SELECTION OF API 614, FOURTH EDITION, CHAPTER 3— GENERAL PURPOSE LUBE OIL SYSTEM COMPONENTS FOR ROTATING PROCESS EQUIPMENT

by

Vinod P. Patel

Senior Principle Machinery Engineer

Kellogg-Brown & Root

Houston, Texas

and

Donald G. Coppins

President

Lube-Power, Inc.

Shelby Township, Michigan

Vinod P. Patel is a Senior Principal Machinery Engineer, Machinery Technology, for Kellogg-Brown & Root (KBR), in Houston, Texas. He has been with KBR for 26 years. In his current assignment, he is responsible in the preparation and auditing of specifications, equipment evaluation, engineering coordination, and testing and installation startup of rotating and special equipment. He has worked in the various application of rotating machinery in the petrochemical and refinery processes including ammonia, LNG, olefins, cat-cracking, and hydrotreating for domestic and international projects.

Mr. Patel received B.S. and M.S. degrees (Mechanical and Metallurgical Engineering) from Maharaja Sayajirao University of Baroda, India, and Youngstown University, respectively. He is a registered Professional Engineer in the State of Texas.

Donald G. Coppins is President for Lube-Power, Inc., in Shelby Township, Michigan. He designs and manufactures oil lubrication systems, seal oil systems, seal buffer systems, heat exchangers, and hydraulic systems for the petrochemical, refining, power generating, and process industries. He has 31 years of experience in the oil, hydraulic, and lubrication systems' business. Mr. Coppins started and developed products for each of the active businesses listed above. Emphasis is on production of the highest quality systems with ontime delivery. He performs administrative, quality, and code vessel engineering functions at Lube-Power, Inc.

Mr. Coppins holds multiple technical and business degrees including: AAS (Mechanical Production Technology) from Oakland University; BSME, DIT, and BBA Management/ Marketing, all from Michigan colleges.

ABSTRACT

Lube oil systems are utilized in rotating process equipment to lubricate and cool hydrodynamic bearings. These systems are essential to the life and maintenance-free operation of the process equipment. Dependable performance results in up time for equipment, which increases profits for the process end user. API 614, Fourth Edition, Chapter 3 (1999), defines the requirements of components for general purpose lube oil systems. Conservative design, proper specifications, and application of the components minimizes the possibility for failure and maximizes 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 rotating equipment 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 said equipment.

Larger process pumps and drivers often use hydrodynamic bearings due to required bearing load and 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 within the acceptable temperature and pressure range is required to keep the bearing system in balance. A loss of oil supply means a loss of cooling, loss of oil film properties, and then the loss of a bearing and possibly more.

Proper selection of the lube oil system components and their arrangement within the piping and instrumentation diagram are dependent upon, but not necessarily limited to, the following external and operational factors.

External Factors

- Ambient temperature range
- Tropical area
- Electrical area class
- Seaside or platform location
- Local codes: CSA/CRN, IEC, country codes

Operational Factors

- Lube oil supply pressure higher than cooling water
- Vertical process pump with dual AC motor driven lube oil pumps
- Equipment coastdown time
- Synthetic versus mineral base lube oil systems

API 614, FOURTH EDITION, CHAPTER 3, GENERAL PURPOSE LUBE OIL SYSTEM SPECIFICATIONS

API 614, Fourth Edition, Chapter 3 (1999), general purpose lube oil system standard defines general purpose applications as one that is usually unspared or is for noncritical service.

One of the prerequisites for the design of a proper lube oil system is the basic understanding of the function and material requirements of the lube oil system components.

Another prerequisite is the basic understanding of the rotating equipment's oil system needs. The general purpose lube oil system can be applied to API 610 process pumps, API 611 turbines, API 677 gears, API 672 compressors, API motors, or multiple combinations of rotating process equipment.

Figures 1 and 2 show the minimum requirement of an API 614, Fourth Edition, Chapter 3 (1999), lube oil system.

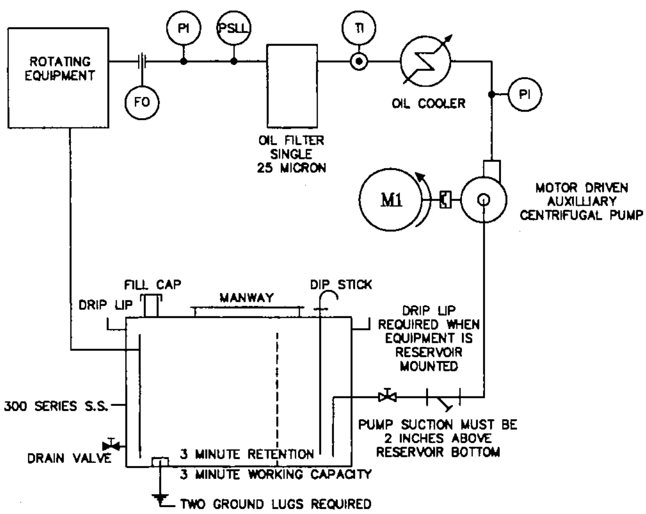

Figure 1. API 614, Fourth Edition, Chapter 3, Lube Oil System Minimum Requirements Using a Centrifugal Pump Schematic.

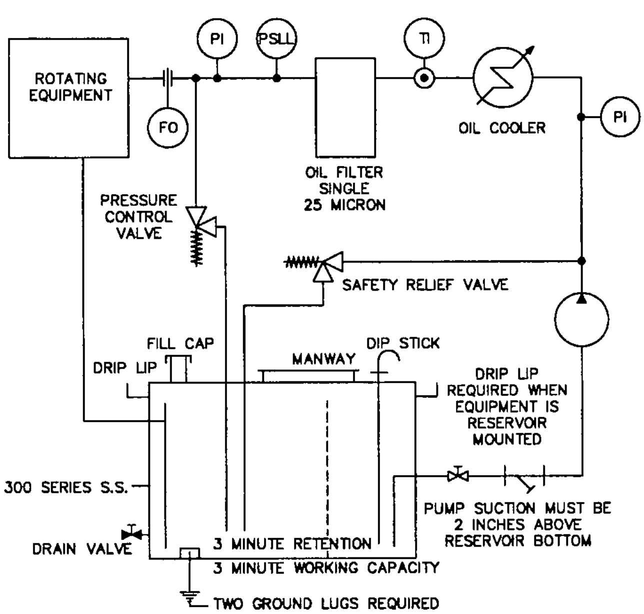

Figure 2. API 614, Fourth Edition, Chapter 3, Lube Oil System Minimum Requirements Using a Positive Displacement Pump.

TYPICAL OIL LUBRICATION SYSTEM

Components, their purpose, API 614, Fourth Edition, Chapter 3 (1999), 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 flow rates in the reservoir determine particulate disposition in the reservoir.
  - *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 614, Fourth Edition, Chapter 3 (1999), design requirements are:

- *Materials*—Austentic stainless steel
- *Retention*—Three minutes retention capacity is defined as the total capacity below the minimum operating level of the reservoir. Normal system flow rate × 3 = retention capacity.
- *Working capacity*—Three minutes working capacity is defined as the volume between the pump minimum operating level and the pump suction loss level. Normal system flow rate × 3 = working capacity.
- *Dip stick*—To cover full charge capacity of the reservoir.
- *Baffle*—The function of the baffle is to separate pump suctions 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 oil pump inlet and return line to allow oil to pass from the return side to the suction side of the reservoir. The oil travel path shall be as long 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 3).

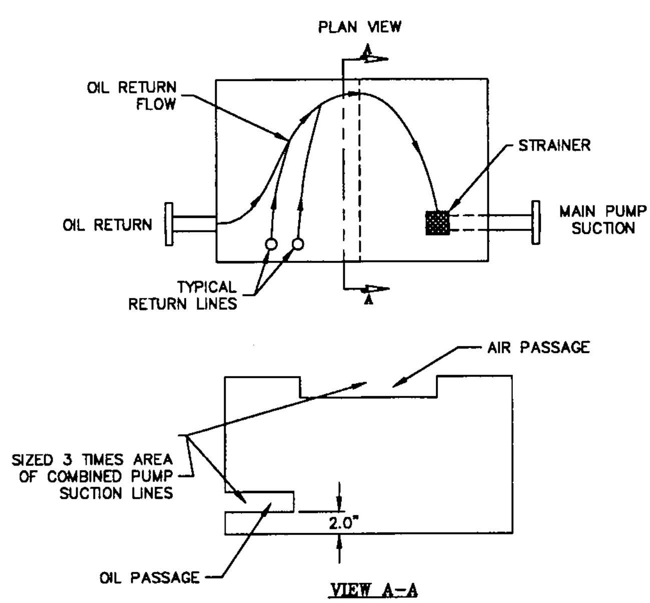

Figure 3. Reservoir Baffle Orientation and Design.

• *Reservoir fill cap*—The filler breather cap should be located on a riser to prevent water from running into the reservoir. The 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.

• *Ground lugs*—Two ground lugs are required. These must be located on opposite corners of the reservoir and must accept a 1/2 inch NC bolt.

• *Manway*—A gasketed manway and riser should be supplied so access is available to all compartments of the reservoir. This manway requires a .25 inch riser and must be 24 inches square if access is necessary to clean 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. A vent is required at the top of each return line.

• *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. Avoid using elbows in the suction lines to prevent air pockets and minimize the potential for cavitation.

Additional items required for a reliable design:

• *Armored sight glass*—A weld pad sight glass should be added to the reservoir. The chamber should be the same material as the reservoir. An armored reflex glass is required. The sight glass should span an area from one inch above the rundown level to one inch below the minimum operating level of the reservoir (Figure 4).

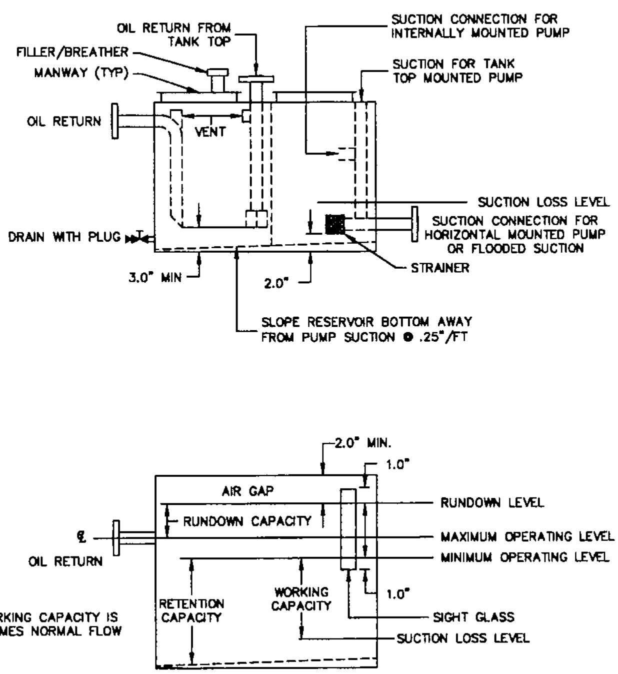

Figure 4. Reservoir Suction and Return Line Orientation/Reservoir Capacities/Sight Glass Installation.

• *Slope bottom of reservoir*—The bottom of the reservoir should slope away from the pump suction toward the return side of the reservoir .25 inch/foot.

• *Riser*—API 614, Fourth Edition, Chapter 3 (1999), calls for a minimum riser of .25 inch for the manway. The suggested design requires a 1.5 inch riser. Bolt holes in risers should not penetrate the top of the reservoir. A .25 inch riser plate does not provide adequate thread engagement for bolting down of the manway cover. Units located outdoors where snow and ice buildup on the top of the reservoir are a possibility, require 1.5 inch risers.

• *Oil purification connections*—To facilitate oil cleanup, the authors recommend adding oil purification connections with isolation valves to the reservoir. The suction connection has a goose neck with a .25 inch siphon breaker hole at the minimum rundown level. The oil return terminates below the oil level and includes a stilling tube. This option allows the user to connect a remote oil purification system.

Reservoir Sizing

Factors involved in reservoir size and selection are:

• System flow rate

• Retention time and working capacity

• Height of return line from process equipment

• Required working capacity

• Rundown capacity

• Location of auxiliary pump (internal or external of reservoir)

Refer to Figure 3 for baffle design and location. Figure 4 shows suction and return locations in the reservoir as well as reservoir capacities.

Assume a total nominal lube oil flow rate of 20 gpm, $20 \times 3 = 60$ (working capacity).

• *Working capacity*—The capacity between minimum operating level and suction loss level.

• *Rundown capacity*—The amount of oil expected to return to the reservoir when the system is shut down. (Use 10 percent of the total capacity of the reservoir as required by API 614, Fourth Edition, Chapter 3, 1999. Refer to Figure 4 for details.)

Lube Oil System Baseplate

The oil lubrication system may be mounted on a baseplate for a standalone console, or the lubrication system can be mounted directly on the rotating equipment skid.

When the customer requires a separate console, the requirements for the baseplate are as follows:

• Major components (pumps, filter, coolers) must be mounted directly on the structural steel.

• The baseplate requires a drip rim with at least one 1-1/2 inch drain connection.

• The top deckplate shall be installed to ensure drainage to the drip lip.

• The baseplate shall be rigid enough to be lifted by a four-point lift, without distorting the skid or damaging the components. Four suitably sized lifting lugs are required.

• Baseplate design must be mutually agreed to by the purchaser and the vendor.

• The purchaser may specify the need for grouting. Adequate vents and grout access holes are required.

• All welding must be performed in accordance with AWS D1.1.

• Adequate maintenance space is a primary requirement for the baseplate design.

Lube Oil Pumps

Only one pump is required for an API 614, Fourth Edition, Chapter 3 (1999), general purpose lube oil system. This pump can be main shaft driven or electric motor driven.

Various API equipment specifications require additional pumps. API 610, Eighth Edition (1995), requires dual pumps. One pump is main shaft driven and the other pump is typically electric motor driven. It is imperative that the customer specify the required number of pumps, their drivers, and orientation on the data sheet.

Figure 1 shows the minimum requirements for the general purpose lube oil system when using a centrifugal pump. You will note that only a flow orifice is required for lube oil system supply pressure control. Figure 2 shows the minimum requirements for the general purpose lube oil system when using a positive displacement (PD) pump. You will note that the PD pump requires both a safety relief valve and a pressure control valve.

Pump Requirements

• *Centrifugal pumps* must deliver the specified system pressure across the pump's stable flow range when the oil temperature is 50°F. The pump must operate between 50 percent and 110 percent of its best efficiency point. The pump curve shall demonstrate a minimum of 5 percent continuous rise in head from the normal operating point to shut off. Pumps should be sized so that upon installation of a new impellor, a future increase of 10 percent in head can be achieved.

• *Positive displacement pumps* must be capable of delivering the required flow at 50°F at the pump relief valve setting. The relief valve pressure setting plus 10 percent shall be a maximum of 90 percent of the manufacturer's maximum differential pressure rating for the lube oil pump.

Both gear type and screw type positive displacement pumps are typically used. The gear pump is most viable for the following applications:

• At 1200 rpm to 1800 rpm input shaft speeds

• With oil viscosity ranges 100 SSU to 500 SSU

• Where lube oil pump discharge pressures are greater than 150 psi

The screw pumps are most viable for the following applications:

• With low noise requirements

• Where steel cast pump casings 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 rotating equipment manufacturer as prime vendor must determine total flow rates, heat loads for the entire process train, 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 gpm divided by .85 = 17.64 gpm. Fifteen percent is used as the minimum acceptable additional value needed to maintain head in the lube oil supply header.

A minimum 1.5 gpm extra must be available on systems in the 5 gpm 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 percent and 20 percent open. The extra oil capacity passes over the pressure control valve back to the reservoir.

When two pumps are required in the system, 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 pump is online 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 614, Fourth Edition, Chapter 3 (1999), requires the pump housing material be cast steel when the pump is located outside the reservoir. Pumps located inside the reservoir can be cast-iron.

Installation

Nonspacer elastomeric couplings are acceptable for drivers up to 30 hp. Therefore, auxiliary pump seals typically cannot be changed during operation of the main pump, unless the auxiliary pump is removed from its soleplate.

Pumps that are mounted vertically in the tank should be mounted so the coupling is above the tank top (Figure 5). Mounting of the coupling below the tank top can result in aeration of the oil due to aerodynamic effects of the coupling.

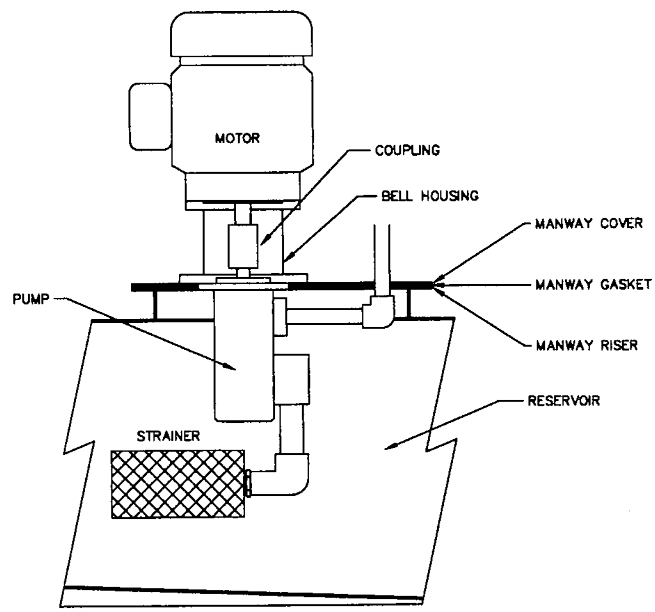

Figure 5. Vertical Pump Mounting Assembly.

• Pump motor bell housing is available line bored to .002 total indicator reading (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 authors recommend the pump installation be vertical on a bell housing with a C face motor per Figure 5. 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, soleplates, 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 the 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.

Permanently installed Y strainers are located externally of the reservoir to allow for easy cleaning of the screen. This application requires additional components such as a suction isolation valve for the pump (Figure 6). The strainer typically is 100 mesh, which is intended to keep only coarse particles out of the pump. Our opinion is, if this strainer ever becomes clogged, it is time you 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.

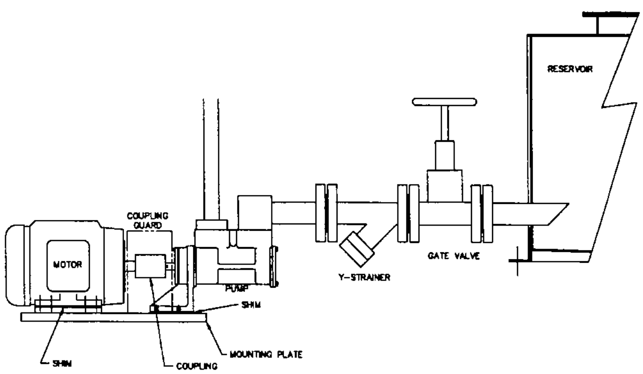

Figure 6. Horizontal Pump Mounting Assembly.

- *Vertically mounted pumps* (with pumps installed inside the reservoir)—Require the tank be opened only if a pump maintenance or replacement 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.

Relief Valves

Any time a positive displacement pump is selected, it is necessary to equip it with a relief valve. This valve should be external of the pump. API 614, Fourth Edition, Chapter 3 (1999), allows the relief valve to be integral with the pump. The authors do not recommend this practice, as the relief discharge should return to the tank.

The authors recommend a foot valve installed on the suction side of any pump that does not have a flooded suction condition.

Electric Motor Requirements

Pump drivers must be sized to handle the maximum brake horsepower (bhp) required by the pumps, plus the extra capacities listed above. This power requirement shall be established at 50°F.

Driver Sizing and Effects of Viscosity/Design Impacts

Total pump discharge is calculated as nominal output flow rate required by the equipment divided by .85.

The test case is 15 gpm nominal flow and, therefore, the pump will produce 17.64 gpm minimum. The main pump speed is 3000 rpm, since this application is 50 Hz, so the electric motor driven pump must run at 3000 rpm (Figures 7 and 8).

Figure 7 shows that Pump A 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 flow rate.

API 614, Fourth Edition, Chapter 3 (1999), indicates the use of ISO VG 32 oil as a typical standard for these systems. The pump draws its oil supply from the reservoir, which 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 can approach 160°F and oil viscosity of approximately 70 SSU to 90 SSU. Therefore, in the example, Pump A is too small for this application (Figure 7).

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

Figure 7. Screw Pump Discharge Capacity and Input Power Chart, Pump A.

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

Figure 8. Screw Pump Discharge Capacity and Input Power Chart, Pump B.

In Figure 8, Pump B will produce the proper flow rate 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, the 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 one has 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

API 614, Fourth Edition, Chapter 3 (1999), general purpose lube oil system requirements are:

- *Type*—Simplex
- *Material*
  - *Housing*—Cast steel
  - *Elements*—Cartridge materials should be corrosion resistant.
  - *Filtration cleanliness level*—Minimum particle removal efficiency of 99.5 percent for 25 micron particles (B25 ≥ 200) per ISO 4572 (1981) when tested to a minimum terminal end. Maximum differential pressure at the end of the test run is 50 psid.
  - *Other*—Filters must be located downstream of the heat exchanger. Oil flows from the outside of the element toward the center post. It must be able to drain oil from the filter housing while avoiding contaminating the clean side oil. Should a filter head exceed 35 pounds, the filter must be equipped with a davit.

Additional Suggested Requirements

- ANSI T3.10.8.8 Standard (1994) was developed for testing and verification of the 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 process pump and auxiliary equipment bearings. The higher the quality of filtration, the longer the service life. ISO 4406 (1987) and National Aerospace Standards (NAS) 1638 (1992) define cleanliness of critical rotating machinery (Table 1). Process machinery is critical to the reliability of the process and, therefore, oil clarity should be NAS 1638, Class 5 (1992). API 614 (1992) cleanliness standard, which has been adopted by most other API rotating equipment standards, allows for a defined number of particles to be caught at the screen of 250 microns maximum. Note this relates to a NAS 1638, Class 11 (1992). The typical quality 10 micron beta 75 element will produce NAS 1638, Class 5 (1992), results. It is recommended that lube oil systems be flushed at the point of manufacture to NAS 1638, Class 5 (1992), 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.

Table 1. NAS 1638 Class Contamination Limits.

SIZE RANGE (μm)	Classes (based on maximum contamination limits, particles per 100mL)													
	00	0	1	2	3	4	5	6	7	8	9	10	11	12
5-15	125	250	500	1,000	2,000	4,000	8,000	16,000	32,000	64,000	128,000	256,000	512,000	1,024,000
15-25	22	44	89	178	356	712	1,425	2,850	5,700	11,400	22,800	45,600	91,000	182,400
25-50	4	8	16	32	63	126	253	506	1,012	2,025	4,050	8,100	16,200	32,400
50-100	1	2	3	6	11	22	45	90	180	360	720	1,440	2,880	5,760
OVER 100	0	0	1	1	2	4	8	16	32	64	128	256	512	1,024

- Filters should be sized so that a clean element passes the entire pump discharge flow rate at maximum 5 psi pressure drop across the elements at design conditions.

- Various API machinery standards will require duplex filters with continuous flow transfer valves. A duplex filter must be specified by the customer on the data sheet. The authors feel the duplex filter is a necessity for a reliable lube oil system.

- Given that API requires the nonbypass filter, and no 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 pump's 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 psid 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 percent 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. The 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. The filter and all maintenance valves shall be located in an accessible location on the skid.

- Supply a balance/prefill line and appropriately sized orifice, for ease of filter maintenance.

- The above items allow the serviced element to be prefilled 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 also is 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 the canister prior to removing it from the system. The operator can also verify that the leakage rate of the transfer valve is acceptable prior to opening the housing. Excessive leakage in the transfer valve will cause a system shut down. Drain valves are useful for oil sampling, particle counting, and prevention of oil spills.

Refer to Figure 9 for filter vent, drain, and balance line details.

Heat Exchangers

The API 610, Eighth Edition (1995), requirements for heat exchangers are:

- *Type*—Shell and tube with .375 inch tubes/ASME code design
- *Supply temperature*—120°F maximum
- *Orientation*—Cooling water is on the tube side.

Other suggested design considerations are:

- *Velocity in tubes*—5 ft/sec minimum, 8 ft/sec maximum
- *Fouling factor tubes*—.002 hr • ft^2 • °F/BTU
- *Maximum pressure drop*—5 psi
- *Capacity*—Maximum heat load of rotating equipment, plus add the horsepower of the lube oil pump driver. The entire lube oil system input horsepower goes to heat.

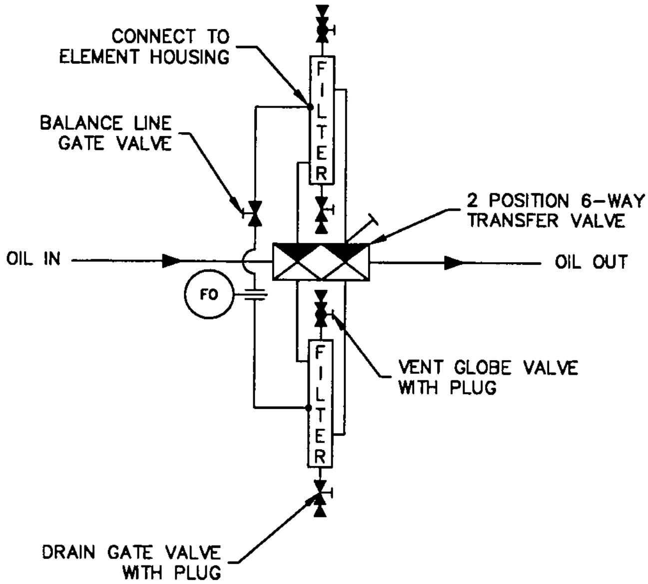

Figure 9. Duplex Filter with Transfer Valve, Vent, Drain, and Balance Lines.

Maintenance Considerations

- Removable bundles add ability to change the bundle without removing the shell.
- Consider adding vent and drain valves in other locations 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, and vent and drain valves on the cooling water chamber should be added to facilitate changing heat exchangers during operation.

Relief Valves

API 614, Fourth Edition, Chapter 3 (1999), requirements are:

- The valve shall have a carbon steel body with stainless steel trim.
- Valves shall be located downstream of each pump discharge (refer to Figures 1 and 2 for location).

Two types of valves are typically used:

- *Direct acting type*—Fulflo-type 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 flow rate increases, the pressure at the inlet increases, i.e., the pressure drop across the valve increases.
- *Pilot operated type*—Crosby, Consolidated, AGCO, etc., manufacture a 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 Design 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 your company follows a lockout policy or you specify car seal open valves.
- Conduct site tests to verify valves do not leak.

Pressure Control Valves

API 614, Fourth Edition, Chapter 3 (1999), requirements are:

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

Other Design Considerations

- *Flow rate*—The pressure control valve must be sized so that it passes excessive main lube oil pump flow when the valve is 15 percent to 20 percent open. The valve must also pass the entire flow rate 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 that both pumps are operated simultaneously.
- System designers are required to determine if an integral or external pilot is required. Valves at 1 inch port size and below work well with integral pilots. Valves 1-½ inch and above typically are far more responsive with external pilots. The reaction time of the valve must be fast enough to maintain pressure between the set point and 10 percent accumulation. Some externally piloted valves will reduce system pressure by overstroking when the second pump starts.
- *External oil pilots versus pneumatic pilots*—The key factor to be considered is time of actuation. In small lube oil packages, response time is acceptable when using oil pilots. Oil pilots are less expensive and are easily maintained.

Maintenance Considerations

If continuous duty is required or the rotating equipment is unspared, the design should include isolation, bypass, and drain valves as shown in Figure 10. Note that for reducing valves, two isolation valves are required.

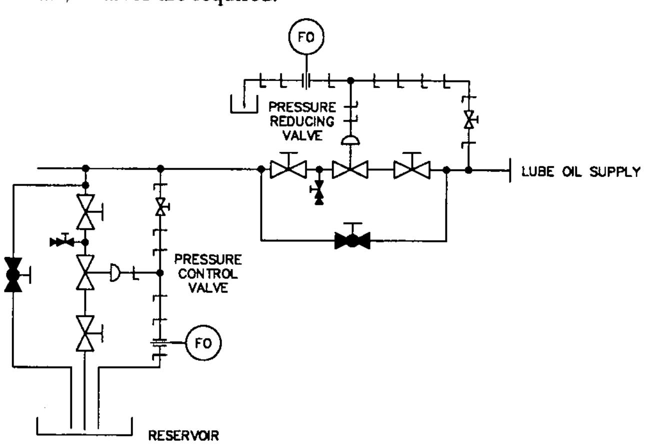

Figure 10. Pressure Control and Pressure Reducing Valves with Isolation and Bypass Valves.

Instrument Isolation Valves/Root Valve

API 614, Fourth Edition, Chapter 3 (1999), requirements are:

- No instrument valves are required.

Suggested Considerations

- Add instrument valves.
- *Type*—Block and bleed valves, valves can be combination style
- *Materials*—Carbon steel bodies with stainless steel trim
- *Size*—½ inch NPT minimum
- *Connection*—Each pressure instrument must have its own pressure tap.

• Install a test port as shown in Figure 11(b), so the instrument can be checked and calibrated during operation.

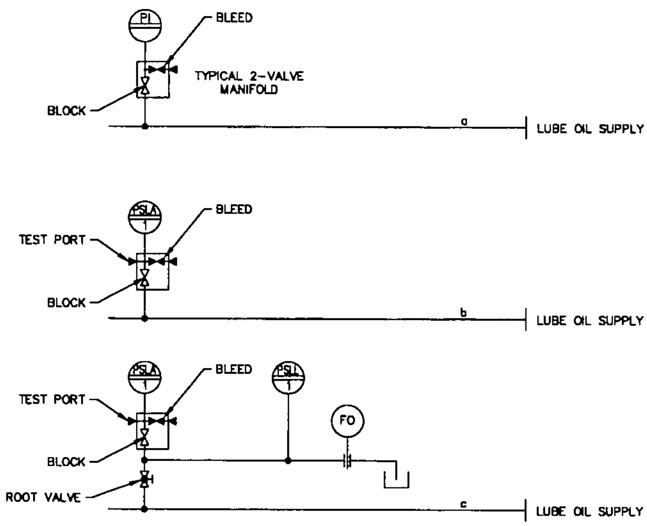

Figure 11. Instrument Valving.

• Do not install an isolation valve on the PSLL switch. If isolated, the process pump will be unprotected from alarms due to loss of lube oil pressure.

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.

Lube Oil Piping

API 614, Fourth Edition, Chapter 3 (1999), requirements are:

• Type of piping connections and fittings:

  • Socketweld flanged connection upstream of filter

  • Buttweld flanged connection downstream of filter

• Flanges:

  • 150# RF, socketweld or slipon upstream of filter

  • 150# RF, buttweld or slipon 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 (1999) piping code. Five percent radiography for buttwelds is not required.

  • Materials—300 series pipe schedule is per API standard.

  • Flush per API 614 (1999).

  • Hydro per API 614 (1999).

  • Long shank plugs only

  • Bushings are not allowed.

Other Design and Maintenance Considerations

• Always use pipe support clamps of the same material as the piping, otherwise isolation pads and nonmetallic dampeners 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 614, Fourth Edition, Chapter 3 (1999), requirements are:

• Devices located per schematic D6 (Figures 1 and 2)

• Pressure connections—1/2 inch NPT

• Wetted materials—316 stainless steel

• Pressure dials—4-1/2 inch dial with safety back

• Thermometers—5 inch dial with a thermowell

Design Considerations

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

Rotating Equipment Needs

Each piece of API equipment has specific needs and is operated to meet process requirements. This equipment may require two pumps, remote pressure indicators or transmission, differential switches, level transmitters, alarm, or shutdown switch. The owner must indicate on the data sheet exactly what instrumentation is required for his process.

API 614, Fourth Edition, Chapter 3 (1999), describes a general purpose lube oil system. The customer must detail out on the data sheet the specific needs of his system.

EFFECTS OF EXTERNAL FACTORS ON LUBE SYSTEM COMPONENT SELECTIONS

External factors bear significantly in the arrangement of the schematic of the lube oil system components. The following discussion briefly analyzes the effects of these factors on schematic design and component selections.

Ambient Conditions, Low Ambient (Use Low Ambient Schematic)

Reservoir

• Include reservoir heater with Incoloy® sheath. Watt density should not exceed 15 Watts/in^2. Above 15 Watts/in^2 density oil will coke out. The addition of the heater should prompt the designer to install a thermostat for control and an oil level switch to shut down the heater on low oil level.

• The heater shall be sized to bring the oil up to permissive start temperature in a low ambient condition within four hours.

• Reservoirs may require insulation.

• Design consideration should be given an open coil heater that is mounted in an atmospheric well within the reservoir. The heater well combination allows the heater to be replaced without having to first drain the reservoir. All heaters should be installed below the minimum operating level in the reservoir.

• Consider the installation of an oil purifier. Low ambient conditions can result in a buildup of condensation in the reservoir and water in the oil.

Pump/Motor

The size of the electric motor is dependent upon fluid viscosity and ambient conditions with the mineral base oils. As ambients drop, viscosity increases, resulting in an increase in a higher bhp at the pump. In Figure 7, one can see that at 100 psi, bhp increased from 1.4 to 3.7 with a viscosity range of 100 to 5000 SSU.

For ambient ranges below 20°F the authors recommend space heaters in the electric motors.

Filters

If low ambient startups are required, the design should include selection of filter elements that can withstand lube oil pump relief settings, plus 15 percent.

Heat Exchangers

If ambient conditions are low, a temperature control valve should be installed on the oil side of the cooler. This valve should be set up as a mixing valve to facilitate a flow of warm oil through the cooler to keep the charge of oil in the cooler warm.

Consideration should be given to an air-to-oil cooler with a mixing valve (Figure 12).

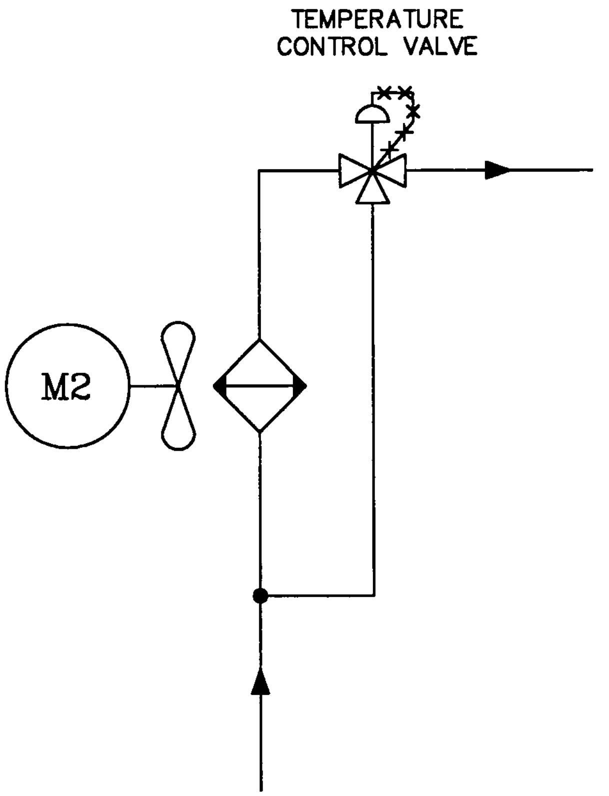

Figure 12. Air-to-Oil Cooler with Mixing Action Temperature Control Valve.

Pressure Control Valves

Pressure control valves can be equipped with a pilot operated actuator. A needle valve and orifice are plumbed into the circuit per Figure 13 to maintain the temperature of the oil in the actuator.

Instrumentation

Figure 11(c) arrangement should be provided for instruments operating in low ambient conditions. The authors recommend frost guards for reservoir level glasses when ambients are below 15°F.

High Ambients Above 120 F and/or Direct Sunlight (Figure 12)

Reservoir

- Two inches of thermal insulation is suggested.

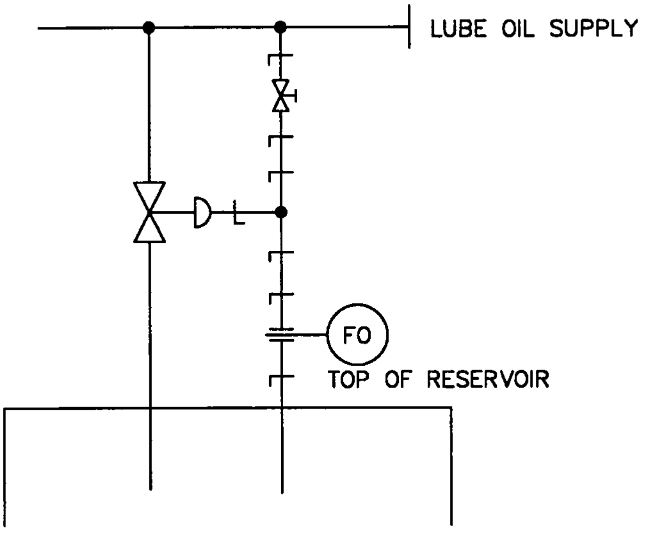

Figure 13. Pressure Control Valve with External Pilot Vented to the Reservoir.

- Sight glass with UV protective guards
- Sunshields over the instrument gauge board

Pumps/Motors

Be sure to verify lube oil return line temperature in the reservoir. Where oil return temperatures exceed 170°F, the authors recommend changing elastomers from Buna™ to Viton®.

Heat Exchangers

Solar loads and high ambient loads must be included in the total heat load from bearings and latent heat transmitted through the shaft to the lube oil.

When an air-to-oil cooler is specified, the closest ΔT between lube oil supply temperature and ambient temperature is 15°F. If the ambient is 105°F, the lowest economical oil temperature out to the bearings is 120°F. This is referred to as ΔT 15°F as the approach. As the approach temperature becomes less than 15°F, the cooler price increases exponentially.

Instrumentation

Figures 11(a) or 11(b) can be used.

Tropical Area/Seaside or Platform Locations

Tropical Areas

- The reservoir should be carbon steel with epoxy paint interior or stainless steel.
- Duplex filters should include stainless steel internal fasteners and polyester elements. The paper elements tend to absorb more water and this causes premature clogging.
- Use stainless steel shim stock under pumps and motors.

Seaside or Platform Location

Special coating efforts should be made for all components.

- Galvanized skid, frame, supports, conduit, pipe, flange, bolting, etc.
- Stainless steel or galvanized gauge boards
- Eliminate aluminum materials typically found in pump motor couplings, pump seat retainers, and instruments.
- If sea water is used for cooling, change cooler tubes to 20/30 copper, nickel, or titanium. Where air-to-oil coolers are required, choose phenylic coatings.

Electrical Area Class/CSA, CRN, IEC, Country Codes

Electrical Area Class

• Select electric motors, reservoir heaters, and instruments to meet electrical code class.

• Conduit, conduit fittings, and conduit seals should be selected to meet local codes, customer's standards, and National Electrical Code (NEC) area classifications.

CSA/CRN, UL, FM

• Canadian electrical standards require that all electrical components need Canadian Standards Association (CSA) labels for use within their specific area class. Further, for any hazardous location wiring, it is necessary to obtain a CSA certificate. Today, the provinces of Canada individually require Canadian Registration Numbers (CRN) for all vessels, pipe fittings, and some valves. Vessel manufacturers, fitting manufacturers, and system assemblers can apply to the local provincial authorities for the necessary permits and review of designs.

• Underwriters Laboratories Inc. (UL) and Factory Mutual (FM) labels are not available for all the electrical component manufacturers typically used on lube oil systems. Check with the manufacturers of the lube oil system components.

• Note that many foreign governments have written their codes around other countries. Therefore, many countries will accept CE, European Committee for Electrotechnical Standardization (CENELEC), CSA, or other standards certificates.

Country Codes

Countries such as China, Malaysia, and others have their own ASME type codes or inspection programs. China has its own pressure vessel code. Malaysia requires Department of Occupational Safety and Health (DOSH) inspections. Verify with the end user or application engineer which codes are required and which are acceptable alternatives.

Equipment Coastdown Time

Few pieces of rotating equipment have the requirement of extended coastdown times. In remote locations where power is not always reliable, an additional lube oil supply with a different power source may be necessary during coastdown.

• Rundown tanks are mounted above the process pump and are sized to provide the system with lube oil flow during coastdown as a result of power loss. Note that the coastdown reservoir should be equipped with an atmospheric check to allow air into the vessel on coastdown.

• For vertical process pumps, a coastdown tank is used because the main lube oil pump is AC motor driven, not shaft driven, and on loss of power, the AC motor driven pump stalls.

• A coastdown tank bypass is recommended for all applications to maintain a warm slug of oil in the coastdown tank. For low ambient, a heater and level switch or insulation are additional options.

• Remember to size the lube oil system reservoir to allow for coastdown capacity. The reservoir sight glass should be arranged such that it spans from two inches above the coastdown level to one inch below the operating level.

Oil Selection

Various types of lubrication oil, such as mineral base oils and synthetics, are available. The selection of these fluids affects the selection of some of the components.

Mineral Base Oils

• Mineral base fluids, including paraffin base oils, are typically compatible with Buna™ elastomers up to 2000 psi and 180°F; and are generally compatible with all materials typically used in the lube oil system components.

• Paraffin base fluids are usable up to 1500 psi loading. Beyond 1500 psi, the fluid molecules may separate under pressure. This migration can result in metal-to-metal contact.

Synthetic Fluids

• Synthetic fluids are derived from both animal fat and plants. These fluids are typically compatible with Viton® or Teflon® elastomers. The designer must not supply pumps and close running components where brass or bronze materials are present, as a chemical reaction may result in the formation of lead soaps. This lead soap will result in plugged lubrication galleys within the system components, causing failures.

• For low ambient conditions, synthetic fluids are a beneficial solution, as their viscosity is relatively constant throughout a temperature range. Note that the design should consider a coalescing filter element and an oil purifier when selecting synthetic oils. The addition of water to the synthetic oil can result in plating out (coking) onto hot elements, such as immersion heaters, rendering them inefficient.

Maintenance

• All fluids should be mentioned for chemical makeup, particulate count, pH level, total acid number (TAN), and kinematic viscosity. Oil samples should be drawn during operations from the reservoir and the lube oil supply and return lines. The National Fire Protection Association (NFPA) sampling method is applied to result in quality analysis.

• Many service companies provide a spectrographic analysis of oils where 12 elements are measured in parts per million (ppm) (Table 2).

Table 2. Spectrographic Analysis of Oils.

Elements	Normal Range	Oil Change Required
Aluminum	1.0	4.75
Copper	5.0	10.0
Chromium	4.5	7.75
Lead	3.25	6.75
Iron	3.5	7.75
Magnesium	1.25	4.75
Molybdenum	3.0	6.75
Nickel	3.0	6.75
Tin	13.5	22.0
Silver	1.0	4.0
Silicon	17	22.0
Titanium	0-3	6.75

measured TAN>1.0 Mg KOH/g

• *Oil sampling*—Spectrographic analysis is used as a preventive maintenance tool to obtain a snapshot of the fluid condition and determine the makeup of fluid. High ppm readings for some elements may allow prediction for premature failure of a component. Chemical analysis is linked to fluid life. Every fluid has a service life, and chemicals can be added to prolong their life. Particulate counts are used to determine the system cleanliness. NAS 1638 (1992) defines cleanliness for critical rotating equipment as Class 5 (Table 1).

• *Oil change*—Some customers change the viscosity or type of fluid after a few years of operation. Any time the oil viscosity index is changed, the system pressure controls and bearing lube orifices must also be changed to accommodate a nonoil. Customers should contact the OEM for recommendations and approval of changes.

Changing from a mineral base oil to a synthetic requires draining 98 percent of the oil volume within the entire system, and venting filter element and elastomer compatibility with the new fluid.

REQUIREMENTS FOR OBTAINING A PROPOSAL

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

- Total oil flow rate is 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, environmental conditions (dust, saline atmosphere, etc.)
- Electrical area classification—Class, Group, and Division
- API requirements/options
- Voltage/frequency/phase for motors, heaters, and instrumentation
- Cooling water type and quality, including supply and return temperatures. Maximum allowed cooling water pressure drop. Maximum cooling water pressure.
- Sound level limitations, if any
- Type of piping and fitting—stainless or carbon with listed material and pipe schedule, flange style/type/finish, socket or buttweld fittings
- 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).

"A picture is worth a thousand words." The hydraulic flow schematic (Figure 15) 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. Pumps, their drivers, and gears rotate on, and are supported by, the oil film in the hydrodynamic bearing. The life of this equipment and, therefore, the process reliability is a function of a properly designed lube oil system producing the appropriately conditioned oil film.

Detailed data sheets are the beginning to an optimized lube oil system design and component selection to result in a reliable system to maximize revenues for the process pump user.

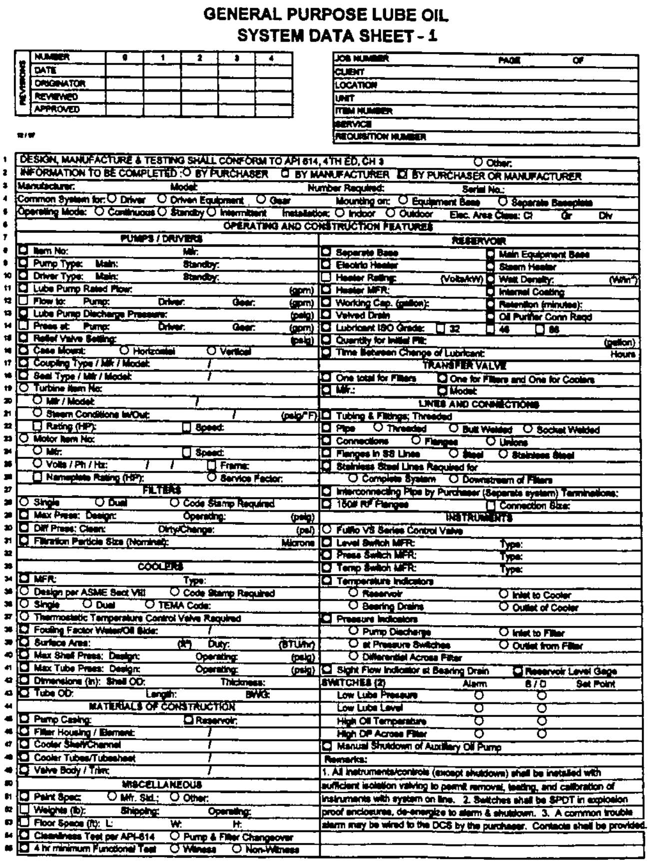

Figure 14. General Purpose Lube Oil System Data Sheet.

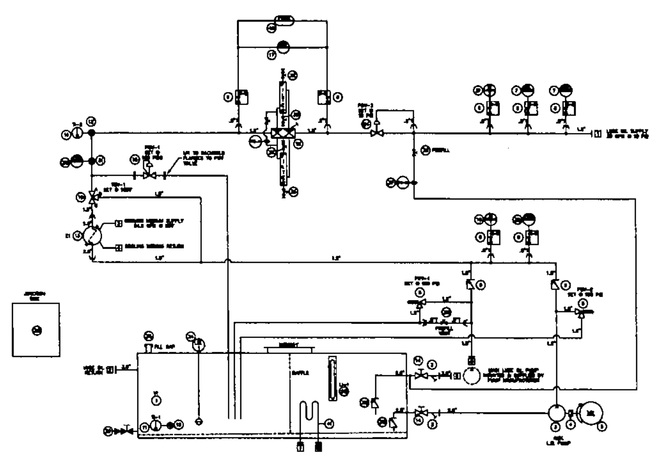

Figure 15. API 610 Schematic with Typical Options.

REFERENCES

ANSI/ASME B31.3, 1999, "Process Piping," American Society of Mechanical Engineers, New York, New York.

ANSI/NFPA T3.10.8.8, 1994, "Hydraulic Fluid Power-Filters-Multi-Pass Method for Evaluating Filtration Performance," National Fluid Power Association, Milwaukee, Wisconsin.

API Standard 610, 1995, "Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry Services," Eighth Edition, American Petroleum Institute, Washington, D.C.

API Standard 614, 1999, "Lubrication Shaft-Sealing and Control-Oil Systems for Special-Purpose Applications," Fourth Edition, American Petroleum Institute, Washington, D.C.

NAS 1638, 1992, "Cleanliness Requirements of Parts Used in Hydraulic System," National Aerospace Standards, Aerospace Industries Association of America, Washington, D.C.

ISO 4572, 1981, "Hydraulic Fluid Power Filters Multi-Pass Method," International Organization for Standardization, Geneva, Switzerland.

ISO 4406, 1999, "Hydraulic Fluid Power-Fluids-Method for Coding the Level of Contamination by Solid Particles," International Organization for Standardization, Geneva, Switzerland.