
ENGINEERING

SEA TERM 2016

EN-2231 Sea Term II - Engine Third Class Cadet Marine Engineering Lab Program

Massachusetts Maritime Academy
Buzzards Bay, Massachusetts

January 2016

Third Class Maintenance Training U.S.T.S. Kennedy

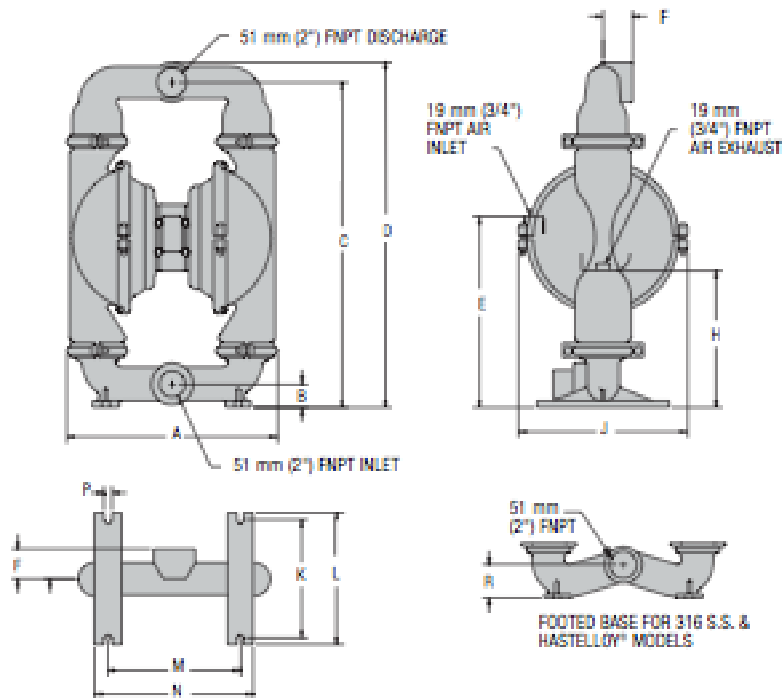
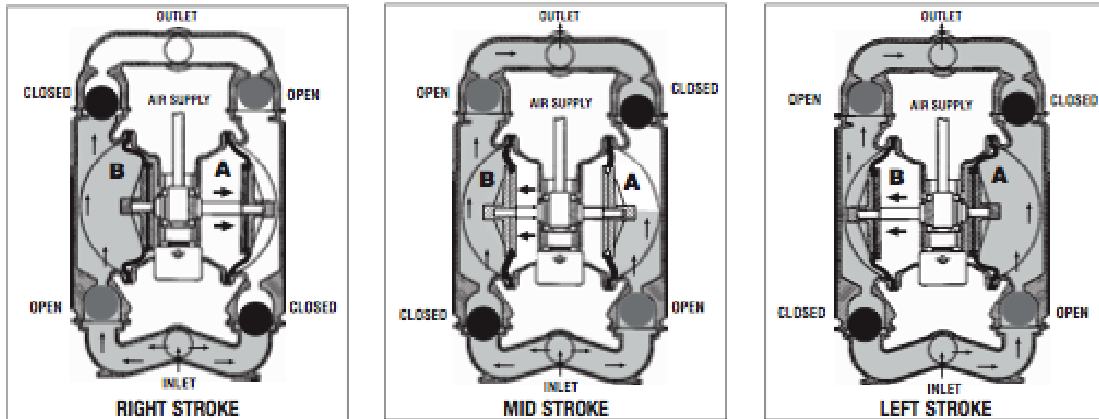
Table of Contents

| | |
|---|----|
| Lab #1 - Operation and Maintenance of the Wilden Diaphragm Pump | 5 |
| Lab #2 - Hydronic Zone Control Valve System..... | 23 |
| Lab #3 - Gauge Glass Maintenance | 29 |
| Lab #4 - Valve Manifold and Valve Maintenance..... | 39 |
| Lab #5 - Pump Alignment | 49 |
| Lab #6 - Gear Pump Maintenance | 69 |
| Lab #7 - Heat Exchangers..... | 83 |
| Notes | 95 |

Lab #1 - Operation and Maintenance of the Wilden Diaphragm Pump

THE WILDEN PUMP — HOW IT WORKS

The Wilden diaphragm pump is an air-operated, positive displacement, self-priming pump. These drawings show the flow pattern through the pump upon its initial stroke. It is assumed the pump has no fluid in it prior to its initial stroke.



Massachusetts Maritime Academy
Third Class Maintenance Training

Operation and Maintenance of the Wilden Diaphragm Pump

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the operation of the Wilden Diaphragm Pump
2. Breaks down, cleans, and reassembles the Wilden Diaphragm Pump
3. Tests the Wilden Diaphragm Pump after reassembly and maintenance
4. Places the Wilden Diaphragm Pump into service.

Special Tools and Equipment supplied by the Marine Engineering Department:

- ☉ Wilden Diaphragm Pump
- ☉ Gaskets and maintenance equipment specific to the Wilden Diaphragm Pump

Basic hand tools are supplied by 3rd class cadets as required¹.

Discussion²

Wilden's legendary Original™ Series pumps were designed for demanding utilitarian type of applications that require a robust design. The clamped configuration is a classic design that evolved from 1955 with the invention of Jim Wilden's first air operated double diaphragm pump. The Original™ Series pumps ensure reliability without sacrificing ease of maintenance. Wilden's metal pump line lends itself to various processes and waste applications. Wilden also offers a multitude of elastomer options including Teflon® PTFE, to meet your abrasion, temperature, and chemical compatibility concerns.

Wilden diaphragm pumps are used in many demanding roles aboard the training ship, most notably as permanently mounted bilge pumps and portable de-watering pumps. Because the pumps are exclusively air operated, they can be used in areas that would make electrically operated pumps hazardous. The ability to quickly and effectively place this pump into service or remove, maintain, and return the pump to service is the subject of the laboratory project presented here.

Wilden pumps have excelled in difficult fluid transfer applications where other pump types have failed. Wilden's success is attributed to inherent pump features which include: intrinsic safety, deadhead capability, the ability to run dry and self-prime, and ease of operation and maintenance.

As air-operated pump technology is refined, the Wilden pump is being placed in process applications requiring liquid transfer on demand. Liquid transfer must be initiated and concluded without hesitation to assure process integrity.

¹ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

² Courtesy Wilden Pump & Engineering Company

The Wilden Pump – How It Works

The Wilden diaphragm pump is an air-operated, positive displacement, self-priming pump. These drawings show flow pattern through the pump upon its initial stroke. It is assumed the pump has no fluid in it prior to its initial stroke.

THE WILDEN PUMP — HOW IT WORKS

The Wilden diaphragm pump is an air-operated, positive displacement, self-priming pump. These drawings show the flow pattern through the pump upon its initial stroke. It is assumed the pump has no fluid in it prior to its initial stroke.

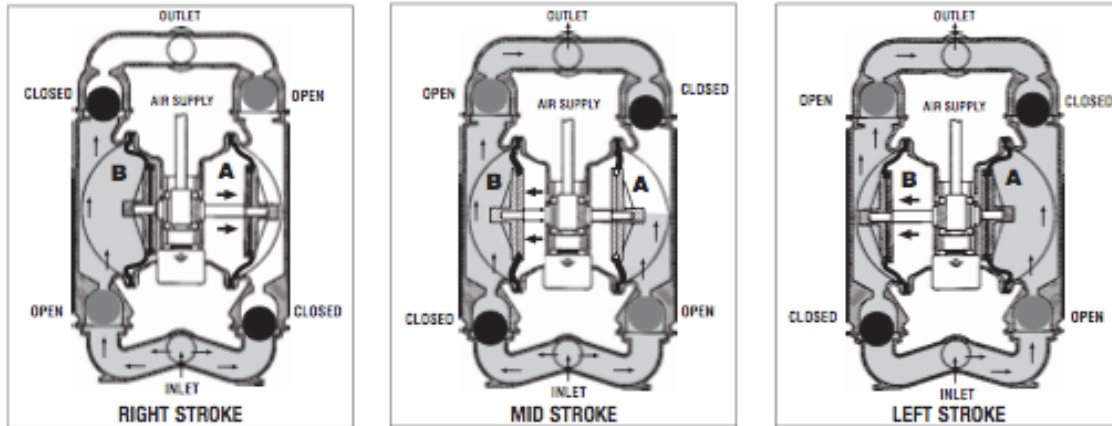


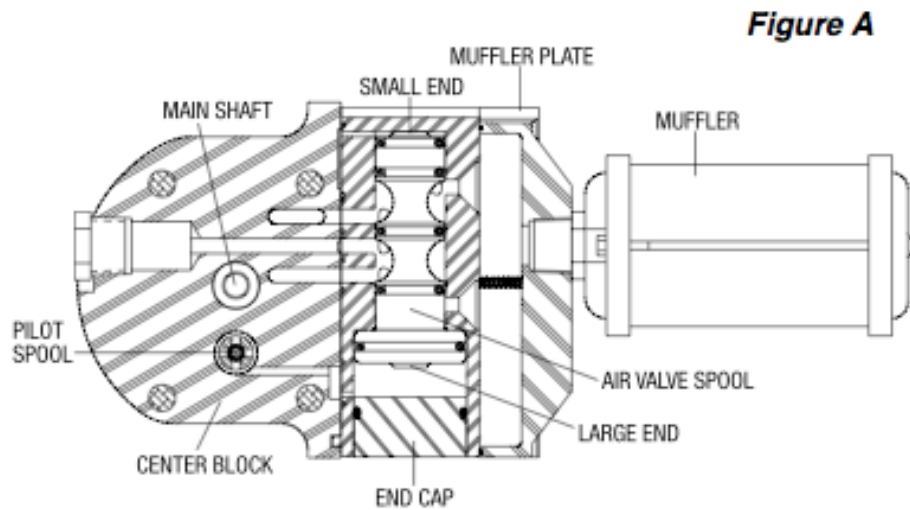
FIGURE 1 The air valve directs pressurized air to the back side of diaphragm A. The compressed air is applied directly to the liquid column separated by elastomeric diaphragms. The diaphragm acts as a separation membrane between the compressed air and liquid, balancing the load and removing mechanical stress from the diaphragm. The compressed air moves the diaphragm away from the center block of the pump. The opposite diaphragm is pulled in by the shaft connected to the pressurized diaphragm. Diaphragm B is on its suction stroke; air behind the diaphragm has been forced out to the atmosphere through the exhaust port of the pump. The movement of diaphragm B toward the center block of the pump creates a vacuum within chamber B. Atmospheric pressure forces fluid into the inlet manifold forcing the inlet valve ball off its seat. Liquid is free to move past the inlet valve ball and fill the liquid chamber (see shaded area).

FIGURE 2 When the pressurized diaphragm, diaphragm A, reaches the limit of its discharge stroke, the air valve redirects pressurized air to the back side of diaphragm B. The pressurized air forces diaphragm B away from the center block while pulling diaphragm A to the center block. Diaphragm B is now on its discharge stroke. Diaphragm B forces the inlet valve ball onto its seat due to the hydraulic forces developed in the liquid chamber and manifold of the pump. These same hydraulic forces lift the discharge valve ball off its seat, while the opposite discharge valve ball is forced onto its seat, forcing fluid to flow through the pump discharge. The movement of diaphragm A toward the center block of the pump creates a vacuum within liquid chamber A. Atmospheric pressure forces fluid into the inlet manifold of the pump. The inlet valve ball is forced off its seat allowing the fluid being pumped to fill the liquid chamber.

FIGURE 3 At completion of the stroke, the air valve again redirects air to the back side of diaphragm A, which starts diaphragm B on its exhaust stroke. As the pump reaches its original starting point, each diaphragm has gone through one exhaust and one discharge stroke. This constitutes one complete pumping cycle. The pump may take several cycles to completely prime depending on the conditions of the application.

Air Distribution System Operation – How It Works

The Pro-Flo patented air distribution system incorporates three moving parts: the air valve spool, the pilot spool, and the main shaft/diaphragm assembly. The heart of the system is the air valve spool and air valve. As shown in Figure A, this valve design



incorporates an unbalanced spool. The smaller end of the spool is pressurized continuously, while the large end is alternately pressurized then exhausted to move the spool. The spool directs pressurized air to one air chamber while exhausting the other. The air causes the main shaft/diaphragm assembly to shift to one side — discharging liquid on that side and pulling liquid in on the other side. When the shaft reaches the end of its stroke, the inner piston actuates the pilot spool, which pressurizes and exhausts the large end of the air valve spool. The repositioning of the air valve spool routes the air to the other air chamber.

Wilden Pump Safety Precautions

- **Warning:** Prevention of static sparking — If static sparking occurs, fire or explosion could result. Pump, valves, and containers must be grounded to a proper grounding point when handling flammable fluids and whenever discharge of static electricity is a hazard.
- **Caution:** Do not apply compressed air to the exhaust port — pump will not function.
- **Caution:** Do not over-lubricate air supply — excess lubrication will reduce pump performance. Pump is prelubed.
- **Caution:** When choosing pump materials, be sure to check the temperature limits for all wetted components.
- **Caution:** Maximum temperature limits are based upon mechanical stress only. Certain chemicals will significantly reduce maximum safe operating temperatures.
- **Caution:** Do not exceed 125 psig air supply pressure.
- **Caution:** The P8 Pro-Flo® is not submersible. If your application requires the pump to be submersed, the T8 model can be used.
- **Caution:** Tighten all hardware prior to installation.

Massachusetts Maritime Academy Third Class Maintenance Training

- **Caution:** The process fluid and cleaning fluids must be chemically compatible with all wetted pump components
- **Caution:** Always wear safety glasses when operating pump. If diaphragm rupture occurs, material being pumped may be forced out air exhaust.
- **Caution:** Before any maintenance or repair is attempted, the compressed air line to the pump should be disconnected and all air pressure allowed to bleed from pump. Disconnect all intake, discharge and air lines. Drain the pump by turning it upside down and allowing any fluid to flow into a suitable container.
- **Caution:** Blow out air line for 10 to 20 seconds before attaching to pump to make sure all pipeline debris is clear. Use an in-line air filter. A5 μ (micron) air filter is suggested.
- * **NOTE:** When installing Teflon diaphragms, it is important to tighten outer pistons simultaneously (turning in opposite directions) to ensure tight fit.
- * **NOTE:** Before starting disassembly, mark a line from each liquid chamber to its corresponding air chamber. This line will assist in proper alignment during reassembly.

INSTALLATION

The P8 Pro-Flo model has a 51 mm (2") inlet and 51 mm (2") outlet and is designed for flows to 496 131 gpm. The P8 Metal pump is manufactured with wetted parts of 316 Stainless Steel, and Hastelloy. The center block of the P8 Metal is constructed of polypropylene. A variety of diaphragms, valve balls, valve seats and O-rings are available to satisfy temperature, chemical compatibility, abrasion and flex concerns.

The suction pipe size should be at least 51 mm (2") diameter or larger if highly viscous material is being pumped. The suction hose must be non-collapsible, reinforced type as the P8 is capable of pulling a high vacuum. Discharge piping should be at least 51 mm (2"); larger diameter can be used to reduce friction losses. It is critical that all fittings and connections are airtight or a reduction or loss of pump suction capability will result.

INSTALLATION: Months of careful planning, study, and selection efforts can result in unsatisfactory pump performance if installation details are left to chance. Premature failure and long term dissatisfaction can be avoided if reasonable care is exercised throughout the installation process.

LOCATION: Noise, safety, and other logistical factors usually dictate where equipment will be situated on the production floor. Multiple installations with conflicting requirements can result in congestion of utility areas, leaving few choices for additional pumps. Within the framework of these and other existing conditions, every pump should be located in such a way that key factors are balanced against each other to maximum advantage.

- **ACCESS:** First of all, the location should be accessible. If it's easy to reach the pump, maintenance personnel will have an easier time carrying out routine inspections and adjustments. Should major repairs become necessary, ease of access can play a key role in speeding the repair process and reducing total downtime.

Massachusetts Maritime Academy Third Class Maintenance Training

- ❑ **AIR SUPPLY:** Every pump location should have an air line large enough to supply the volume of air necessary to achieve the desired pumping rate. Use air pressure up to a maximum of 8.6 bar (125 psig) depending on pumping requirements. For best results, the pumps should use a 5 micron air filter, needle valve and regulator. The use of an air filter before the pump will ensure that the majority of any pipeline contaminants will be eliminated.
- ❑ **SOLENOID OPERATION:** When operation is controlled by a solenoid valve in the air line, three-way valves should be used. This valve allows trapped air between the valve and the pump to bleed off which improves pump performance. Pumping volume can be determined by counting the number of strokes per minute and then multiplying the figure by the displacement per stroke.
- ❑ **MUFFLER:** Sound levels are reduced below OSHA specifications using the standard Wilden muffler. Other mufflers can be used to further reduce sound levels, but they usually reduce pump performance.
- ❑ **ELEVATION:** Selecting a site that is well within the pump's dynamic lift capability will assure that loss-of-prime troubles will be eliminated. In addition, pump efficiency can be adversely affected if proper attention is not given to site location.
- ❑ **PIPING:** Final determination of the pump site should not be made until the piping problems of each possible location have been evaluated. The impact of current and future installations should be considered ahead of time to make sure that inadvertent restrictions are not created for any remaining sites. The best choice possible will be a site involving the shortest and straightest hook-up of suction and discharge piping. Unnecessary elbows, bends, and fittings should be avoided. Pipe sizes should be selected so as to keep friction losses within practical limits. All piping should be supported independently of the pump. In addition, the piping should be aligned so as to avoid placing stress on the pump fittings.

Flexible hose can be installed to aid in absorbing the forces created by the natural reciprocating action of the pump. If the pump is to be bolted down to a solid location, a mounting pad placed between the pump and the foundation will assist in minimizing pump vibration. Flexible connections between the pump and rigid piping will also assist in minimizing pump vibration. If quick-closing valves are installed at any point in the discharge system, or if pulsation within a system becomes a problem, a surge suppressor should be installed to protect the pump, piping and gauges from surges and water hammer.

If the pump is to be used in a self-priming application, be sure that all connections are airtight and that the suction lift is within the model's ability. Note: Materials of construction and elastomer material have an effect on suction lift parameters.

When pumps are installed in applications involving flooded suction or suction head pressures, a gate valve should be installed in the suction line to permit closing of the line for pump service.

Pumps in service with a positive suction head are most efficient when inlet pressure is limited to 0.5–0.7 bar (7–10 psig). Premature diaphragm failure may occur if positive suction is .68 bar (10 psig) and higher.

Massachusetts Maritime Academy Third Class Maintenance Training

The model P8 will pass 4.8 mm (0.19”) solids. Whenever the possibility exists that larger solid objects may be sucked into the pump, a strainer should be used on the suction line. P8 pumps cannot be submerged. For submerged applications, use a Wilden T8 pump.

To stop the pump from operating in an emergency situation, simply close the shut off valve (user supplied) installed in the air supply line. A properly functioning valve will stop the air supply to the pump, therefore stopping output. This shut off valve should be located far enough away from the pumping equipment such that it can be reached safely in an emergency situation. NOTE: In the event of a power failure, the shut off valve should be closed, if the restarting of the pump is not desirable once power is regained.

Suggested Operation And Maintenance Instructions

OPERATION: The P8 is pre-lubricated, and does not require in-line lubrication. Additional lubrication will not damage the pump, however if the pump is heavily lubricated by an external source, the pump’s internal lubrication may be washed away. If the pump is then moved to a non-lubricated location, it may need to be disassembled and re-lubricated as described in the ASSEMBLY/DISASSEMBLY INSTRUCTIONS. Pump discharge rate can be controlled by limiting the volume and/or pressure of the air supply to the pump (preferred method). An air regulator is used to regulate air pressure. A needle valve is used to regulate volume. Pump discharge rate can also be controlled by throttling the pump discharge by partially closing a valve in the discharge line of the pump. This action increases friction loss which reduces flow rate. This is useful when the need exists to control the pump from a remote location. When the pump discharge pressure equals or exceeds the air supply pressure, the pump will stop; no bypass or pressure relief valve is needed, and pump damage will not occur. The pump has reached a “deadhead” situation and can be restarted by reducing the fluid discharge pressure or increasing the air inlet pressure. The Wilden P8 pump runs solely on compressed air and does not generate heat, therefore your process fluid temperature will not be affected.

MAINTENANCE AND INSPECTIONS: Since each application is unique, maintenance schedules may be different for every pump. Frequency of use, line pressure, viscosity and abrasiveness of process fluid all affect the parts life of a Wilden pump. Periodic inspections have been found to offer the best means for preventing unscheduled pump downtime. Personnel familiar with the pump’s construction and service should be informed of any abnormalities that are detected during operation.

RECORDS: When service is required, a record should be made of all necessary repairs and replacements. Over a period of time, such records can become a valuable tool for predicting and preventing future maintenance problems and unscheduled downtime. In addition, accurate records make it possible to identify pumps that are poorly suited to their applications.

Massachusetts Maritime Academy
Third Class Maintenance Training

TROUBLESHOOTING

Pump will not run or runs slowly.

1. Ensure that the air inlet pressure is at least .4 bar (5 psig) above startup pressure and that the differential pressure (the difference between air inlet and liquid discharge pressures) is not less than .7 bar (10 psig).
2. Check air inlet filter for debris (see recommended installation).
3. Check for extreme air leakage (blow by) which would indicate worn seals/bores in the air valve, pilot spool, main shaft.
4. Disassemble pump and check for obstructions in the air passageways or objects which would obstruct the movement of internal parts.
5. Check for sticking ball check valves. If material being pumped is not compatible with pump elastomers, swelling may occur. Replace ball check valves and seals with proper elastomers. Also, as the check valve balls wear out, they become smaller and can become stuck in the seats. In this case, replace balls and seats.
6. Check for broken inner piston which will cause the air valve spool to be unable to shift.
7. Remove plug from pilot spool exhaust.

Pump runs but little or no product flows.

1. Check for pump cavitation; slow pump speed down to allow thick material to flow into liquid chambers.
2. Verify that vacuum required to lift liquid is not greater than the vapor pressure of the material being pumped (cavitation).
3. Check for sticking ball check valves. If material being pumped is not compatible with pump elastomers, swelling may occur. Replace ball check valves and seals with proper elastomers. Also, as the check valve balls wear out, they become smaller and can become stuck in the seats. In this case, replace balls and seats.

Pump air valve freezes.

1. Check for excessive moisture in compressed air. Either install a dryer or hot air generator for compressed air. Alternatively, a coalescing filter may be used to remove the water from the compressed air in some applications. Air bubbles in pump discharge.
2. Check for ruptured diaphragm.
3. Check tightness of outer pistons (refer to Section 8C).
4. Check tightness of clamp bands and integrity of o-rings and seals, especially at intake manifold.
5. Ensure pipe connections are airtight.

Product comes out air exhaust.

1. Check for diaphragm rupture.
2. Check tightness of outer pistons to shaft.

Model P8 Metal Directions For Disassembly & Reassembly

Disassembly:

Step 1: (Figure 1)

Before starting disassembly, mark a line from each liquid chamber to its corresponding air chamber. This line will assist in proper alignment during reassembly.

CAUTION: Before any maintenance or repair is attempted, the compressed air line to the pump should be disconnected and all air pressure allowed to bleed from the pump.

Disconnect all intake, discharge, and air lines. Drain the pump by turning it upside down and allowing any fluid to flow into a suitable container. Be aware of any hazardous effects of contact with your process fluid. The Wilden P8 metal pump has a 51 mm (2") inlet and 51 mm (2") outlet and is designed for flows up to 496 lpm (131 gpm). Its air distribution system is based on a revolutionary design which increases reliability and performance. The model P8 is available in 316 Stainless Steel, or Hastelloy wetted parts. For highly corrosive applications, polypropylene and PVDF models are available.

NOTE: The model photographed for these instructions incorporates rubber diaphragms, balls, and seats. Models with Teflon diaphragms, balls and seats are the same except where noted.

Step 2: (Figure 2)

Utilizing a 13 mm (1/2") wrench, remove the two small clamp bands that fasten the discharge manifold to the liquid chambers.

Step 3: (Figure 3)

Remove the discharge manifold to expose the valve balls and seats. Inspect ball cage area of manifold for excessive wear or damage.

| Tools Required |
|---------------------------|
| 11 mm (7/16") Wrench |
| 13 mm (1/2") Wrench |
| 5 mm (3/16") Allen Wrench |
| 6 mm (7/32") Allen Wrench |
| Adjustable Wrench |
| Vise equipped w/soft jaws |

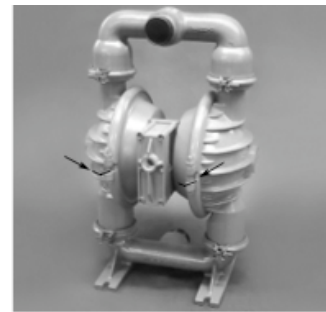


Figure 1



Figure 2

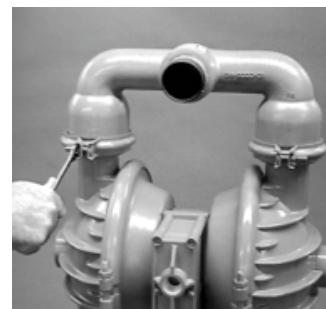


Figure 3

Massachusetts Maritime Academy
Third Class Maintenance Training

Step 4: (Figure 4) Remove the discharge valve balls and seats from the liquid chambers and inspect for nicks, chemical attack or abrasive wear. Replace worn parts with genuine Wilden parts for reliable performance.



Figure 4

Step 5: (Figure 5) Remove the two small clamp bands which fasten the intake manifold to the liquid chambers.

Step 6: (Figure 6) Lift liquid chambers and center section from intake manifold to expose intake valve balls and seats. Inspect ball cage area of liquid chamber for excessive wear or damage.

Step 7: (Figure 7) Remove one set of large clamp bands which secure one liquid chamber to the center section.



Figure 5



Figure 6

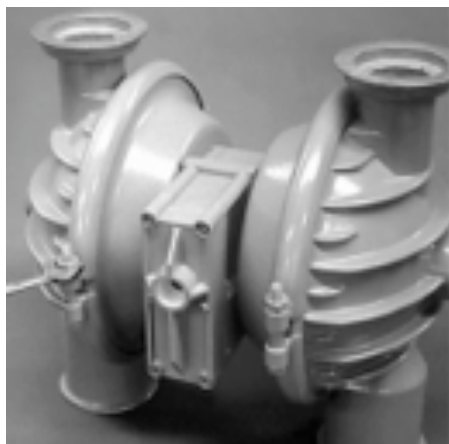


Figure 7

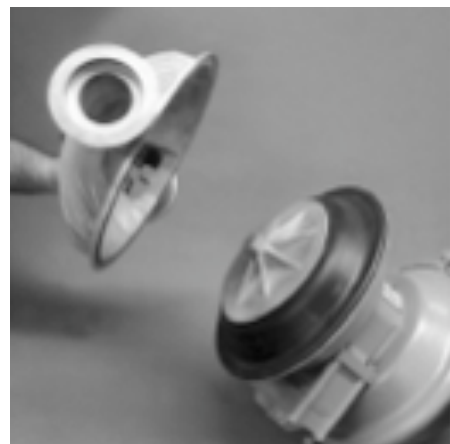


Figure 8

Massachusetts Maritime Academy
Third Class Maintenance Training

Step 9: Using an adjustable wrench, or by rotating the diaphragm by hand, remove the diaphragm assembly.

NOTE: Due to varying torque values, one of the following two situations may occur:

- ☉ The outer piston, diaphragm and inner piston remain attached to the shaft and the entire assembly can be removed from the center section (Figure 9A).
- ☉ The outer piston, diaphragm and inner piston separate from the shaft which remains connected to the opposite side diaphragm assembly (Figure 9B).

Repeat disassembly instructions for the opposite liquid chamber. Inspect diaphragm assembly and shaft for signs of wear or chemical attack. Replace all worn parts with genuine Wilden parts for reliable performance.



Figure 9A



Figure 9B

Step 10: To remove diaphragm assembly from shaft, secure shaft with soft jaws (a vise fitted with plywood, plastic or other suitable material) to ensure shaft is not nicked, scratched or gouged. Using an adjustable wrench, remove diaphragm assembly from shaft. (Figure 10)



Figure 10

PRO-FLOTMAIR VALVE/CENTER SECTION DISASSEMBLY, CLEANING, & INSPECTION

AIR VALVE DISASSEMBLY:

CAUTION: Before any maintenance or repair is attempted, the compressed air line to the pump should be disconnected and all air pressure allowed to bleed from the pump. Disconnect all intake, discharge, and air lines. Drain the pump by turning it upside down and allowing any fluid to flow into a suitable container. Be aware of hazardous effects of contact with your process fluid.

The Wilden Metal P8 utilizes a revolutionary Pro-Flo air distribution system. A 13 mm (1/2") air inlet connects the air supply to the center section. Proprietary composite seals reduce the coefficient of friction and allow the P8 to run lube-free. Constructed of Acetal or Polypropylene, the Pro-Flo air distribution system is designed to perform in on/off, non-freezing, non-stalling, tough duty applications.

Step 1: Loosen the air valve bolts utilizing a 5 mm (3/16") hex head wrench and then remove muffler plate screws. (Figure 1)

Step 2: Remove muffler plate and air valve bolts from air valve assembly (Figure 2) exposing muffler gasket for inspection. Replace if necessary.

Step 3: Lift away air valve assembly and remove air valve gasket for inspection. (Figure 3). Replace if necessary.

Step 4: Remove air valve end cap to expose air valve spool by simply lifting up on end cap once air valve bolts are removed. (Figure 4)

| Tools Required |
|------------------------------|
| 5 mm (3/16") Hex Head Wrench |
| 6 mm (7/32") Hex Head Wrench |
| Snap Ring Pliers |
| O-Ring Pick |



Figure 1

Replace

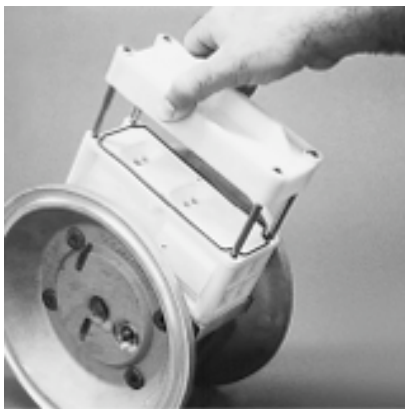


Figure 2



Figure 3



Figure 4

Massachusetts Maritime Academy
Third Class Maintenance Training

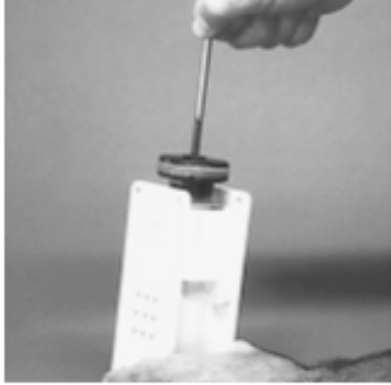


Figure 5

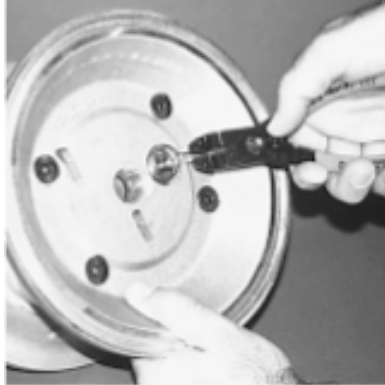


Figure 6



Figure 7

Step 5: Remove air valve spool from air valve body by threading one air valve bolt into the end of the spool and gently sliding the spool out of the air valve body (Figure 5). Inspect seals for signs of wear and replace entire assembly if necessary. Use caution when handling air valve spool to prevent damaging seals. *NOTE: Seals should not be removed from assembly. Seals are not sold separately.*

Step 6: Remove pilot spool retaining snap ring on both sides of center section with snap ring pliers (Figure 6).

Step 7: Remove air chamber bolts with 6 mm (7/32") hex head wrench (Figure 7).

Step 8: Remove pilot spool bushing from center block (Figure 8).

Step 9: With o-ring pick, gently remove the o-ring from the opposite side of the “center hole” cut on the spool. Gently remove the pilot spool from sleeve and inspect for nicks or gouges and other signs of wear. Replace pilot sleeve assembly or outer sleeve o-rings if necessary. During reassembly never insert the pilot spool into the sleeve with the “center cut” side first; this end incorporates the urethane o-ring and will be damaged as it slides over the ports cut in the sleeve. *NOTE: Seals should not be removed from pilot spool. Seals are not sold separately.*

Step 10: Check center block Glyd rings for signs of wear. If necessary, remove Glyd rings with o-ring pick and replace. (Figure 10) *NOTE: Threaded sleeves (see A — Figure 10) are removable and can be replaced if necessary. Sleeves can be press fit by hand.*

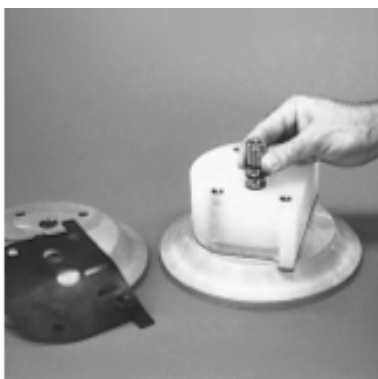


Figure 8



Figure 9

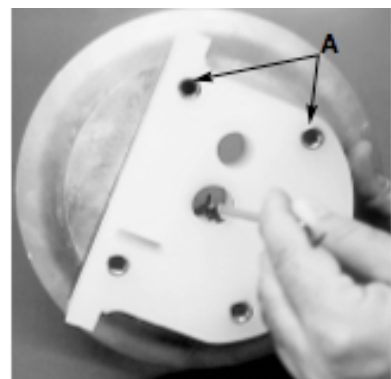


Figure 10

Massachusetts Maritime Academy
Third Class Maintenance Training

REASSEMBLY HINTS & TIPS

ASSEMBLY:

Upon performing applicable maintenance to the air distribution system, the pump can now be reassembled. Please refer to the disassembly instructions for photos and parts placement. To reassemble the pump, follow the disassembly instructions in reverse order. The air distribution system needs to be assembled first, then the diaphragms and finally the wetted path. Please see the applicable torque specifications in the table below. The following tips will assist in the assembly process.

- Lubricate air valve bore, center section shaft and pilot spool bore with NLGI grade 2 molybdenum disulfide based grease or equivalent.
- Clean the inside of the center section shaft bushing to ensure no damage is done to new Glyd ring seals.
- A small amount NLGI grade 2 molybdenum disulfide based grease can be applied to the muffler and air valve gaskets to locate gaskets during assembly.
- Make sure that the exhaust port on the muffler plate is centered between the two exhaust ports on the center section.
- Stainless bolts should be to reduce the possibility of seizing during tightening.
- Use a mallet to tamp lightly on the large clamp bands to seat the diaphragm before tightening.

| Maximum Torque Specifications | |
|----------------------------------|--------------------|
| Description of Part | Metal Pumps Torque |
| Air Valve | 45 ft-lbs |
| Outer Piston | 58 ft-lbs |
| Small Clamp Band | 30 ft-lbs |
| Large Clamp Band (Teflon Fitted) | 120 inch-lbs |
| Air Chamber Bolts | 35 ft-lbs |

GLYD RING INSTALLATION:

PRE-INSTALLATION

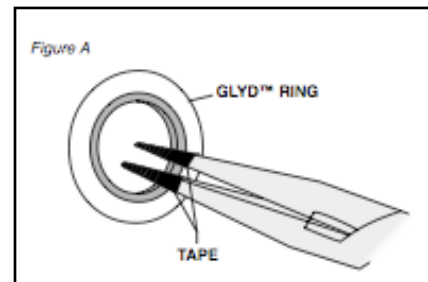
- Once all of the old seals have been removed, the inside of the bushing should be cleaned to ensure no debris is left that may cause premature damage to the new seals.

INSTALLATION

- The following tools can be used to aid in the installation of the new seals:

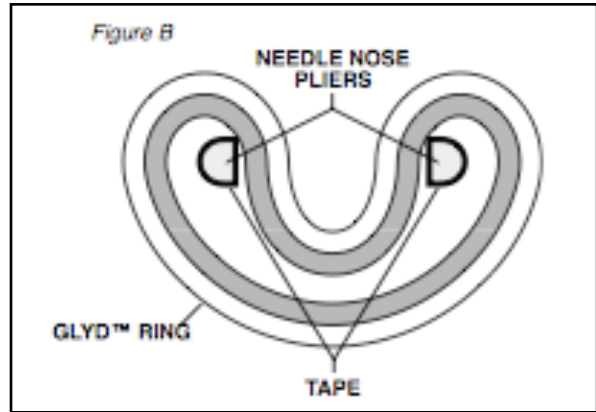
- Needle Nose Pliers
- Phillips Screwdriver
- Electrical Tape

- Wrap electrical tape around each leg of the needle nose pliers (heat shrink tubing may also be used). This is done to prevent damaging the inside surface of the new seal. • With a new seal in hand, place the two legs of the needle nose pliers inside the seal ring. (See *Figure A.*)

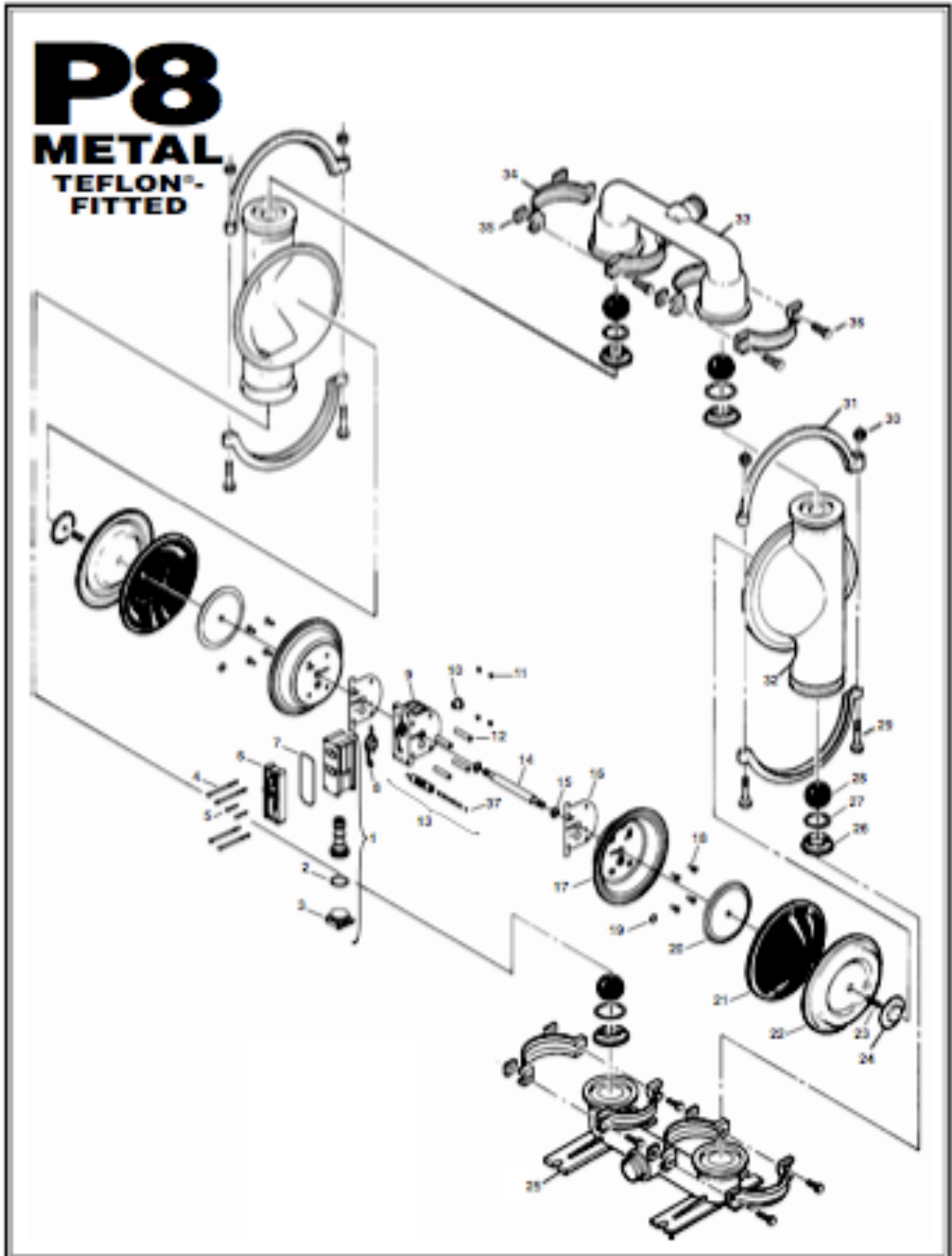


Massachusetts Maritime Academy
Third Class Maintenance Training

- Open the pliers as wide as the seal diameter will allow, then with two fingers pull down on the top portion of the seal to form kidney bean shape. (See *Figure B*.)
- Lightly clamp the pliers together to hold the seal into the kidney shape. Be sure to pull the seal into as tight of a kidney shape as possible, this will allow the seal to travel down the bushing bore easier.
- With the seal clamped in the pliers, insert the seal into the bushing bore and position the bottom of the seal into the correct groove. Once the bottom of the seal is seated in the groove, release the clamp pressure on the pliers. This will allow the seal to partially snap back to its original shape.
- After the pliers are removed, you will notice a slight bump in the seal shape. Before the seal can be properly resized, the bump in the seal should be removed as much as possible. This can be done with either the Phillips screwdriver or your finger. With either the side of the screwdriver or your finger, apply light pressure to the peak of the bump. This pressure will cause the bump to be almost completely eliminated.
- Lubricate the edge of the shaft with NLGI grade 2 molybdenum disulfide based grease.
- Slowly insert the center shaft with a rotating motion. This will complete the resizing of the seal.
- Perform these steps for the remaining seal.



EXPLODED VIEW/PARTS LISTING



Massachusetts Maritime Academy
Third Class Maintenance Training

| Item # | Description | Item # | Description |
|---|---------------------------------------|-----------|---|
| 1 | Pro-Flo®Air Valve Assembly | 20 | Inner Piston |
| 2 | O-Ring (-225), End Cap (1.859 X .139) | 21 | Back-up Diaphragm |
| 3 | End Cap | 22 | Diaphragm |
| 4 | Screw, HHC, Air Valve (1/4" x 4.5") | 23 | Stud |
| 5 | Screw, SHCS, 10-16 x 1 3/4" | 24 | Outer Piston |
| 6 | Muffler Plate | 25 | Inlet Manifold |
| 7 | Gasket, Muffler Plate | 26 | Valve Seat |
| 8 | Gasket, Air Valve | 27 | Valve Seat |
| 9 | Center Block | 28 | Valve Ball |
| 10 | Bushing, Reducer | 29 | Large Carriage Bolt (3/8"-16 x 3") |
| 11 | Nut, Square, 1/4"-20 | 30 | Large Hex Nut (3/8"-16) |
| 12 | Sleeve, Threaded, Center Block | 31 | Large Clamp Band Assy. (Includes 29 & 30) |
| 13 | Removable Pilot Sleeve Assembly | 32 | Liquid Chamber |
| 14 | Shaft | 33 | Discharge Manifold |
| 15 | Glyd Ring | 34 | Small Clamp Band Assy. (Includes 35 & 36) |
| 16 | Gasket, Center Block | 35 | Hex Nut (5/16"-18) |
| 17 | Air Chamber | 36 | Small Hex Cap Screw (5/16"-18 x 1 3/8") |
| 18 | Screw, HSFHS, 3/8"-16 x 1" | 37 | Pilot Spool Retaining O-Ring |
| 19 | Retaining Ring | | |
| All bold face items are primary wear parts. | | | |

Lab #2 - Hydronic Zone Control Valve System



Massachusetts Maritime Academy
Third Class Maintenance Training

Assemble Hydronic Zone Valve, Piping System, and Controls

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the control system of a zone control valve.
2. Can pipe the system to include valves, piping, and pump.
3. Is able to read the control system schematic and accurately wire both the high voltage and low voltage control circuits.
4. Is able to test and troubleshoot the system.

Special Tools and Equipment supplied by the Marine Engineering Department:

- ✓ Control Valve
- ✓ 120 v - 24 v transformer
- ✓ 120 v - 24 v octal DPDT relay
- ✓ Sump Pump
- ✓ Associated valves and piping

Basic hand tools are supplied by 3rd class cadets as required³.

Discussion

The zone valve and control system lab is a multi-step project requiring the cadet to build a thermostatically controlled piping system which will pump water from a reservoir through a pump, relief valve, globe valve, and electric zone control valve. The electrical control system includes a 120 volt AC circuit which provides power to a sump pump via a 120 V GFCI receptacle. The receptacle is controlled by a DPDT octal base relay which is in turn controlled by a 24 volt thermostat via the electric zone valve.

Plumbing System

The plumbing system is designed to be integrated into the laboratory piping stands set up in the after center section of the ship board lab.

Piping consists of the cadet designing the piping system utilizing a combination of black iron, copper, and PEX piping so that the sump pump will take suction from a reservoir and discharge into the piping stand. Each project must include a globe valve, union, and electric control valve. The system will ultimately discharge back into the reservoir. Each two person team will design and build the piping system, again utilizing the piping stand as a starting point. Because the design is up to the two person team, only a conceptual piping schematic is provided at the end of this section.



³ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

Massachusetts Maritime Academy
Third Class Maintenance Training

Electrical System - Relay

The electrical control system in this project, while schematically straightforward, presents a number of interesting and challenging concepts which will require the teams to understand the system before attempting to wire the system.

The components of the electrical system include:

- ✓ 120 volt – 24 volt AC transformer
- ✓ 24 volt thermostat
- ✓ 24 volt zone control valve
- ✓ double pole double throw (DPDT) 120 volt – 24 volt AC octal base relay
- ✓ 120 volt ground fault circuit interruption (GFCI) receptacle⁴
- ✓ sump pump

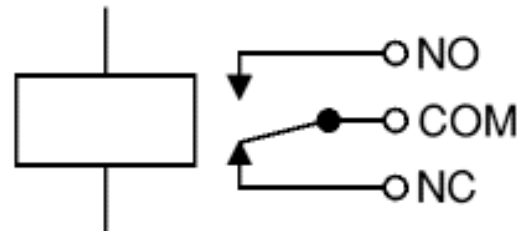
A "solenoid" is a coil of wire that, when electricity is sent through it, becomes a magnet. The resulting magnet is attracted to iron objects. Being able to turn a magnet on and off allows you to exert a pull or push from a distance, and under electronic control.

The most common application for a solenoid is to activate an air or pneumatic valve. But the magnetic pull of a solenoid coil can also be used to open or close an electric switch. This configuration is called a "relay". A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches.

A relay provides isolation from one electrical circuit to another. Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.

The relay's switch connections are usually labeled COM, NC and NO:

- COM = Common, always connect to this, it is the moving part of the switch.
- NC = Normally Closed, COM is connected to this when relay coil is off.
- NO = Normally Open, COM is connected to this when relay coil is on.



Circuit symbol for a relay

Two independent values, the first being the coil voltage, the second being the contact voltage and amperage rate relays. The coil voltage is the voltage that will be used to control the relay or energize the coil, causing the switching mechanism to close. **For this project, the coil voltage is 24 VAC.** The contact rating determines the current and voltage limitations of the contacts. The

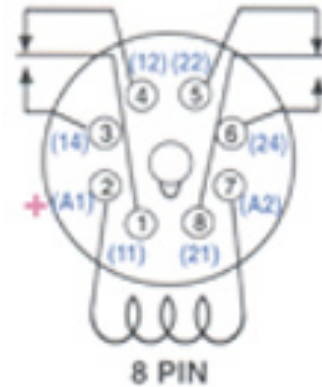
⁴ Note that some GFCI receptacles utilize a normally open contact with low voltage protection (LVP). If this is the case with the GFCI in the lab, then it must be reset everytime the relay cycles or it must be replaced with a non GFCI receptacle.

Massachusetts Maritime Academy
Third Class Maintenance Training

contacts are typically rated as *x amperes at y volts (AC or DC)*. The relay for this project will have a nominal rating of 10A @ 250VAC or 20A @ 125 VAC.

The operation of the relay for this project is as follows:

- The relay is a 8-pin octal base relay, each pin is numbered according to the schematic to the right.
- When the coil is charged, the relay switch will close the normally open (NO) contacts, allowing 120 VAC to flow to the receptacle to which the pump is plugged in, in turn operating the pump.
- The 8 pins of the relay are:
 1. 120 VAC power supply (COM) (L1)
 2. 24 VAC power to the coil (C1)
 3. 120 VAC NO (L1)
 4. 120 VAC NC (L1)
 5. 120 VAC NC (L2)
 6. 120 VAC NO (L2)
 7. 24 VAC power to the coil (C2)
 8. 120 VAC power supply (COM) (L2)
- For this project, the connections are:
 1. 120 VAC power supply (COM) (L1)
 2. 24 VAC to the coil (C1), from the transformer
 3. 120 VAC NO (L1), power to the receptacle
 4. not used
 5. not used
 6. 120 VAC NO (L2), power to the receptacle
 7. 24 VAC to the coil (C2), from the zone valve
 8. 120 VAC power supply (COM) (L2)



Electrical System - Thermostat

The thermostat used in this project is a common Honeywell T87 “round” thermostat, shown below. The thermostat is a simple single pole single throw (SPST) low voltage switch utilizing a bi-metallic element and a mercury switch. After the desired room temperature is set, a bimetallic spring attached to a mercury switch is used to close or open the low voltage circuit. As the room cools, the bimetallic spring coils, causing the mercury in the switch to flow to the left, closing the low voltage contacts. As the room warms, the spring extends causing the mercury to flow to the right, opening the switch. By placing the thermostat in series with the low voltage (24 VAC) circuit, the closing of the switch will allow current to flow first to the zone valve, then to the DPDT relay.



Massachusetts Maritime Academy
Third Class Maintenance Training

Electrical System – Zone Valve Operation and Wiring⁵

There have always been questions surrounding how the 3-wire terminal block design of the Taco Heat Motor Zone Valve works. The explanation below and associated diagrams explain step-by-step the operation of the zone valve.

As the air temperature at the thermostat drops to the thermostat setting, a normally open contact in the thermostat closes. This completes a circuit between the thermostat, the zone valve transformer and the heat motor of the zone valve power head (terminals 1 and 2). 24 VAC now flows through the wires wrapped around the heater section of the element inside the zone valve heat.

The expandable wax substance inside the element is heated. It expands and pushes the piston inside the element down against the valve stem. Since the valve is an upside down globe valve, this downward push on its stem moves the valve disc away from its seat, opening the valve.

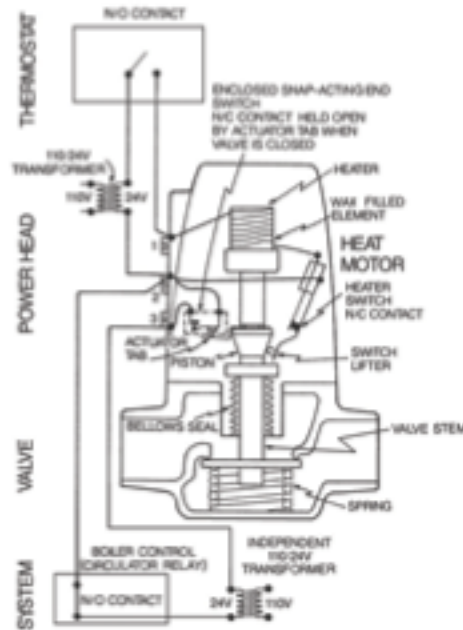
As the piston continues to move down, further opening the valve, the contacts inside the enclosed end switch close as the actuator tab attached to the piston moves away from the end switch. This dry contact end switch closure completes the circuit through terminals 2 and 3 of the power head to the boiler control (T T) and separate system transformer.

The relay in the boiler (or zone control box) starts the circulator. The piston continues to move down until the valve is fully open.

An interruption of current to the power unit heater occurs in the fully open mode because the outer blade of the heater switch is deflected causing the heater element to open, interrupting the 24 VAC power from flowing through the heater wires. As the piston retracts slightly, the contacts on the heater switch meet again, resuming power to the heater wires wrapped around the wax filled element. This slight back and forth motion is repeated as long as the thermostat contact is closed.

When the thermostat is satisfied, its contacts open and cut off the 24 VAC power to the power head. The wax inside the element cools and contracts. The force of the valves spring moves the valve disc up against the valve seat. Hence the valve stem also moves up, pushing the piston back into the element. Now that the heater switch is closed, the snap-acting end switch between terminals 2 and 3 is open.

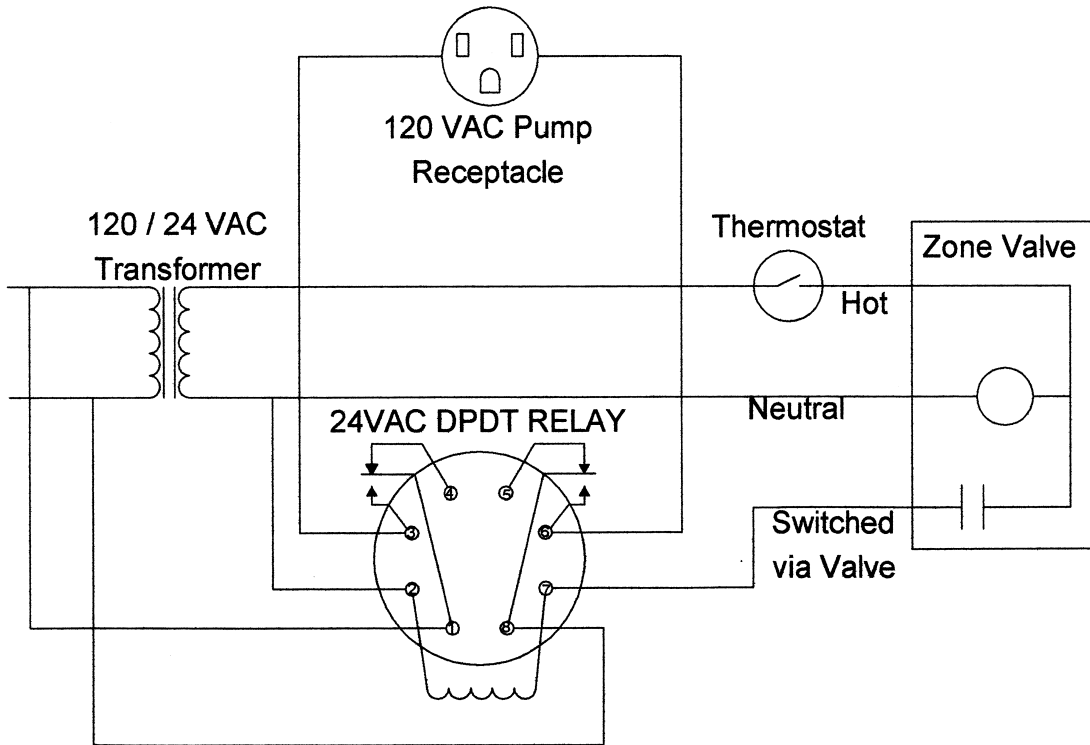
Wiring Note: While two circuits, each with its own transformer, touch at terminal #2, they do not communicate or interfere with each other in any way. Each circuit flows only in that circuit. This



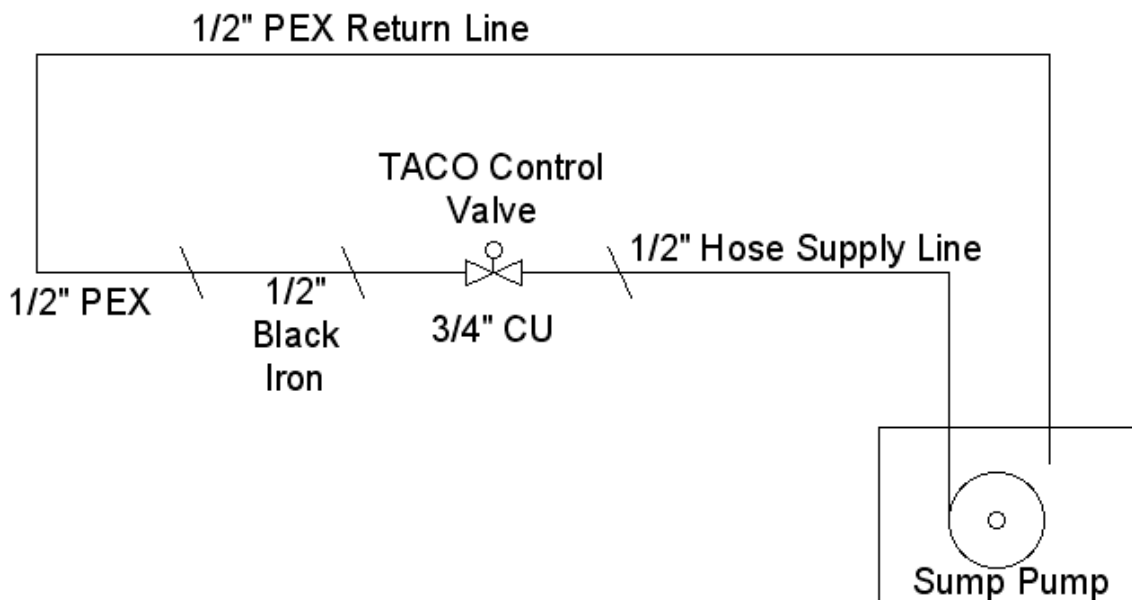
⁵ Courtesy of Taco, Inc., Cranston, RI

Massachusetts Maritime Academy
Third Class Maintenance Training

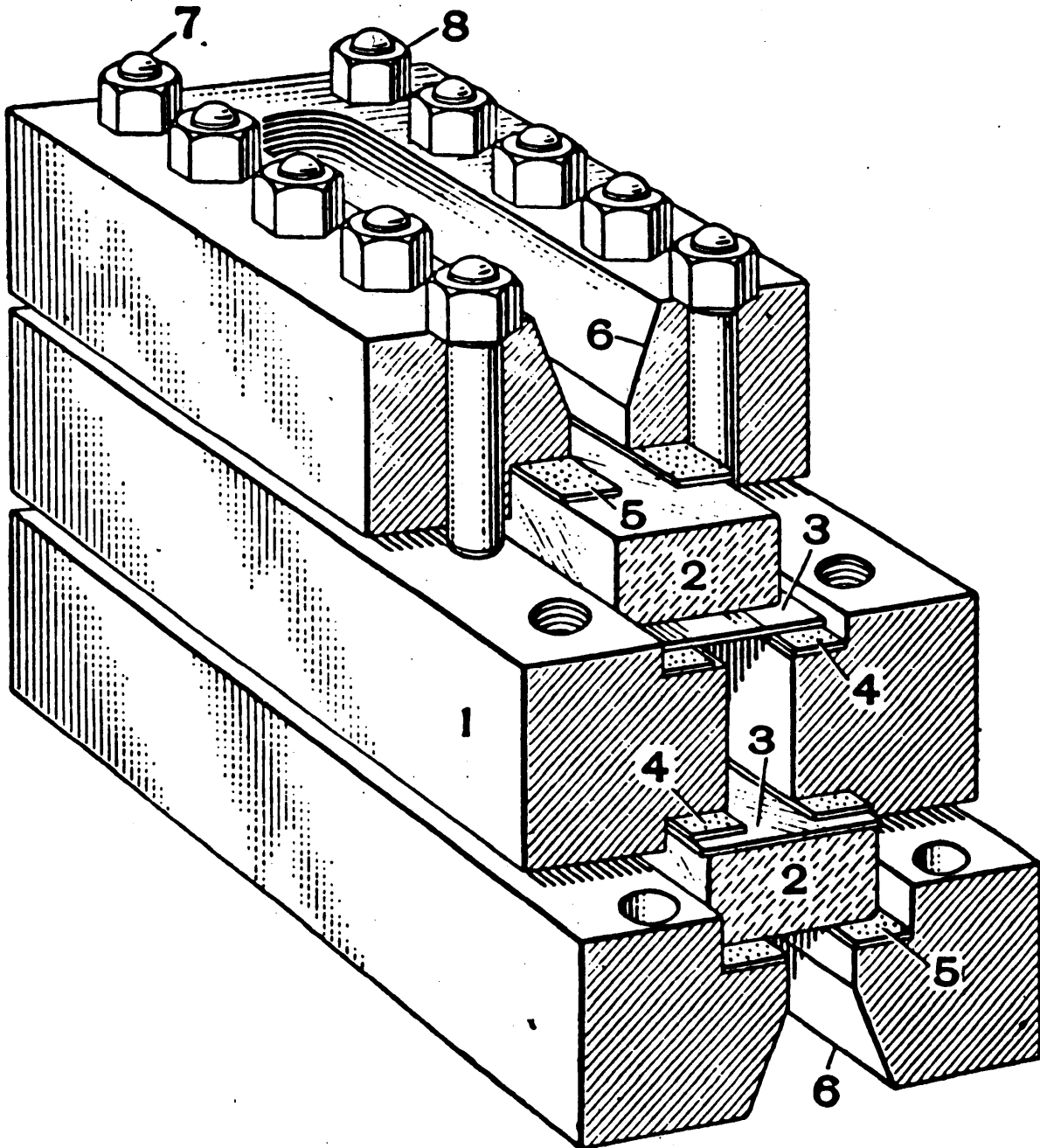
occurs because the transformer in either circuit cannot cause a voltage or current driving force to be realized in the other circuit when joined only at one point to that circuit. The complete electrical schematic for the project is shown below.



A conceptual piping drawing for the system is shown here.



Lab #3 - Gauge Glass Maintenance



Massachusetts Maritime Academy
Third Class Maintenance Training





Gage Glass Maintenance

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the construction and operation of a high pressure gage glass.
2. Disassembles and inspects the gage glass for wear and deterioration.
3. Cleans gage housing and replaces the glass.
4. Reassembles the gage glass and pressure tests the gage glass.
5. Will learn how to identify the construction details of various types of gage glasses.

Special Tools and Equipment supplied by the Marine Engineering Department:

-  Calipers
-  Torque Wrench
-  Gage Glass
-  Test Equipment

Basic hand tools are supplied by 3rd class cadets as required⁶.

Water Levels in Steam Boilers⁷

The task of any steam boiler is to provide the correct amount of high quality steam safely, efficiently, and at the correct pressure.

Steam is generated by heat from the combustion of fuel in a furnace, or by waste heat from a process. The heat is transferred to water in the boiler shell, which then evaporates to produce steam under pressure.

A certain area of water surface is required in a boiler from which to release the steam. A certain height should also be allowed above the normal working level to allow the water level to rise with increasing load, but still allowing sufficient area to release the steam without carryover of water taking place.

In horizontal shell boilers, the water level rises with increasing load (due to the presence of more steam being below the water level in the boiler). As it does so, the water surface area (steam release area) will decrease because, as the water level is above the centre line of the boiler, the sides of the containing shell converge.

The boilermaker will have designed the boiler to ensure that the area of the normal water level (NWL) is such that steam will be released at an acceptable velocity. The design will also allow a specific minimum height of the steam off-take above the NWL.

Clearly, as steam is generated, the water in the boiler evaporates, and the boiler must receive a supply of water to maintain the level. Because of the factors outlined above, water must be maintained at the correct level.

⁶ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

⁷ Courtesy of Spirax Sarco, Inc.

Massachusetts Maritime Academy Third Class Maintenance Training

Safety is also of paramount importance. If the boiler operates with insufficient water, severe damage could occur and there is ultimately the risk of explosion.

For this reason, controls are required which will:

- Monitor and control the water level.
- Detect if a low water level point is reached, and take appropriate action. This action may include sounding an alarm, shutting down the feedwater supply and shutting down the burner(s).

It is also essential to provide an external indication of the water level. The following sections give basic information on the automatic level controls and alarms as applied to shell and tube boilers. This information is also generally applicable to the steam drum of water-tube boilers.

Water Level Indication And Boiler Water Levels

Water level indication applies to steam boilers where the water level can be detected. It includes most steam boilers, the exception being those of the 'once through' or coil type, where there is no steam drum. In such cases, steam outlet temperatures exceeding a pre-set value are taken to indicate insufficient water input.

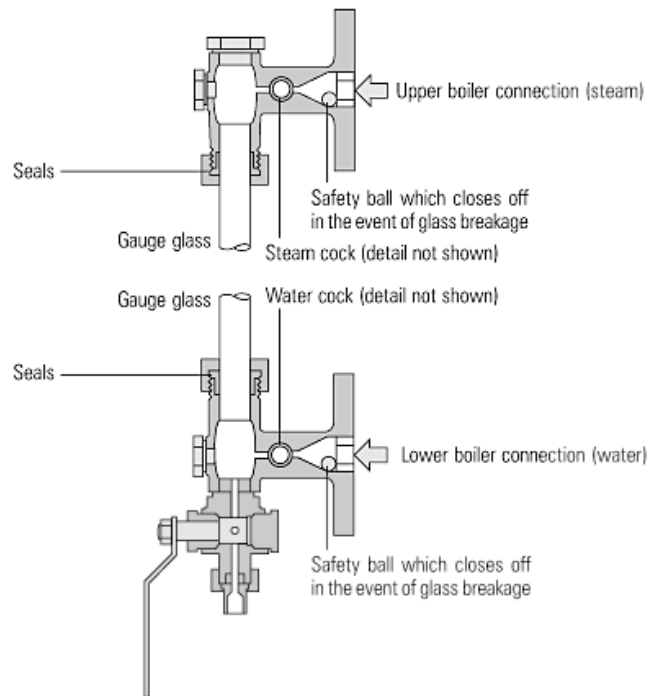
In most cases, the simple gauge glass on the steam / water drum or boiler shell is used as the indicator. Many standards stipulate the provision of two gauge glasses. Arrangements are usually required to prevent a breakage from causing a hazard to the operator. The most common form of protection is a toughened glass screen to the front and sides of the water gauge glass.

Water gauge glass constructed from flat or prismatic glass may be required for high-pressure boilers.

The gauge glass device, which has stood the test of time, is used on the vast majority of boilers and is usually arranged to give a visible range of water level above and below the normal water level.

It is essential to understand what is seen in a boiler gauge glass. The following section explains some of the factors which will influence the level of water indicated in the gauge glass.

It is not possible to define the exact water level in a steaming boiler, because the water surface is made up of a mass of bubbles with a strong horizontal circulation. There are therefore, level variations both across and along the boiler shell. Conversely, the gauge glass contains water

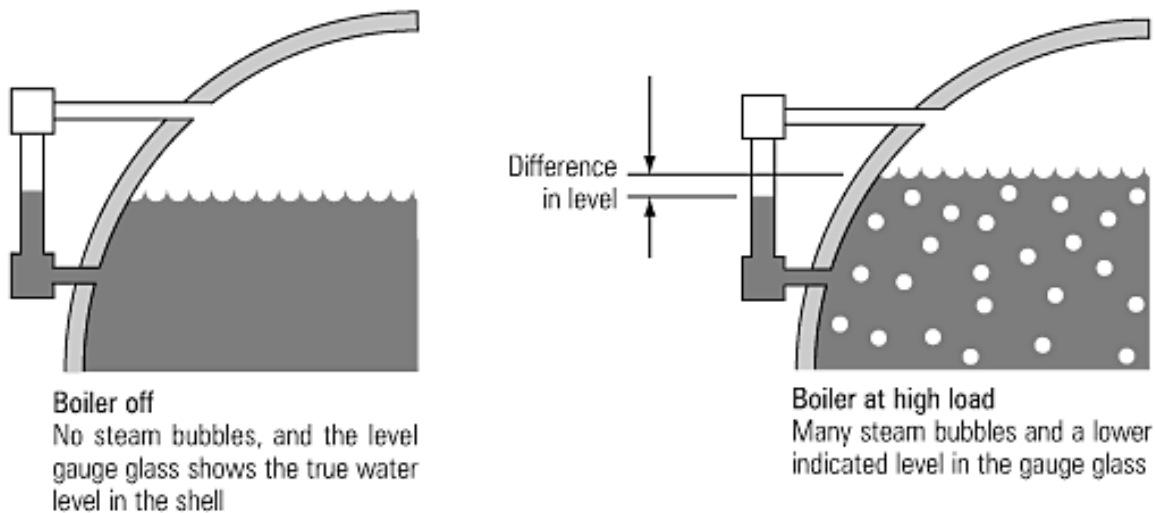


Massachusetts Maritime Academy
Third Class Maintenance Training

which:

- Is not subject to current and agitation.
- Does not contain steam bubbles.
- Is cooler than the water in the boiler.

This means that the water in the gauge glass (and other external fittings) is denser than the water within the boiler shell. This in turn, means that the level gauge glass will show a lower level than the average water surface level in the boiler shell.



The difference between the level in the gauge glass and the level in the boiler shell at high steaming rates, depends on such factors as:

- The boiler steam generation rating.
- The height of the gauge glass water connection into the boiler.
- The TDS and chemical analysis of the boiler water.
- The size of the boiler shell.

Level Changes Due To Boiler Circulation

With a boiler on high load, the strong circulation of the boiler water will cause the water level to vary along the length of the boiler. These circulation currents are normally considered to be upwards along the front and back of the boiler, and upwards along the center line over the furnace.

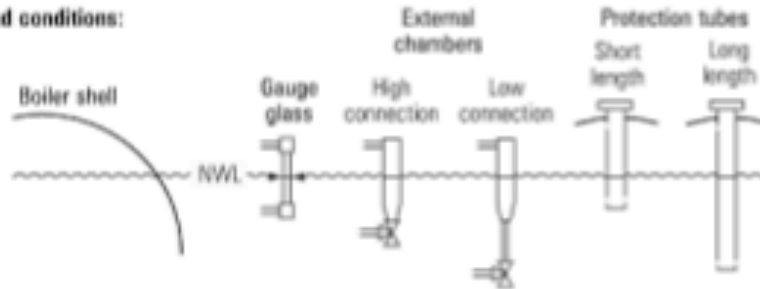
The downward circulation must therefore be at the sides, in the centre section of the boiler. There could also be a 'drawing' effect from the steam off-take connection which will tend to raise the water locally.

During sudden load changes there is also the possibility of waves developing in the boiler, which can often be seen in the level gauge glass, but should ideally be ignored by the water level controls. A summary of the level changes to be expected under various boiler conditions is illustrated.

Massachusetts Maritime Academy Third Class Maintenance Training

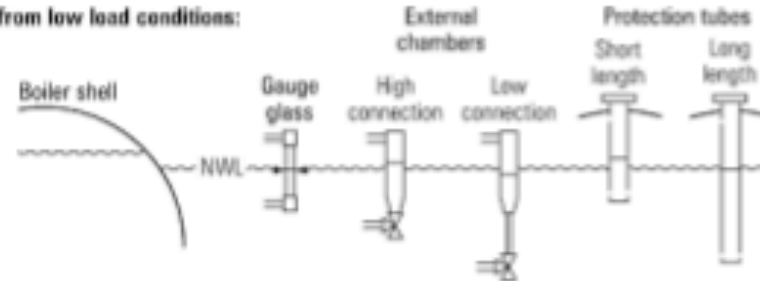
Boiler off-load or at low load conditions:

- All levels are the same.



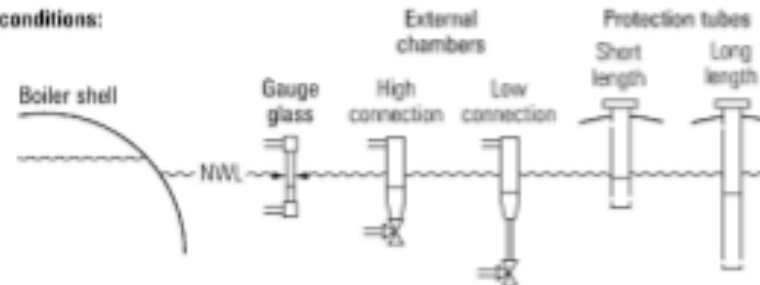
Boiler on sudden high load from low load conditions:

- Water quantity in the boiler is initially the same as at low load.
- If control is in a short length protection tube, feed supply will be cut off and high alarm may sound.



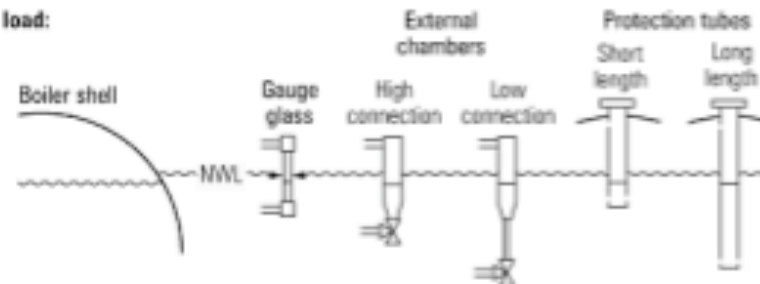
Boiler on high load, steady conditions:

- Control in short length protection tube.
- Level drops in boiler and gauge glass.



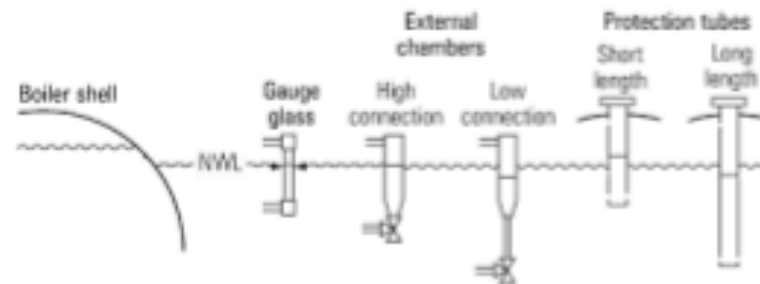
Boiler load drops from high load:

- Boiling rate reduces.
- Far fewer steam bubbles are formed so water level drops rapidly in the boiler shell.
- Low alarm may sound.



Boiler at high steady load:

- Control in external chamber with low connection or in long length protection tube.
- Level in boiler is high, but control is stable.
- Levels at the control point hardly change with load or feedwater flowrate.
- Boiler at high steady load.



Massachusetts Maritime Academy
Third Class Maintenance Training

Gauge Glass Regulations

U.S. Coast Guard Rules and Regulations (§ 52.01-110) regarding water-level indicators, water columns, gauge-glass connections, gauge cocks, and pressure gauges (modifies PG-60) state that:

(a) Boiler water level devices. Boiler water level devices shall be as indicated in PG-60 of the ASME Code except as noted otherwise in this section.

(b) Water level indicators (modifies PG-60.1). (1) Each boiler, except those of the forced circulation type with no fixed water line and steam line, shall have two independent means of indicating the water level in the boiler connected directly to the head or shell. One shall be a gage lighted by the emergency electrical system (See Subpart 112.15 of Subchapter J (Electrical Engineering) of this chapter) which will insure illumination of the gages under all normal and emergency conditions. The secondary indicator may consist of a gage glass, or other acceptable device. Where the allowance pressure exceeds 1724 kPa (250 psi), the gage glasses shall be of the flat type instead of the common tubular type. (2) Gage glasses shall be in continuous operation while the boiler is steaming. (3) Double-ended firetube boilers shall be equipped as specified in this paragraph and paragraph (e) of this section except that the required water level indicators shall be installed on each end of the boiler. (4) Externally fired flue boilers, such as are used on central western river vessels, shall be equipped as specified in paragraphs (b) (1) through (3) of this section except that float gages may be substituted for gage glasses.

(c) Water columns (modifies PG-60.2). The use of water columns is generally limited to firetube boilers. Water column installations shall be close hauled to minimize the effect of ship motion on water level indication. When water columns are provided they shall be fitted directly to the heads or shells of boilers or drums by 1 inch minimum size pipes with shutoff valves attached directly to the boiler or drums, or if necessary, connected thereto by a distance piece both at the top and bottom of the water columns. Shutoff valves used in the pipe connections between the boiler and water column or between the boiler and the shutoff valves required by PG-60.6 of the ASME Code for gage glasses, shall be locked or sealed open. Water column piping shall not be fitted inside the uptake, the smoke box, or the casing. Water columns shall be fitted with suitable drains. Cast iron fittings are not permitted.

(d) Gage glass connections (modifies PG-60.3). Gage glasses and gage cocks shall be connected directly to the head or shell of a boiler as indicated in paragraph (b)(1) of this section. When water columns are authorized, connections to the columns may be made provided a close hauled arrangement is utilized so that the effect of ship roll on the water level indication is minimized.

(e) Gage cocks (modifies PG-60.4). (1) When the steam pressure does not exceed 250 pounds per square inch, three test cocks attached directly to the head or shell of a boiler may serve as the secondary water level indicator. (2) See paragraph (d) of this section for restrictions on cock connections.

(f) Pressure gages (modifies PG-60.6). Each double-ended boiler shall be fitted with two steam gages, one on either end on the boiler.

(g) Salinometer cocks. In vessels operating in salt water, each boiler shall be equipped with a salinometer cock or valve which shall be fitted directly to the boiler in a convenient position.

Massachusetts Maritime Academy
Third Class Maintenance Training

They shall not be attached to the water gage or water column.

(h) High-water-level alarm. Each watertube boiler for propulsion must have an audible and a visible high-water-level alarm. The alarm indicators must be located where the boiler is controlled.

Flat Gauge Glasses Versus Tubular Type

The boiler pressure determines whether or not flat gauge glasses should be used. United States Coast Guard Rules and Regulations state that where the maximum allowable pressure exceeds 250 psi, the gauge glasses shall be of the flat type instead of the common tubular type.

Changing A High Pressure Gauge Glass

The high pressure gauge glass is a general designation for the flat type consisting of steel frames enclosing flat glasses held together by bolts. It is distinguished from the low pressure glass, which is the common tubular type.

The gauge may be renewed with pressure on the boiler provided the stop valves are shut tightly. The procedure is as follows:

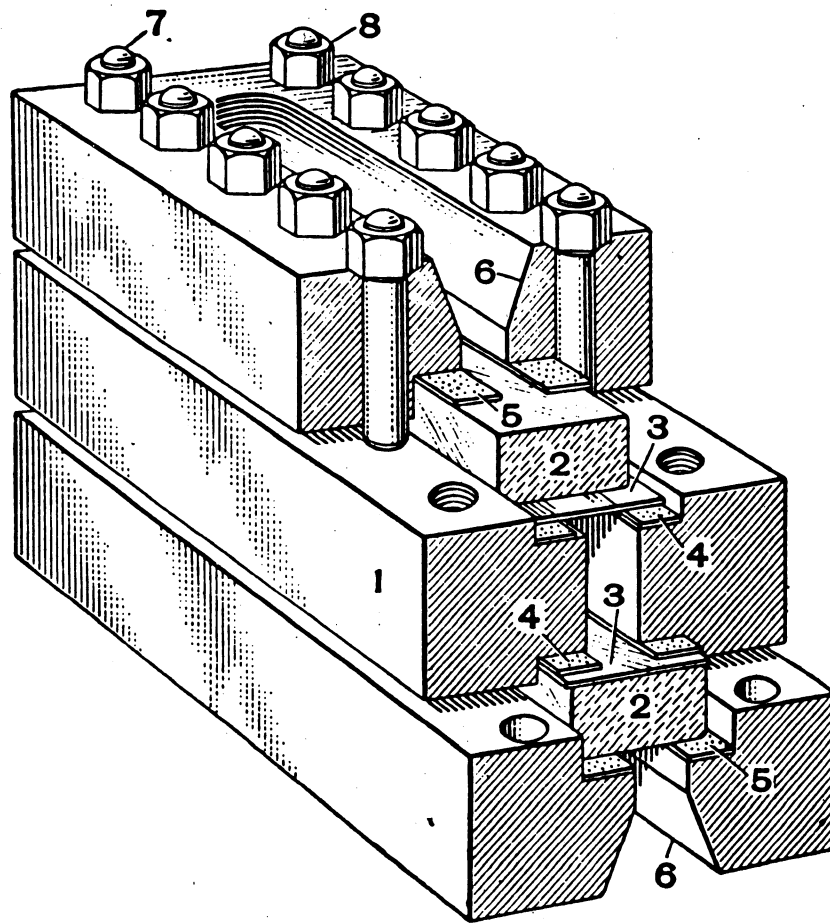
1. Secure the stop valves tightly and open the drain valve. Let the gauge cool and be certain there is no pressure on it. Loosen upper and lower gland nuts, pull out the glands and remove the packing. Remove the gauge glass assembly from the valves by shoving it up into the top valve as far as it will go and then swinging it clear of the bottom valve. Remove the gauge glass to a clean work bench.
2. Before dismantling the gauge glass, punch mark the steel frames so that they may be replaced in the same relationship. Remove all nuts and dismantle the covers. Carefully clean the inside of the covers and both sides of the center plate, so that all surfaces are free of gasket material. Do not use tools which will cut or gouge the surfaces of the plates. Renew both glasses with new gaskets on both sides of the center plate. The glass is assembled in the following order: Center plate, asbestos gasket, mica, glass, asbestos gasket, and cover plate. Then repeat this assembly on the other side.
3. Put the studs in place and run all nuts up finger tight; then use short handle wrenches to tighten the nuts. Tighten the nuts in a definite sequence, starting at the center and proceeding alternately to both ends. Go over the nuts methodically in this way about three times. Do not tighten more at this time. If the bolts are pulled up hard when the gauge is cold, the asbestos gasket will be pressed into the vision space, carrying the mica with it. This will wrinkle the mica, and as the gauge is put under pressure, the mica will be pressed against the glass, cracking at the wrinkles. This will permit water to contact the glass and dissolve it.
4. Replace the assembly in the valves by shoving the top stud all the way up into the top valve then swing the assembly into vertical position and lower it into the bottom valve. Be certain that the guard washer and glands are positioned on the gauge before installation so that they may be pushed respectively into the gauge valves before and after

**Massachusetts Maritime Academy
Third Class Maintenance Training**

the packing is installed. Then cut packing rings and repack the valves, staggering the butts on the rings. Tighten the glands when the gland boxes are full.

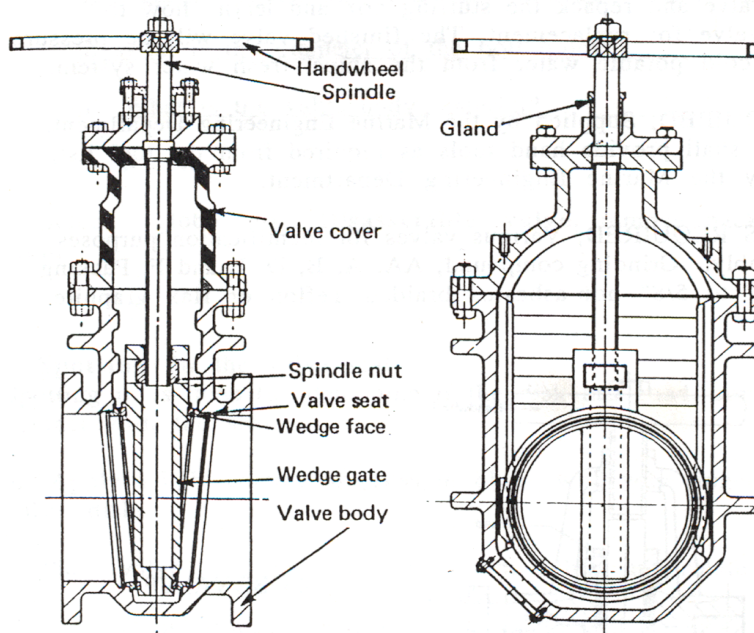
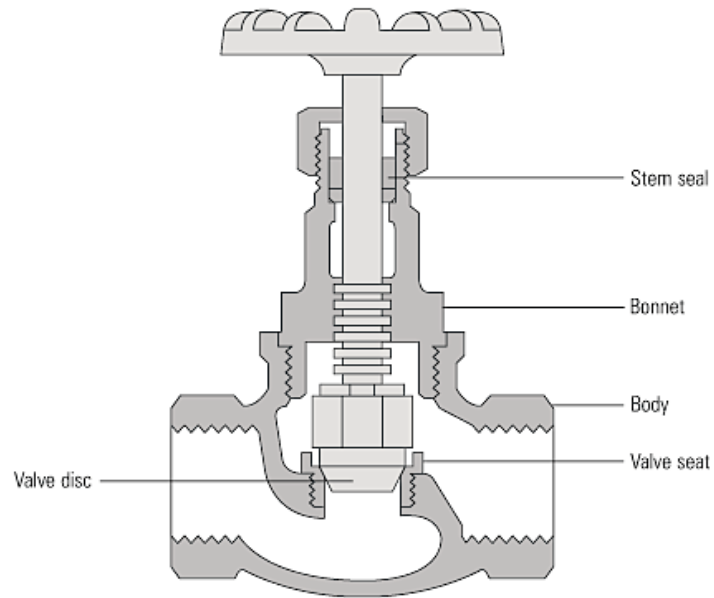
5. It is necessary to keep the mica flat during the process of making the gauge pressure tight. The following procedure will assure this. After the gauge is mounted on the valves and the glands are packed, open the upper gauge valve slightly. Steam should blow through the glass and out the drain heating up the gauge. Close the upper gauge valve and again tighten the nuts using the sequence of starting at the center and working outward, as before. Open and close the upper gauge valve again, and retighten the nuts. Repeat this three or four times until the gauge is reasonably tight and hot. Then open the upper gauge valve and slowly close the drain valve while inspecting carefully for leaks. If none are found, when the drain valve is completely closed, open the lower gauge valve and put the gauge in service.
6. Blow down the glass to insure that the level responds properly. Continue to examine the gauge as it picks up heat, and if any leaks are present the nuts must be tightened as before. Note: do not tighten nuts while gauge is in service; before going over the nuts, close both upper and lower gauge valves, and drain the gauge. When the sequence of tightening is finished, close the drain and put the gauge back into service again following the same procedure as outlined above.

Flat Type Gauge Glass Assembly



- | | |
|--------------------|--------------------|
| 1 Body | 5 Asbestos Cushion |
| 2 Flat Gauge Glass | 6 Cover plate |
| 3 Mica Sheet | 7 Studs |
| 4 Asbestos Gasket | 8 Nuts |

Lab #4 - Valve Manifold and Valve Maintenance



Massachusetts Maritime Academy
Third Class Maintenance Training

OICEW-8-2D Inspect Valve Manifold

| | |
|------------------------------|---|
| Assessment | OICEW-8-2D |
| Task: | Inspect Valve Manifold |
| Level: | Third Class |
| Location | Maintenance Training Workshop |
| Prerequisite | 3/c Status on Cruise, Completion of Auxiliary Machinery I |
| Performance Condition | In workshop, equipment, tools, and supplies provided |

MMA Performance Standards

| Assessment Criteria | Specific Expectations | Suggested Emphasis |
|---|---|---------------------------|
| <i>The student will:</i> | <i>During assessment, the student shall at a minimum:</i> | |
| <ul style="list-style-type: none"> • Lockout/Tagout valve manifold | Identify contents of pipe Isolate pipe section Relieve pressure and drain section | 20 |
| <ul style="list-style-type: none"> • Use tools to open up piping for inspection | Use: <ul style="list-style-type: none"> • combination wrenches • socket sets • other tools as necessary | 20 |
| <ul style="list-style-type: none"> • Inspect and clean pipe and manifold | Dismantle flanges Inspect interior of pipe Clean and prepare joints for reassembly | 20 |
| <ul style="list-style-type: none"> • Use tools and proper joint materials to close up piping system | Use: <ul style="list-style-type: none"> • combination wrench • socket set • torque wrench • gasket cutter • hole punch | 20 |
| <ul style="list-style-type: none"> • Test system to identify leaks | Perform hydrostatic test for leakage Prove joint leak free | 20 |

Massachusetts Maritime Academy
Third Class Maintenance Training

OICEW-8-2E Overhaul Valve

| | |
|------------------------------|---|
| Assessment | OICEW-8-2E |
| Task: | Overhaul Valve |
| Level: | Third Class |
| Location | Maintenance Training Workshop |
| Prerequisite | 3/c Status on Cruise |
| Performance Condition | Access to necessary tools, materials, and blueprints. |

MMA Performance Standards

| Assessment Criteria | Specific Expectations | Suggested Emphasis |
|------------------------------------|---|---------------------------|
| <i>The student will:</i> | <i>During assessment, the student shall at a minimum:</i> | |
| • Disassemble a glove valve | Remove old packing from stuffing box | 20 |
| • Inspect valve | Examine disk and seat Blue in valve disk and seat | 30 |
| • Repair valve as necessary | Machine, grind in and bed-in valve disk and seat as required Replace bonnet gasket Select and install new packing | 30 |
| • Reassemble valve | Prove valve leak free with hydrostatic test | 20 |

Valve Maintenance

STCW Assessment: OICEW-8-2D: Inspect Valve Manifold

STCW Assessment: OICEW-8-2E: Overhaul Valve

Project Time: 4 hours

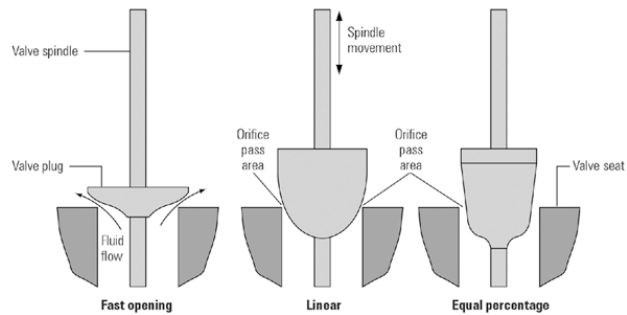
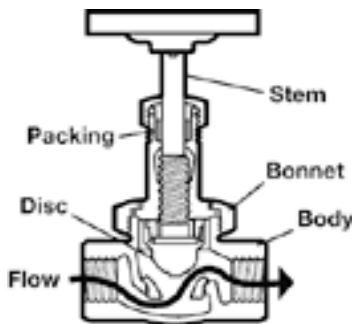
“The expected learning outcome is that the trainee...”

1. Understands how to classify valves;
2. Performs preventative maintenance on valves;
3. Resurfaces valve seats and disks;
4. Repairs valve seats and valves;
5. Repacks valves and returns valve to service.

Special Tools and Equipment supplied by the Marine Engineering Department:

- 🔧 Calipers
- 🔧 Torque wrench
- 🔧 Valve schematics
- 🔧 Various hand tools
- 🔧 Various valves for identification purposes and disassembly
- 🔧 Packing material ¼” to 5/8” non-asbestos braided Teflon or flax graphite coated
- 🔧 Grinding Compound

Basic hand tools are supplied by 3rd class cadets as required⁸.



⁸ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

Massachusetts Maritime Academy
Third Class Maintenance Training

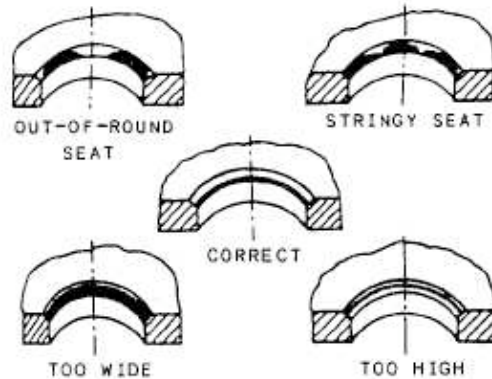
Procedure

1. Select a flanged valve and provide the following data:

| | |
|---|--|
| a. What type of valve is it? | |
| b. Is it a raised face valve? | |
| c. What is the valve size? | |
| d. What is the distance between flange faces? | |
| e. What is the flange thickness? | |
| f. What is the flange diameter? | |
| g. What is the bolt circle diameter? | |
| h. What is the diameter of the bolt holes? | |
| i. What is the valve body material? | |

2. Select a globe valve. Disassemble valve, remove packing and stem.
3. Spotting in the valve seat. Spotting in is done to determine if the disk has good, complete, contact with the seat.

- a. Apply a light coating of Prussian blue (commonly called Blue Dykem) with your finger to the valve disk.
- b. Place valve disk on seat, press down lightly and rotate a quarter turn.
- c. Remove and inspect the disk. A good seal will be shown by a even transfer of blue to the seat. Gaps or grooves will indicate leak points.



- d. Clean disk, apply Prussian blue to the seat, repeat the quarter turn test and inspect. The Prussian blue will adhere to the valve seat at those points where the disk makes contact. The diagram shows the appearance of a correct seat when it is spotted-in and the appearance of various kinds of imperfect seats. After noting 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 making proper contact with the seat.

Massachusetts Maritime Academy
Third Class Maintenance Training

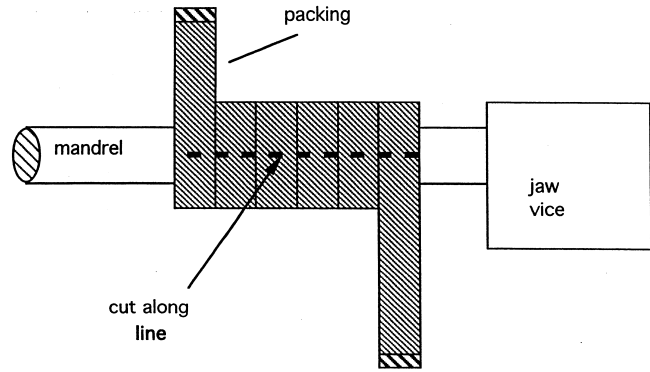
4. Grinding in the valve seat. Small defects (grooves, gaps, pits) on the valve disk or seat can be removed by grinding in.
- a. Inspect the stem for straightness, grooving or pitting. Attach valve disk to stem so it will not rotate freely on stem. Insert valve stem into bonnet.
 - b. Grinding compound is a paste with carbide grit in it. Grit sizes are from extremely fine, 600 to 50, extremely coarse. The letter on the can indicates the fineness of the grit. Commonly used grits for valve refinishing are: AA (220), A, B, D, E and F (80). Fine grits leave a smooth finish but remove material slowly.
 - c. Start with a medium to coarse grit, B or D. Apply a coating to the valve disk contact surface. Go easy at first, 80 grit can remove a lot of metal quickly.
 - d. Place valve stem with bonnet (used to align the valve) on to the valve body, without the bolts.
 - e. Rotate stem with light pressure back and forth 4 or 5 times, lift valve seat clear of disk, redistribute grinding compound and rotate again. This prevents peaks and valleys from forming.
 - f. Inspect seat and disk frequently for the disappearance of the defects. Switch to a finer compound as you progress. *Do not over grind or a groove will be formed.*
 - g. When you think you have good contact, spot it in again. If it looks good after spotting in, clean valve, free up disk on stem and reassemble the valve.

Note: Badly damaged valves, such as wire drawing on steam valves and deep corrosion pitting on sea or fire main valves may require the valve disk be cut on a lathe and the seat cut with specially made seat cutter kits. If the valve disk is cut on the lathe, it is cut 1.50 degrees less than the seat to provide a narrow seating line. The valve disk and seat are finishing by grinding in. Example if the seat is 45 degrees, then the disk should be cut at 43.50 degrees. Some high quality valves have replaceable seat inserts that are quite often made out of hard non-corrosive material. Coatings on valves can be stellite, carbides, bronze, or stainless steel and may be difficult to grind in.

5. Valve repacking. . Valve stems are repacked with the proper type of packing for the intended service and the correct thickness. High temperature steam may have steel wire reinforcing (which should never be used on pump shafts since it will score the shaft) and heat resistant material. Sea water service, lube oil, and fuel systems should all utilize packing suitable for it.
- a. To determine the correct packing thickness subtract shaft diameter from the inside diameter of the stuffing box, then divide the result by two.
 - b. To determine the number of packing rings to be used, divide the depth of the stuffing box by the thickness of the packing.
 - c. Wrap the stuffing as it comes out of the box or off the spool around the mandrel, pipe, or rod the same diameter as the pump shaft. Cut the packing with a sharp knife. If the packing is even slightly longer than necessary, it will be difficult to fit it into the stuffing box.

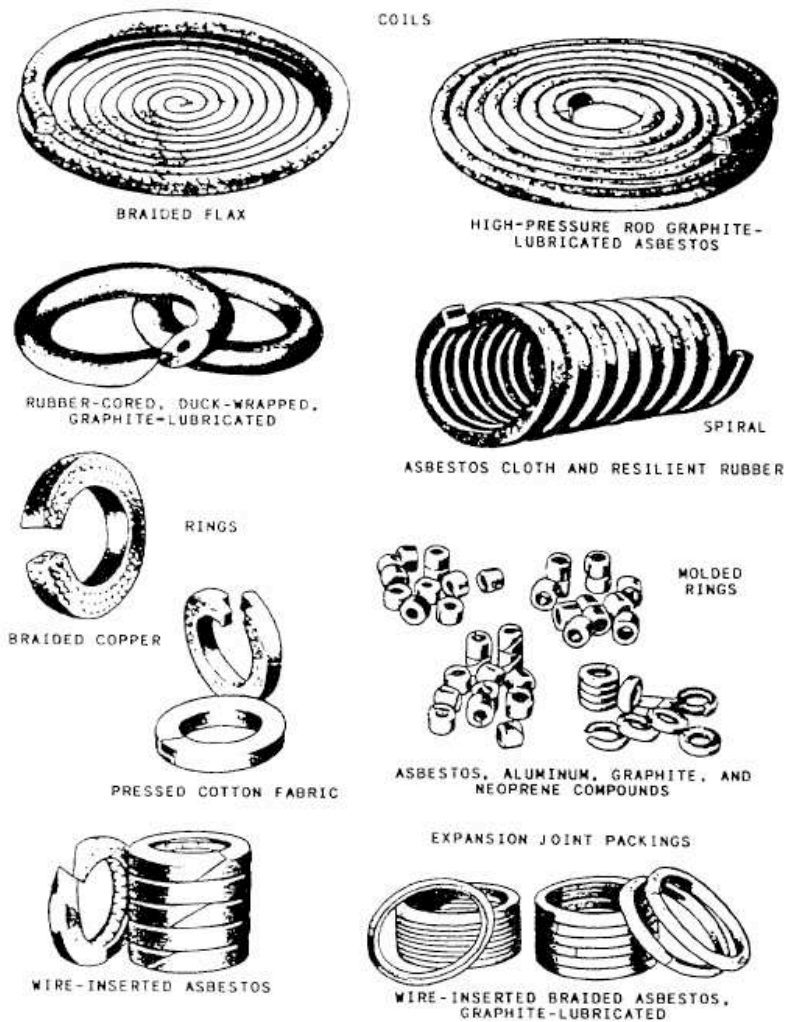
Massachusetts Maritime Academy
Third Class Maintenance Training

- d. Packing the stuffing box. Twist the packing around the shaft and insert into the stuffing box. The use of grease or never seize may ease the installation. Push the packing into place staggering the butt ends by 90 degrees to reduce the probability of leaks.



- e. When all of the rings of packing have been installed tighten the gland nuts only enough to hold the packing firmly but still allows the valve stem to be turned freely.
- f. Pressure test the valve observing any leakage. Adjust packing nuts slightly in order to stop the leakage.

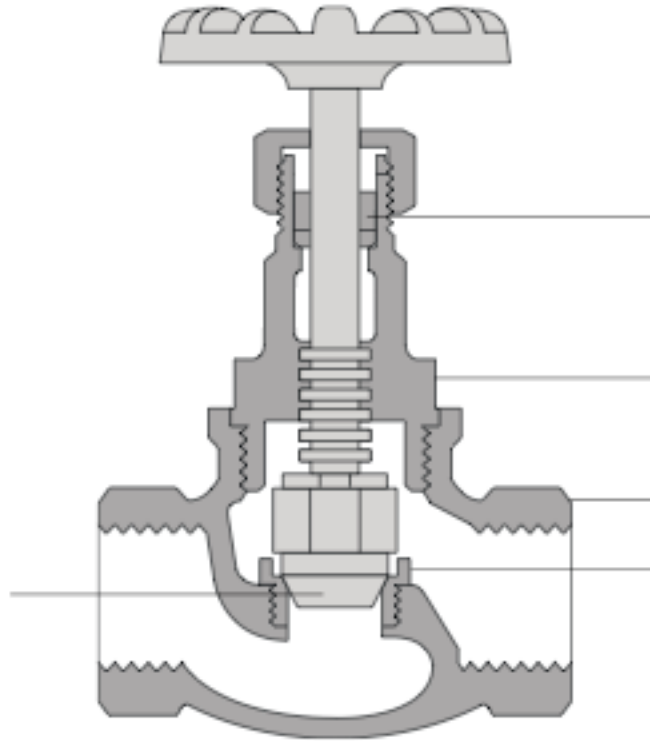
Asbestos, flax, Teflon, and many other fibers are used for valve packing. Coatings of graphite, wax and grease are common on the packing. Packing is square in cross section and comes in many thicknesses, 1/8", 1/4", 5/16", 3/8", 1/2" etc.



Massachusetts Maritime Academy
Third Class Maintenance Training

Valve Repair Questions

1. Label the arrows on cross sectional drawing.

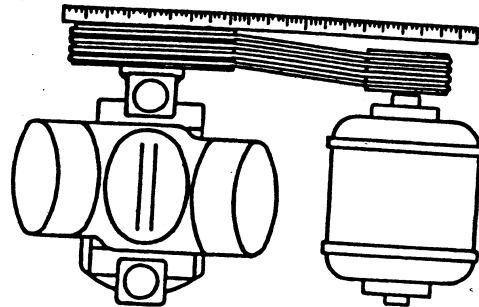
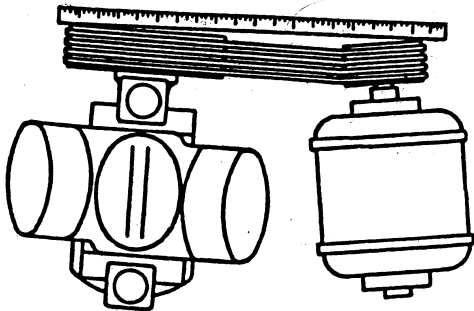
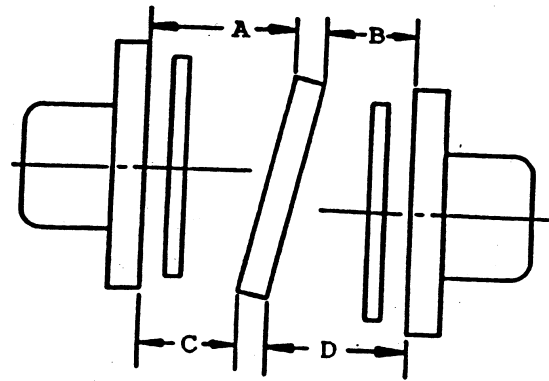
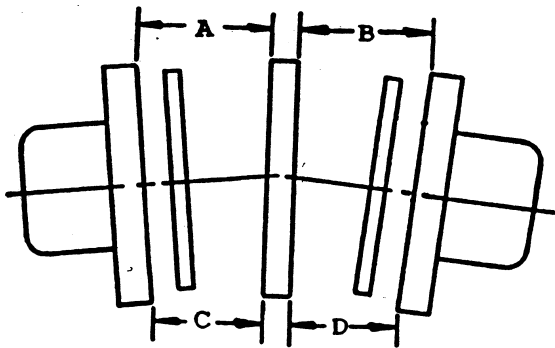


2. Why is spotting in done to a valve seat and disk prior to grinding in?
3. What is the name of the dye used for spotting in?
4. If a valve seat and disk have only minor damage what can be done to restore the tight seal?
5. What grades of lapping compound is finer a AA, or an E grit?
6. The inside diameter of the stuffing box of a valve is 1.75" and the shaft is 1.25". What size (thickness) packing is required?
7. Why are globe valves used more often than gate valves aboard the Kennedy?
8. Why are raised flange valves used instead of flat faced?
9. What type of gasket is used between flanges on high pressure steam?

Massachusetts Maritime Academy
Third Class Maintenance Training

10. Why is the steel ring used around the outside diameter of flexitallic gaskets?
11. Where and for what type of service would packless valves be found on the ship?
12. If valve seat and disk on a globe valve are badly pitted what should be done to restore the seal?
13. What are three types of valve stem packing material?
14. What type of service would wire reinforced asbestos packing be used for?
15. What is the formula for determining the size of the packing to be used?
16. What is the formula for determining the number of packing rings to used for a valve stuffing box?
17. What can be used to help the packing slide into the stuffing box easier?
18. What does 150 W.O.G. stand for on the side of a valve?
19. What is the advantage of using a rising stem valve?
20. Can gate valves be ground in to restore the seal?
21. Name one gate valve used in the engine room of the Kennedy?
22. What part of the valve locks the disk to the stem but still allows the valve to float?
23. What is the angle (in degrees) for most valve seats and disks?
24. When installing packing rings, how should the ends of adjacent rings be positioned?

Lab #5 - Pump Alignment



Massachusetts Maritime Academy
Third Class Maintenance Training

Pump Alignment

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the definition of alignment as that relates to a pump and motor combination.
2. Measures the alignment between an existing pump and motor combination.
3. Prepares and implements an alignment solution procedure for the pump and motor.
4. Measures the final alignment between the pump and motor and certifies that the alignment is within acceptable tolerances.

Special Tools and Equipment supplied by the Marine Engineering Department:

- ☉ Calipers
- ☉ Torque Wrench
- ☉ Alignment tools and dial indicators
- ☉ Pump and motor combinations

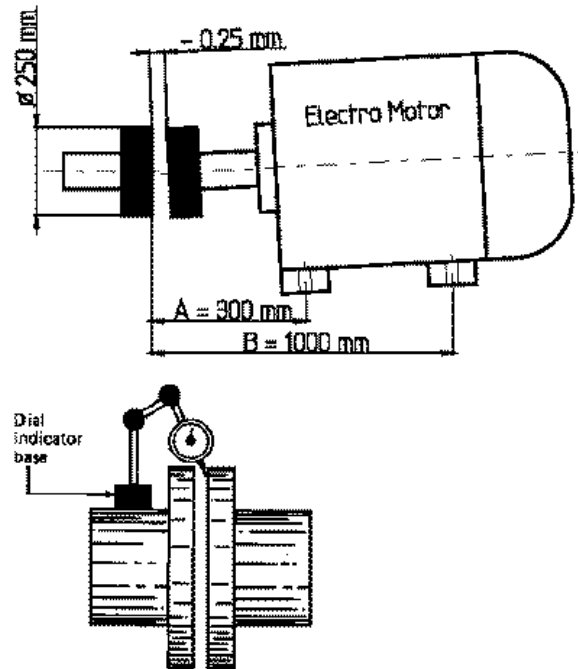
Basic hand tools are supplied by 3rd class cadets as required⁹.

INTRODUCTION TO PUMP ALIGNMENT:

Not only must you insure that a pump or machine is in proper working condition, lubricated and not leaking, you must also insure it is properly aligned. Improper alignment is one of the major causes of machine failure.

Machinery is made to specifications that permit operation for long periods of time before the machine wears out. Machine failures are normally caused as the result of alignment or lubrication problems. The machine ***does not wear out***. Misalignment causes vibration. This vibration destroys the critical parts of the machine (bearings, seals, gears, couplings, etc.). Failures of this type are usually evident, however, they are often mistakenly identified as *“normal wear and tear”*. To decrease the chance of failures, it is important to precisely align your equipment. High quality craftsmanship is necessary, but high quality does not mean harder work. It means smarter work.

Proper alignment is not mysterious. The fact is that the operator has a basic understanding of some of the trigonometric principles involved and uses his/her tools properly. Some tools available to you will take all the guesswork out of the alignment procedure and enable you to easily determine the exact amount of correction necessary for proper alignment of your



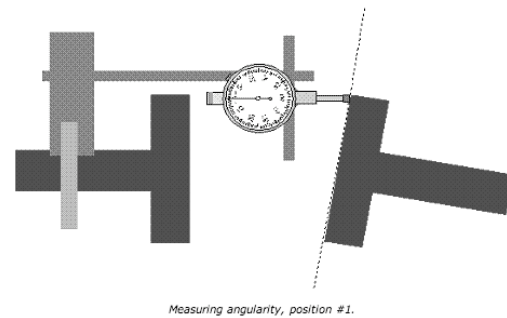
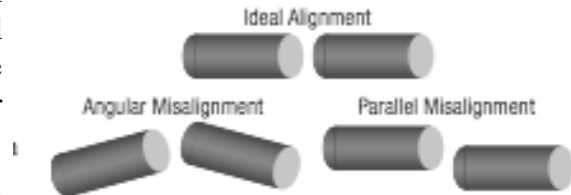
⁹ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

Massachusetts Maritime Academy
Third Class Maintenance Training

machinery. We will use two types of alignment tools: Laser and Dial Indicator. They are not difficult, but like any tool it takes time to learn them. Experience with alignment tools is a great teacher; however, it is difficult to fully understand what the eye is unable to see. Differences of a few thousandths of an inch cannot be seen. Answers can only be as accurate as the measurements that are taken.

BRIEF EXPLANATION OF SOME COMMON USED TERMS

1. **MACHINE TO BE SHIMMED (MTBS)** - When two machines must be aligned to each other, any necessary adjustment will usually be done on only one of the machines. The other machine may be difficult to adjust because of its size, physical attachment to other objects (such as a pump that is attached to its piping), or its anchorage system (some machines are permanently mounted in place). In most industrial applications (pump-motor, fan-motor, fan-turbine, pump-turbine, gear reducer-motor, etc.), the driver (the motor or the turbine) will be the machine that will be adjusted. In some applications, however, such as the main fuel oil pump on a gas turbine, the driven machine will be adjusted.
2. **STATIONARY MACHINE** - The term “STATIONARY MACHINE” will be used to describe the machine that will not be adjusted (the pump, fan, gear reducer, air compressor).
3. **ALIGNMENT** - The process of adjusting a piece of machinery (the MTBS) so that its shaft will be in line with the shaft of the machine to which it is coupled (the stationary machine). The MTBS must be adjusted vertically and horizontally in most cases before correct alignment can be achieved.
4. **PURE OFFSET MISALIGNMENT** – Sometimes called **Parallel Misalignment**, this type of misalignment means that the centerlines of the two shafts are parallel to each other (not at an angle), but do not form one continuous straight line.
5. **ANGULAR MISALIGNMENT** - Sometimes called **Face Misalignment**. This is the term for the condition created when the centerlines of the two shafts meet at an angle.
6. **SKEWED MISALIGNMENT** - This is the most common type of misalignment problem encountered and is a combination of angular and skewed misalignment.
7. **VERTICAL MISALIGNMENT** - When the MTBS must be adjusted vertically with shims to bring it into its correct position.
8. **HORIZONTAL MISALIGNMENT** - When the MTBS must be adjusted horizontally to bring it into its correct position. Shims are not used to correct horizontal misalignment.



Massachusetts Maritime Academy
Third Class Maintenance Training

9. **ANGULARITY** - The angle that one shaft centerline makes in relation to the other shaft centerline. For clarity, this is expressed as a slope of so many *thousandths of an inch per inch*, rather than as an angle of so many degrees. The slope must be determined in both the vertical and horizontal planes and named *Vertical Angularity* and *Horizontal Angularity*.

10. **OFFSET** - The distance (in thousandths of an inch) between two shaft centerlines. For purposes of standardization, this distance will always be calculated or measured at the centerline of the coupling. This must be determined in both the vertical and horizontal planes and named *Vertical Offset* and *Horizontal Offset*.

11. **RIM READINGS** - Readings obtained as the shafts are rotated and the dial indicator stem is at a 90 degree angle to the shaft centerline.

12. **FACE READINGS** - Readings obtained as the shafts are rotated and the dial indicator stem is parallel to the shaft centerline. (See Illustration 2)

13. **FRONT FEET (FOOT)** - The Inboard feet of the MTBS

14. **BACK FEET (FOOT)** - The outboard feet of the MTBS

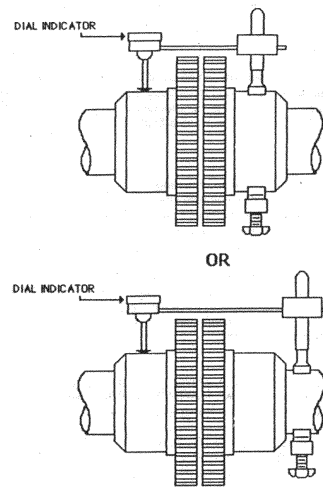
15. **ZERO** - The process of setting the dial indicator to zero when the dial indicator is in the TOP position.

16. **INDICATOR SAG** -The bending of the dial indicator mounting hardware that occurs when the dial indicator is rotated from the top position to the bottom position. In many cases, this bending may be large enough to cause a significant error in the dial indicator readings. This *sag* must be compensated for when the mechanic *sets* the Indicator in the top position.

17. **SOFT FOOT** - A condition that exists when the bottom of all four feet of the moveable machine are not on the same plane. This can be compared to a chair that has one short leg.

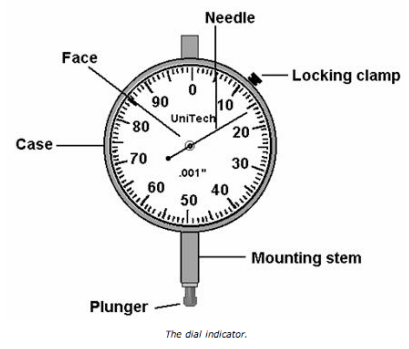
18. **HOLD-DOWN BOLTS AND NUTS** - The bolts and nuts that we used to secure each foot of the moveable machine to the machine base.

19. **JACKING BOLTS** - Horizontally positioned bolts on the machine base that are located at each foot of the machine and are used to adjust the horizontal position of the machine.



Note: Rotate both shafts equal amounts while obtaining dial indicator readings to ensure proper shaft alignment. Erroneous coupling alignment may occur if only one shaft is rotated.

Obtaining Rim Readings with a Dial Indicator Off of Coupling Hub



Massachusetts Maritime Academy
Third Class Maintenance Training

INTERPRETATION OF READINGS

Before a true understanding of alignment procedures can be obtained, it is necessary for you to realize that all **Face** and **Rim** Readings are **RELATIVE**, that is, dependent upon the location at which they are taken.

Face Readings, which are used to determine angular misalignment, are proportionate to the diameter at which the readings are taken. For example, if readings were being taken on a coupling face and the path of the dial indicator travel had a 6 inch diameter the bottom reading (assuming the indicator was zeroed at the top) would be 1.5 times as great as it would be if the indicator were moved 1 inch closer to the shaft (the diameter of the path would then be 4 inches [6 = 1.5 x 4]). For this reason, you must always consider the diameter at which the **Face Reading** was taken before you can evaluate the accuracy of the alignment.

A Face Reading of 0.008 inches at a 4 inch diameter would not be considered a close alignment. However, a 0.008 reading at a 16 inch diameter on the same machine would be four times as accurate and would be considered acceptable by most standards.

Manufacturer's tolerances are usually given in terms of **thousandths of an inch per inch** for angular misalignment or in **degrees of error**. Generally speaking, it is always best to set your dial indicators to read at the largest diameter that is practical. Greater accuracy is obtainable in this manner because:

1. The face reading is amplified, thus decreasing the percentage of error if a small mistake is made when reading the indicator.
2. Small errors made in measuring the diameter of travel have less effect on the alignment calculations.

Rim Readings are dependent on a combination of:

1. At what point along the shaft centerline the dial indicator is placed; and
2. The angular misalignment that is present.

A Rim Reading of 0.0 on the TOP and BOTTOM may be theoretically obtained at some point along the shaft centerline of a misaligned machine, however, if the dial indicator was moved to another point along the shaft centerline, the resulting Rim Reading would not be 0.0. This principal, in fact, is the basis of the Indicator Reverse Method.

MACHINERY ALIGNMENT USING DIAL INDICATORS

1. The three (3) methods of aligning machinery with dial indicators which will be discussed are:
 - A. **Two Indicator Method - Dial indicator readings taken at the stationary machine.**
This method requires the taking of one rim reading and one face reading at the stationary machine. The dial indicator mounting brackets and posts are attached to the machine to be shimmed.
 - B. **Two Indicator Method - dial indicator reading taken at the machine to be shimmed.**
This method is the same as method the previous except the rim and face readings are taken at the -machine to be shimmed. The dial indicator mounting brackets and posts are attached to the -stationary machine.

Massachusetts Maritime Academy
Third Class Maintenance Training

- C. **Indicator Reverse Method** - This method requires the taking of two rim readings - one set at the MTBS and one set at the stationary machine

In all of these methods, It is usually possible to attach two dial indicators to the machinery in such a manner that both sets of readings can be taken simultaneously. If for any reason only one dial indicator can be attached, it is entirely permissible to take one set of readings and then change the mounting arrangement and take the other required set of readings.

2. Half A Method

The most common alignment mistake made is attempting to align, or checking the alignment-of. two pieces of machinery by taking only rim readings on only one of the machines. The above descriptions of the three alignment methods make it obvious that this procedure supplies only half the information needed for any of the methods. It is possible to get a set of rim readings that *appear* to be perfect on a machine that is considerably misaligned. Never use half of a method.

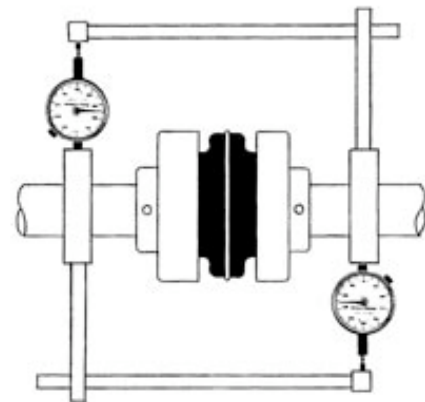
3. Selection of Method

Any of the three listed methods can be used for aligning machinery. Two basic factors should determine the method to be used, **END PLAY** and **DISTANCE vs RADIUS**. Due to these factors, some manufacturers insist on the use of the Indicator Reverse Method for alignment or, at least, a final check of the alignment. The two determining factors are:

- A. **End Play** - Does End Play or Float create an unmanageable problem in obtaining accurate Face Readings? Nearly all machines with journal or sleeve bearings have some end play, but it may be manageable. Sufficient pressure can be applied to the end of the shaft during rotation to keep it firmly seated against the thrust bearing or plate. In the case of large machinery or machinery that must be energized and bumped to obtain the desired rotation, application of sufficient pressure on the shaft is often difficult and/or dangerous. When end play is unmanageable, the indicator reverse method should be used because axial movement of the shaft or end play, causes large errors in face readings. However, the affect on rim readings, which are the only readings needed with the indicator reverse method, is negligible.

- B. **Distance Vs. Radius** - If end play is manageable, a choice of methods exists. As both of the Two Indicator Methods are basically the same, they will be considered as one method in this discussion. When a choice exists, the best method is determined by the following rule:

If the distance between the points of contact of the two dial indicators set up to take rim readings for the indicator reverse method is larger than one-half the diameter of travel of the dial indicator set up to take face readings for the two indicator method, the indicator reverse method should be used. (See Illustration).



Massachusetts Maritime Academy Third Class Maintenance Training

The basis for this rule is that misalignment will be more apparent (dial indicator reading will be larger) under these circumstances and, therefore, corrections will be more accurate. Both of the two indicator methods are basically the same.

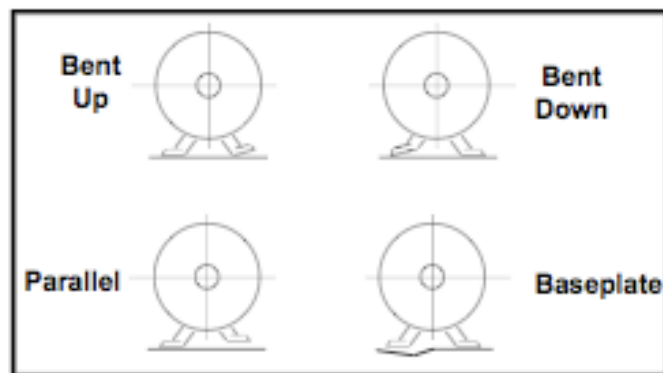
SOFT FOOT

Soft-foot is the term commonly applied to the condition that exists when all four of the machine feet are not supporting the weight of the machine. This condition, when not corrected before starting the alignment procedure, is probably the largest cause of frustration and lost time.

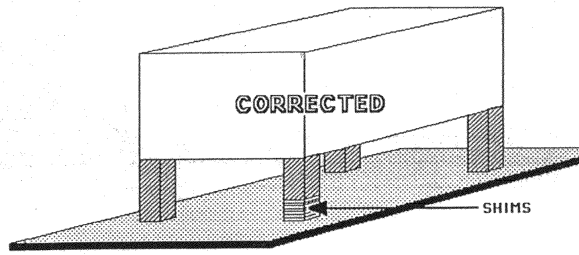
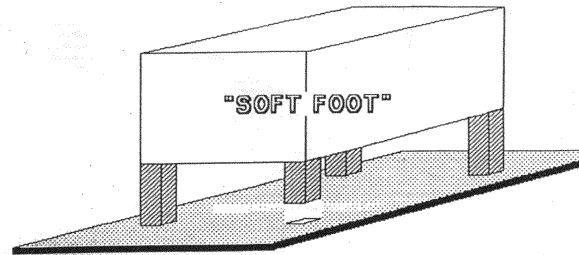
Consider a chair with one short leg. The chair will never be stable unless the other three legs are shortened or the short leg is shimmed up. When a machine is in this condition, the dial indicator readings can be different each time the hold-down nuts are tightened, loosened, and retightened. This is frustrating because attempted corrections may not produce the results desired. When machinery is placed in service with soft-foot uncorrected, the results are:

1. The nuts securing the feet to the base may loosen. This can result in either looseness and/or misalignment. Either of these conditions will cause vibration that can be dangerous to you and to the machinery.
2. If the nuts do not loosen, metal fatigue may occur at the soft-foot and cracks will develop. In extreme cases, the soft-foot may break off.

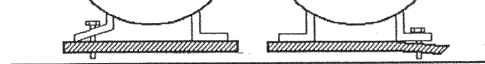
The basis for understanding and correcting Soft-Foot is the knowledge that three points determine a plane. In the case of the chair, the floor is the plane that we speak of, and the bottom tips of the legs are the points. Three tips will always rest on the floor, even if a person is sitting with his weight positioned above the short leg. The short leg will then be on the floor and the normal leg that is diagonally opposite the short leg will be off the floor.



By using this example, it can easily be seen that when a machine is initially placed on its base, it will be resting on three of its support feet unless the base and the bottom of the feet are perfectly machined. Also, because the feet of the machine are actually square pads, not true points, it is possible that the machine will be resting on only two support feet which are diagonally opposite each other. In this case, the machine will have two soft-feet.



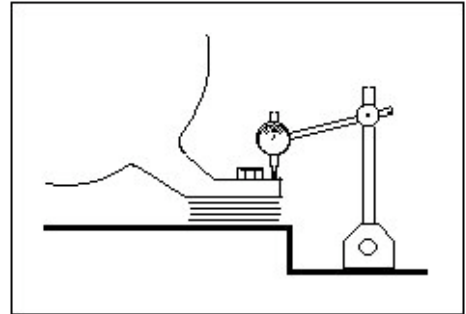
NOTE: "SOFT FOOT" IS SOMETIMES A RESULT OF A BENT "FOOT" OR A BENT BASEPLATE. IN SUCH CASES, IT MAY BE NECESSARY TO INSTALL A TAPERED SHIM OR "JURY RIG" BY "SANDWICHING" A STRIP OF SHIM STOCK BETWEEN TWO NORMAL SHIMS. ALSO, BEWARE THAT WARPED OR BENT SHIMS CAN CAUSE "SOFT FOOT".



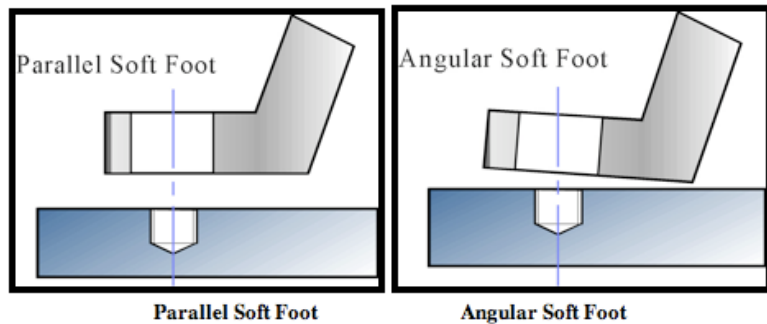
Massachusetts Maritime Academy
Third Class Maintenance Training

DETERMINING AND CORRECTING SOFT-FOOT

Soft-foot should always be checked and corrected before beginning the alignment procedure. The following should be done in order to check for and correct soft-foot.



1. Remove all dirt, rust, and burrs from the bottom of the machine's feet, the shims to be used, and the base at the areas where the machine's feet will rest before setting the machine in place.
2. Set the machine in place, but do **NOT** tighten the hold-down nuts.
3. Attempt to pass a thin feeler gap or piece of shim stock underneath each of the four feet. Any foot that is not solidly resting on the base is a Soft-Foot. Bear in mind that a foot may be considered soft if the feeler gap passes beneath most of it and only contacts a small point or one edge. If the feeler passes beneath a foot, determine the exact amount of gap beneath the foot with feeler gages and place this amount of shims beneath that foot. This will be considered as being the initial Soft-Foot correction. Final soft-foot correction should be done as follows:



If the feeler passes beneath a foot, determine the exact amount of gap beneath the foot with feeler gages and place this amount of shims beneath that foot. This will be considered as being the initial Soft-Foot correction. Final soft-foot correction should be done as follows:

- a) Tighten all hold-down nuts on the MTBS. Refer to the tighten hold down bolt section.
- b) Secure a dial Indicator holder to the base of the MTBS in such a manner that the stem of dial indicator is placed vertically above the foot which is to be checked for soft-foot. A magnetic base indicator holder is usually suitable for this purpose. Set dial indicator to 0.000. Completely loosen the hold-down nuts on that foot only. Watch dial indicator for foot movement during the loosening process.
- c) If the foot rises from the base when the hold-down nut is loosened, place beneath the foot an amount of shim stock equal to the amount of deflection shown on the dial indicator.
- d) Retighten the hold-down nut and repeat the entire process once more, to be sure no movement is present.
- e) Move the dial indicator and holder to the next foot to be checked and repeat the process. Remember that all other feet must remain securely tightened when a foot is being checked for a soft-foot condition.
- f) Repeat this process for each machine foot.

Massachusetts Maritime Academy
Third Class Maintenance Training

TIGHTENING OF HOLD-DOWN NUTS

This section is devoted to the correct procedure for tightening the hold-down nuts. Because of the importance of the procedure, even though you may have corrected for 'soft-foot" before starting the alignment procedure, it is always best to avoid any possibility of errors by using the correct tightening procedure. This procedure will help insure that any unequal stresses that may cause a shifting of the moveable machine during the tightening procedure will remain the same throughout the entire alignment process. Thus, unexpected results tend to be eliminated. The following procedure should be followed:

1. After the elimination of soft-foot, ***loosen*** all hold-down nuts.
2. Number each foot of the moveable machine in the sequence in which you will be tightening the hold-down nuts during the alignment procedure.
3. It is generally considered a good idea to tighten the nuts in an "X" pattern; however, there is no real evidence to support this theory. The numbers 1, 2, 3 and 4 should be permanently marked on or near the feet.
4. Always tighten the nuts in the sequence in which the positions are numbered (1, 2, 3, 4) and loosen nuts In the opposite sequence (4, 3, 2, 1).
5. Tighten all nuts with the same amount of force. The use of a torque wrench is desirable.
6. Always tighten the nuts as though you had made the final adjustment, even if you have not even taken you first set of readings.

Massachusetts Maritime Academy
Third Class Maintenance Training

PROCEDURE FOR ALIGNING MOTOR AND PUMP

1. Check for runout on both the motor and pump shaft coupling rims. Use procedure (a) or (b) below:
 - a. Use magnetic base and measure at coupling rims. Reading should be less than 0.005 TIR (total indicator reading - amount of + and - readings added together)
 - b. Or mount indicator on one shaft and read coupling rim readings on other. Hold shaft end in place and turn indicator through 360 degrees.
2. If TIR is greater than 0.005 this could mean a mis-bored coupling or a bent shaft. To determine this remove coupling and take readings shaft to shaft.
3. Find and correct soft foot.
 - a. Use 0.002 feeler gauges under all feet. If able to slide under a foot increase size of feeler to know how much this foot needs to be shimmed.
 - b. Now use dial indicator to check for soft foot.
4. Perform rough alignment.
 - a. Measure angular misalignment in the *side view*. This is done by measuring the gap at the top and bottom of the coupling using a dial indicator at the rim face. Use shims at front or back motor feet to reduce the difference.
 - b. Measure Parallel misalignment in the *side view*. This may be done by using a straight edge from the pump coupling rim to the motor coupling rim. Add shims at all four motor feet to correct this.
 - c. Measure angular misalignment in the *top view*. This is done by measuring the gap at the sides of the coupling using a dial indicator at the rim face. Correct this by using a dead blow hammer to shift position.
 - d. Measure Parallel misalignment in the *top view*. This may be done by using a straight edge from the pump coupling rim to the motor coupling rim. Add shims at all four motor feet to correct this.
5. Correct angular misalignment in the side plane
 - a. Set up dial indicator attached to motor shaft or hub, and indicator button reading on face of pump coupling. Turn indicator 180- degrees note the readings at top and bottom.
 - b. Measure the distance between the motor hold down bolts on one side and the diameter of the circle that the indicator made.
 - c. Calculate the amount of shims to be placed at the front or back feet of the motor. Amount of shims required = amount of difference between the top and bottom dial indicator readings multiplied by the distance between the feet on one side divided by the diameter of the indicator travel. i.e., $0.016'' * 12'' / 4'' = 0.048''$.
 - d. Place shims as calculated either front or back legs.

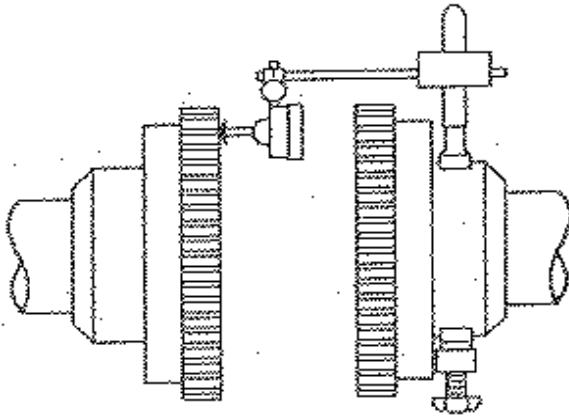
Massachusetts Maritime Academy
Third Class Maintenance Training

6. Correct parallel misalignment in the side plane
 - a. Mount dial indicator so that tip is against rim of pump coupling. Rotate motor shaft 180 degrees top and bottom and note difference between top and bottom readings.
 - b. Calculate shims that must be added or removed ($1/2 \times$ Dial Indicator Reading). If indicator reading was negative add shims, if indicator reading was positive remove shims.
 - c. Add or remove shims from all four motor legs.
7. Correct angular misalignment in the top view plane
 - a. Mount dial indicator to read from motor to pump. The dial indicator should be set to read the face of the pump coupling. Take measurements at the sides of the coupling at 90 degrees and 270 degrees.
 - b. Move only the back or front of the motor to correct.
8. Correct parallel misalignment in the top view plane
 - a. Mount dial indicator to read from motor to pump. The dial indicator should be set to read the rim of the pump coupling. Take measurements at the sides of the coupling at 90 degrees and 270 degrees.
 - b. Move entire motor to correct.

Massachusetts Maritime Academy
Third Class Maintenance Training

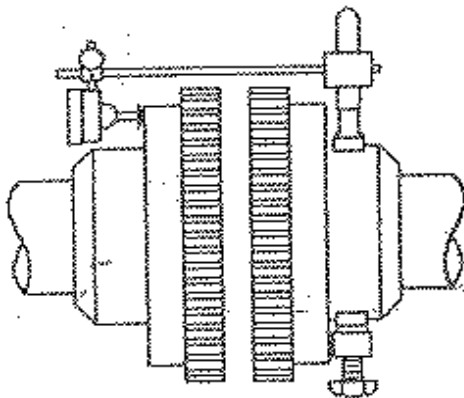
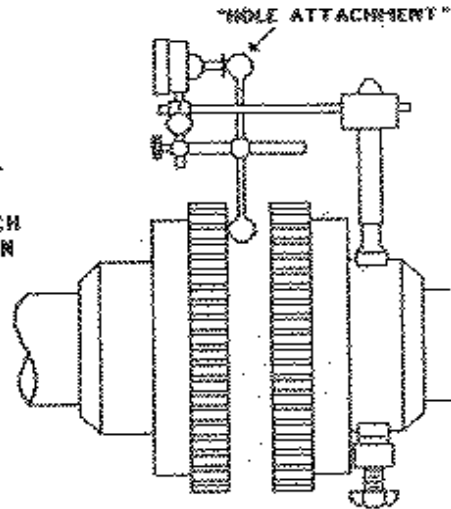
NOTE: THE "FACE" READING MAY BE TAKEN OFF OF EITHER COUPLING HALF FACE WHEN USING EITHER THE M1 OR M2 METHOD (THE DIAL INDICATOR WILL STILL READ THE SAME). THE "RIM" READING MUST BE TAKEN OFF OF THE APPROPRIATE COUPLING HALF.

©1985, INDUSTRIAL MAINTENANCE SYSTEMS, I



STANDARD METHOD OF TAKING "FACE" READINGS WHEN COUPLING GAP PERMITS.

NOTE: BE SURE TO INSTALL THE "HOLE ATTACHMENT" IN THE MANNER SHOWN (DIAL INDICATOR SHOULD ALWAYS POINT BACK TOWARD THE MACHINE TO WHICH IT IS ATTACHED, NOT TOWARD THE COUPLING HALF ON WHICH IT IS READING). IF IT IS POINTING IN THE OTHER DIRECTION, THE SIGN OF THE READING MUST BE REVERSED BEFORE IT IS ENTERED INTO THE MAC.



THE SIGN OF THE READING MUST BE CHANGED WHEN THE DIAL INDICATOR IS PLACED AGAINST THE "BACK" OF THE COUPLING FACE (IF THE READING WAS +23, ENTER -23 INTO MA)

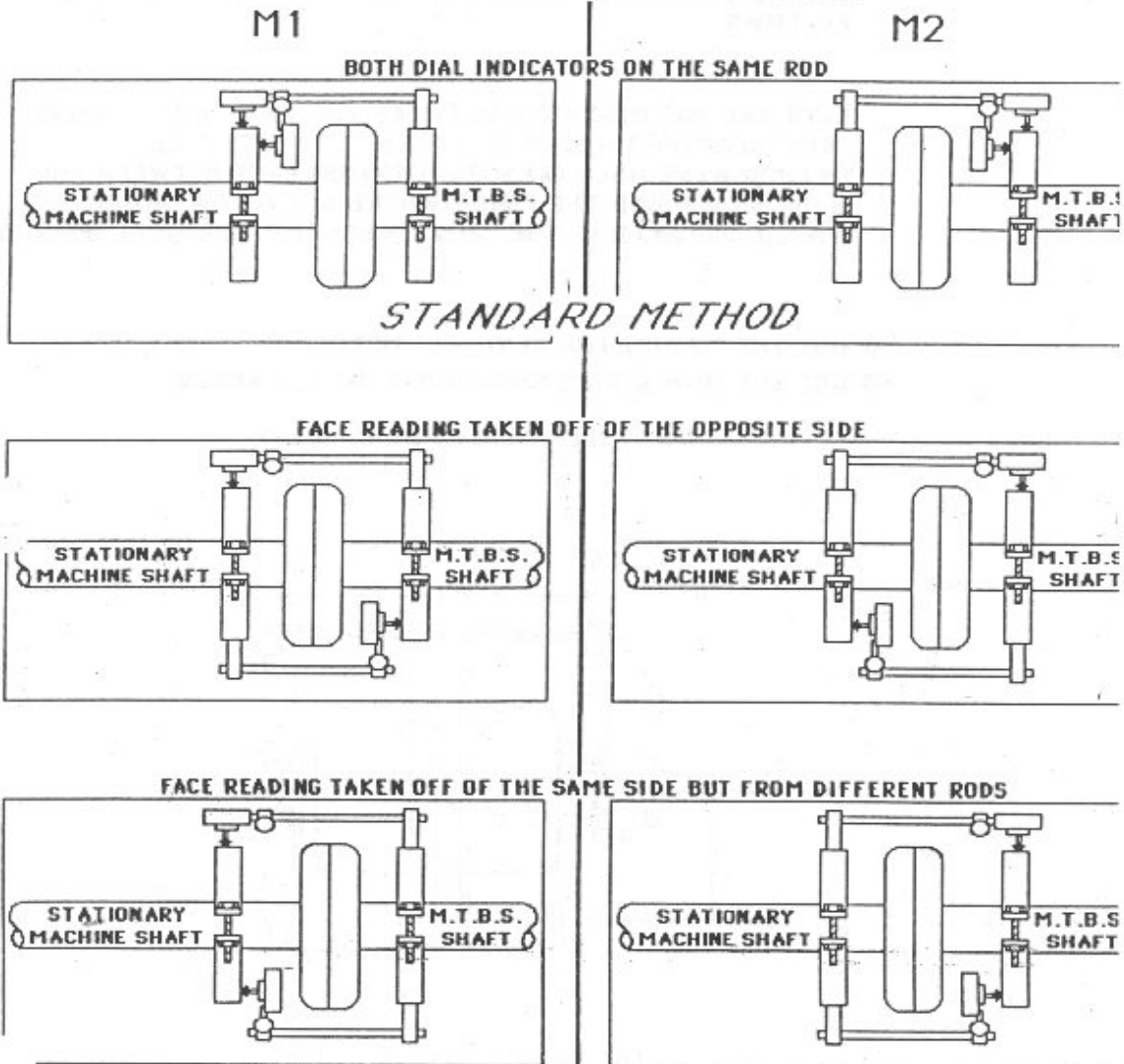
OBTAINING FACE READINGS WITH A DIAL INDICATOR
OFF OF COUPLING HUB

ILLUSTRATION NO.2

Massachusetts Maritime Academy
Third Class Maintenance Training

©1985, INDUSTRIAL MAINTENANCE SYSTEMS,

(NOTE: THE FACE READING WILL BE THE SAME, REGARDLESS OF WHICH SIDE OF THE COUPLING IT IS TAKEN ON)



ALTERNATE WAYS TO PLACE DIAL INDICATORS WHEN USING THE "RIM & FACE" (M1 OR M2) METHODS OF ALIGNMENT

ILLUSTRATION NO. 9

Massachusetts Maritime Academy
Third Class Maintenance Training

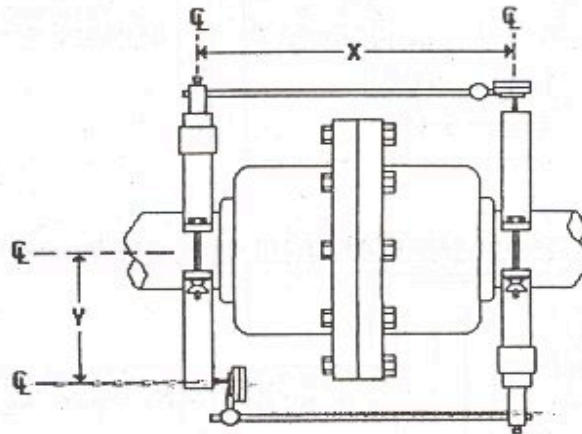
© 1985, INDUSTRIAL MAINTENANCE SYSTEMS

WHEN SHAFT "FLOAT" (END PLAY) IS NOT CONSIDERED TO BE A PROBLEM, A GOOD "RULE OF THUMB" TO USE WHEN TRYING TO DECIDE BETWEEN USING EITHER THE "RIM & FACE" OR THE "INDICATOR REVERSE" METHOD OF ALIGNMENT IS AS FOLLOWS:

COMPARE THE DISTANCE BETWEEN THE TWO POINTS WHERE "RIM" READINGS WOULD BE TAKEN IF THE "REVERSE" METHOD WERE USED (X) WITH THE DISTANCE BETWEEN THE ϕ OF SHAFT AND THE POINT WHERE A "FACE" READING WOULD BE TAKEN IF THE "RIM & FACE" METHOD WERE USED (Y).

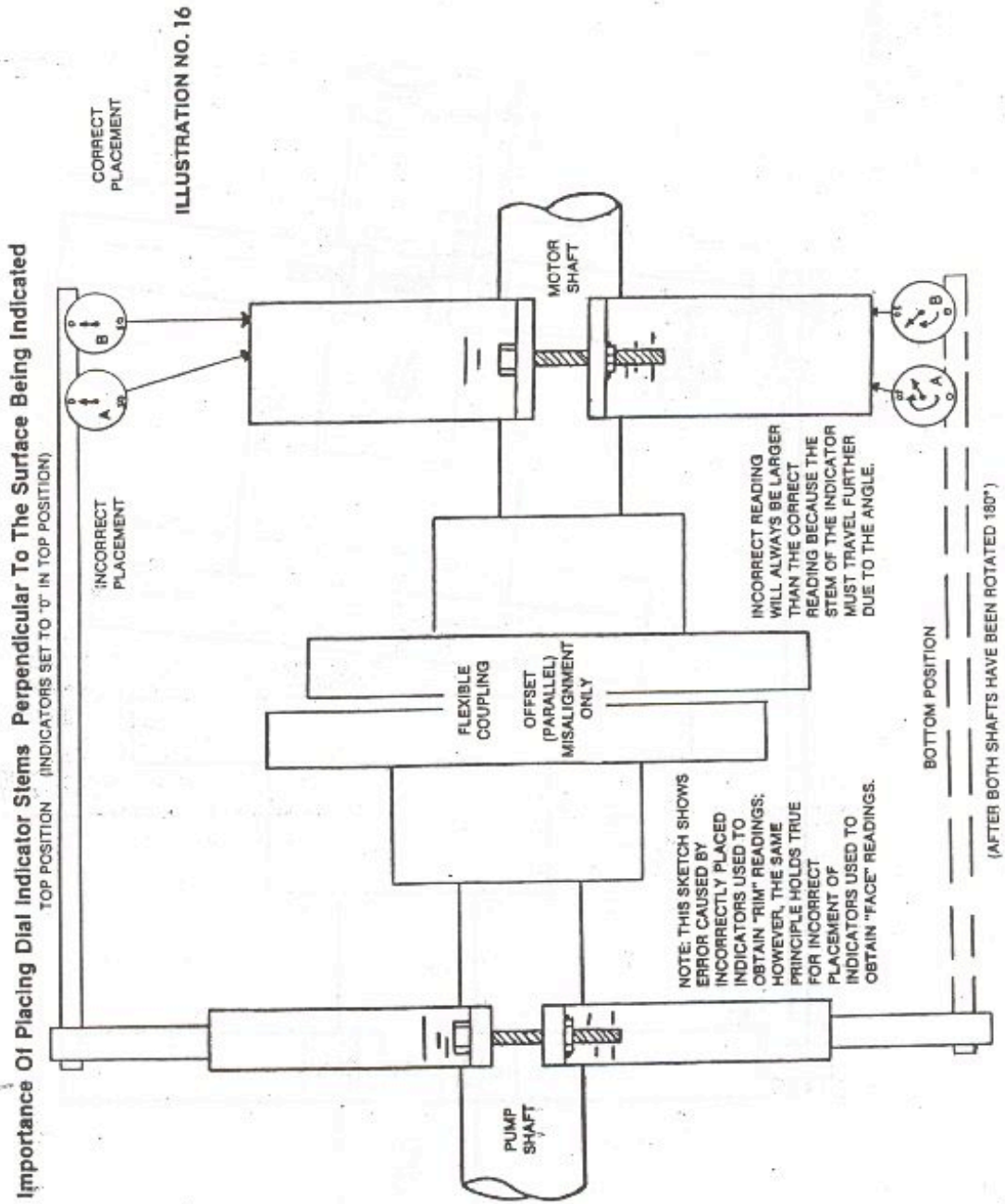
- USE THE "INDICATOR REVERSE" METHOD IF "X" IS LARGER.
- USE THE "RIM & FACE" METHOD IF "Y" IS LARGER.

("X" WILL USUALLY BE LARGER)



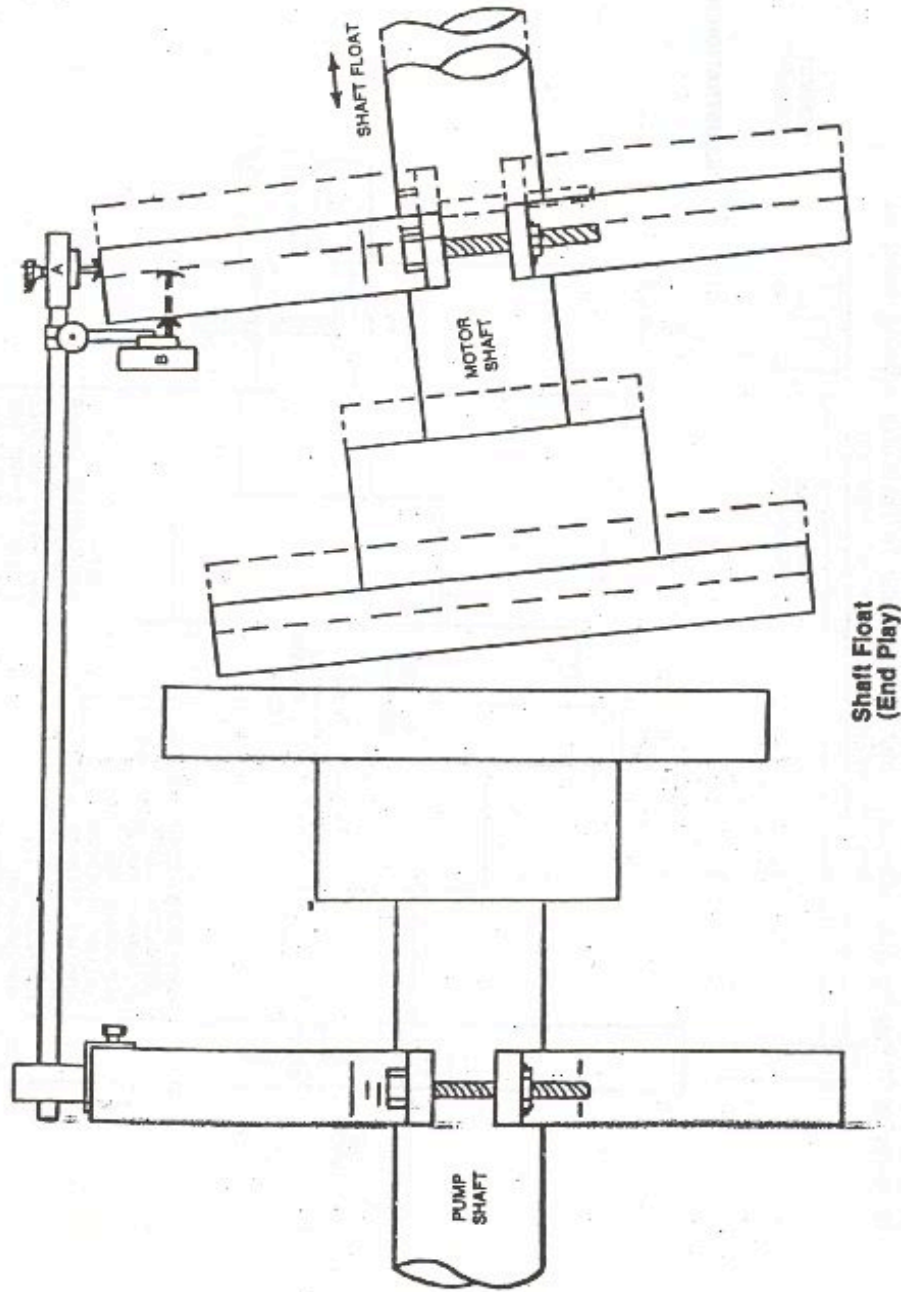
DISTANCE VS. RADIUS

ILLUSTRATION NO. 10

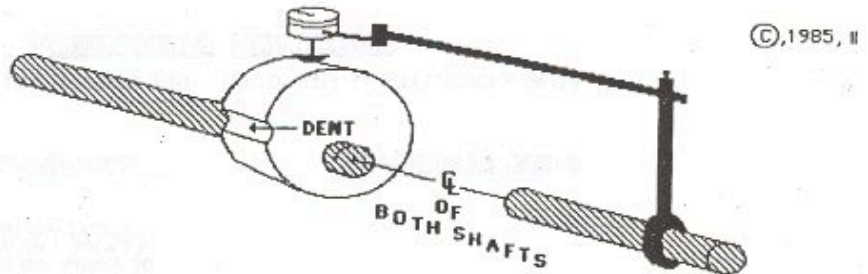


Massachusetts Maritime Academy
Third Class Maintenance Training

ILLUSTRATION NO. 18



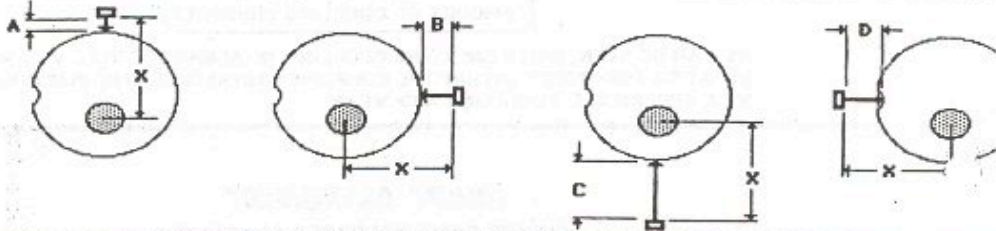
AS CAN BE SEEN IN THE ABOVE SKETCH, SHAFT FLOAT CAN GREATLY AFFECT "FACE" READINGS; HOWEVER, IT HAS VERY LITTLE (IF ANY) EFFECT ON "RIM" READINGS. THIS IS THE BASIS OF THE "INDICATOR REVERSE METHOD."



THE ABOVE ILLUSTRATION SHOWS TWO PERFECTLY ALIGNED SHAFTS WITH THE DIAL INDICATOR BRACKET ATTACHED TO THE SHAFT ON THE RIGHT AND THE DIAL INDICATOR STEM POSITIONED AGAINST THE COUPLING HUB WHICH IS ATTACHED TO THE SHAFT ON THE LEFT. NOTE THAT THE COUPLING HUB HAS BEEN MISBORED (OFF-CENTER) AND THAT THERE IS A LARGE DENT ON THE RIM OF THE COUPLING.

COUPLING ALIGNMENT

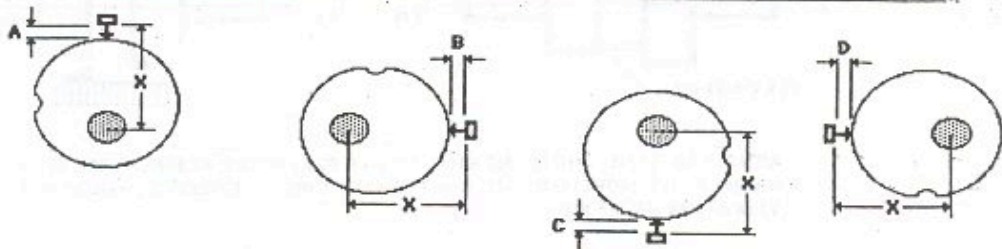
(ONLY THE SHAFT ON THE RIGHT IS ROTATED TO OBTAIN DIAL INDICATOR READINGS)



DISTANCE "X" MUST ALWAYS REMAIN A CONSTANT AS IT IS DETERMINED BY THE BRACKET LENGTH. NOTE THAT THE LENGTH OF THE DIAL INDICATOR STEM CHANGES AS EACH OF THE FOUR READINGS ARE TAKEN (STEM LENGTH = A, B, C, and D) EVEN THOUGH THE SHAFTS ARE PERFECTLY ALIGNED. IF ADJUSTMENTS WERE MADE TO THE MACHINE SO THAT THE DIAL INDICATOR READ "ZERO" AT ALL FOUR POINTS, THE AMOUNT OF ADJUSTMENT WOULD HAVE TO BE DEPENDENT UPON THE AMOUNT OF MISBORE AND THE DEPTH OF THE DENT. *WE SURELY DON'T WANT TO ALIGN A MACHINE TO A DENT OR A MISBORE.*

SHAFT ALIGNMENT

(BOTH SHAFTS ARE ROTATED EQUALLY WHEN TAKING READINGS)



NOTE THAT THE LENGTH OF THE INDICATOR STEM DOES NOT CHANGE WHEN THE READINGS ARE TAKEN (THUS SHOWING PERFECT SHAFT ALIGNMENT).

SHAFT ALIGNMENT VS COUPLING ALIGNMENT

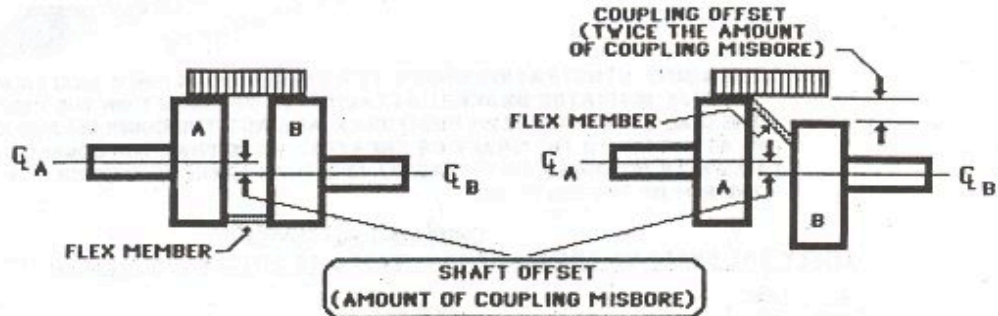
ILLUSTRATION NO. 19

COUPLING ALIGNMENT

(WHEN COUPLING IS MISBORED--OFF CENTER BUT NOT ANGLED)

FINAL ALIGNMENT

AFTER SHAFTS ROTATE 180°



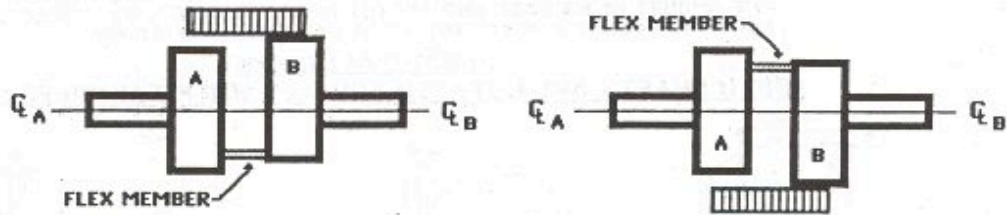
AS CAN BE SEEN, WHEN ONLY THE COUPLING IS ALIGNED, THERE WILL BE RELATIVE MOVEMENT WITHIN THE COUPLING; THEREFORE, THE MACHINERY WILL EXPERIENCE VIBRATION AND WEAR.

SHAFT ALIGNMENT

(USING SAME MISBORED COUPLING)

FINAL ALIGNMENT

AFTER SHAFTS ROTATE 180°

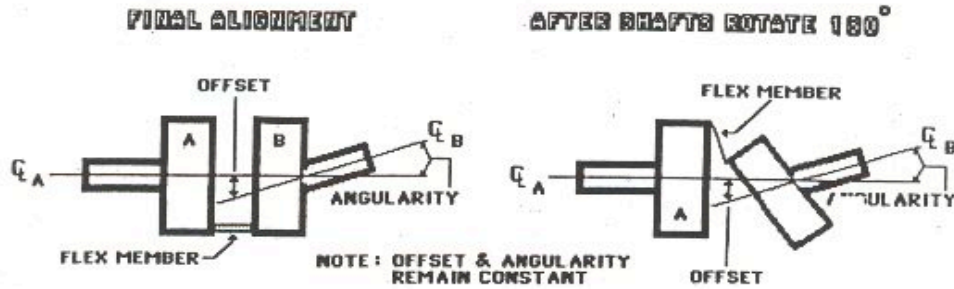


AS CAN BE SEEN, WHEN THE SHAFTS ARE PERFECTLY ALIGNED, THERE IS NO RELATIVE MOVEMENT WITHIN THE COUPLING; THEREFORE, THERE IS NO VIBRATION OR WEAR.

COUPLING ALIGNMENT VS SHAFT ALIGNMENT

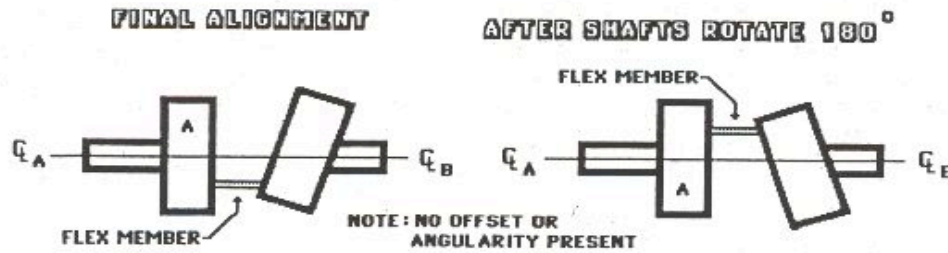
ILLUSTRATION NO. 20

COUPLING ALIGNMENT
(WHEN COUPLING IS MISBORED-- ANGULAR MISBORE)



AS CAN BE SEEN, WHEN ONLY THE COUPLING IS ALIGNED, THERE WILL BE RELATIVE MOVEMENT WITHIN THE COUPLING; THEREFORE, THE MACHINERY WILL EXPERIENCE VIBRATION AND WEAR.

SHAFT ALIGNMENT
(USING SAME MISBORED COUPLING)

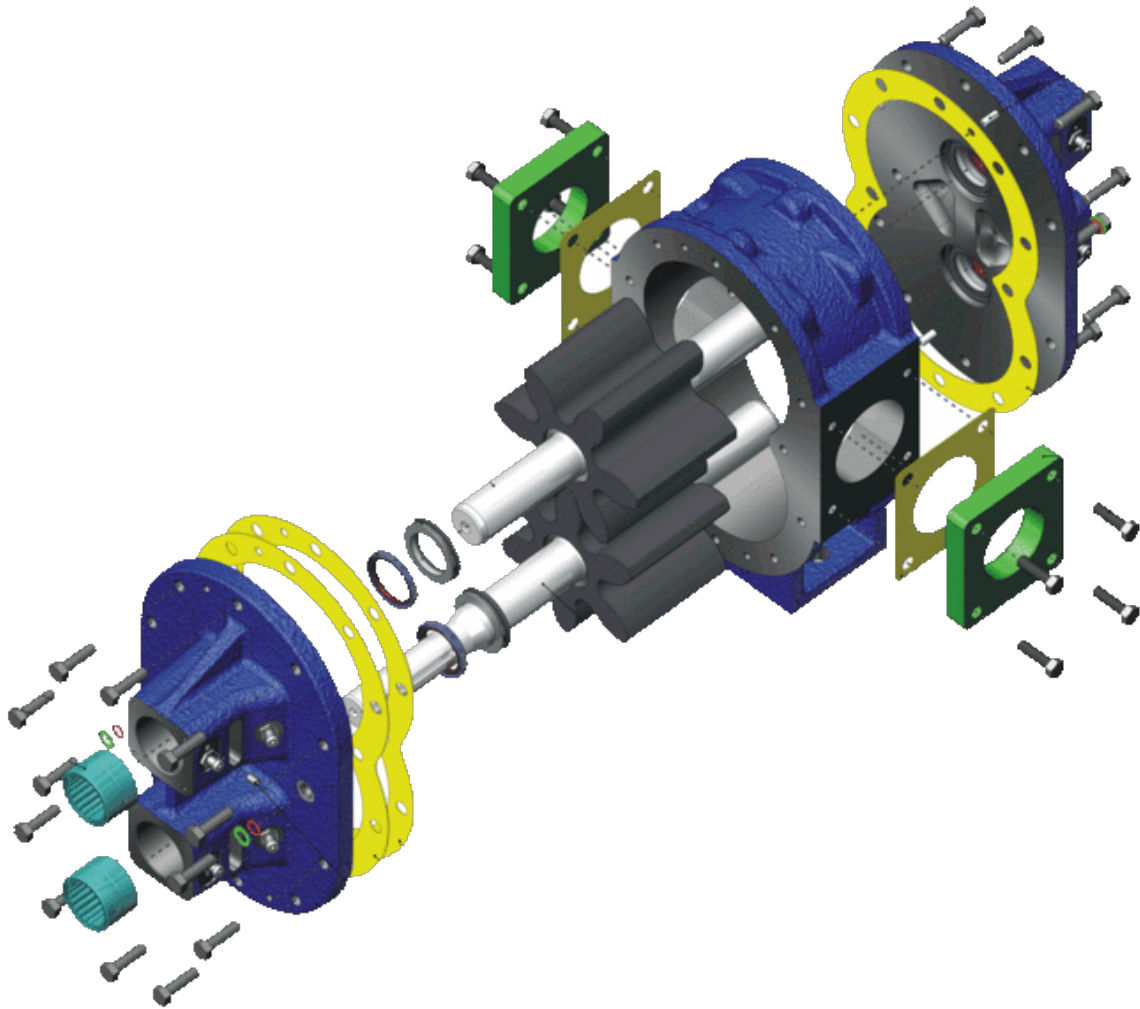


AS CAN BE SEEN, WHEN THE SHAFTS ARE PERFECTLY ALIGNED, THERE IS NO RELATIVE MOVEMENT WITHIN THE COUPLING; THEREFORE, THERE IS NO VIBRATION OR WEAR.

COUPLING ALIGNMENT VS SHAFT ALIGNMENT

ILLUSTRATION NO. 21

Lab #6 - Gear Pump Maintenance



Massachusetts Maritime Academy
Third Class Maintenance Training

OICEW-8-2C Gear Pump Maintenance

| | |
|---------------------|---|
| Assessment | OICEW-8-2C |
| Task: | Gear pump maintenance |
| Level: | Third Class |
| Location | Maintenance Training Workshop |
| Prerequisite | 3/c Status on Cruise |
| Performance | Access to necessary tools, materials, blueprints or manufacturers manuals |
| Condition | |

MMA Performance Standards

| Assessment Criteria | Specific Expectations | Suggested Emphasis |
|---|---|---------------------------|
| <i>The student will:</i> | <i>During assessment, the student shall at a minimum:</i> | |
| • Disassemble gear pump | | 20 |
| • Inspect all parts for wear and deterioration | Check the following clearances: <ul style="list-style-type: none"> • end plate • radial • shaft bearings | 30 |
| • Repair gear pump | Replace parts as necessary to bring pump to manufacturers specifications | 30 |
| • Reassemble gear pump | Replace and adjust seals/gaskets as necessary | 20 |

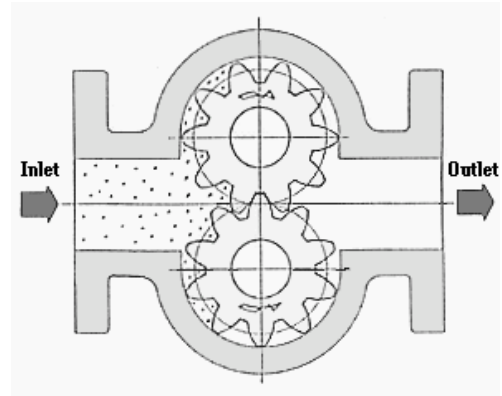
Gear Pump Maintenance

STCW Assessment: OICEW-8-2C: Gear Pump Maintenance

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the construction and operation of an external gear pump.
2. Disassembles and inspects pump for wear and deterioration.
3. Measures shaft/bearing clearance, total end and radial clearance.
4. Reassembles pump and replaces mechanical seal.
5. Will learn how to identify the construction details of various types of gear pumps.



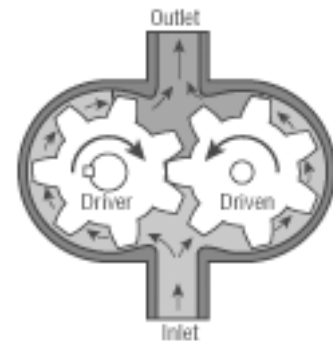
Special Tools and Equipment supplied by the Marine Engineering Department:

- Calipers
- Torque Wrench
- Brass Driving Pins
- Brawn and Sharpe 3S Helical Gear Pump
- Pump Schematics

Basic hand tools are supplied by 3rd class cadets as required¹⁰.

Gear Pump Components and Operation

1. The GEAR pump is the most common variety of rotary pumps. Figure 1 illustrates the pumping action of a simple gear pump. One of the gears is driven directly by the power source (the DRIVEN GEAR) while the other (the IDLER GEAR) rotates with it in the opposite direction. Direct contact between the driven gear teeth and the idler gear teeth at the center of the pump chamber causes the idler gear to rotate.
2. The RADIAL CLEARANCE denotes the close clearances between the gear teeth and pump casing or housing. The END CLEARANCE denotes the clearance between the flat surfaces on the gear ends and the end plates or caps. GEAR BACKLASH denotes the clearance between the teeth of the two gears at their point of contact where they form a continuous liquid tight joint.
3. As the gears rotate in the direction indicated, liquid is trapped between each set of gear teeth and the casing and is carried away from the suction side of the pump. As the teeth unmesh in the center of the pump chamber, a low pressure area is left in the empty space between the gear teeth. Liquid, from the

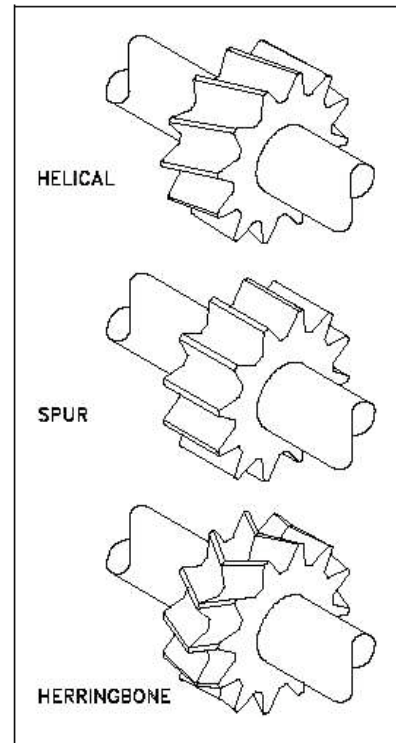


¹⁰ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

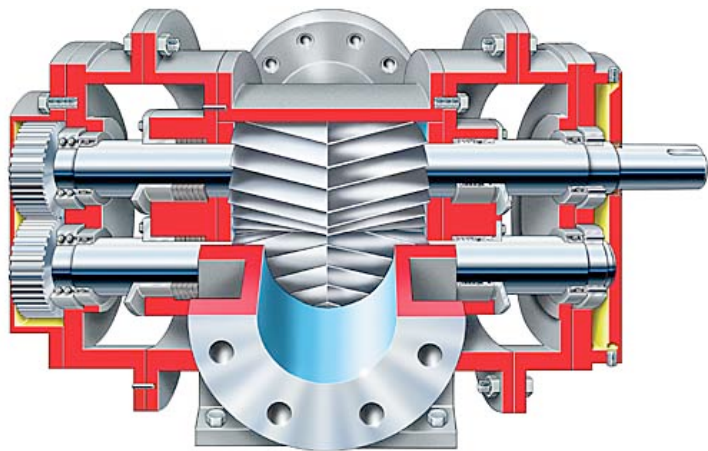
Massachusetts Maritime Academy
Third Class Maintenance Training

source of supply, flows in to fill the low pressure areas between the gear teeth. As the gear teeth remesh on the discharge side of the pump, the liquid in between the gear teeth is forced out, eventually flowing to the discharge connection on the pump casing.

4. Gear pumps are Positive Displacement, as they are designed to deliver a fixed quantity of liquid for each revolution of the driven shaft. The pump will continue to deliver fluid even if the discharge is closed or blocked. If the discharge of the gear pump were closed with the pump operating, and no pressure relief valve were installed in the pump discharge line, the pressure on the discharge side of the pump would build up until:
 - a. the pump casing or piping gaskets blow out;
 - b. the driven shaft seal fails;
 - c. the motor driving the pump overloads and stops; or
 - d. the pump casing or pipe ruptures.
5. Three kinds of true gears are used in gear pumps: spur, helical, and herringbone. Spur and helical gear pumps can be rotated in the opposite direction to reverse the flow through the pump. A herringbone gear pump is generally not reversible because liquid trapped in the “vee” of the gears upon reverse rotation will result in pressure strains on the shafts and bearings.



The herringbone gear shown in to the right utilizes gears with a very sharp “vee” shape to the gear teeth. These designs are used to provide a very smooth discharge flow. The steep angle of the gear teeth prevents the driven gear from driving the idler gear; the teeth will jam rather than rotate freely. Rotary motion is transmitted to the idler shaft via a set of timing gears located on the ends of both shafts. The timing gears prevent driving contact between the pumping gears to eliminate the jamming problem.



6. When a gear pump is operating at a fixed speed, it should deliver a fixed quantity of liquid. Doubling the speed of a gear pump will theoretically double the discharge capacity. Gear pumps are not 100% efficient meaning that not all of then pumped liquid discharges through the outlet side of the pump, a small portion of the liquid returns to the suction side of the pump through the close clearances between the stationary and moving parts in the pump casing. The internal

Massachusetts Maritime Academy
Third Class Maintenance Training

leakage is known as SLIP and is expressed as a percentage of theoretical pump capacity.

Example: A gear pump running at constant speed has a theoretical capacity of 100 GPM and a true delivery of 94 GPM. Determine the pump efficiency and slip.

$$\text{Efficiency} = \frac{\text{Actual delivery}}{\text{Theoretical delivery}} = \frac{94 \text{ gpm}}{100 \text{ gpm}} = 94\%$$

$$\text{Slip} = \frac{\text{Theoretical} - \text{Actual Flow}}{\text{Theoretical Flow}} = \frac{100 - 94 \text{ gpm}}{100 \text{ gpm}} = 6\% \text{ slip}$$

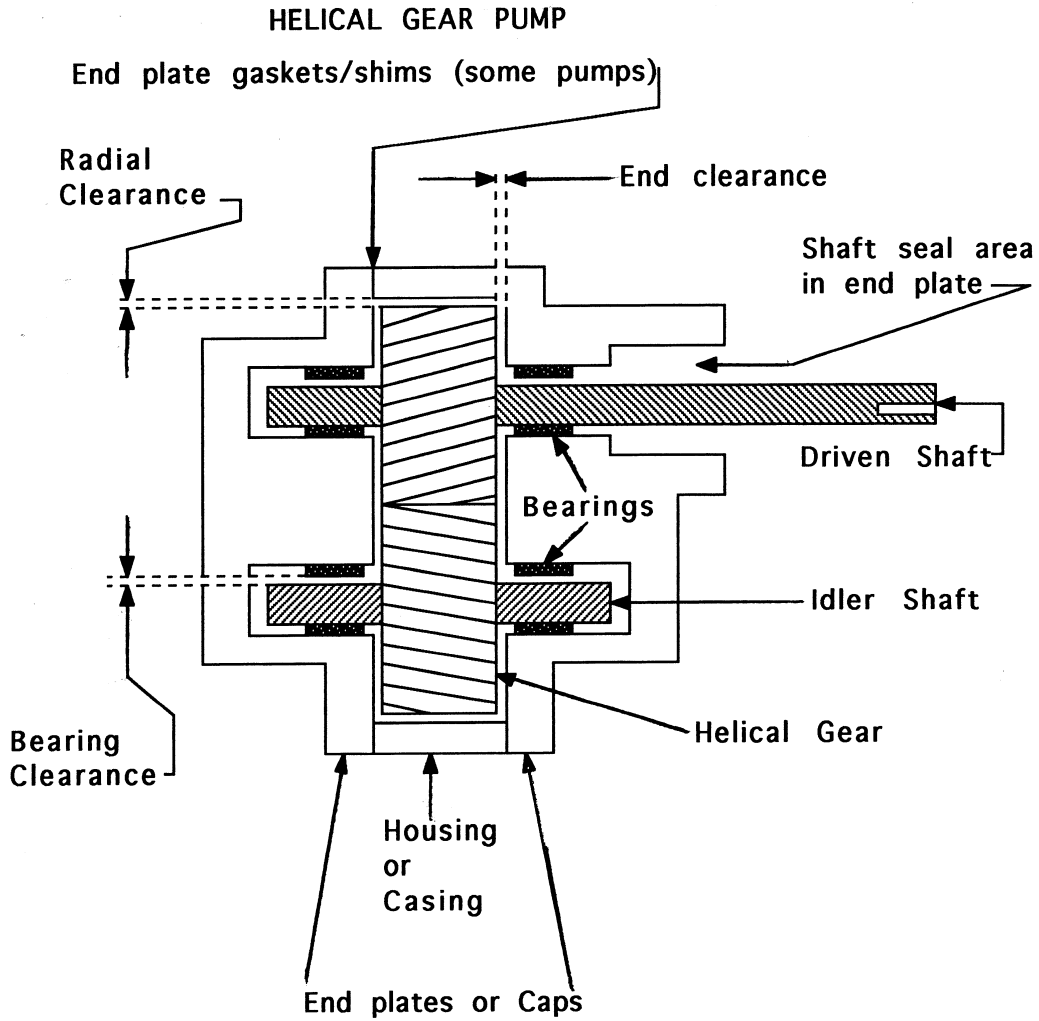
The following will cause slip to increase and discharge capacity of the gear pump to decrease:

- a. Increasing the pump discharge pressure;
- b. Pumping a lower viscosity (thinner) liquid than the pump is designed for; or
- c. Any wear increasing the close clearances (radial or end) between the moving and stationary parts inside the pump housing.

7. Brown & Sharpe 3S Pump Details:

The pump is positive displacement, self-priming and unidirectional. The discharge port is located on the side of the pump toward which the top shaft rotates and is marked by an arrow located on the top of the pump stand. The housing, end cap and stand are constructed of cast iron. The pump gears and shafts are hardened steel and the bearing sleeves are replaceable. Lubrication of the shafts and sleeve bearings, the gear ends, end caps, and the gear teeth contact points is accomplished by the circulation of the pumped liquid. The best results are obtained by when the liquid is clean and possesses good lubricating qualities. The 3S pump is suited to handle oils in the 300 to 750 SSU viscosity range which includes various types of lubricating, coolant and hydraulic fluids. Non-lubricating liquids may be pumped with some sacrifice to service life and performance. At it's maximum operating speed (1725 RPM) and it's maximum discharge pressure (200 PSI), the pump delivers 15.7 GPM of oil with a viscosity of 300 SSU and requires 3.1 HP to drive it.

Massachusetts Maritime Academy
Third Class Maintenance Training



Clearances for Brown & Sharpe 3S pump
New pump

Worn pump

| | | |
|--------------------------|----------------------|------------|
| Radial clearance: | ----- .003" to .004" | .008" max. |
| TOTAL end clearance | ----- .003" to .005" | .010" max |
| Shaft diameter ground to | ---- .749" | |
| Bearing clearance | ----- .001" to .002" | .003" max |

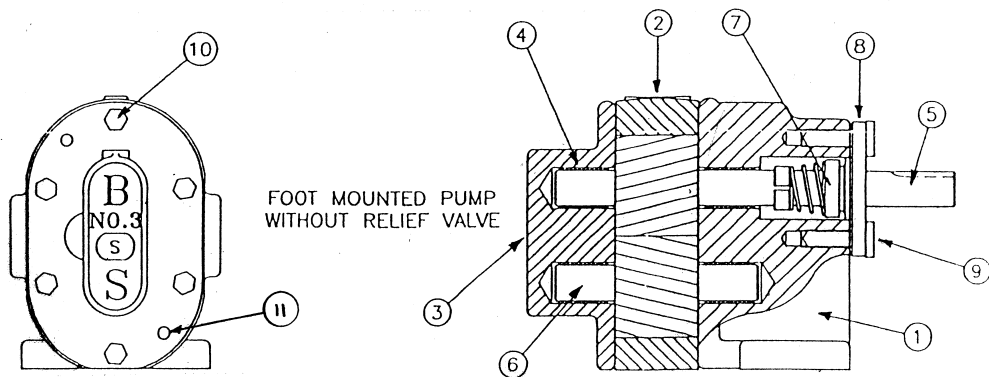
Massachusetts Maritime Academy
Third Class Maintenance Training

Disassembly And Inspection Of B&S 3S Pump

A gear pump generally needs inspection when it will no longer maintain its designed capacity (GPM) or discharge pressure (PSI).

1. Pump Removal
 - a. Lock-out and tag-out the engine or motor starting controls.
 - b. Close, lock-out and tag-out the suction and discharge valves.
 - c. Remove coupling between the pump and motor shaft.
 - d. Loosen the suction and discharge piping to drain fluid from pump, then disconnect piping from pump housing.
 - e. NOTE: The pump manufacturer recommends removing the pump to a work bench for all repairs.

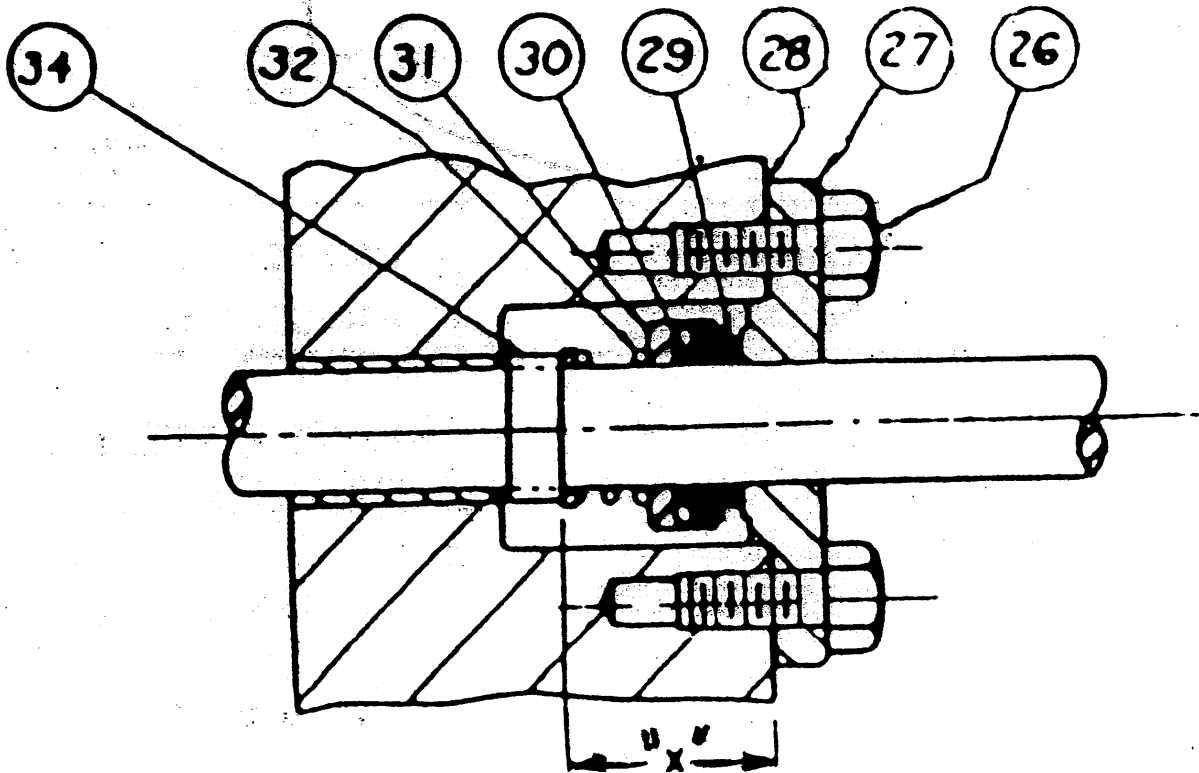
2. With the pump on a workbench, place ID marks on the end cap (#3), stand (#1) and the housing to aid in pump reassemble. *Note that there are center punch marks already made on the top of these parts.*



| B&S - 3S Pump Parts | | |
|---------------------|------------------------|-----|
| Ref # | NAME | QTY |
| 1 | Stand | 1 |
| 2 | Housing or Casing | 1 |
| 3 | End Plate or End Cap | 1 |
| 4 | Bearing | 4 |
| 5 | Driven Gear Shaft/Gear | 1 |
| 6 | Idler Gear Shaft/Gear | 1 |
| 7 | Mechanical Seal | 1 |
| 8 | Gland | 1 |
| 9 | Gland Bolt | 2 |
| 10 | Housing Bolt | 6 |
| 11 | Dowel Alignment Pin | 4 |

Massachusetts Maritime Academy
Third Class Maintenance Training

3. Using the mechanical seal drawing (below) as a reference:
 - a. Remove gland bolts (#26) and gland (#27).
 - b. Protect the stationary seal surface on the gland from damage then carefully remove gland gasket (#28).
 - c. *Carefully* pull out the moving seal, carbon seal (#29). **Protect the seal from damage and set aside.**
 - d. *Carefully* remove “O” ring (#30) and seal cup (#31) and set aside.



| Mechanical Seal Data for 3S Pump | |
|--|--------------|
| Ref # | Name |
| 26 | Gland Bolt |
| 27 | Gland Bolt |
| 28 | Gland Gasket |
| 29 | Carbon Ring |
| 30 | “O” Ring |
| 31 | Steel Cup |
| 32 | Seal Spring |
| 34 | Seal Stop |
| NOTE: “X” Dimension for 3S Pump = 31/32” or 0.96875” | |

4. Remove 6 housing bolts (#10) from end cap (#3).
5. End Cap Removal

Massachusetts Maritime Academy
Third Class Maintenance Training

Do not use a screwdriver or any other object to pry the end cap or the stand from the housing! The end cap, housing and stand do not use gaskets between them for a seal. They use a machined metal-to-metal fit with only a light coat of shellac to help with the seal. Any damage to the seal faces could result in joint leakage!

- a. Tap end of driven shaft (#5) with brass hammer or regular hammer and brass rod to push the end cap away from the housing.
 - b. When the alignment pins (#11) clear the housing, remove the end cap and the idler shaft/gear assembly (#6).
 - c. Place the outside of the cap, near a dowel pin, on the top of the bench vice and tap the dowel pins down flush with seal surface. ***DO NOT HIT THE SEAL SURFACE!***
 - d. Set the end cap down with the shaft holes pointed up. Place the idler shaft into the correct hole of the end cap to prevent damage.
6. Although the manufacturer recommends complete disassembly of the pump, ***DO NOT REMOVE THE HOUSING FROM THE STAND!*** Instead place a housing bolt (with a washer, spacer nut, and washer under each bolt head) and firmly bolt the housing to the stand using the top and bottom bolt holes.
7. Continue to tap out the driven shaft (the rod with the pointed end will be needed to completely drive the shaft out) until seal spring (#32) and seal stop (#34) fall off the end of the shaft. ***Be careful that the spring and stop do not spring away or the driven shaft will fall out and becomes damaged.***
8. Place the driven shaft in the end cap to prevent damage.
9. Note Construction Features:
- a. There are no gaskets between the end cap, housing and stand, and there are also no shims at these locations to adjust end clearance.
 - i. Type of gears are installed? _____
 - ii. Type of bearings are installed? Bushings or Ball Bearings
 - b. Note the relief hole cut in the end cap and stand at the point where the gear teeth mesh:
 - i. End cap relief is on the discharge side of the pump and allows the small amount of liquid trapped between the gear teeth to escape through this relief to the pump discharge. It prevents high-pressure build-up between the gear teeth that could place heavy loads on the shaft bearings.
 - ii. Stand relief is on the suction side of the pump and is connected to the stuffing box/seal area by a small drilled hole. This prevents high-pressure liquid (leaking between the driven shaft and its bearing) from building up excess pressure behind the mechanical seal. Excess liquid is recycled back to the suction side of the pump instead.

Massachusetts Maritime Academy
Third Class Maintenance Training

- c. Note: For the reliefs to work properly, the pump can only be turned in one direction of rotation.
- d. If the driven shaft is viewed from the coupling end, the correct direction of rotation is? *Clockwise Counter or Clockwise*

10. Inspect Pump Components For Wear And Deterioration:

- a. Corrosion: Should be none if pump is being used with the liquids it was designed for. Small pits will not interfere with pump operation, deep pits requires replacement of parts.
- b. Erosion: Identified by roughened surfaces where high velocity fluid passes between close fitting surfaces. Look for this on the end of the gear teeth and housing and sometimes on the gear sides and the end caps. Mild roughness is not a problem, but deeply grooved surfaces require replacement of the affected parts.
- c. Grooves or Scratches: Found on sides of gears and end caps and ends of gear teeth and housing. Caused by contact between these moving and stationary parts or dirt caught between the moving and stationary parts. Small grooves that a fingernail will just catch on are not a problem.
- d. Deep grooves will present pump operating problems can be solved in the following manner:
 - i. Deep grooves in the housing or on the ends of the gear teeth require replacement of the parts;
 - ii. If the pump uses shims between the end caps and housing, than it is possible to machine the sides of the gears smooth again, machine the end cap surfaces smooth again and readjust the gear end clearance with the shims.
 - iii. With the B&S 3S pump, the end cap, housing and stand are made from relatively soft cast iron while the shafts and gears are hardened steel. Most wear will take place on the end caps or housing. The end caps on this pump can be machined down a maximum of .060" from their original thickness to remove grooves. *No more than this is recommended since this machining reduces the pressure reliefs in the cap and stand to half their original depth.*
 - iv. It is possible that worn bearings caused the contact between the gears and the stationary parts. They should be examined, measured and replaced if necessary .

11. Measuring Pump Clearances

Although other precision measuring instruments can be used, a 6" dial micrometer will be used for this pump. This dial micrometer will measure distances between two surfaces and to the outside of two surfaces. It also has an extension on the end to measure depth. Be sure to "zero" the indicator before using it and wipe off any dirt on the measuring surfaces of the micrometer and the surfaces being measured. *A small piece of dirt could change the actual reading by several thousandths of an inch.*

Massachusetts Maritime Academy
Third Class Maintenance Training

a. END CLEARANCE:

| | Driven Gear | | Idler Gear | |
|----------------------------|-------------|----|------------|----|
| Minimum Depth of Housing | | | | |
| Minimum Thickness of Gear | | | | |
| TOTAL End Clearance | | | | |
| Are Clearances Acceptable? | YES | NO | YES | NO |

b. BEARING CLEARANCE:

| | Top | | Bottom | |
|-------------------------------|-----|----|--------|----|
| Maximum ID of Bearing Bushing | | | | |
| Maximum OD of Shaft | | | | |
| Bearing Clearance | | | | |
| Are Clearances Acceptable? | YES | NO | YES | NO |

c. RADIAL CLEARANCE:

Although it is possible to obtain radial clearance by subtracting the maximum OD of the gear from the minimum ID of the housing the gear rotates in and then dividing this answer by 2, it is difficult to get an accurate OD on a helical gear and impossible to measure the OD on a gear with an odd number of teeth as no two teeth are directly opposite one another and the measurement will show a diameter smaller than actual. The radial clearance will therefore be measured using a "feeler gage".

- i. Hold the stand in a vice with the housing up.
- ii. Install the driven and idler shafts into the housing.
- iii. Look up the original radial clearance and use the feeler gage blade that matches the smallest original clearance.
- iv. Carefully insert the blade between the gear tooth and the housing. The correct reading will be obtained when a slight force is required to push the blade all the way into the space between the gear tooth and housing. If the first blade goes in easily, use the next thicker blade and so on until a slight push or pull is required to move the blade between the gear tooth and housing.

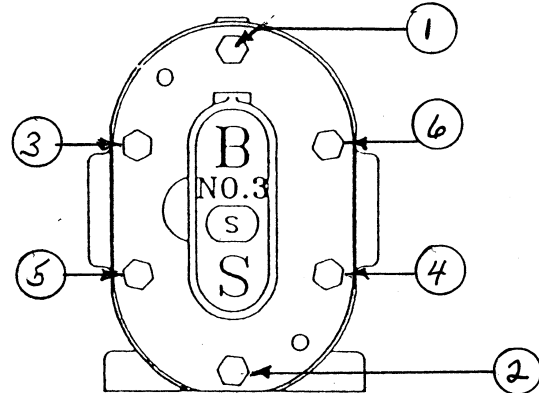
| | | |
|--|-----|----|
| Feeler gage reading driven gear tooth to housing = | | |
| Clearance Acceptable? | Yes | No |
| Feeler gage reading idler gear tooth to housing = | | |
| Clearance Acceptable? | Yes | No |

Massachusetts Maritime Academy
Third Class Maintenance Training

12. REASSEMBLING PUMP

- a. Prior to reassembly, thoroughly clean all parts. If pump was to be placed in service, all sealing surfaces would also be thoroughly cleaned, dried and free of oil or grease. A light coat of shellac would be applied to the housing, end cap and stand sealing surfaces.
- b. With stand still in vice, lightly oil bearings and insert the driven and idler shafts. Remove the 2 housing bolts with the washer and nut spacers.

- c. Lightly oil the bearings in the end cap. Note the alignment marks on the end cap and install it over the gear shafts onto the housing. Lightly lube the six housing bolts with anti-seize, install them and just snug them up.



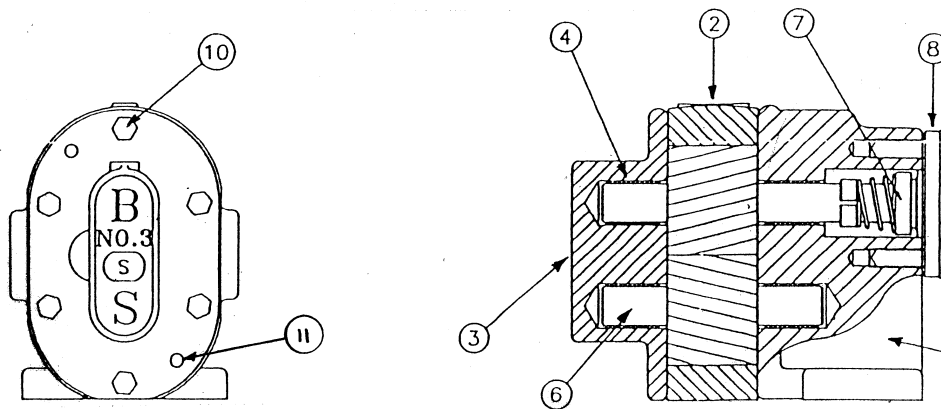
- d. Tap the alignment pins into place. Check pump for ease of rotation. Tighten housing bolts to 25 inch/lbs then to 55 inch/ lbs following the tightening pattern below. Check pump for ease of rotation.
- e. Using the mechanical seal drawing (figure xx), tap the seal stop (#34) onto the pump shaft with the split end even aligned with the keyway. Use the piece of 3/4" pipe to tap the seal stop onto the shaft to the "X" dimension shown on the seal drawing.
- f. Install the small tight end of the seal spring (#32) towards the seal stop. by pushing it into place with the 3/4" pipe. Install the flat side of the seal cup (#31) against the spring.
- g. Install the "O" Ring (#30) carefully over shaft to avoid nicks or damage from keyway.
- h. Install carbon ring (#29) with the chamfer next to the "O" ring and the lapped seal surface facing outward toward the gland. The 2 recesses in the outer edge of the carbon ring must line up and engage the detents in the seal cup.
- i. If the pump were going to be placed in actual operation a light coat of shellac would be applied to each side of the gland gasket. Install the gland gasket (#28).
- j. Install seal side of gland (#27) against the carbon ring. Install and start the gland bolts (#26). Push the gland down tightly against the gasket and tighten the gland bolts finger tight.
- k. Tighten gland screws to 144 inch-lbs with torque wrench and check pump for ease of rotation.
- l. To place pump back in operation, bolt it back down to foundation, reattach piping, check shaft alignment between pump and motor, reinstall coupling, line up pump and motor and test for proper operation.

Massachusetts Maritime Academy
Third Class Maintenance Training

QUESTIONS FOR MT GEAR PUMPS:

1. What turns the idler in most gear pumps?
2. List the three types of gears that are used in gear pumps.
3. What turns the idler in steep-vee herringbone pumps and why?
4. What causes the liquid to flow in on the suction side of a gear pump?
5. If the discharge valve were closed on a operating gear pump and the relief valve failed to open, list 4 failures that could result from this.
6. What is slip?
7. A gear pump delivers 42 GPM, but is designed to deliver 65 GPM. What is the pump efficiency and what is the slip?
8. List 3 things that increase gear pump slip and decrease discharge capacity.
9. Name the pump parts from the drawing below.

| | |
|----|-----|
| #1 | #4 |
| #2 | #6 |
| #3 | #11 |

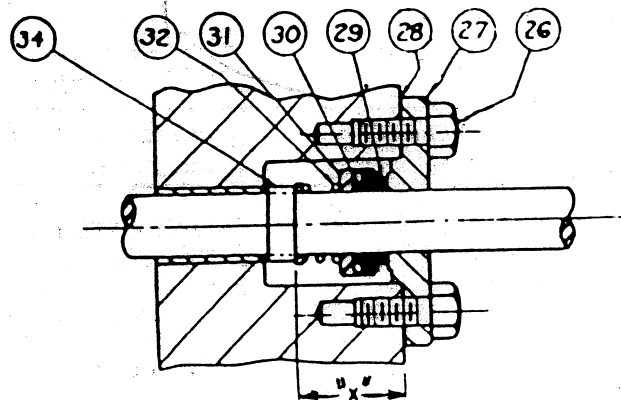


10. List three clearances that are important for proper gear pump performance.
11. What lubricates the stationary and moving contact surfaces in a gear pump?

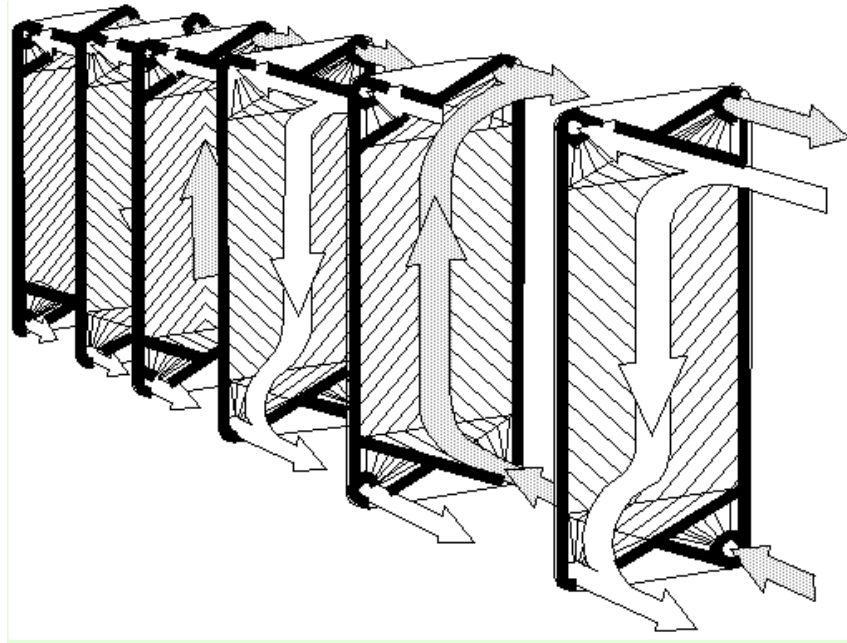
Massachusetts Maritime Academy
Third Class Maintenance Training

12. What safety steps should be done prior to opening up an operating gear pump for inspection, maintenance and repair?
13. What parts of a mechanical seal must be handled with care and why?
14. If the bearing clearance is too great in the B&S 3S pump, what can be done?
15. What is the relief for in the end cap of the 3S pump?
16. What is the relief for in the stand of the 3S pump?
17. How can you tell the correct direction of rotation of the 3S pump?
18. What can be done if grooves 0.040" deep were found on the machined surfaces of the end cap and stand of the 3S pump?
19. List two things that could cause the deep grooves in question 18.
20. How is end clearance measured?
21. How is bearing clearance measured?
22. How is radial clearance measured?
23. When using a feeler gage, how do you know when you have a good reading?
24. What is used to seal the joints of the B&S 3S gear pump?

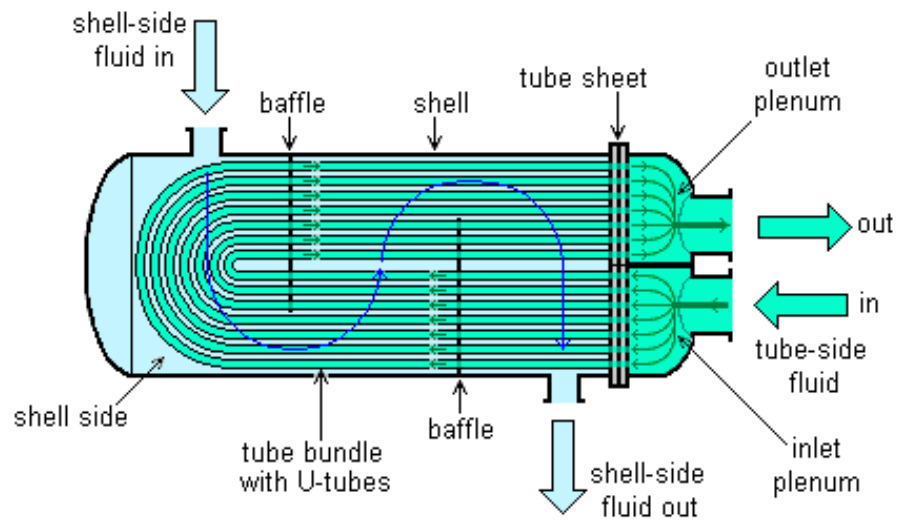
25. Regarding the gland seal drawing to the right, what part must be adjusted properly so that the seal spring applies the proper pressure to the carbon ring and the gland?



Lab #7 - Heat Exchangers



U-tube heat exchanger



Massachusetts Maritime Academy
Third Class Maintenance Training

OICEW-8-2F Overhaul Heat Exchanger

| | |
|------------------------------|--|
| Assessment | OICEW-8-2F |
| Task: | Overhaul Heat Exchanger |
| Level: | Third Class |
| Location | Maintenance Training Workshop |
| Prerequisite | 3/c Status on Cruise |
| Performance Condition | Access to necessary tools, materials, blueprints or manufacturer's manuals |

MMA Performance Standards

| Assessment Criteria | Specific Expectations | Suggested Emphasis |
|-------------------------------------|--|---------------------------|
| <i>The student will:</i> | <i>During assessment, the student shall at a minimum:</i> | |
| • Disassemble heat exchanger | | 20 |
| • Inspect heat exchanger | Perform hydrostatic test or black light / dye test for tube and seal leakage. Note indication of corrosion, erosion, and fouling | 30 |
| • Maintain heat exchanger | As necessary: <ul style="list-style-type: none"> • clean, de-scale and plug tubes • check, clean or replace zincs • replace head gaskets or seals | 30 |
| • Reassemble heat exchanger | Fill and prove leak free | 20 |

STCW Assessment: OICEW-8-2F: Overhaul Heat Exchanger

Project Time: 4 hours

“The expected learning outcome is that the trainee...”

1. Understands the construction and operation of a shell and tube and plate type heat exchangers.
2. Disassembles a small floating tube sheet shell and tube heat exchanger for inspection, maintenance, and repair. Reassembles same.
3. Conducts a leak test on a shell and tube heat exchanger.
4. Will learn to identify the construction details of the various types of heat exchangers used aboard ship.

Special Tools and Equipment supplied by the Marine Engineering Department:

- ☉ Leak detection kit with black light and dye
- ☉ Torque wrenches
- ☉ Gasket cutters
- ☉ Gasket material

Basic hand tools are supplied by 3rd class cadets as required¹¹.

Discussion

A heat exchanger is any device or apparatus designed to allow the transfer of heat from one fluid to another. A temperature difference must exist between the two substances for any heat transfer to take place. The fluid trying to give up its heat is called the “heat source.” The fluid receiving the heat is the “heat sink”. Per the Second Law of Thermodynamics, heat must flow from the higher temperature fluid to the lower temperature fluid.

There are two basic types of heat exchangers:

- a. Direct type - Fluids mix together to exchange heat.
- b. Indirect (surface) type - Fluids are prevented from mixing by a surface (usually metal) that the heat has to pass through.

The rate of heat transfer between the two fluids for both direct and indirect types is determined by:

- a. The temperature difference between the two fluids.
- b. The rate of flow of each fluid into the heat exchanger.

Additionally, for indirect types, the heat transfer rate is further governed by:

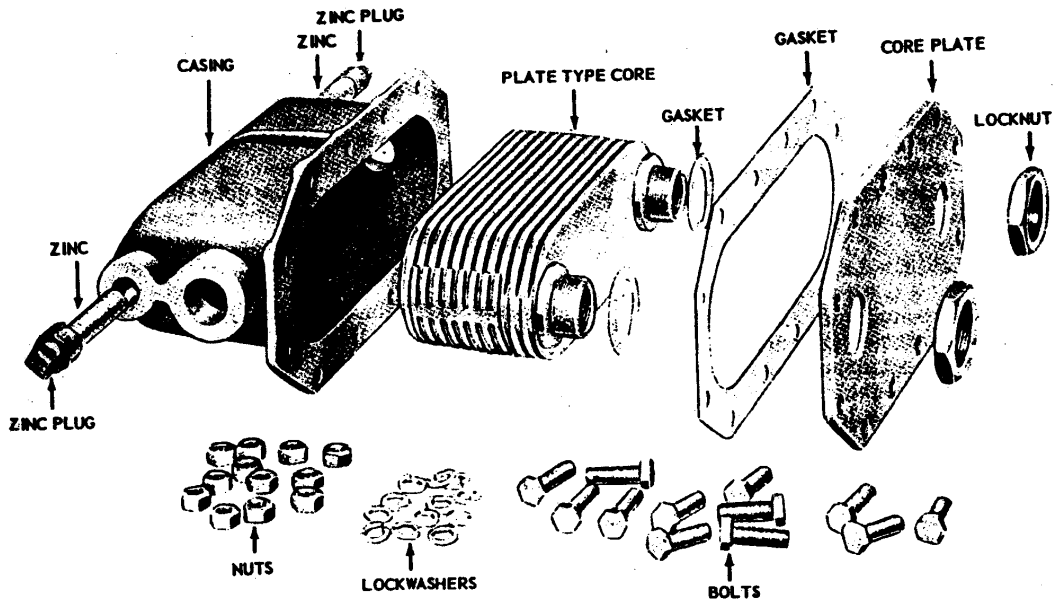
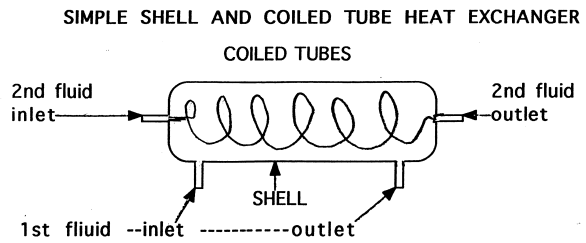
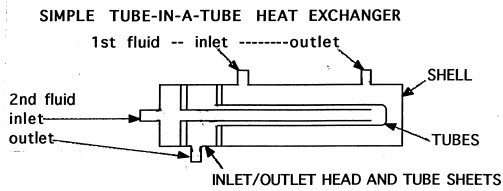
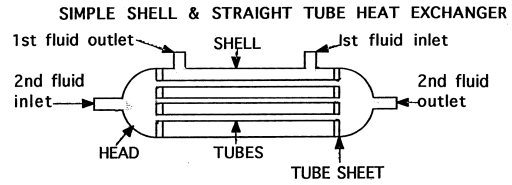
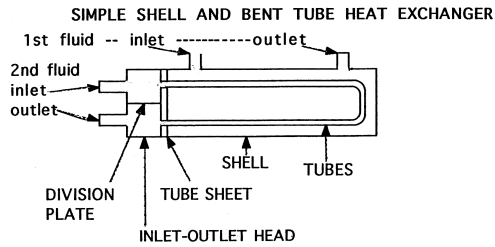
- a. The surface area that the two fluids come in contact with;
- b. The size of the heat exchanger;
- c. The material the heat exchanger is made from;
- d. The thickness of the material; and
- e. The flow paths of the fluids through the heat exchanger.

¹¹ The Marine Engineering Department requires all students to provide basic hand tools as listed in the Tools Requirements for the Sea Term.

Massachusetts Maritime Academy Third Class Maintenance Training

There are five basic types of indirect heat exchangers:

- a. Shell and straight tube, the most common on the Training ship
- b. Shell and bent tube
- c. Shell and coil
- d. Tube with in a tube
- e. Plate type

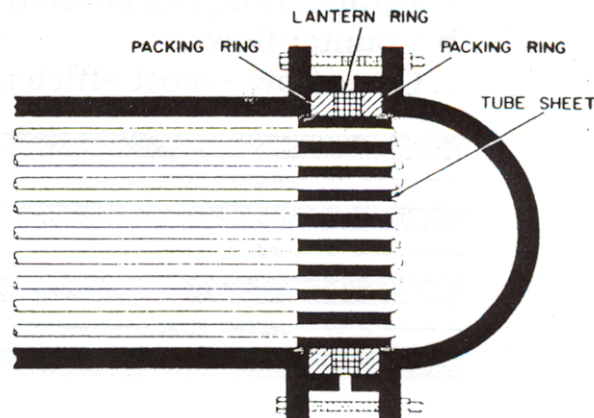
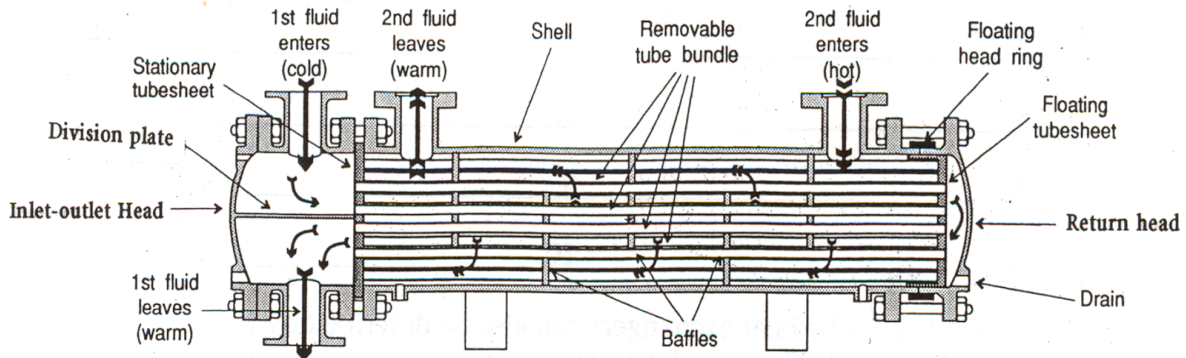


Massachusetts Maritime Academy
Third Class Maintenance Training

List 10 different shell and tube heat exchangers used aboard the Kennedy

| | |
|---|----|
| 1 | 6 |
| 2 | 7 |
| 3 | 8 |
| 4 | 9 |
| 5 | 10 |

Shell and tube heat exchangers can also be described by the direction of the fluid flow in relation to each other. These include parallel flow (uncommon), counter flow, and cross flow which is the most efficient. In practice, most shell and tube heat exchangers utilize a combination of the three flow paths.



Materials.

Most ship board seawater cooled heat exchangers utilize copper, copper-nickel or steel for the shell material. The tube sheets are generally bronze. The tubes are normally a 90-10 copper-nickel alloy that is 90% copper & 10% nickel. Nickel adds strength to copper. The heads on

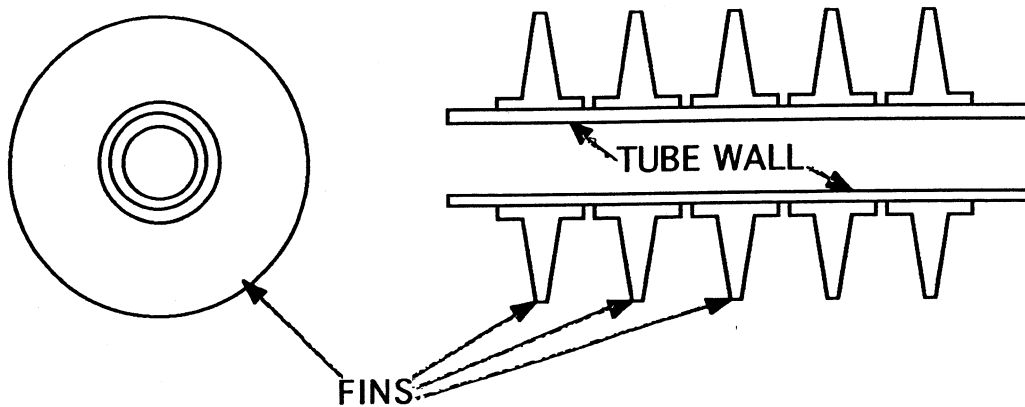
Massachusetts Maritime Academy
Third Class Maintenance Training

small heat exchangers are generally bronze. On large heat exchangers, like condensers, heads are generally welded steel with coatings on the surface in contact with the seawater to reduce corrosion. Stainless steel can also be used for all the above components. Platinum is used in some plate type heat exchangers in contact with salt water because it is corrosion resistant and very strong.

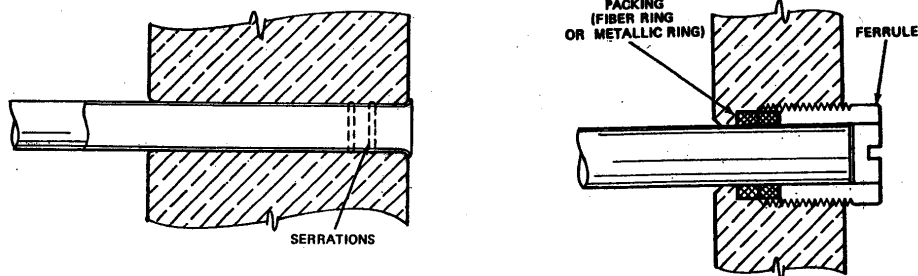
Increasing Tube Surface Area

The external surface of the tube can be enlarged to transfer more heat by cutting grooves around the outer circumference or by adding circular fins on the outside of the tubes.

ONE TYPE OF FINNED TUBE



Fins add more surface area on outside of the tube to increase heat transfer rate between the 2 fluids.

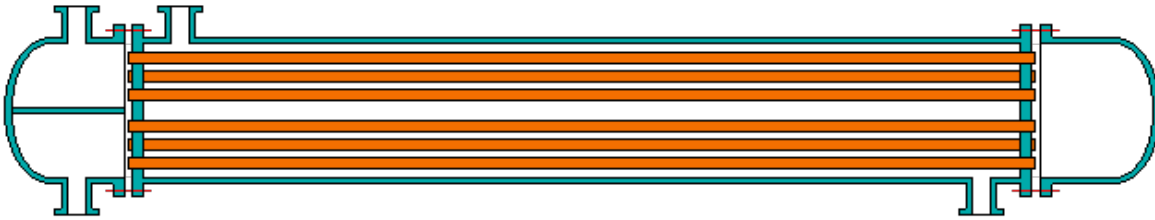


Allowances for expansion: Since the tubes and shells operate at different temperatures and sometimes have different expansion rates because they are made of different materials, the heat exchanger must be constructed to allow the tubes and shell to expand and contract at different rates without creating stresses on each other. The following methods are utilized to accommodate differing expansion rates between the shell and the tubes:

- a. Tubes are fixed into the tube sheet at one end and floating at the other end.
- b. The tubes are bowed upwards. This method also allows for the tubes to be easily and completely drained.

Massachusetts Maritime Academy
Third Class Maintenance Training

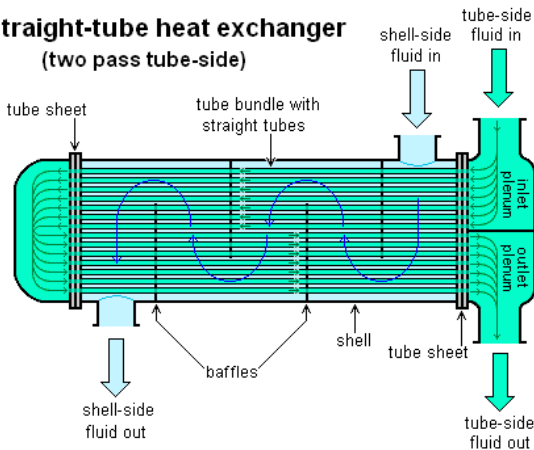
- c. Tubes are expanded into the tube sheet on one end while the other end utilizes a packing material between the tube and the shell.



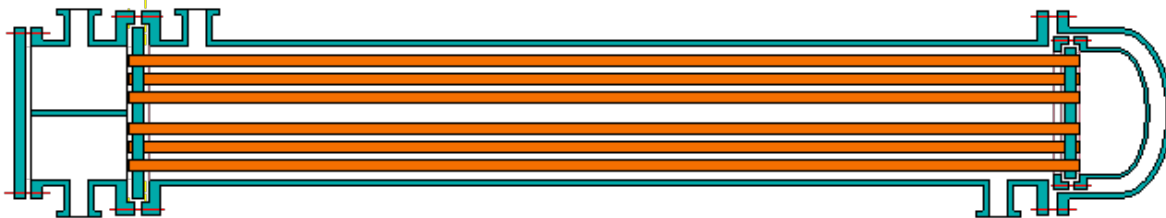
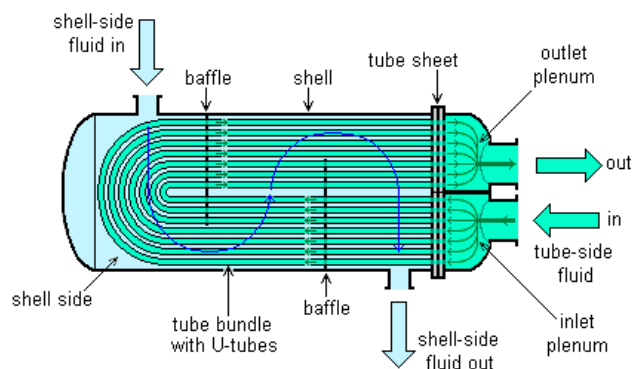
BEM - Bonnet (Intergral Cover), One Pass Shell, Fixed Tubesheet Bonnet

Fixed tubesheet heat exchanger. This is a very popular version as the heads can be removed to clean the inside of the tubes. The front head piping must be unbolted to allow the removal of the front head, if this is undesired this can be avoided by applying a type A front head. In that case only the cover needs to be removed. It is not possible to clean the outside surface of the tubes as these are inside the fixed part. Chemical cleaning can be used. Shown is a version with one shell pass and two tube passes.

Straight-tube heat exchanger (two pass tube-side)



U-tube heat exchanger



AES - Channel and Removable Cover, One Pass Shell, Floating Head with Backing Device.

Floating Head Heat Exchanger. A floating head is excellent for applications where the difference in temperature between the hot and cold fluid causes unacceptable stresses in the axial direction of the shell and tubes. The floating head can move, i.e. provides the possibility to expand in the axial direction. Note that the bundle can not be pulled from the front end. For maintenance both the front and rear end head, including the backing device, must be disassembled. If pulling from the front head is required a type AET should be selected.

- d. Bent or U-Type tubes arranged so that they begin and end on the same tube sheet.
- e. The utilization of a tube-in-tube design.

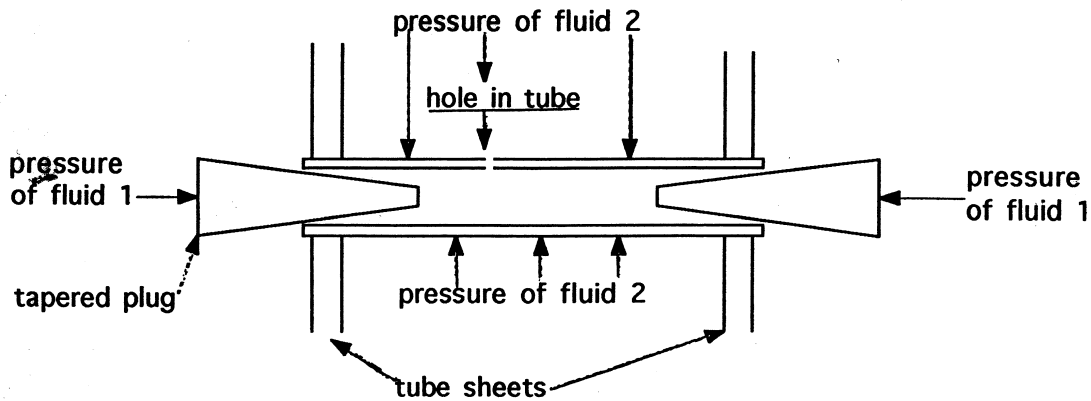
Corrosion protection is done by sacrificial metal, such as zinc rods, which should be checked monthly and replaced if 50% wasted.

Performing A Leak Test On A Shell & Tube Heat Exchanger.

- Isolate both sides of the heat exchanger from the liquid systems. Drain the head side of the heat exchanger.
- Remove the heads or the access covers on the heads.
- Add a fluorescent dye (compatible with the liquid) on the shell side of the tubes. Completely fill shell side with the liquid that normally flows here.
- Apply pressure to the dyed liquid on the shell side. *Caution: when doing a hydrostatic (liquid pressure) test, never exceed the pressure rating of the heat exchanger.*
- Shining the ultra-violet light in the test kit on the tube sheet and the tube with the leak should show the brightly dyed liquid trickling out the end of the tube.

Plugging Tubes:

Wooden, plastic or metal tapered plugs can be driven into each end of a leaky tube and will successfully stop the leak provided that the pressure of fluid which flows inside the tubes is normally higher than the pressure of the fluid which surrounds the tubes. If tube fluid pressure is higher than the outside fluid pressure, the plugs are driven tighter into the ends of the tubes. If the reverse is true, the plugs will be pushed out of the ends of the tubes allowing leakage to resume.



Cleaning Tube Type Heat Exchangers.

Depending on what type contamination is present, cleaning can be done by:

- Back flushing - Causing fluid to flow opposite the normal direction through the tubes. This is especially helpful on the seawater sides of heat exchangers clogged with plant life such as seaweed, leaves, etc.
- Punching the tubes by forcing a long handled brush or rod through the tube.
- Cleaning the tubes with compressed air.
- Chemical cleaning to remove hard scale such as heating coils used in salt-water evaporators.

Massachusetts Maritime Academy
Third Class Maintenance Training

When cleaning the tubes, always punch or use compressed air against the normal flow through the tube when it was in service. Most plate and frame type heat exchangers have to be completely disassembled to be properly cleaned.

Heat Transfer Area

The available heat transfer area is the sum of the surface area of the tubes which is in contact with both fluids. The heat transfer area is given by:

$$HTA = \frac{\pi \times \text{Tube OD} \times \text{tube length} \times \text{number of tubes}}{144 \text{ sq. inches/sq. foot}}$$

Assuming a shell and tube heat exchanger with 180 tubes each 0.625 inches in diameter with an effective tube length of 30”, the available heat transfer area is then:

$$HTA = \frac{\pi \times 0.625 \times 30" \times 180 \text{ tubes}}{144 \text{ sq. inches/sq. foot}} = 73.6 \text{ ft}^2$$

Disassemble, Inspect And Reassemble The Floating Head Heat Exchanger

1. Shut down the heat exchanger.
 - a. Close the valves in both of the liquid systems leading in and out of the heat exchanger.
 - b. Lock and tag out the valves.
 - c. Drain the liquids from shell side of the heat exchanger using the shell drain plugs.
 - d. Liquids on the tube side will be drained when the piping is disconnected and the heads loosened.
 - e. Note construction: Heat exchanger is two-pass, with an inlet-outlet head on one end and a return head on the other. It is of the floating tube sheet design. The tube sheet on the inlet-outlet end is fixed to the shell with a gasket. The other tube sheet “floats” or slides through the shell with a rubber type seal preventing leakage between the shell and tube sheet. This design allows the shell and tube bundle to expand and contract at different rates.
2. Remove the three zinc corrosion arrestors from the heads. Inspect for corrosion and size. If the zincs are less than 50% of their original size, they must be replaced. The white zinc oxide coating on corroded zincs should be brushed off periodically to keep fresh zinc in contact with the seawater.
3. Place a reference mark on the edge of the heads, called Bonnets and the shell. This will help identify which head belongs on which end of the heat exchanger and will align the head with the piping. Disconnect the piping to the inlet-outlet head.
4. Remove the 4-head bolts on each head.
 - a. Note the orientation of gasket seals particularly the bonnet to tube sheet gasket on the inlet-outlet head.

Massachusetts Maritime Academy
Third Class Maintenance Training

- b. Carefully remove the gasket from the inlet-outlet head and the packing ring that seals against return head.
- c. Mark the stationary tube sheet edge and the shell so the tube bundle will be installed correctly into the shell during reassembly.
5. Locate the lantern ring around the tube sheet on the return head end (has 4 small holes drilled through it spaced 90 degrees apart). *Do not try to pry the ring out - you could damage it.*
6. Set up the custom made jacking tool (modified bearing puller) on the on the end of the shell the lantern ring is installed in. Place the 2-3/4" aluminum disk between the end of the jacking tool and the tube sheet to prevent damage to the tube sheet. Operate the jacking tool to push the tube bundle assembly out of shell. When the tube assembly becomes loose, carefully remove by hand and set down securely on workbench.
7. Carefully remove tube sheet to shell gasket. Note the tube bundle construction features: Tubes are rolled and expanded in both tube sheets. Baffle plates create cross flow across the outside of the tubes.
8. Inspect tube inlet ends for erosion and interiors for corrosion and pitting. Inspect tube sheets and inside of heads for pitting and corrosion. Make sure any protective coating inside the head is intact - if not, make repairs.
9. Clean all surfaces that gaskets or seals come in contact. Single edge razor blades will clean off stuck on material and surfaces can be cleaned with fine grit paper or emery cloth.

Begin Reassembly

10. Place a new tube sheet to shell gasket over the floating tube sheet and slide it down against the stationary tube sheet flange.
11. Carefully insert the tube bundle assembly back into the shell. Line up the reference marks you made between the stationary tube sheet edge and the shell. Make sure the gasket is centered as you push the stationary tube sheet up against the shell.
12. Clean the threads on the head bolts and lightly apply anti-seize compound to them. Insert the four head bolts on the inlet-outlet head end of the shell, through the shell bolt holes towards the head. Place a new bonnet to tube sheet gasket inside the four head bolts and align the centerpiece of the gasket with the flat space between the tubes of the tube sheet.
13. Carefully slide the inlet-outlet head over the head bolts. Make sure that the division plate in the inlet-outlet head, the center of gasket, and the flat space between the tubes on the tube sheet line up. If misalignment occurs here, the heat exchanger will not operate up to capacity.
14. Once these pieces are aligned, put the nuts on the head bolts and tighten them finger tight. Place a new packing ring over the floating tube sheet and press it into the space between the tube sheet and shell. Slide the lantern ring over the floating tube sheet

Massachusetts Maritime Academy
Third Class Maintenance Training

and push it up against the packing ring just inserted. Place the last packing ring over the floating tube sheet and push it up against the lantern ring.

15. Insert the four head bolts through the holes in the shell. Slide the return head onto the head bolts, lining it up and sliding it over the outside packing ring. Put the bolt nuts on finger tight.
16. Use a torque wrench to tighten the fasteners on the inlet-outlet head first. Using a criss-cross pattern, tighten all nuts to first to 4-ft-lbs then increase to 8-ft-lbs. Repeat this same procedure on the return head.
17. Complete assemble.
 - a. Tighten shell drain plugs.
 - b. Install and tighten zinc corrosion arrestors.
 - c. Reconnect and tighten liquid piping to inlet-outlet head.
 - d. Remove the lockout-tagout devices from valves isolating the heat exchanger.
 - e. Conduct a hydrostatic test on both sides of the heat exchanger to detect any leaks by just cracking the valves and allowing the normal liquids that flow through the heat exchanger to slowly pressurize each side while inspecting for leaks.

Massachusetts Maritime Academy
Third Class Maintenance Training

Questions for MT heat exchangers

1. What is the one single factor that has the most influence in how much heat is transferred in a heat exchanger?
2. What are three factors that influence heat transfer in a heat exchanger?
3. What are two ways heat exchangers are built to compensate for thermal expansion?
4. What is the most common type of heat exchanger found aboard the training ship?
5. Why is copper-nickel used in many of the heat exchangers in the engine room?
6. Where can plate type heat exchanger be found in the engine room?
7. Why is mechanical cleaning of the tubes done against the normal flow when it is in service?
8. List two ways tubes can be attached to the tube sheet?
9. In a deaerating feed heater heat exchanger, what is considered the heat sink and which is the heat source?
10. List one direct contact heat exchanger.
11. Why are fins placed on the surface of heat exchanger tubes?
12. If a bent tube type heat exchanger suddenly had the lube oil outlet temperature rise equal to the lube oil inlet temperature and the sea water inlet and outlet temperatures are the same, what has happened?
13. Why are zinc's used with heat exchangers and when should they be checked and changed?

Notes
