

OIL LUBRICATION SYSTEMS FOR PROCESS PUMPS AND RELATED EQUIPMENT

by

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ABSTRACT

Oil lubrication systems, when required and provided for the pumping system, are the life insurance policy for the process. If the oil lubrication system should fail to perform, the results are bearing failures in pumps, gears, or drivers, ultimately shutting down the process.

Conservative design and proper specifications minimize the possibility for failure and maximize the potential for long, trouble free service life of the rotating equipment. Understanding the system's needs, optimizing component selections, allowing for operational maintenance, and proper application of the system are the keys to reliability.

INTRODUCTION

The pump user's objective is to maximize revenue from his process. In order to meet this objective, it is extremely important to have safe and reliable operation of pumps and auxiliaries.

Larger process pumps and drivers often use hydrodynamic bearings due to their noted reliability over antifriction bearings at higher bearing surface velocity. The oil film that forms in the hydrodynamic bearings provides the needed separation between shaft and bearing. This continuously replenished oil film removes bearing heat and wear particles.

The oil film properties are a function of many things including oil viscosity, bearing/shaft clearance, bearing load, etc. Constant oil supply is required to keep the bearing system in balance. A loss of oil supply means a loss of cooling, loss of oil film properties, then the loss of a bearing, and possibly more.

API 610, 8th EDITION LUBE OIL SYSTEM SCHEMATIC

Base orientation requires the main lube oil pump to be shaft driven off the process pump. A single auxiliary lube oil pump is electric motor driven. Balance of system includes reservoir, single shell and tube cooler, and duplex filter. Each pump is equipped with its own relief and check valves. Instrumentation includes three pressure switches, one pressure differential indicator, two pressure gauges, two thermometers, flow indicators in oil return line, and a sight glass on the reservoir (Figure 1).

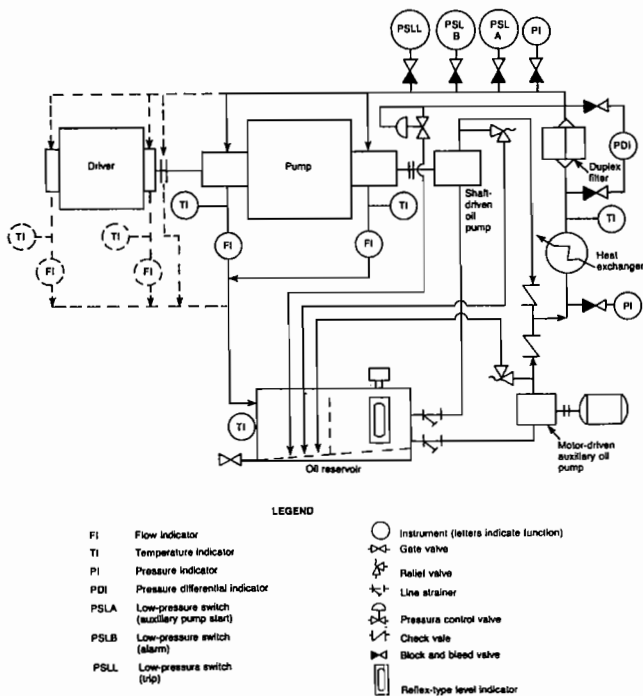
TYPICAL OIL LUBRICATION SYSTEM

Components, their purpose, API 610 requirements, details of application, and maintenance considerations are evaluated below.

Lube Oil System Reservoir

Purpose—The oil reservoir has these basic purposes:

- Dissipate or settle contaminants.
- *Air*—Air is dissipated via proper baffling and adequate residence time.
- *Particulate*—Particulate matter is allowed to settle in the low end of the reservoir. Residence time and flowrates in the reservoir determine particulate disposition in the reservoir.



Note: This illustration is a typical schematic and does not constitute any specific design, nor does it include all details (for example, vents and drains).

Figure 1. API 610, 8th Edition Lube Oil System Schematic [1] used with permission of the American Petroleum Institute.

- **Water**—Water is heavier than oil. The low end of the reservoir must be designed for water drainage.

- Store a prescribed amount of oil and provide for rundown capacities.
- Provide for temperature fluctuations, expansion volumes, location for heating, and oil purifier connections.

API 610, 8th Edition and other good design requirements are:

- **Materials**—Austenitic stainless steel
- **Retention**—three minutes retention time is defined as the total capacity below the minimum operating level of the reservoir. Normal system flowrate $\times 3$ = retention capacity.
- **Armored sight glass**—Internal chamber is the same material as the reservoir. The sight glass should extend from one inch above center line of oil return to one inch below minimum operating level.

- **Baffle**—The function of the baffle is to separate pump suction from oil returns. Oil returns include return from process pumps and auxiliaries, lube oil pump relief valves, returns from pressure control valves, filter vents, control valve head, and instrument vents. Baffles should have an air passage at the tank top equal to three times the area of the auxiliary and main pump suction lines combined. A baffled passage is strategically located two inches above the tank bottom. This baffle should have the greatest possible distance between the main pump inlet and return line to allow oil to pass from the return side to the suction side of the reservoir. Try to make the oil travel as long a path as possible from the time it returns to the reservoir until it reaches the pump suction to provide the maximum amount of time for settling of contaminants (Figure 2).

- **Sloping bottom**—Reservoir bottom should slope a minimum of $\frac{1}{4}$ in/ft away from the pump suction. Low end of reservoir should be equipped with a drain.

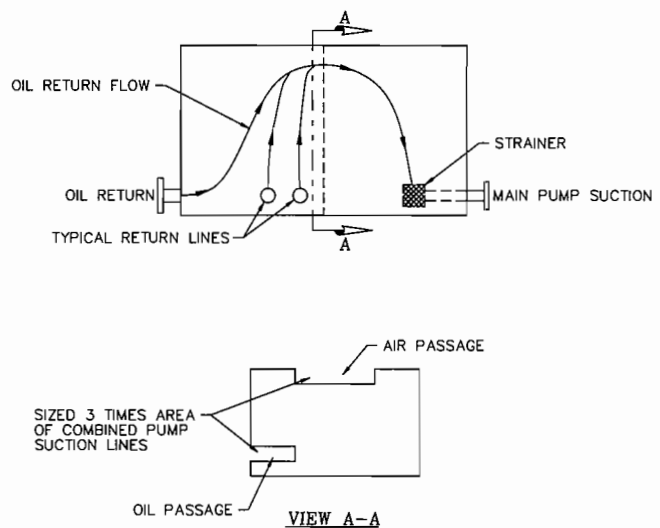


Figure 2. Reservoir Baffle Orientation and Design.

- **Reservoir fill cap**—Filler breather cap should be located on a riser to prevent water from running into reservoir. Fill cap should have a 40 micron breathing element and a 60 mesh strainer to prevent foreign airborne particles and objects found in new drum oil from being ingested into the system.

- **Mounting pads**—Mounting pads should be used for any attachments to the reservoir. Side mounted devices require a pad to prevent the foot of the device from piercing the reservoir skin. This is especially important during transportation. Top mounted devices should be bolted to pads. Bolt hole for top mounting components should not penetrate the top of the reservoir to prevent water ingress into the reservoir.

- **Manway**—A gasketed manway and riser should be supplied so access is available to all compartments of the reservoir.

- **Return line**—Return lines should terminate below the oil level to prevent foaming. Return lines should be equipped with end baffles, diffusers, or angle cut at 45 degrees. Return lines should discharge away from the pump suction and the reservoir bottom.

- **Pump suction lines**—Pump suction lines should be straight pipe with a minimum number of elbows to avoid accumulation of air and result in smooth pump transfers.

Reservoir Sizing

- Factors involved in reservoir size and selection are:
 - System flowrate.
 - Retention time.
 - Height of return line from process equipment.
 - Required working capacity.
 - Rundown capacity.
 - Location of auxiliary pump (internal or external of reservoir).

Baffle design and location are shown in Figure 2. Suction and return locations in the reservoir and reservoir capacities are shown in Figure 3.

Assume a total lube oil flowrate of 20 gpm. The process pump, a gear, and a turbine driver are lubricated.

$$20 \times 3 = 60$$

60 = retention capacity (total capacity below alarm level)

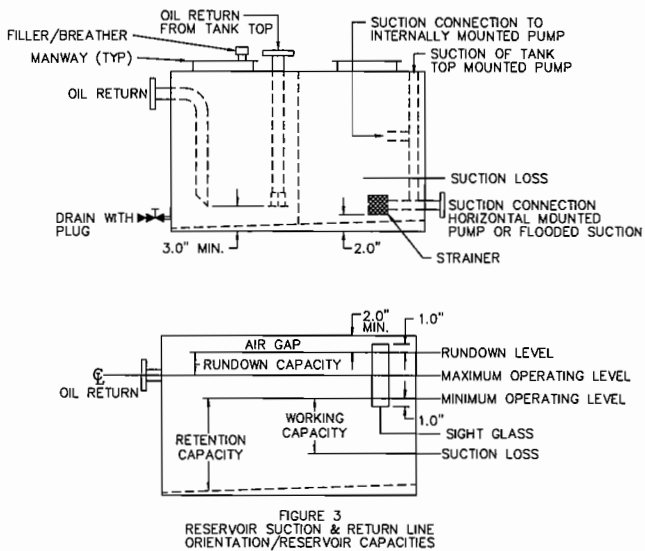


FIGURE 3
RESERVOIR SUCTION & RETURN LINE
ORIENTATION/RESERVOIR CAPACITIES

Figure 3. Reservoir Suction and Return Line Orientation/Reservoir Capacities.

Working capacity is the capacity between minimum operating level and suction loss level.

Rundown capacity is the amount of oil expected to return to the reservoir when the system is shutdown. (If this is unknown, use 10 percent of the total capacity of the reservoir.) The details are shown in Figure 3.

Other design concerns, issues, and maintenance considerations:

- Heavy snow or rain locations.
 - Equipment mounting pads should be continuously seal welded around the outside and inside edge of pad.
 - Manways and reservoir fill caps should have a minimum 1-1/2 in riser.
 - Tank top mounted pumps should have gaskets where the flange of the bell housing meets the tank top and where the pump mounting flange meets the bell housing.
 - Frost or rain guards should be considered for sight glasses.
 - Extreme ambient conditions, such as below 20°F and above 112°F.
 - Consider oil purifier connections as condensation is likely to result in free water in the reservoir.
 - Increase slope and water storage area in reservoir.
 - Consider installation of insulation and/or reservoir heater.
- Caution**—Always add a level switch to the reservoir to shut down the heater on low oil level. When the oil level becomes tangent with the heating element, a risk of fire is present.
- Dirty/Desert atmosphere
 - Add oil purifier to purify oil and remove condensation. Oil purifiers extend the life of the oil.
 - Add oil sampling connection in reservoir or return line piping.
 - Add oil sampling connection in the supply line downstream of the duplex filter.

- Avoid:

- Reservoir end covers with a single bolt mounted on the side of the reservoir. When these leak, and they all do, the tendency for maintenance personnel is to tighten the bolt. This distorts the cover and results in a bigger leak.

- Horizontal heaters that require draining the tank to change the elements.

Open coil heaters installed in atmospheric thermowells will lower the element watt density, prevent oil coking, and allow for element changes without having to drain the oil.

- Locating level switch floats in or near oil flow paths can lead to bent stems or the float falling off the stem. In both cases, the alarm does not function.

- Recommended:

- Reservoirs should be washed with a safety solvent prior to filling with oil. Use lint-free rags and solvent that do not leave a residue.

Lube Oil Pumps

The *purpose* of the main shaft driven lube oil pump is to provide a flowrate to the process pump and other equipment in the drive train any time the process pump is operating. The purpose of the auxiliary lube oil pump is to provide a lube oil flowrate to process pump bearings and other equipment in the drive train prior to startup of the process equipment and any time the lube oil supply pressure drops below the specified minimum.

Many *styles of pumps* are available for lube oil system applications. The API community has favored two types: gear and screw pumps.

- Both pumps are positive displacement.
- The gear pump is most viable for applications:
 - At 1200 to 1800 rpm input shaft speeds.
 - With oil viscosity ranges 100 to 500 SSU.
 - Where lube oil pump discharge pressures are greater than 150 psi.
- The screw pumps are most viable for applications:
 - With low noise requirements.
 - Where steel cast pumps are required.
 - Where pump input speed exceeds 1500 rpm.
 - Where high viscosity fluids are predominant.
 - Where pump discharge pressure is 150 psi or less. (Note screw pumps are available for higher pressure applications; however, gear pumps tend to be more economical and more efficient in higher pressure applications.)

Pump Sizing

- The process pump manufacturer as prime contractor must determine total flowrates and heat loads and specify this requirement to the lube oil system supplier.

Assuming the train requires 15 gpm, the actual minimum required pump flow is calculated as

$$15 \text{ gpm} / 0.85 = 17.64 \text{ gpm}$$

where:

0.85 is used as the minimum acceptable value added to maintain head in the lube oil supply header.

A minimum 1.5 gpm extra must be available on systems in the five to 12 gpm range for proper valve sizing and maintaining head.

The pressure control valve is sized along with the pump and it should be sized so that the excess flow of 2.64 gpm will pass over the pressure control valve when it is between 15 and 20 percent open. The extra oil capacity passes over the pressure control valve back to the reservoir.

- It is most important to size the main pump and auxiliary pump displacements as close to identical as possible. In any event, major deviations in flow between the two pumps will result in a change in pressure when the auxiliary pump runs alone, as compared to when the main pumps on line alone. Further, consideration must be given to the pressure control valve sizing so that the valve is only 80 percent open when the excess flow of the auxiliary pump and the full flow of the main pump pass over the pressure control valve. This situation occurs whenever both pumps operate simultaneously.

Material Requirements

- API 610 requires the pump housing material be cast steel when the pump is located outside the reservoir. Pumps located inside the reservoir can be of any suitable material.

Installation

- API 610 does not address the issue of spacer couplings for the auxiliary pump. Therefore, auxiliary pump seals typically cannot be changed during operation of the main pump, unless the auxiliary pump is removed from its sole plate.

- Pumps that are mounted vertically in the tank should be mounted so the coupling is above the tank top (Figure 4). Mounting of the coupling below the tank top can result in aeration of the oil due to aerodynamic effects of the coupling.

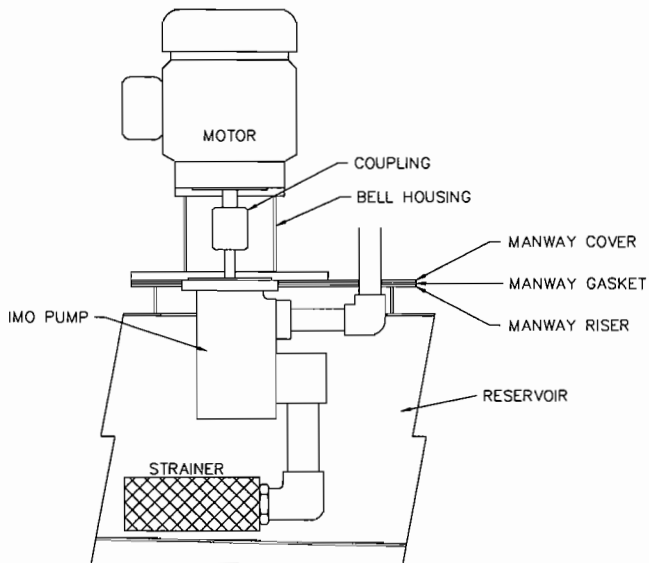


Figure 4. Vertical Pump Mounting Assembly.

- Pump motor bell housings are available line bored to 0.002 TIR. This tolerance eliminates the need for field alignments at the time of initial startup or when replacing a pump. Shimming is not required.

- The recommended pump installation is vertical on a bell housing with C face motor per Figure 4. The bell housing ensures a permanent alignment. The vertical pump reduces skid size (real estate is valuable) and the installation is far cleaner and the most economical.

- Horizontal pump installation can be made either as foot mounts or as C face bell housing mounts.

- Foot mounting requires shims, sole plates, and field alignments.

- Horizontal pump applications typically include a Y strainer mounted externally of the reservoir in the pump suction line.

Maintenance Considerations

- Horizontal pump mounts

- When equipped with proper soleplate and a spacer coupling, a field seal change can be made on larger screw pumps. Not all screw pump designs and sizes can have their seal changed from the shaft end.

- Y strainers located externally of the reservoir allow for easy cleaning of the screen. This application requires additional components such as a suction isolation valve for the pump (Figure 5). The strainer typically is 100 mesh, which is intended to keep only coarse particles out of the pump. Opinion is, if this strainer ever becomes clogged; it is time to enter the tank and clean it thoroughly. Therefore, vertical pump mounts with internal strainers make the most economical design as the extra pump suction isolation valve is eliminated.

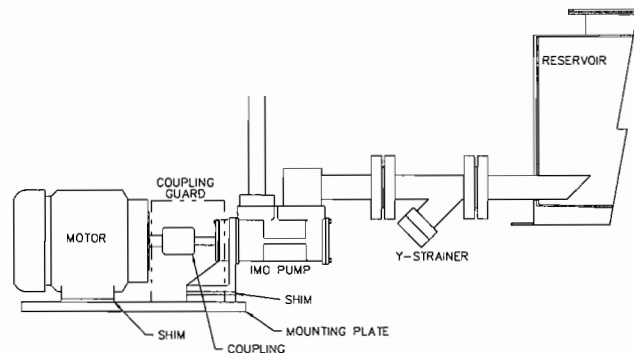


Figure 5. Horizontal Pump Mounting Assembly.

- Vertically mounted pumps (with pumps installed inside the reservoir) require the tank be opened if a pump change is necessary. Opening the reservoir presents an opportunity for contamination to enter the tank.

- Due to improved auxiliary pump suction conditions and the pump's proximity to the reservoir heater, a vertically mounted pump will be available sooner for cold starting than a horizontally mounted pump.

Driver Sizing and Effects of Viscosity/Design Impacts

- Total pump discharge is calculated as nominal output flowrate required by the equipment divided by 0.85.

The test case is 15 gpm nominal flow and, therefore, the pump will produce 17.64 gpm minimum. Main pump speed is 3000 rpm, since this application is 50 Hz, so the electric motor driven pump must run at 3000 rpm (Tables 1 and 2).

The pump shown in Table 1 is only acceptable at discharge pressures at or below 50 psi. Further, oil viscosity must be at least 150 SSU to expect a pump discharge above the required minimum flowrate.

Applications in the process pump industry generally use ISO VG 32 or VG 46 oil. The pump draws its oil supply from the reservoir that is upstream of the heat exchanger, so this is hot oil, oil that has just rinsed heat out of the pump bearings and into the tank. At this point, oil temperatures approach 160°F, and oil viscosity is approximately 70 to 90 SSU. Therefore, pump model A is too small for this application (Table 1).

Table 1. Screw Pump Discharge Capacity and Input Power Chart (0.0065 g/rev) (Pump Model A).

PUMP MODEL A
Theoretical: .0065 g/rev

Speed: 3000 rpm -----

Flow Rate - gpm

Viscosity ssu	Pressure - psi.					
	25	50	75	100	125	150
33	16.7	15.6	14.7	14.0	13.3	12.8
65	17.5	16.7	16.0	15.5	15.1	14.7
100	17.8	17.2	16.7	16.3	15.9	15.6
150	18.1	17.6	17.2	16.9	16.6	16.3
650	18.8	18.5	18.3	18.2	18.0	17.9
1000	18.9	18.7	18.5	18.4	18.3	18.2
5000	19.2	19.1	19.0	19.0	18.9	18.9
10000	19.2	19.2	19.1	19.1	19.0	19.0

BHP - hp

Viscosity ssu	Pressure - psi					
	25	50	75	100	125	150
33	.6	.9	1.1	1.4	1.7	2.0
65	.6	.9	1.1	1.4	1.7	2.0
100	.6	.9	1.1	1.4	1.7	2.0
150	.6	.9	1.1	1.4	1.7	2.0
650	1.0	1.3	1.6	1.9	2.1	2.4
1000	1.2	1.5	1.8	2.1	2.4	2.7
5000	2.9	3.2	3.4	3.7	4.0	4.3
10000	4.3	4.5	4.8	5.1	5.4	5.7

Table 2. Screw Pump Discharge Capacity and Input Power Chart (0.0086 g/rev) (Pump Model B).

PUMP MODEL B
Theoretical: .0086 g/rev

Speed: 3000 rpm -----

Flow Rate - gpm

Viscosity ssu	Pressure - psi					
	25	50	75	100	125	150
33	22.6	21.2	20.2	19.3	18.6	17.9
65	23.5	22.5	21.8	21.2	20.6	20.1
100	23.9	23.2	22.6	22.1	21.6	21.2
150	24.3	23.6	23.2	22.8	22.4	22.1
650	25.1	24.8	24.5	24.3	24.2	24.0
1000	25.2	25.0	24.8	24.6	24.5	24.4
5000	25.5	25.4	25.3	25.3	25.2	25.2
10000	25.6	25.5	25.5	25.4	25.4	25.3

BHP - hp

Viscosity ssu	Pressure - psi					
	25	50	75	100	125	150
33	.9	1.3	1.7	2.0	2.4	2.8
65	.9	1.3	1.7	2.0	2.4	2.8
100	.9	1.3	1.7	2.0	2.4	2.8
150	.9	1.3	1.7	2.0	2.4	2.8
650	1.7	2.1	2.4	2.8	3.2	3.6
1000	2.1	2.5	2.8	3.2	3.6	4.0
5000	5.0	5.4	5.7	6.1	6.5	6.9
10000	7.4	7.8	8.2	8.6	8.9	9.3

Pump model B, shown in Table 2, will produce the proper flowrate at low viscosities. Many applications require the lube oil pressure to be higher than the cooling water pressure (to prevent water leakage into the oil from a leaky tube). Typically, pump discharge pressure is around 100 psi. At 100 psi and 100 SSU the pump produces 22.1 gpm and requires a brake horsepower of 2.0 to drive it. If there is a cold start condition, the brake horsepower becomes 3.2 hp when the oil viscosity is 1000 SSU. Oil temperature of 45°F relates to 1000 SSU. The customer needs to specify if a cold startup is required and, if so, either a heater should be installed or the pump driver and coupling sized for maximum load. Higher pressures also affect the selections of the relief valves, pressure control valves, etc.

Filters

Requirements of API 610, 8th Edition

- Type-Duplex
- Material:
 - Housing-Cast steel
 - Elements-Cartridge materials should be corrosion resistant.
 - Filtration-25 Micron or finer
 - Other-Non bypass, stainless steel valve spool in transfer valve

Additional suggested requirements

- Previously filters were rated by micron size. Subsequently, filter ratings were changed to nominal vs absolute micron ratings. Today filter elements are rated with micron and beta ratios. In the API Process Pump Industry, the typical duplex filter is 10 micron nominal. This means that some particles in excess of 10 micron regularly pass through the element. Today, filter manufacturers typically rate their elements at 10 micron, with a filtration ratio of 200 (beta 200). This means that one particle in 200 of a size greater than 10 micron will pass through the element.

ANSI T.3.10.8.8. Standard was developed for testing and verification of effectiveness of the filter.

Many OEMs have determined that there is a direct relationship between the quality (level) of filtration on the lube oil system and the life of the bearings. The higher the quality of filtration the longer the service life. ISO 4406 and NAS (National Aerospace Standards) 1638 define cleanliness of critical rotating machinery. The process pump is critical to the reliability of the process and, therefore, oil clarity should be NAS 1638 Class 5. API 614 cleanliness standard, which has been adopted by API 610, 8th Edition, allows for a defined number of particles to be caught at the screen of 250 microns maximum. This relates to a NAS 1638 Class 11. The typical quality 10 micron beta 75 element will produce NAS 1638 Class 5 results. It is recommended that customers require their lube oil systems be flushed at the point of manufacture to NAS 1638 Class 5 or finer with oil at 160°F for a one hour duration. During testing, the oil system is mechanically agitated. Have the manufacturer provide a test report from a certified particle counting device as evidence of clarity.

- Filters should be sized so that a clean element passes the entire pump discharge flowrate at five psi pressure drop across the elements, filter housing, and transfer valve at design conditions. Therefore (for the test case), the filter should be designed to pass the entire flowrate at viscosities between 70 SSU and 650 SSU, if minimum ambient is 50°F and unit is not equipped with a heater.

- Given that API 610 requires the nonbypass filter and only a pressure differential indicator is provided to visually determine

filter condition, specific considerations should be made in the filter selection process.

- Collapse pressure of the element should exceed the pumps relief settings. If the element gets very dirty, oil will pass over the pump relief and the lube oil supply pressure will decrease until oil pressure at the header drops, causing an alarm condition. This alerts the operator to look at filter condition and transfer to the clean element. A bypass design or a low collapse pressure element will allow dirt to flow into the bearing when the element clogs and the bypass works or the element fails. Bypass design elements are equipped with a relief valve poppet. Any time the differential across the element exceeds the bypass valve setting, the bypass opens and allows unfiltered oil downstream.

A better solution is the addition of a pressure differential switch across the filter housing to alarm at a dirty filter condition. Presetting the alarm at 25 to 30 psid will give the operator plenty of time to schedule the element change. A filter element that is properly sized will be contaminated/clogged 60 to 70 percent of its capacity, at a pressure drop of 30 psid.

- ASME code stamped filters should be considered based on size, pressure, volume, and geographic locations where code vessels are mandated.

- Filter transfer valves should be open in the neutral position. Inlet port of the transfer valve should be open to the inlet of both elements. The outlet of the transfer valve should be open to the outlets of both elements. This will guarantee continuous flow when transferring from one filter to another.

Maintenance Considerations

- The single component expected to be maintained frequently is the filter element. The old saying "Cleanliness is next to godliness" certainly applies here. Replacing the element regularly increases bearing life.

- Consideration should be given to locating the filter at the outside edge of the skid for ease of maintenance.

- Equip the filter with individual canister vents and drain valves.

- Supply a balance/prefill line and appropriately sized orifice.

- The above two items allow the serviced element to be prefiltered and vented of air prior to placing it in service. The orifice is used to restrict flow into the serviced element canister to prevent an unwanted loss of system pressure. The orifice is also used to balance the pressure on both sides of the transfer valve to facilitate a valve shift. Drain valves allow the operator to drain hot oil from canisters prior to removing it from the system. The operator can also verify the leakage rate of the transfer valve is acceptable prior to opening the housing. Excessive leakage in the transfer valve will cause a system shutdown. Drain valves are useful for oil sampling, particle counting, and prevention of oil spills.

Filter vent, drain and balance line details are shown in Figure 6.

- Two types of duplexing of heat exchangers and filters are shown in Figures 7 and 8.

Heat Exchangers

The API 610, 8th Edition requirements for heat exchangers are:

- Type—Shell and tube
- Material—Tubes inhibited admiralty
Shell steel (pressure retaining)

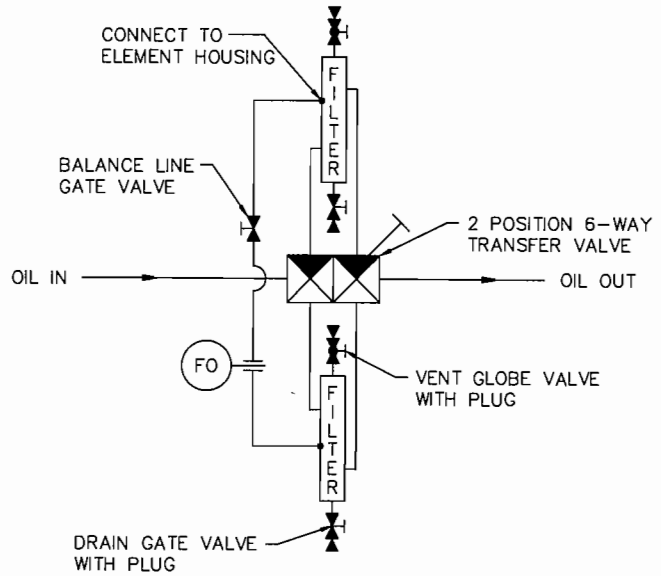
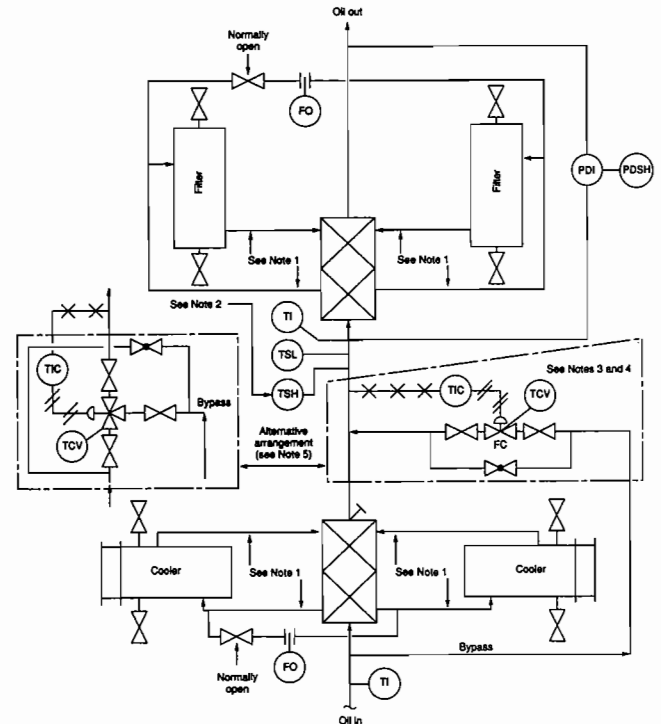


Figure 6. Duplex Filter with Transfer Valve, Vent, Drain, and Balance Lines.



Notes:
 1. Option A-17a: The purchaser may specify tight shutoff requiring spectacle blinds.
 2. Option A-17b: The purchaser may specify a high-temperature switch (TSH) and/or a low-temperature switch (TSL).
 3. Option A-17c: The purchaser may specify a bypass oil line and a constant-temperature control valve.
 4. Option A-17d: If the fail-closed (FC) feature of the direct-acting temperature control valve is not acceptable, the purchaser may specify a valve with a fail-tucked (FL) feature.
 5. Option A-17e: The purchaser may specify a constant-temperature three-way control valve as an alternative.

Figure 7. Twin Oil Coolers and Filters with Separate Continuous-Flow Transfer Valves [2] used with permission of the American Petroleum Institute.

- Orientation—Cooling water is on the tube side.

Other design considerations:

- Velocity in tubes—five ft/sec minimum
Fouling factor tubes—0.002 hr × ft² × °F/BTU
Fouling factor shell—0.002 hr × ft² × °F/BTU

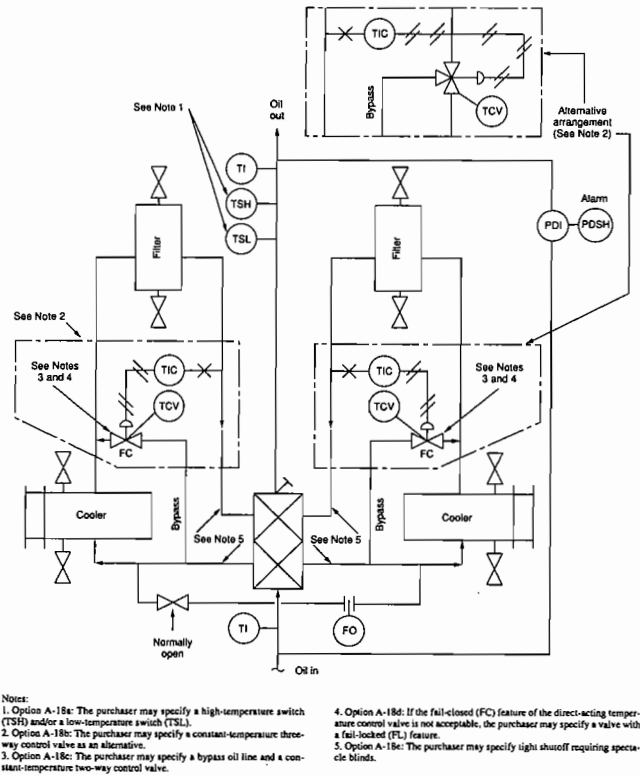


Figure 8. Twin Oil Coolers and Filters with a Single Continuous-Flow Transfer Valve [2] used with permission of the American Petroleum Institute.

Maximum oil temperature out of cooler: 120°F

Maximum water temperature rise: 10°F

Maximum pressure drop—five psi

Capacity—Maximum heat load of pump, gear, and driver plus add the horsepower of the lube oil pump driver. The entire lube oil system input horsepower goes to heat.

Maintenance Considerations

- Removable bundles add ability to change bundle without removing shell.
- Consider adding vents and drains to facilitate maintenance.
- Duplex heat exchanger arrangements are necessary on unspared equipment. In the case of duplexed heat exchangers, a balance valve, vents and drain valves on the shell, vent and drain valves on the cooling water chamber should be added to facilitate changing heat exchangers during operation.

Air to Oil Coolers

- Air to oil coolers can be considered where water is not available.
 - Note that cooler tube and headers for the economical air to oil coolers are usually manufactured from aluminum or copper. If carbon steel or stainless steel tubes are used, the price of the cooler increases along with the size.
 - For installations where ambient conditions fall below 60°F, the addition of a temperature control valve is recommended. This valve should be selected as a mixing type rather than the bypass type (Figure 9).

A mixing type temperature control valve mixes hot and cold oil at its outlet. This allows a continuous flow through the cooler keeping it warm and available. The lube oil supply temperature rises at a steady rate, thus avoiding thermal shock. The bypass type

temperature control valve opens at set point. This can cause a momentary loss of supply oil as the cold oil must be pushed out of the cooler. This cold oil can cause a thermal shock in the system.

A thermostatic bypass valve applied in a mixing application mode with an air to oil heat exchanger is shown in Figure 9.

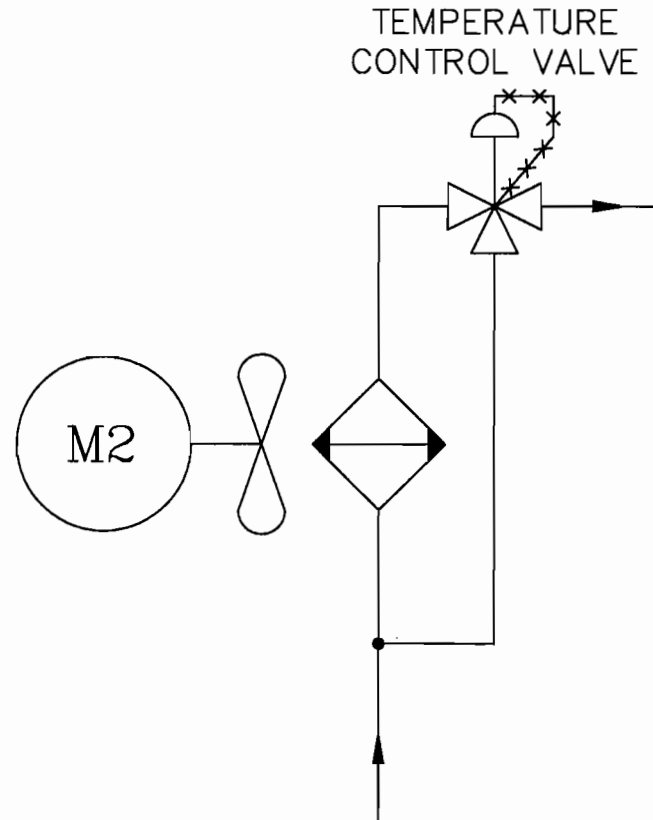


Figure 9. Air to Oil Cooler with Mixing Action Temperature Control Valve.

Relief Valves

API 610 8th Edition requirements are:

- Valve shall have a carbon steel body with stainless steel trim.
- Valves shall be located downstream of each pump discharge (Figure 1).

Two Types of Valves Are Typically Used:

- **Direct acting type**—Full flow valves are direct acting. A spring retains a piston in a bore. Oil working against the piston overcomes the spring and pushes the piston back allowing oil to pass to the tank port. As flowrate increases, the pressure at the inlet increases, i.e., pressure drop across valve increases.
- **Pilot operated type**—In case of pilot operated valve, oil works against the area of a small control poppet. When oil pressure overcomes the spring, oil passes to the tank. This allows a pressure drop to occur at the main/slave spool that backs off. One advantage of the pilot operated valves is that within the suggested flow range of the valve, an increase in flow does not have an effect on the set pressure.

Other Considerations:

- Relief valve oil return lines should always terminate below the oil level in the reservoir.

- Do not install isolation valves either immediately upstream or downstream of the relief valve unless the company follows a lockout policy or car seal open valves are specified.
- Conduct site tests to verify valves do not leak.

Pressure Control Valves

API 610 8th Edition requirements are:

- **Material**—Cast steel bodies with stainless steel trim.
- **Location**—Downstream of filter and immediately upstream of lube oil supply connection.
- **Size**—Must handle the excess flow of the auxiliary pump and the entire flowrate of the main pump simultaneously at an 80 percent open condition.

Design Considerations:

- **Flowrate**—The pressure control valve must be sized so that it passes excessive main lube oil pump flow when the valve is 15 to 20 percent open. The valve must also pass the entire flowrate of the auxiliary lube oil pump and the excess flow of the main lube oil pump at an 80 percent open condition. The situation occurs any time both pumps are operated simultaneously.

- System designers are required to determine if an integral or external pilot is required. Valves at one inch port size and below work well with integral pilots. Valves 1-1/2 inch and above typically are far more responsive with external pilots. The reaction time of the valve must be fast enough to maintain a pressure between set point and 10 percent accumulation. Some externally piloted valves will reduce system pressure by over stroking when the second pump starts.

- External oil pilots vs pneumatic pilots:

- The key factor to be considered is time of actuation. In small API 610 packages, response time is acceptable when using oil pilots. Oil pilots are less expensive and are easily maintained.

- External pilot valves should have needle valves to isolate the pilot and the actuator of the control valve should be drained to the reservoir below the oil level (Figure 10). This is a requirement of API 614 and is especially important in cold applications. The orifice allows for warm oil to maintain temperature at the valve head. Since this line is now a dynamic or flowing line, the operation is much smoother and the actuator level is repeatable.

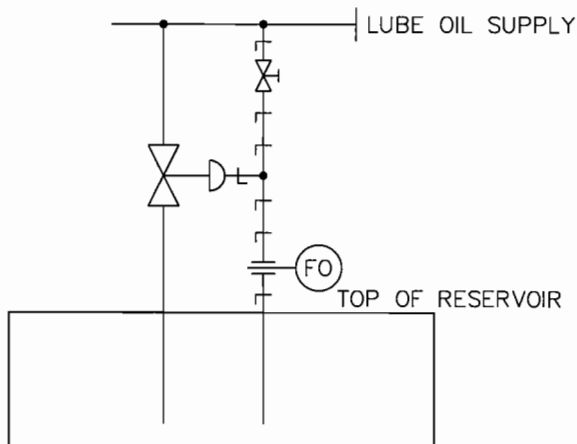


Figure 10. Pressure Control Valve with External Pilot Vented to Reservoir.

Maintenance Considerations

- If continuous duty is required or the process pump is unspared, the design should include isolation bypass and drain valves as shown in Figure 11. Note that for reducing valves, two isolation valves are required.

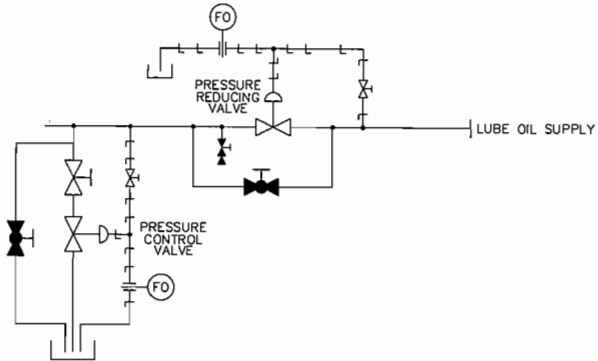


Figure 11. Pressure Control and Pressure Reducing Valves with Isolation and Bypass Valves.

Instrument Isolation Valves/Root Valve

API 610, 8th Edition requirements are:

- **Type**—Block and bleed valves, valves can be combination style.
- **Materials**—Carbon steel bodies with stainless steel trim.
- **Size**—1/2 in NPT minimum.
- **Connection**—Each pressure instrument must have its own pressure tap.

Design Considerations

- Low temperature applications
 - Suggested approach is per Figure 12 (a) allowing a continuous flow through the instrument tubing will result in a more accurate and repeatable set point.
- Install a test port as shown in Figure 12 (b) so the instrument can be checked and calibrated during operation.
- Do not install an isolation valve on PSSL switch. If isolated, the process pump will be unprotected from alarms due to loss of lube oil pressure.

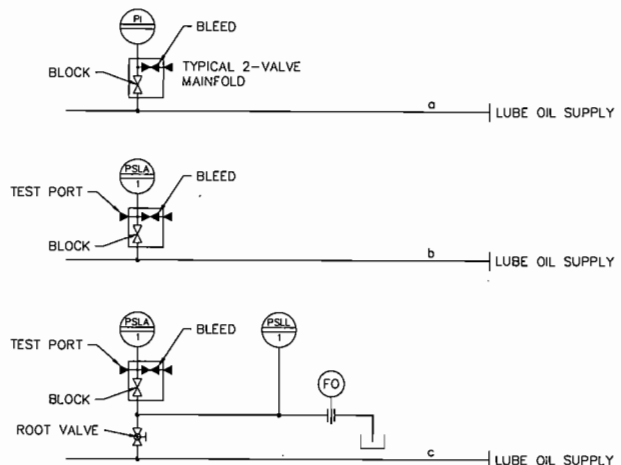


Figure 12. Instrument Valving.

Maintenance Considerations

- Always install a union at the electrical connection of the instrument, so it can be removed without cutting the conduit.
- Always install a pipe union or tube union between the isolation valve and the instrument, so the switch can be removed without having to shut the system down.
- Consider the use of stainless steel for gauge boards, less galvanic action occurs.
- The data reflected in Figure 12 (c) are optimum for low ambient applications.

Lube Oil Piping

Requirements of API 610, 8th Edition are:

- Type of construction, fittings:
 - Socketweld upstream of filter.
 - Buttweld downstream of filter.
- Flanges:
 - 150# RF, socketweld or slip on upstream of filter
 - 150# RF, slip on or buttweld downstream of filter
- Bolts and studs—ANSI-A193-B7 studs or hex head bolts, and ANSI-A194-2H nuts.
- Bending is preferred over welded joints.
- Other requirements—ANSI B31.3 Piping Code with five percent radiography for buttwelds.
- Materials—Per Table 3 (API 610, 8th Edition).
- Flush per API 614.
- Hydro per API 614.
- Long shank plugs only.
- Bushings are not allowed.

Table 3. Requirements for Piping Materials [1] used with permission of the American Petroleum Institute.

System	Auxiliary Process Fluid				Seam		Cast Iron		Lubricating Oil	
	Nonhazardous	Hazardous	≤ 3000 psi (≤ 13 psig)	> 3000 psi (> 13 psig)	Standard	Optional	≤ 1 NPS	≥ 1 1/2 NPS		
Pipe	Seamless ^a	Seamless ^a	Seamless ^a	Seamless ^a	—	ASTM A33 Type F Schedule 40 galvanized to ASTM A153	—	—	ASTM A312 Type 316L stainless steel ^b	—
Tubing	ASTM A269 seamless Type 316 stainless steel ^c	ASTM A269 seamless Type 316 stainless steel ^c	ASTM A269 seamless Type 316 stainless steel ^c	ASTM A269 seamless Type 316 stainless steel ^c	ASTM A269 seamless Type 316 stainless steel ^c	ASTM A269 seamless Type 316 stainless steel ^c	—	—	ASTM A269 seamless Type 316 stainless steel ^c	—
All valves	Class 800	Class 800	Class 800	Class 800	Class 200 bronze	—	—	Carbon steel Class 800	Carbon steel Class 800 flanged	—
Gate and globe valve	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	—	—	—	Bolted bonnet and gland	Bolted bonnet and gland	—
Pipe fittings and unions	Forged Class 3000	Forged Class 3000	Forged Class 3000	Forged Class 3000	ASTM A338 and A197 Class 150 multichannel iron galvanized to ASTM A153	—	—	Type 316L stainless steel	Type 316L stainless steel	—
Tube fittings	Manufacturer's standard	Manufacturer's standard	Manufacturer's standard	Manufacturer's standard	Manufacturer's standard	—	—	Manufacturer's standard	—	—
Fabricated joints ≤ 1 NPS	Threaded	Socket-welded	Threaded	Socket-welded	Threaded	—	—	Threaded	—	—
Fabricated joints ≥ 1 1/2 NPS	—	—	—	—	Purchaser to specify	—	—	—	Welded (see 3.2.3.5)	—
Gaskets	—	Type 316 stainless steel spiral wound	—	Type 316 stainless steel spiral wound	—	—	—	—	Type 316 stainless steel spiral wound	—
Flange bolting	—	ASTM A193 Grade B7 ASTM A194 Grade 2H	—	ASTM A193 Grade B7 ASTM A194 Grade 2H	—	—	—	—	ASTM A193 Grade B7 ASTM A194 Grade 2H	—

Note: Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A214 or API Specification 3L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A193 and A194. Stainless steel piping shall conform to ASTM A312, Type 316L. (See Appendix A for corresponding international materials.)
^a Schedule 80 for diameters from 1/2 NPS to 1 1/2 NPS; Schedule 40 for diameters of 2 NPS and larger.
^b Schedule 40 for a diameter of 1 1/2 NPS; Schedule 10 for diameters of 2 NPS and larger.
^c Acceptable tubing sizes are as follows (refer to ISO 4030): 1.25 mm diameter × 1.66 mm wall (1/4 in. diameter × 0.065 in. wall); 19 mm diameter × 2.6 mm wall (3/4 in. diameter × 0.095 in. wall); 25 mm diameter × 2.9 mm wall (1 in. diameter × 0.109 in. wall).
^d Carbon steel slip-on flanges are permitted.

Design and Maintenance Considerations

- Always use pipe support clamps of the same material as the piping otherwise isolation pads and nonmetallic dampers should be considered.
- Always install flanges so they are located immediately downstream of the valve and are in line with the valve body. This

allows the flange to be tightened in 1/4 inch turn increments if a threaded valve is used.

- Provide vent and drain valves for maintenance purposes in piping.

Instruments

API 610, 8th Edition Requirements Are:

- Devices located per schematic D6 (Figure 1).
- Pressure connections—1/2 in NPT.
- Wetted materials—316 stainless steel.
- Pressure Dials: 4-1/2 in dial with safety back.
- Thermometers—five in dial with a thermowell.

Design Considerations:

- Low ambient conditions are shown in Figure 12 (c).
- Applications with a test port are shown in Figures 12 (b) and (c).

• When selecting pressure temperature switches, always verify the switch dead band. Be sure switches are selected, so the dead band of one switch does not overlap a set point of another switch function.

If permissive pressure switch is set at 30 psi increasing, and the alarm for low oil pressure switch is set at 25 psi decreasing, be sure the permissive switch resets on decreasing before reaching 25 psi. Failure to look at dead band results in system instrumentation indicating both an okay pressure and low pressure signal simultaneously.

• Pump suction line sizes should be designed at four ft/sec maximum. Return lines should slope towards reservoirs and run half full as a maximum. Pressure lines should be designed for 10 ft/sec maximum velocities.

- Instrument sense tubing is seamless, 0.065 wall 1/2 in OD.
- Three inch pipe size is required as a minimum when thermowells are required in the piping.

Function of pressure switches during startup, alarm—lube oil pump transfer and trip of process pump.

• The lube oil system in Figure 1 includes three pressure switches. The instrument legends for these switches are PSLA, PSLB, and PSLC. The functions of these switches are as follows:

- PSLA—Low pressure switch—Starts auxiliary lube oil pump. Typically set at 15 psi, decreasing.
- PSLB—Low pressure switch—Alarms low lube oil pressure. Typically set at 15 psi, decreasing.
- PSLC—Low low pressure switch—Trips process equipment. Typically set at 12 psi, decreasing.
- The lube oil supply header pressure is controlled by the pressure control valve, which is typically set at 20 psi.

• Typical operating sequence for startup/alarm pump transfer/trip function are:

• Startup—In the shelf or low pressure state all switch elements are open. The customer starts the auxiliary lube oil pump and as pressure rises above 12 psi switch PSLC closes. Pressure continues to rise to 15 psi where switch PSLA and PSLB close. This indicates lube oil supply pressure is adequate and from a lube oil supply stand point it is okay to start the process pump. Pressure continues to rise to 20 psi, which is the set point for the pressure control valve. If all other process permissives have been satisfied, the customer starts the

process pump. As the process pump comes up to speed, a flowrate is discharged from the main lube oil pump into the lube oil system. At this point, both the main lube oil pump and the auxiliary lube oil pump are operating simultaneously. The pressure control valve must open to pass the excess flowrate of the main pump and the total flowrate of the auxiliary pump back to the reservoir. System pressure with both pumps running may equal the original PCV set point, or may increase a maximum of 10 percent. Refer to this 10 percent increase as 10 percent accumulation. The customer verifies via pressure gauge and pressure switch signal, the lube oil pressure is adequate and shuts down the auxiliary lube oil pump.

- Low pressure alarm and lube oil pump transfer—Should lube oil pressure drop to 15 psi, PSLA switch contact opens and the auxiliary lube oil pump starts. PSLB switch contact opens simultaneously at 15 psi decreasing and sounds the low lube oil pressure alarm. Normally, the addition of the auxiliary lube oil pump flow to the circuit raises the lube oil supply pressure. Pressure switches PSLA and PSLB will close. At this point, the electrical control circuit should not shut down the auxiliary lube oil pump, as pressure will again drop off to the low pressure alarm setting. The operator should be forced to acknowledge the low lube oil pressure alarm and determine the root cause for it. If the operator cannot determine the cause, the auxiliary lube oil pump is left operating until the spare process pump can be started. Items as simple as a dirty filter can result in a low supply header pressure.

- Trip—Should the lube oil supply pressure drop to 12 psi during operation, pressure switch PSLC will open. This is the trip signal for low lube oil supply pressure and the process pump should be shut down immediately. During shutdown, the auxiliary lube oil pump continues to run.

TYPICAL SCHEMATICS (Figure 13)

An API 610 typical schematic (Figure 13) that shows a system with some standard options as listed below.

- Balance valves for filters
- Temperature control valve
- Reservoir heater
- Level switch
- Pressure differential switch
- Lube oil pressure higher than cooling water pressure
- Oil over temperature switch
- Prefill line for main lube oil pump

REQUIREMENTS FOR OBTAINING A PROPOSAL

The following information is required as a minimum to secure an accurate proposal.

- Total oil flowrate required. Verify flows to each piece of equipment.
- Pressure required at each piece of equipment.
- Heat load for each piece of equipment.
- Location of skid
 - Site elevation
 - Indoors or outdoors
 - Ambient temperatures

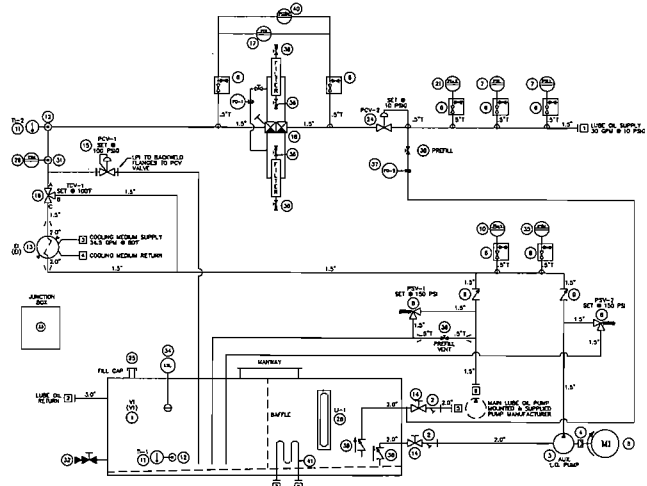


Figure 13. API 610 Schematic with Typical Options used with permission of the American Petroleum Institute.

- Electrical area classification—Class, group, and division.
- API requirements/options.
- Voltage/frequency/phase for motors, heaters, and instrumentation.
- Cooling water supply and return temperatures. Maximum allowed cooling water pressure drop. Maximum cooling water pressure.
- Sound level limitations if any.
- Type of piping and fitting.
 - API 610 or others
- Code stamp requirement for cooler and or filter
- Purchasing specifications and data sheet.

As a guide, complete the purchaser "General Purpose Lube Oil System Data Sheet" (Figure 14).

Rev. No.	0	1	2	3	Job No.	Page	of
Date:					Client		
Designer:					Location		
Reviewed:					Unit		
Approved:					Item No.		
					Service		
					Equipment No.		

Design, manufacture, inspection and testing shall conform to specification:	
1. Information to be completed by: <input type="checkbox"/> Purchaser <input type="checkbox"/> Manufacturer <input type="checkbox"/> Purchaser/Manufacturer:	Serial No. _____ No. Req'd: _____
2. Manufacturer:	Model: _____
Operating and Construction Features	
Pumps	Reservoir
4. Item No. <input type="checkbox"/> Mfr. <input type="checkbox"/> Electric Heater <input type="checkbox"/> Steam Heater:	
7. Pump Type: Main: Standby:	8. Heater Mfr.:
9. Driver Type: Main: Standby:	10. Internal Coating: <input type="checkbox"/> Oil Purifying Conn.:
11. Raced Cap. (GPM): Discharge Press (psig):	12. Working Cap. (gal.): Retention (gal.):
13. RV Set point (psig):	14. Lubricant Type/Initial Fill (gal.):
15. Casing Mount: <input type="checkbox"/> Horizontal <input type="checkbox"/> Vertical	Lanes and Connections
16. Coupling Type/Mfr.:	17. Tubing For Instruments: <input type="checkbox"/> Min Size:
18. Seal Type/Mfr.:	19. Pipe: <input type="checkbox"/> Butt Welded <input type="checkbox"/> Socket Welded <input type="checkbox"/> Threaded
20. Materials of Construction:	21. Flanged: <input type="checkbox"/> Customer Conn. On skid edge:
22. Pump Case: <input type="checkbox"/> Reservoir:	Instrumentation <input type="checkbox"/> Electrical Area Class:
23. Filter: Housing: Element:	24. Temperature Indicators: <input type="checkbox"/> Mfr.:
25. Cooler: Shell: Tubes:	26. Reservoir: <input type="checkbox"/>
27. Typing: Upstream/Downstream Filter:	28. Cooler In/Out: <input type="checkbox"/> Bearing Drain:
29. Valves: Body/Trim:	30. Pressure Indicators: <input type="checkbox"/> Mfr.:
31. Accumulator: <input type="checkbox"/> Instr. Tubing:	32. Pump Disch.:
33. Filter: Item No.:	34. Filter Inlet: <input type="checkbox"/> At switches/transmitters
35. <input type="checkbox"/> Single <input type="checkbox"/> Dual <input type="checkbox"/> Code Design/Stamp:	36. Filter Outlet: <input type="checkbox"/> Filter Diff. Press:
37. Design Pressure/Hydro (psig):	38. Level Indicator: <input type="checkbox"/> Mfr.:
39. Diff. Press (psi): Citan: Allowable:	40. Reservoir:
41. Filtration Particle Size (microns):	42. Sight Flow Indicators: <input type="checkbox"/> Mfr.:
43. Three Way Transfer Valves: <input type="checkbox"/> Mfr.:	44. Bearing Drain: <input type="checkbox"/> Relief Valve Outlet:
45. Filter/Cooler: <input type="checkbox"/> Filter: <input type="checkbox"/> Cooler:	46. Switch/Transmitter Mfr. (Note 1):
Coolers: Item No.:	Switches/Trans.: Alarm Shutdown Setpoint
47. <input type="checkbox"/> Mfr. <input type="checkbox"/> Type:	48. Lo L.O. Press. _____ psig
49. ASME Design/Stamp:	49. Hi L.O. Temp. _____ deg F
50. Duty (BTU/hr):	51. Lo L.O. Level: _____ psi
52. Temp. Conn. Vlv. Req'd: <input type="checkbox"/> Mfr.:	53. Hi Fill Diff. _____
54. <input type="checkbox"/> Single <input type="checkbox"/> Dual <input type="checkbox"/> TEMA C: <input type="checkbox"/> TEMA R	54. Transfer: <input type="checkbox"/> Mfr. <input type="checkbox"/> Item No.:
55. Design/Hydro Press. (psig): Shell: / Tubes: /	56. Sim. Conn. In/Out: _____ (psig, deg F)
57. Dimensions (inches): Shell OD: _____	58. Raising (RPM): <input type="checkbox"/> Speed (RPM)
59. Water Flow (gpm):	60. Mfr. <input type="checkbox"/> Mfr.:
61. Feeding Factor: <input type="checkbox"/> Tube Vd. (ft/sec):	62. Voltage/Phase/Freq: / / <input type="checkbox"/> Speed:
63. <input type="checkbox"/> Max delta P (psi):	64. Insect & Testing: Required Witness Test Log
65. Accumulator: <input type="checkbox"/> Mfr. Capacity (gal.):	66. Cleanliness: _____
67. Required: <input type="checkbox"/> ASME Code Design/Stamp:	68. 1 Hour Test Run _____
68. Type: <input type="checkbox"/> Design/Hydro Press. (psig): /	69. Check Controls _____
69. Heating: <input type="checkbox"/> On equipment skid <input type="checkbox"/> Separate baseplate	70. Changeovers _____
70. Dimensions: _____ ft. _____ in. _____ dia.	71. 1 & 2 Pump Op. _____
Notes:	
44(1) Switches shall be SPDT and rated for the specified electrical area	
44(2) Instruments shall be de-energize to alarm and shutdown.	
44(3) Instruments shall have isolation valves.	

Figure 14. General Purpose Lube Oil System Data Sheet.

- Several other more detailed data sheets that can be used to incorporate specific details on several components. The more detail provided by the purchaser, the more accurate the proposal.

- “A picture is worth a thousand words.” The hydraulic flow schematic is a picture that includes the quantity and orientation of components. If a component is not on the schematic, then it will not be on the system. Schematics, data sheets, and customer specifications are all necessary information to formulate a design for the lube oil system.

CONCLUSION

The North American Reliability Council (NARC) determined that turbine bearing and lube system failures were the leading

cause of forced outages in the turbine related failures. A lube oil system is the life insurance policy for the process. Accurately defining scope of supply, specification requirements, and completing a data sheet results in an optimized lube oil system design. Safe and reliable pump operation with shafts riding on a properly conditioned oil film will yield maximized revenues to the process pump user.

BIBLIOGRAPHY

1. API 610, 8th Edition, American Petroleum Institute.
2. API 614, 3rd Edition, American Petroleum Institute.