signs of weakness or unusual conditions exist. Inspect the

hose in other systems semiannually. To assist you when performing this inspection, you should compile a checkoff list of hose assemblies and locations for your assigned spaces or equipment. This list will consist of all flexible devices installed (and their locations) together with a list of inspections to be performed on each flexible device. When you perform the listed inspections, note the following:

1. Evidence of leakage at fitting ends.

2. Discoloration of fittings (possible indication wire reinforcement is rusting).

3. Slippage of hose out of fitting.

4. Twisting of hose or other distortion or unusual appearance.

5. Cracking of outer rubber cover.

6. Rubber cover rubbed thin by abrasion or chafing.

7. High pulsations, fluid hammer, or whipping caused by pressure pulsations.

8. Large vibrations due to improper supports at the fixed end.

9. Large area of hose covered with paint (The intent of this requirement is to eliminate having the flexible hose connections deliberately painted. The hose does not have to be replaced if a few paint drops inadvertently fall onto it. Do not attempt to clean off dried paint from the hose).

10. Broken, distorted, or otherwise damaged hangers.

11. Soft spots or bulges on hose body (indicates weakening of bond between outer rubber cover and wire braid or deterioration of the reinforcing wire).

12. If results of visual inspection indicate weakening of hose or fittings, or makes hose configuration suspect, replace the hose immediately, if at all possible. Keep under surveillance while under pressure until it is replaced.

13. If necessary to remove a flexible hose configuration from the system, examine the interior of the hose for cracks or other signs of deterioration of the inner liner. Do not damage the liner by trying to dislodge sea growth. Do not remove the end fittings from any section of hose that is to be installed.

14. Presence of identification tag.

Age Control and Service Life

Hose or hose assemblies fabricated from age-sensitive materials are subject to age control. The following definitions are provided to clarify age control, acceptance life, shelf life, and service life:

- Age control—This refers to the efforts made during manufacture, purchase, and storage of age-sensitive items and parts made from natural or synthetic rubber materials to assure conformance to the applicable material and performance specifications. Age control is further defined in terms of acceptance life and shelf life

- Acceptance life—This is the period of time from cure date to the procuring activity's (organizational-, intermediate-, or depot-level activity) date of acceptance

- Shelf life—This refers to the period of time from the date of acceptance or delivery by the organizational-, intermediate-, or depot-level activity to the date of use

- Service life—This is the period of time from the date of installation to the date of removal

- Installation date of the hose or hose assemblies must be identified by a tag

Acceptance Life and Shelf Life for Synthetic Rubber Hose and Hose Assemblies

The acceptance life (MIL-STD-1523) and shelf life (DOD 4140.27M) for synthetic rubber hose and hose assemblies are established as follows:

> **NOTE**
>
> Teflon® (PTFE) rubber hose and hose assemblies do not have shelf life limitations.

> **NOTE**
>
> Teflon® (PTFE) hose assemblies are replaced only on a conditional basis.

- Synthetic rubber hose (bulk or assembly) must not exceed 8 years (32 quarters) from the cure date, which must be stenciled on the rubber covering of the bulk hose or provided on an identification band on the metal braid hose or on the hose assemblies

- Synthetic rubber hose and hose assemblies must not exceed 5 years (20 quarters) from the date of delivery to the organizational-, intermediate-, or depot-level activity. The repair activity maintains a record of delivery dates for bulk hose and hose assemblies to monitor shelf life expiration dates

Service Life for Synthetic Rubber Hose Assemblies

Service life is 7 years (28 quarters) for synthetic rubber hoses in critical applications; that is, medium- and high-pressure synthetic rubber hoses exposed to heat, weather, or fuel.

> **NOTE**
>
> Service life for Teflon® (PTFE) hose assemblies is determined by Cognizant Field Activity and may be on a conditional replacement or hard-time replacement.

Rejection Standards

Rejection and replacement of hose or hose assemblies after inspections are based on the standards normally specified in the applicable maintenance instruction manual (MIM), MRC, and depot-level specifications. Where rejection standards are not specifically outlined or if doubt exists as to the acceptability of a hose or hose assembly, the hose or hose assembly should be replaced.

> **NOTE**
>
> Teflon® (PTFE) hose assemblies are replaced only on a conditional basis.

Storage

Hose and hose assemblies fabricated from age-sensitive materials are subject to deterioration by oxygen, ozone, sunlight, heat, moisture, or other environmental factors. These types of hoses and hose assemblies should be stored in a dark, cool, dry place protected from circulating air, sunlight, fuel, oil, water, dust, and ozone. (Ozone may be generated in an atmosphere where electricity is

discharged through oxygen or ambient air.) Hose or hose assemblies should be stored by sealing both ends of bulk hose. Each hose or hose assembly should also be capped or plugged and stored on racks that support and protect them. Hose or hose assemblies should be stored so that the oldest items are issued first.

> ⚠️ **CAUTION** ⚠️
>
> Do not store hose or hose assemblies in piles. Improper storage will cause accelerated deterioration due to both heat and moisture factors.

FITTINGS

Some type of connector must be provided to attach the pipe, tube, or hose to the other components of the system and to connect sections of the line to each other. There are many different types of connectors (commonly called fittings) provided for this purpose. Some of the most common types of fittings are covered in the following paragraphs.

Threaded Joints

The threaded union joints are the simplest type of pipe fittings. *Figure 9-57* shows some commonly used types of unions. Threaded fittings are not widely used aboard modern ships except in low-pressure water piping systems. The pipe ends connected to the union are threaded, silver-brazed, or welded into the tail pieces (union halves); then the two ends are joined by setting up (engaging and tightening up on) the union ring. The male and female connecting ends of the tail pieces are carefully ground to make a tight metal-to-metal fit with each other. Welding or silver-brazing the ends to the tail pieces prevents contact of the carried fluid or gas with the union threading.
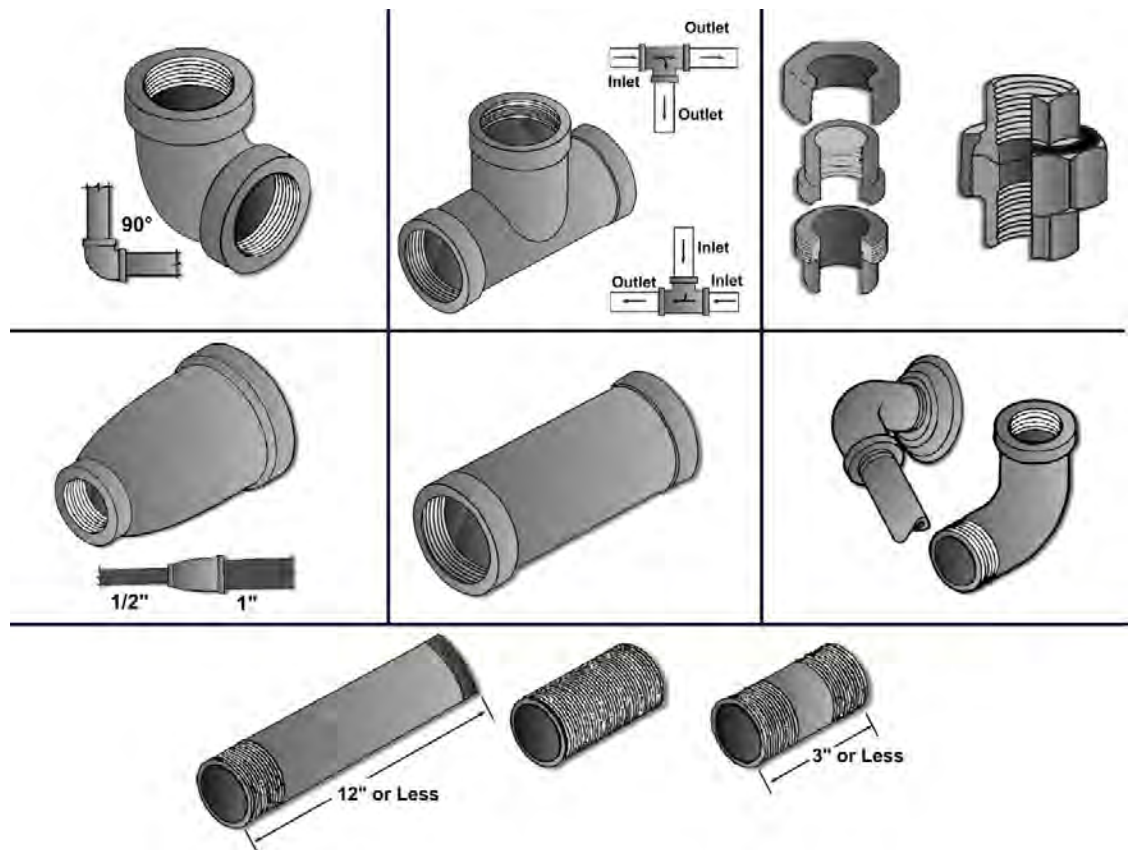
Figure 9-57 — Unions.

Bolted Flange Joints

Bolted flange joints are suitable for all pressures now in use. The flanges are attached to the piping by welding, brazing, screw threads (for some low-pressure piping), or rolling and bending into recesses. Those illustrated in *Figure 9-58* are the most common types of flange joints used. Flange joints are manufactured for all standard fitting shapes, such as the tee, cross, elbow, and return bend. The Van Stone and the welded-neck flange joints are used extensively where piping is subjected to high pressures and heavy expansion strains. The design of the Van Stone flange makes it easier to line up the fastening holes in the two parts of the flange.
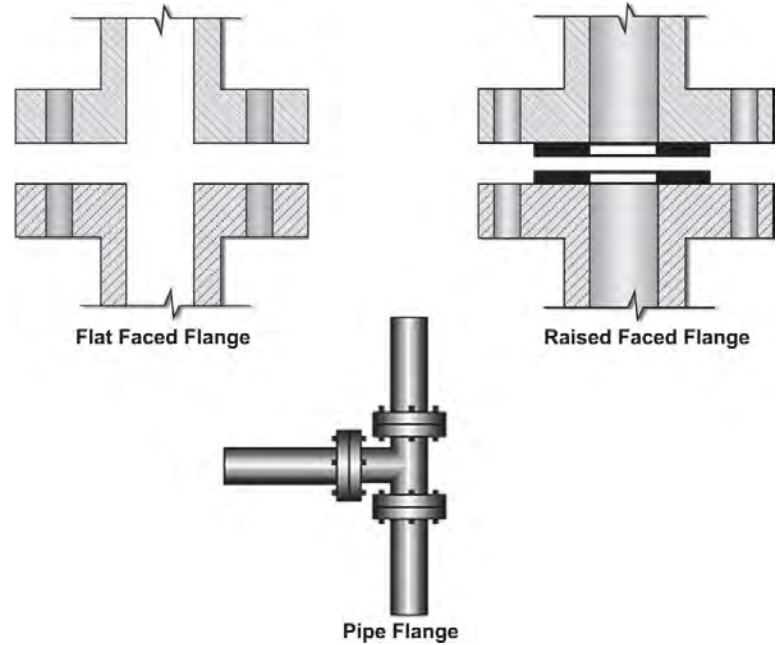
Figure 9-58 — Bolted flange piping joints.

Welded Joints

The majority of joints found in subassemblies of piping systems are welded joints, especially in high-pressure piping. The welding is done according to standard specifications, which define the material and techniques. Three general classes of welded joints are fillet-weld, butt-weld, and socket-weld (*Figure 9-59*).
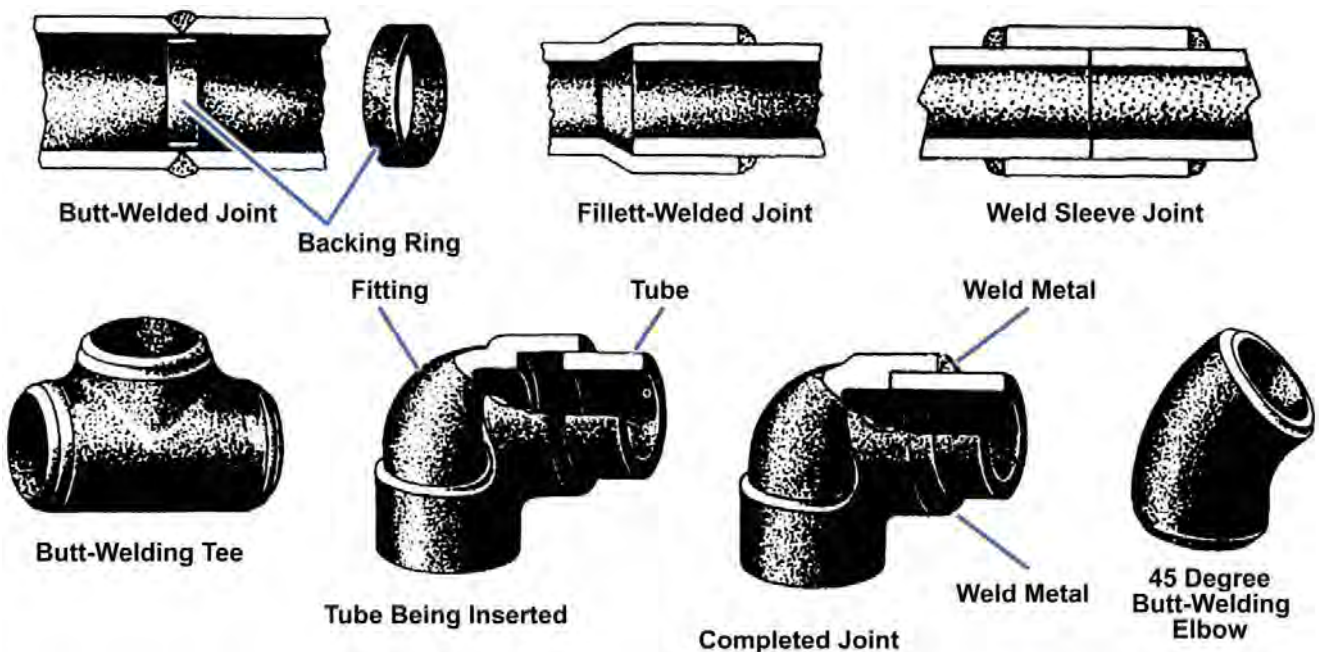
Figure 9-59 — Various types of welded joints.

Silver-Brazed Joints

Silver-brazed joints (*Figure 9-60*) are commonly used for joining nonferrous piping when the pressure and temperature in the lines make their use practicable—temperatures must not exceed 425 °F; for cold lines, pressure must not exceed 3,000 psi. The alloy is melted by heating the joint with an oxyacetylene torch. This causes the molten metal to fill the few thousandths of an inch annular space between the pipe and the fitting.
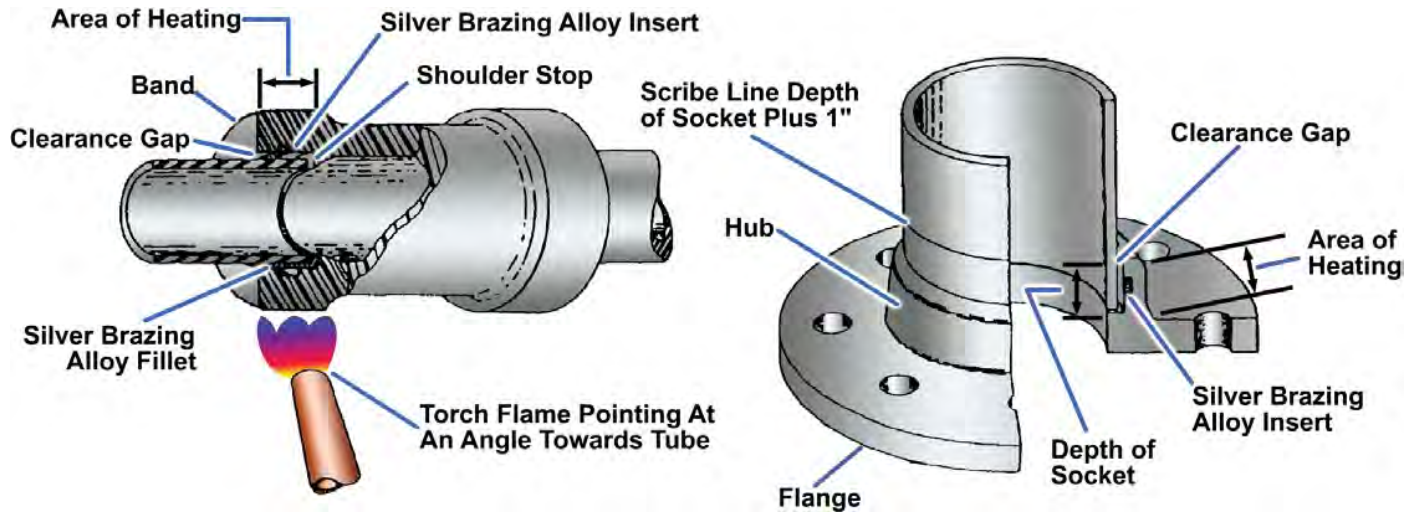
Figure 9-60 — Silver-brazed joints.

Unions

The union fittings are provided in piping systems to allow the piping to be taken down for repairs and alterations. Unions are available in many different materials and designs to withstand a wide range of pressures and temperatures. *Figure 9-61* shows some commonly used types of unions/threaded pipe connectors. The union is most commonly used for joining piping up to 2 inches in size.
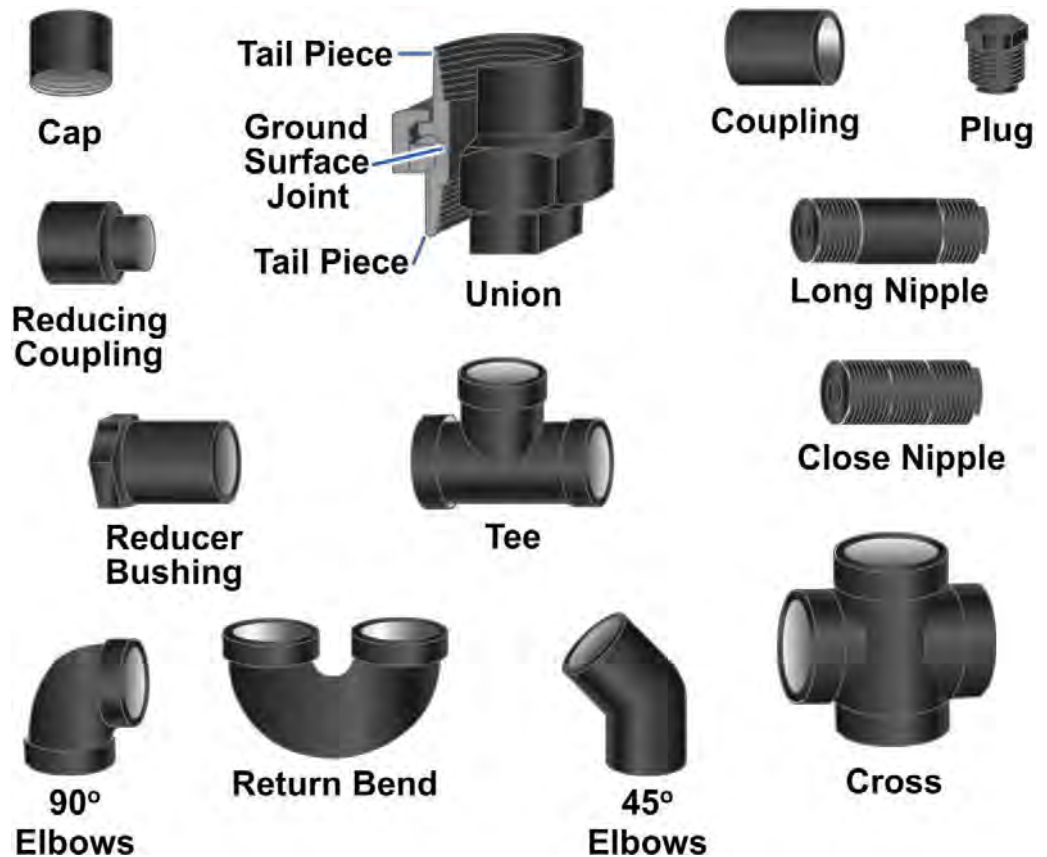
Figure 9-61 — Threaded pipe connectors.

Flared Fittings

Flared-tube connectors are commonly used in circulatory systems consisting of lines made of tubing. These connectors provide safe, strong, dependable connections without the necessity of threading, welding, or soldering the tubing. The connector consists of a fitting, a sleeve, and a nut (*Figure 9-62*).

The fittings are made of steel, aluminum alloy, or bronze. The fitting used in a connection should be made of the same material as that of the sleeve, the nut, and the tubing. For example, use steel connectors with steel tubing and aluminum alloy connectors with aluminum alloy tubing. Fittings are made in union, 45-degree and 90-degree elbows, tees, and various other shapes (*Figure 9-63*).
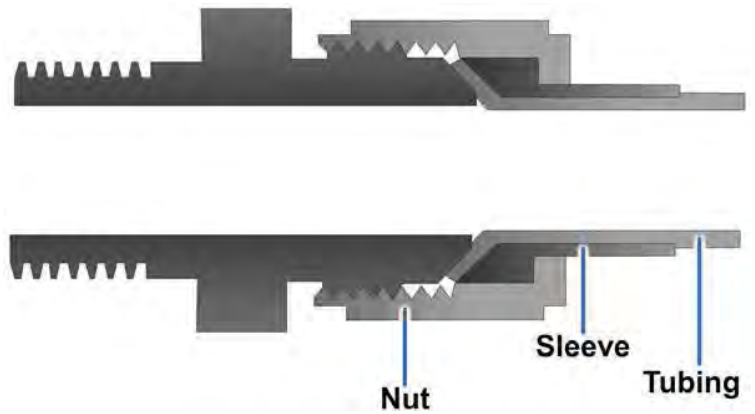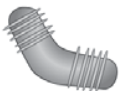

Figure 9-62 — Flared-tube connector.
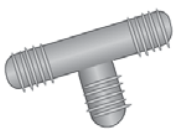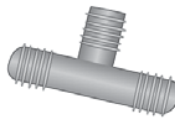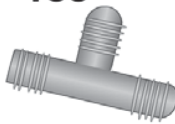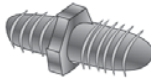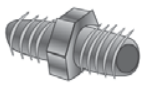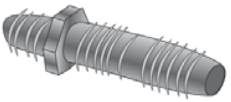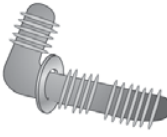
Figure 9-63 —Flared-tube fittings.

Flareless Fittings

Flareless fittings are installed to conserve space and to reduce weight, installation time, and system cleaning time. Do not use flareless fittings if you do not have enough space to properly tighten the nuts or if you have to remove the equipment or piping for access to the fittings. An exception to this rule is a gauge board. It is designed so it may be removed as a unit for repairs or alterations. Do not use flareless fittings where you cannot easily deflect the piping to permit assembly and disassembly.

The flareless-tube connector (*Figure 9-64*) eliminates all tube flaring, yet provides a safe, strong, and dependable tube connection. This connector consists of a fitting, a sleeve or ferrule, and a nut.

Before assembly, ensure the tubing end is square, concentric, and free of burrs. For an effective fitting, be sure the cutting edge of the sleeve or ferrule bites into the periphery of the tube; you can do this by presetting the ferrule.

FLANGE SPRAY SHIELDS

Flange spray shields (*Figure 9-65*) capture any fuel that sprays from a fuel system flanged joint that has developed a leak. The flange shield directs the fuel to drip or dribble to a safe place. Dribbling fuel leaks are much less dangerous than spraying leaks, but repairs of any fuel leak must be accomplished immediately.

PIPE HANGERS

Pipe hangers and supports are designed and located to support the combined weight of the piping, fluid, and insulation. They absorb the movements imposed by thermal expansion of the pipe and the motion of the ship. The pipe hangers and supports prevent excessive vibration of the piping and resilient mounts or other materials.

They are used in the hanger arrangement to break all metal-to-metal contact to lessen unwanted sound transmissions.

One type of pipe hanger you need to become familiar with is the variable spring hanger. This is used to support the ship's bleed air piping. It provides support by directly compressing a spring or springs. The loads carried by the hangers are equalized by adjustment of the hangers when they are hot. These hangers have load scales attached to them with a traveling arm or pointer that moves in a slot alongside the scale. This shows the degree of pipe movement from cold to hot. The cold and hot positions are marked on the load scale. You should check the hangers when they
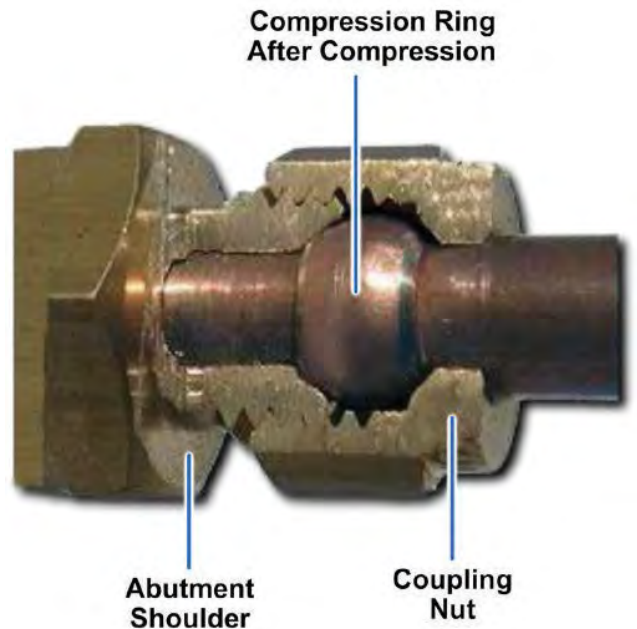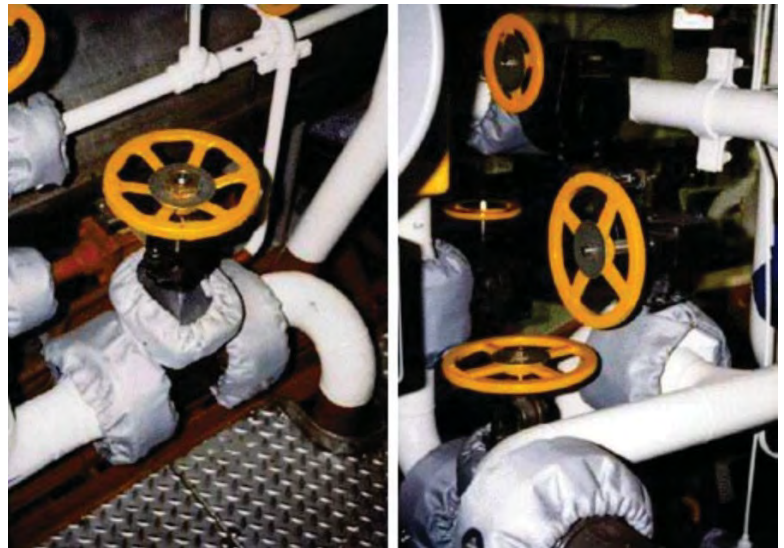
Figure 9-64 — Flareless-tube connector.

Figure 9-65 — Flange spray shields.

are hot to ensure that the pointers line up with the hot position on the load scales. You can adjust hangers that are out of position by loosening the jam nut on the hanger rod and turning the adjusting bolt of the hanger.

INSPECTIONS AND MAINTENANCE

Reasonable care must be given to the various piping assemblies as well as to the units connected to the piping systems. Unless the piping system is in good condition, the connected units of machinery cannot operate efficiently and safely. You should be familiar with all the recommended maintenance procedures and observe the safety precautions when working on piping systems.

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

Piping should be tested at the frequency and test pressure specified following the PMS and the applicable equipment technical manual. Test pressure must be maintained long enough to show any leaks or other defects in the system.

Instruction manuals should be available and followed for the inspection and maintenance of piping systems and associated equipment; however, if the manufacturer's instruction manual is not available, you should refer to the NSTM, chapter 505, for details of piping inspection and maintenance.

PIPING SYSTEM IDENTIFICATION MARKING

All piping should be marked to show the name of the service, destination (where possible), and direction of flow (*Figure 9-66*).

The name of the service and destination should be painted on by stencil or hand lettering, or by application of previously printed, stenciled, or lettered adhesive-backed tape. Lettering will be 1 inch high for a 2-inch or larger outside diameter (OD) bare pipe or insulation. For smaller sizes, lettering size may be reduced or label plates attached by wire or other suitable means.

Figure 9-66 — Pipe markings.

Direction of flow will be indicated by an arrow 3 inches long pointing away from the lettering. For reversible flow, arrows are to be shown on each end of the lettering.

Black is used for lettering and arrows. However, on dark-colored pipe (including oxygen piping), white is used.

Markings will be applied to piping in conspicuous locations, preferably near the control valves and at suitable intervals so every line will have at least one identification marking in each compartment through which it passes. Piping in cabins and officers' wardrooms will not normally be marked.

PACKING AND GASKET MATERIAL

Packing and gasket materials are required to seal joints in steam, water, gas, air, oil, and other lines and to seal connections that slide or rotate under normal operating conditions. There are many types and forms of packing and gasket materials available commercially.
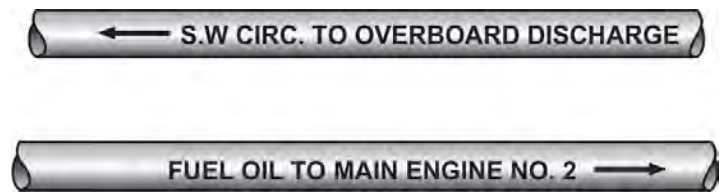
Packing and Gasket Selection

To simplify the selection of packing and gasket materials commonly used in naval service, NAVSEA has prepared a packing and gasket chart, Mechanical Standard Drawing B-153. It shows the symbol numbers and the recommended applications for all types and kinds of packing and gasket materials.

The symbol number used to identify each type of packing and gasket has a four-digit number. The first digit shows the class of service with respect to fixed and moving joints; the numeral 1 shows a moving joint (moving rods, shafts, valve stems), and the numeral 2 shows a fixed joint (flanges, bonnets). The second digit shows the material of which the packing or gasket is primarily composed—asbestos, vegetable fiber, rubber, metal, and so forth. The third and fourth digits show the different styles or forms of the packing or gasket made from the material.

Practically all shipboard packing and gasket problems can be solved by selection of the correct material from the listings on the packing and gasket chart. The following examples show the kind of information that you can get from the packing and gasket chart.

Suppose you are required to repack and install a valve in a 300 psi saturated steam line. By referring to the packing and gasket chart, you will find several materials suitable for repacking the valve:

- Symbol 1103 Asbestos rod, braided, plain
- Symbol 1104 Asbestos rod, braided, wire insertion
- Symbol 1430 Metallic, flexible

Notice that the first digit is 1 in each case, to indicate that the packing is suitable for a moving joint.

To install a valve, you will need suitable gaskets. In this case, the first digit will be 2, indicating that the gasket material is suitable for fixed joints. By referring to the packing and gasket chart, you will find that you can use any of the following gasket materials:

- Symbol 2150 Asbestos, sheet, compressed
- Symbol 2151 Asbestos, metallic, cloth sheet
- Symbol 2410 Gasket, metallic, asbestos, spiral wound

In addition to the standard packing and gasket chart, most ships have a packing and gasket chart made specifically for that ship. The shipboard chart shows the symbol numbers and the sizes of packing and gaskets required in the ship's piping systems, machinery, and hull fittings.

Packing of Moving Joints

Valves are components used to control the transfer of liquids and gases through fluid piping systems. Most valves have moving joints between the valve stem and the bonnet. When fluid is on one or both sides of a moving joint, the joint may leak. Sealing the joint prevents this leakage.
Sealing a moving joint presents a problem because the seal must be tight enough to prevent leakage, yet loose enough to let the valve stem turn without binding. Packing is the most common method of sealing a moving joint.

Packing is a sealing method that uses bulk material (packing) that is reshaped by compression to effectively seal a moving joint. *Figure 9-67* shows graphite filament yarn.

Figure 9-67 — Graphite filament yarn.

Packing is inserted in stuffing boxes that have annular chambers located around valve stems and rotating shafts. The packing material is compressed to the necessary extent and held in place by gland nuts or other devices.

Corrugated ribbon packing (CRP) (*Figure 9-68*) is a relatively new packing material; it is a 100- percent graphite material expressly suited for installation in steam, feed, and condensate valves. CRP contains no binders, resins, fillers, lubricants, or other additives. It has the lubricating quality typical of pure graphite with the capability for rapid heat dissipation, thus reducing wear. Unlike conventional graphite, which is brittle, CRP is flexible and highly resilient. When CRP is formed in a valve stuffing box, it restructures.

This restructuring capability allows CRP to be wrapped around the valve stem in any size valve stuffing box and to be formed into a solid, endless packing ring by compression.

CRP is easily cut to a predetermined length. It does not turn rock-hard or shrink at any temperature. Once installed and after run-in, it normally needs no further adjustment. This means greatly reduced maintenance. The resiliency and no-lint structure of CRP remain unchanged at any temperature. There is no lubricant or additive to be squeezed out, vaporized, or carbonized. Also, it has a long shelf and service life.

Packing of Fixed Joints

Figure 9-69 shows gasket material used for fixed joints. At one time, fixed joints could be satisfactorily sealed with gaskets of compressed asbestos sheet packing (*Figure 9-69, view A*). Today the 15 percent rubber content of the packing makes it unsatisfactory for modern, high-temperature, high-pressure equipment. Two types of gaskets (metallic or semi-metallic) are in use in present day high-temperature and high-pressure installations. Gaskets of corrugated copper or of asbestos and copper are sometimes used on low- and medium-pressure lines.

Serrated-face metal gaskets (*Figure 9-69, view B*) made of steel, Monel, or soft iron have raised serrations to make a better seal at the piping flange joints. These gaskets have resiliency. Line pressure forces the serrated faces tighter against the adjoining flange. The gaskets shown are of two variations.

Figure 9-68 — Corrugated ribbon packing.

Spiral-wound, metallic-asbestos gaskets (*Figure 9-69, view C*) are made of interlocked strands of preformed corrugated metal and asbestos strips, spirally wound together (normally called the filler), and a solid metal outer or centering ring (normally called the retaining ring). The centering ring is used as a reinforcement to prevent blowouts. The filler piece is replaceable. When renewing a gasket, you should remove this piece from the retaining metal ring and replace it with a new filler. Do not discard the solid metal retaining outer or centering ring unless it is damaged. You can compress the gaskets to the thickness of the outer or centering ring.
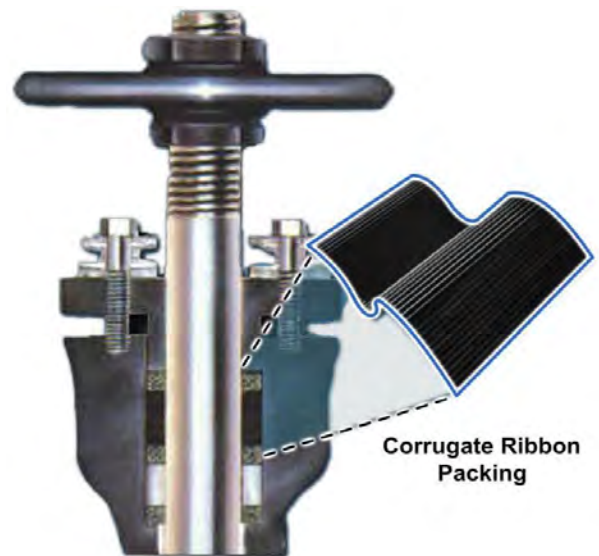
Precautions

When renewing a gasket in a flange joint, you must exercise special precautions when breaking the joint, particularly in steam and hot water lines, or in saltwater lines that have a possibility of direct connection with the sea. Be sure to observe the following precautions:

- No pressure is on the line

- The line pressure valves, including the bypass valves, are firmly secured, wired closed, and tagged

- The line is completely drained

- At least two flange-securing bolts and nuts diametrically opposite remain in place until the others are removed, then slackened to allow breaking of the joint, and removed after the line is clear

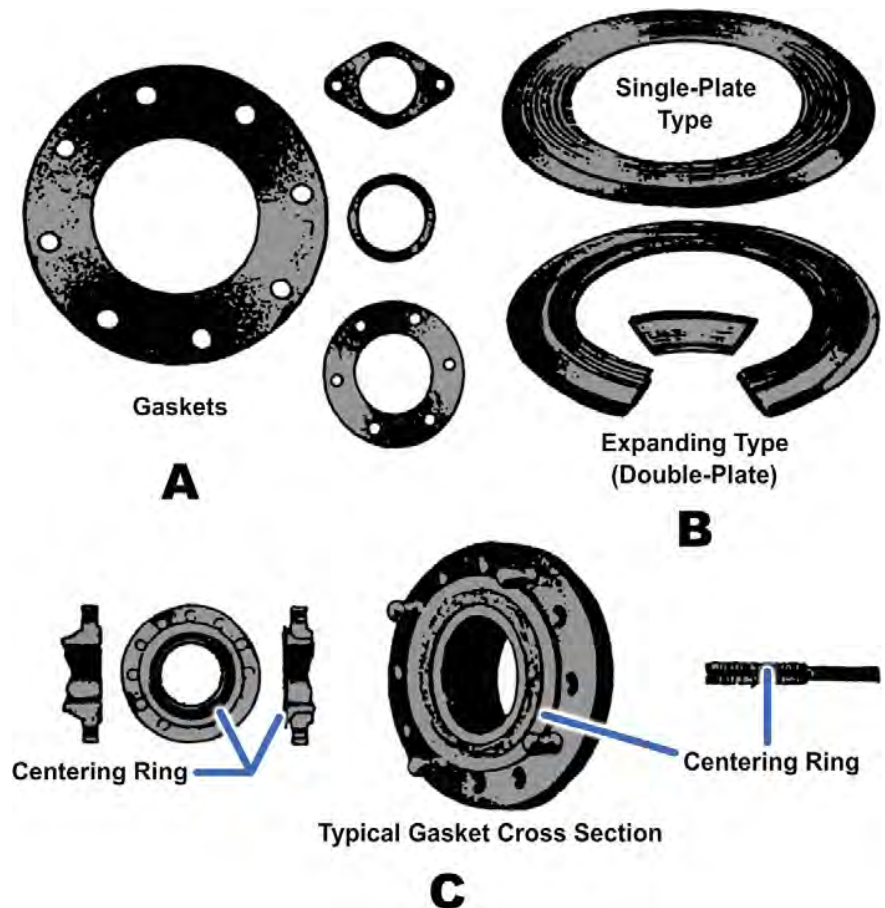- Precautions are taken to prevent explosions or fire when breaking joints of flammable liquid lines

Figure 9-69 — Fixed joint gasket. A. Sheet asbestos gasket. B. Serrated-face metal gasket. C. Spiral-wound, metallic-asbestos gasket.

- Proper ventilation is ensured before joints are broken in closed compartments

These precautions may prevent serious explosions, severe scalding of personnel, or flooding of compartments. You should thoroughly clean all sealing and bearing surfaces for the gasket replacement. Check the gasket seats with a surface plate, and scrape as necessary. This affords uniform contact. Replace all damaged bolt studs and nuts. In flange joints with raised faces, the edges of gaskets may extend beyond the edge of the raised face.

O-RINGS

Another method of preventing leakage in fluid systems is by use of O-ring seals. An O-ring is circular in shape, and its cross section is small in relation to its diameter. O-rings are usually molded from rubber compounds; however, they can be molded or machined from plastic materials. The O-ring is usually fitted into a rectangular groove (usually called a gland) machined into the mechanism to be sealed. An O-ring seal consists of an O-ring mounted in the gland so that the O-ring's cross section is compressed (squeezed) when the gland is assembled (*Figure 9-70*).

When the gland is assembled (*Figure 9-70, view B*), the O-ring cross section is compressed. When installed, the compression of the O-ring cross section enables it to seal low-fluid pressures. The

greater the compression, the greater is the fluid pressure that can be sealed by the O-ring. The pressure of the O-ring against the gland walls equals the pressure caused by the recovery force of the compressed O-ring plus the fluid pressure.

The fluid pressure against the walls of the gland and the stiffness of the O-ring prevent fluid from leaking past the O-ring. If the downstream clearance is large, the O-ring is forced into this clearance (*Figure 9-70, view C*). The stiffness of the O-ring material prevents the O-ring from being forced completely through the downstream clearance unless that clearance is abnormally large or the pressure is excessive.

O-rings are commonly used for sealing because of their simplicity, ruggedness, low cost, ease of installation, ease of maintenance, and effectiveness over wide pressure and temperature ranges. Failure of an O-ring can sometimes begin with the removal of an old O-ring. If you incorrectly remove an O-ring with pointed or sharp tools, you can scratch or dent critical surface finishes that can result in seal failure.

Before installing a new O-ring, inspect the sealing surfaces for any abrasions and wipe them free of any dust, dirt, or other contaminants. Before installation, inspect the O-ring for any damage. If faulty, discard it.

Figure 9-70 — O-ring seal with two cross-sectional views.

When you install the O-ring, lubricate it. In most cases it is already coated with the system fluid or petroleum grease. Do not stretch the O-ring more than twice its original size during installation, and do not roll or twist it into place. This may leave a permanent twist in the O-ring and reduce its effectiveness and shorten its life.

When installing an O-ring, take extreme care to avoid forcing it over sharp edges, corners, and threaded sections. You should use some type of sleeve or cover to avoid damaging the O-ring.

FASTENERS

The proper use of fasteners is very important and cannot be overemphasized. Many shipboard machinery casualties have resulted from fasteners that were not properly installed. Machinery vibration, thermal expansion, and thermal contraction will loosen the fasteners. At sea, loosening effects are increased by the pitch and roll of the ship. You are familiar with such standard fasteners as nuts, bolts, washers, wingnuts, and screws. In this section we will discuss some of the new developments in fastener technology, such as the various types of locknuts, which you may not be familiar with.

Threaded Locking Devices

An important part of fastener technology has included the development of several methods for locking mated threads of fasteners. Many of the latest methods include the locking device or method as an integral part of the fastener assembly and are referred to as self-locking nuts or bolts. Self-locking
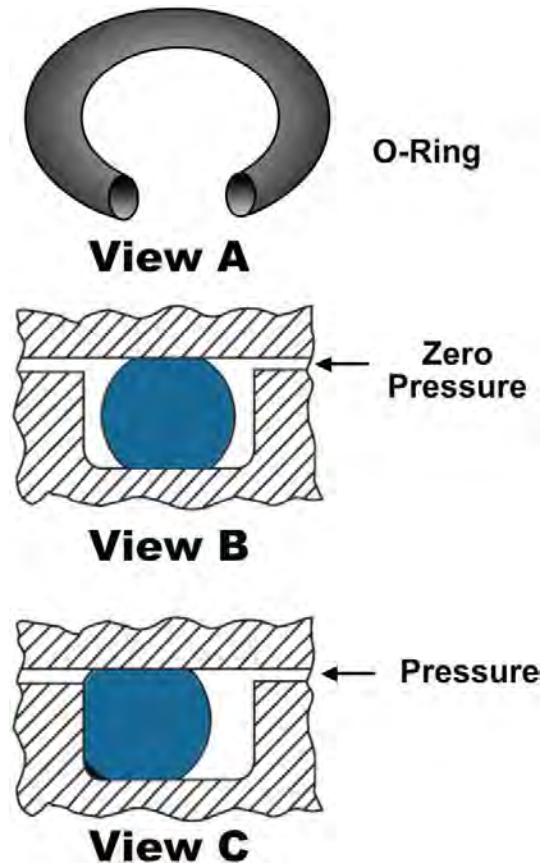
fasteners are more expensive than some older methods but compare favorably in cost with pin or wiring methods.

Length of Protrusion

Male threads on threaded fasteners, when installed and tightened, will protrude the distance of at least one thread length beyond the top of the nut or plastic locking ring. Excessive protrusion is a hazard, particularly where necessary clearances, accessibility, and safety are important. Where practicable, the number of threads protruding should not exceed five. In no case should thread protrusion exceed 10 threads unless specifically approved by the work supervisor. (This is the 1-to-10 rule.)

Where screw threads are used for setting or adjusting (such as valve stem packing glands and travel stops) or where installed threaded fasteners do not strictly follow the 1-to-10 rule but have given satisfactory service, the rule does not apply. An example of an acceptable existing installation would be where a male thread is flush with the top of a nut or where more than 10 threads protruding is of no foreseeable consequence.

Repair of Damaged Threads

You can remedy damaged external threads by replacing the fastener. In large equipment castings, you must repair damaged internal threads to save the part. You can repair internal threads by redrilling the damaged thread; clean and either install a solid wall insert or tap for a helical coil insert. These inserts, in effect, return the tapped hole to its original size so it takes the original mating fastener.

Locknuts

Locknuts are used in special applications where you want to ensure that the components joined by the fasteners will not loosen. Two types of locknuts are in common use. The first type applies pressure to the bolt thread and can be used where frequent removal may be required. The second type deforms the bolt thread and is used only where frequent removal is unnecessary. The first type includes nonself-locking, self-locking, plain hex, castle, castellated, and check nuts. The second type includes distorted collar nuts and distorted thread nuts; they are not commonly found in gas turbine equipment and will not be covered in this section.

Nonself-Locking Nuts

Nonself-locking nuts require the use of a separate locking device for security of installation. There are several types of these locking devices mentioned in the following paragraphs in connection with the nuts on which they are used. Since no single locking device can be used with all types of nonself-locking nuts, one must be selected that is suitable for the type of nut being used.

Self-Locking Nuts

Self-locking nuts provide tight connections that will not loosen under vibrations. Self-locking nuts approved for use on aircraft meet critical strength, corrosion-resistance, and temperature specifications. The two major types of self-locking nuts are prevailing torque and free spinning. The two general types of prevailing torque nuts are the all-metal nuts and the nonmetallic insert nuts. New self-locking nuts must be used each time components are installed in critical areas throughout the entire aircraft, including all flight, engine, and fuel control linkage and attachments. The flexloc nut is an example of the all-metal type. The elastic stop nut is an example of the nonmetallic insert type. All-metal self-locking nuts are constructed with the threads in the load-carrying portion of the nut out of phase with the threads in the locking portion, or with a saw cut top portion with a pinched-in thread.

The locking action of these types depends upon the resiliency of the metal when the locking section and load-carrying section are forced into alignment when engaged by the bolt or screw threads.

Plain Hex Nuts

These nuts are available in self-locking or nonself-locking styles. When the nonself-locking nuts are used, they should be locked with an auxiliary locking device such as a check nut or lock washer (*Figure 9-71*).

Castle Nuts

These nuts are used with drilled shank bolts, hex-head bolts, clevis bolts, eyebolts, and drilled-head studs. These nuts are designed to be secured with cotter pins or safety wire.

Castellated Nuts

Like the castle nuts, these nuts are castellated for safety. They are not as strong or cut as deep as the castle nuts.

Figure 9-71 — Nuts.

Check Nuts

These nuts are used in locking devices for nonself-locking plain hex nuts, setscrews, and threaded rod ends.

Lock washers

Many installations on board naval ships still use lock washers to prevent threaded fasteners from loosening. If loosening has not been a problem, you may replace worn lock washers with an identical type; however, if loosening has been a problem, you should use self-locking fasteners instead of lock washers.

The most common lock washer used is the helical spring washer. Other types are the conical and toothed tab.

Helical Spring Lock washers

The helical spring lock washer (split ring) (*Figure 9-72*) is flattened when the bolt is torqued down. When torqued, it acts as a flat washer contributing normal friction for locking the screw or bolt and the working surface; it also maintains the tension on the bolt. Because of the helical spring lock washer's small diameter, it is usually not used on soft materials or with oversized or elongated holes.

Figure 9-72 — Helical spring lockwasher.

Curved or Conical Spring Lock washers

Curved or conical spring lock washers have almost the same properties as the helical spring lock washer. They provide a constant tension on the bolt or screw when loosened. The tension produced is usually less than that produced by the helical spring lock washer. Like any locking device relying on tension, spring lock washers may loosen on shock loading. When the bolt stretches more

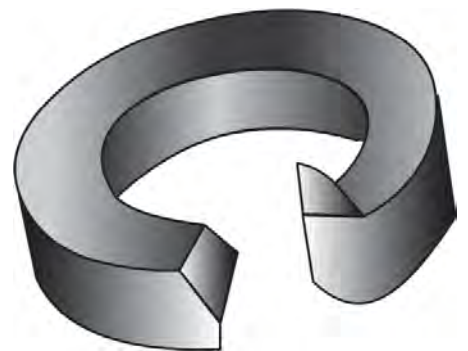than the spring distortion from the shock loading, the washer serves no further purpose. Recheck the washer, where possible, when shock is sufficient to suspect loosening. Some spring lock washers have teeth on the outer edge. These teeth do not aid in locking, but they prevent side slippage and turning.

Toothed Lock washers

Toothed lock washers (*Figure 9-73*) have teeth that are twisted or bent to prevent loosening. Cutting edges engage both working surfaces on the nut and bolt or screw. Some have teeth on the inner diameter for applications where teeth projecting beyond the nut are not desired. The most common type has teeth on the outer diameter. Washers with teeth on both inside and outside diameters are used for soft materials and oversize holes. The teeth are twisted, so as the nut is installed and torqued down, the rim of the washer supports the pressure. Any backing off of the nut or bolt releases tension that allows the teeth to dig into the working surfaces of the nut and bolt.
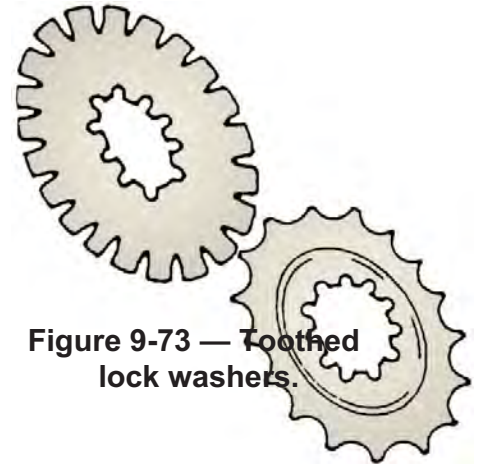

Figure 9-73 — Toothed lock washers.

INSULATION

The purpose of insulation is to retard the transfer of heat from piping that is hotter than the surrounding atmosphere or to piping that is cooler than the surrounding atmosphere. Insulation helps to maintain the desired temperatures in all systems. In addition, it prevents sweating of piping that carries cool or cold fluids. Insulation also serves to protect personnel from being burned by coming in contact with hot surfaces. Piping insulation represents the composite piping covering, which consists of the insulating material, lagging, and fastening. The insulating material offers resistance to the flow of heat; the lagging, usually of painted canvas, is the protective and confining covering placed over the insulating materials; and the fastening attaches the insulating material to the piping and to the lagging.

Insulation covers a wide range of temperatures, from the extremely low temperatures of the refrigerating plants to the very high temperatures of the ship's waste heat boilers. No one material could possibly be used to meet all the conditions with the same efficiency.

Insulation Materials

The following quality requirements for the various insulating materials are taken into consideration by the Navy in the standardization of these materials:

- Low heat conductivity

- Noncombustibility

- Lightweight

- Easy molding and installation capability

- Moisture repellant

- Noncorrosive, insoluble, and chemically inactive

- Composition, structure, and insulating properties unchanged by temperatures at which it is to be used

- Once installed, should not cluster, become lumpy, disintegrate, or build up in masses from vibration

- Vermin proof

- Hygienically safe to handle

The insulating cements are comprised of a variety of materials, differing widely among themselves as to heat conductivity, weight, and other physical characteristics. Typical of these variations are the asbestos substitute cements, diatomaceous cements, and mineral and slag wool cements. These cements are less efficient than other high-temperature insulating materials, but they are valuable for patchwork emergency repairs and for covering small irregular surfaces (valves, flanges, joints, and so forth). Additionally, the cements are used for a surface finish over block or sheet forms of insulation, to seal joints between the blocks, and to provide a smooth finish over which asbestos substitute or glass cloth lagging may be applied.

Flange Safety Shields

A fire in the engine room can be caused by a leak at a fuel or lube oil pipe-flange connection. Even the smallest leak can spray fine droplets of lube oil or fuel on nearby hot surfaces, such as the exhaust manifold of a diesel engine. To reduce this possibility, spray shields (flange safety shields) are installed on piping flanges of flammable liquid systems, especially in areas where the fire hazard is apparent (*Figure 9-74*).

The spray shields are usually made of aluminized glass cloth and are simply wrapped and wired around the flange.

Removable Insulation

Removable insulation will be found on the bleed air systems and waste heat boiler systems. Removable insulation is also installed in the following locations:

Figure 9-74 — Flange safety shields.

- Flange pipe joints adjacent to machinery or equipment that must be broken when units are opened for inspection or overhaul

- Valve bonnets of valves larger than 2 inches internal pipe size (IPS) that operate at 300 psi and above or at 240 °F and above

- All pressure-reducing and pressure-regulating valves, pump pressure governors, and strainer bonnets

General Insulation Precautions

You should observe the following general precautions relative to the application and maintenance of insulation:

- Fill and seal all air pockets and cracks. Failure to do this will cause large losses in the effectiveness of the insulation
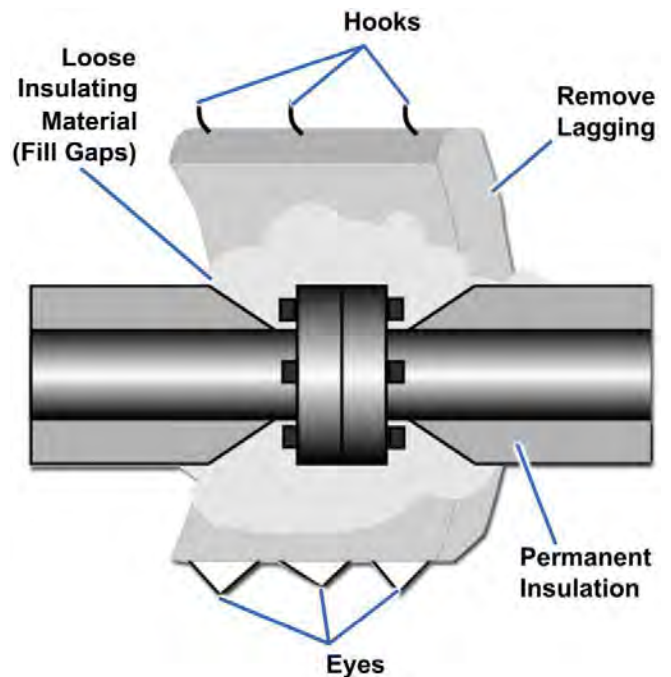
- Seal the ends of the insulation and taper off to a smooth, airtight joint. At joint ends or other points where insulation is liable to be damaged, use sheet metal lagging over the insulation. You should cuff flanges and joints with 6-inch lagging

- Keep moisture out of all insulation work. Moisture is an enemy of heat insulation just as much as it is in electrical insulation. Any dampness increases the conductivity of all heat-insulating materials

- Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting; otherwise, a considerable quantity of heat will be lost via conduction through the support

- Keep sheet metal covering bright and unpainted unless the protective surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects

- Once installed, heat insulation requires careful inspection, upkeep, and repair. Replace lagging and insulation removed to make repairs as carefully as when originally installed. When replacing insulation, make certain that the replacement material is of the same type as had been used originally

- Insulate all flanges with easily removable forms. These forms are made up as pads of insulating material, wired or bound in place, and the whole covered with sheet metal casings, which are in halves

- Asbestos control: Inhalation of excessive quantities of asbestos fiber or filler can produce severe lung damage in the form of disabling or fatal fibrosis of the lungs. Asbestos has also been found to be a casual factor in the development of cancer of the membrane lining the chest and abdomen. Lung damage and disease usually develop slowly and often do not become apparent until years after the initial exposure. If your plans include a long and healthy Navy retirement, you have no business doing asbestos lagging rip-out without proper training, protective clothing, and supervision. Most systems of today's modern Navy have been purged of asbestos and an asbestos substitute material installed in its place. Some of the older class vessels may still have some asbestos insulation installed. Use caution when handling lagging and insulation from these vessels. If in doubt, contact your supervisor and request the medical department conduct a survey of the material in question

SUMMARY

This chapter has given you general information on pumps, valves, and piping. It would be a good idea to get some hands-on experience aboard your ship. Trace various systems out and see how they are set up. Ask your LPO to explain the systems and how each part in the system works. The key phrase here is ASK QUESTIONS!

Additional Resources and References:

Construction Mechanic Basic, NAVEDTRA 14264A, Center for Seabees and Facilities Engineering (CSFE), Port Hueneme, CA, October 2010.

Engineman, NAVEDTRA 14075A, Surface Warfare Officers School (SWOS), Newport, RI, September 2013.

"Gaskets and Packing," *Naval Ships' Technical Manual (NSTM)*, Chapter 078, Volume 2, Naval Sea Systems Command (NAVSEA), Washington, DC, September 1998.

Hull Maintenance Technician, NAVEDTRA 14119, Surface Warfare Officers School (SWOS), Newport, RI, June 1995.

Machinist's Mate (Surface), NAVEDTRA 14150A, Surface Warfare Officers School (SWOS), Newport, RI, September 2013.

"Piping Systems," *Naval Ships' Technical Manual (NSTM),* Chapter 505, Naval Sea Systems Command (NAVSEA), Washington, DC, April 2013.

"Pumps," *Naval Ships' Technical Manual (NSTM),* Chapter 503, Naval Sea Systems Command (NAVSEA), Washington, DC, January 2009.