LUBRICATION SYSTEMS FOR TURBOMACHINERY

by

Fredrick B. Wilcox

Staff Engineer-Lubrication

Shell Oil Company

Houston, Texas

Fredrick B. Wilcox is a staff engineer-lubrication specialist with Shell Oil Company, Houston, Texas. He currently provides technical service in applications of lubricants and in lubrication problems to the operating divisions of Shell Oil Company, U.S.A., and is concerned with design and engineering standards for the lubrication systems of rotating machinery. He joined Shell in 1948 and was engaged in various supervisory positions in refinery laboratory and plant operations. For the last ten years, he has been involved in technical service and research and development of industrial and automotive lubricants. He holds a B.S. degree in Chemistry from Mississippi College and took graduate work in Organic Chemistry at the University of Pittsburg. He was a member of ASTM D-2, Section I, Tech Div C, Joint Committee on Turbine Lubrication Systems, 1968 - 1970, and is currently chairman of the Petroleum and Chemical Industries' Council of ASLE.

ABSTRACT

A lubrication system for turbomachinery of significant size generally consists of a reservoir, pump, filter, cooler, piping and controls. Experience through the years has indicated design criteria required to minimize equipment failures and operational problems. Reservoirs must be designed to allow for proper separation of water and vapor from the circulated oil. Oil flow rates and cooling equipment should be designed to maintain proper oil and bearing temperatures and also optimize the water separation efficiency. Filters should be durable for long life and adequately sized to maintain a low level of contamination.

Proper operating techniques and controls are required to minimize oil contamination and the resultant equipment damage. Special purification considerations may be required to combat oil deterioration due to contamination from sour gases such as H_2S.

INTRODUCTION

The design and operation of a lubrication system is as important as the design and operation of the machine of which it is a part. The larger and more complex the machine, the more significant this factor becomes. The basis for minimizing equipment failure is lubricant system cleanliness. A variety of methods and designs have been developed which obtain a degree of satisfactory results, but are inconsistent and dependent upon opinion [1].

A circulating lube oil system, as shown in Figure 1, consists of a reservoir, pump, cooler, filter, controls, piping, etc. Lubricating oil and the system in which it is used can become contaminated with moisture, solids and gases absorbed from the atmosphere, condensed steam from turbine seal leaks and gases from the compressor if that should be the driven unit. The oil can become contaminated with oxidation and thermal degradation products due to exposure to excessive temperatures for long periods of time. Some materials not only contaminate the oil but also act as catalysts to promote degradation. Corrosion of system materials can form metal oxides which contaminate the oil and cause abrasion.

It is the intent of this paper to emphasize certain design features and operating techniques which have been found beneficial in maintaining the cleanliness in the oil and the system.

DESIGN

Reservoir. The reservoir provides a quiescent place in the circulating system where water and vapors that have gotten into the oil in the bearing housings or other contact areas can separate out. Separation can be effective only if the reservoir is designed and sized properly. Oil should enter near the top and exit near the bottom of opposite ends of the reservoir as shown in Figure 2.

The normal operating volume of the reservoir should provide a total residence time of not less than eight minutes [2]. The required residence time in industrial applications may vary from as low as 3 minutes for low viscosity oils to as high as 40 or 60 minutes for high viscosity oils [3]. Higher viscosity oils have higher gravities. Water separation becomes more difficult as the gravity of the oil approaches that of water. Increasing the temperature in the reservoir will increase the gravity differential between the oil and water, making separation more effective.

Baffling arrangements and dimensions of reservoirs have varied according to individual requirements and space limitations. An ideal design is one in which the linear velocity of the oil is one foot per minute maximum. Excellent separation of water can be accomplished at this velocity.

Reservoirs should be provided with a manway to permit internal cleaning, a vent, an appropriate gauging device and the bottom should be sloped away from the outlet end at a rate of ½ inch per foot. The reservoir should be located off the ground to permit drainage of water.

The return oil should enter the reservoir at or just above the level of oil to minimize splashing, foaming and electrostatic charge buildup.

The reservoir should be made of stainless steel or coated with a corrosion and oil resistant paint.

Cooler. Bearing temperature and oil life as well as other factors are related to the oil temperature. Maximum bearing temperatures allowed will vary depending on how the temperature is measured. When measuring the oil exiting the bearing housing, maximum is about 180°F. Higher temperatures require corrective action. Once the design engineer has all the necessary data, he should have no difficulty in determining the type and size of heat exchanger required to maintain the temperatures of the bearings and the oil at satisfactory levels. The

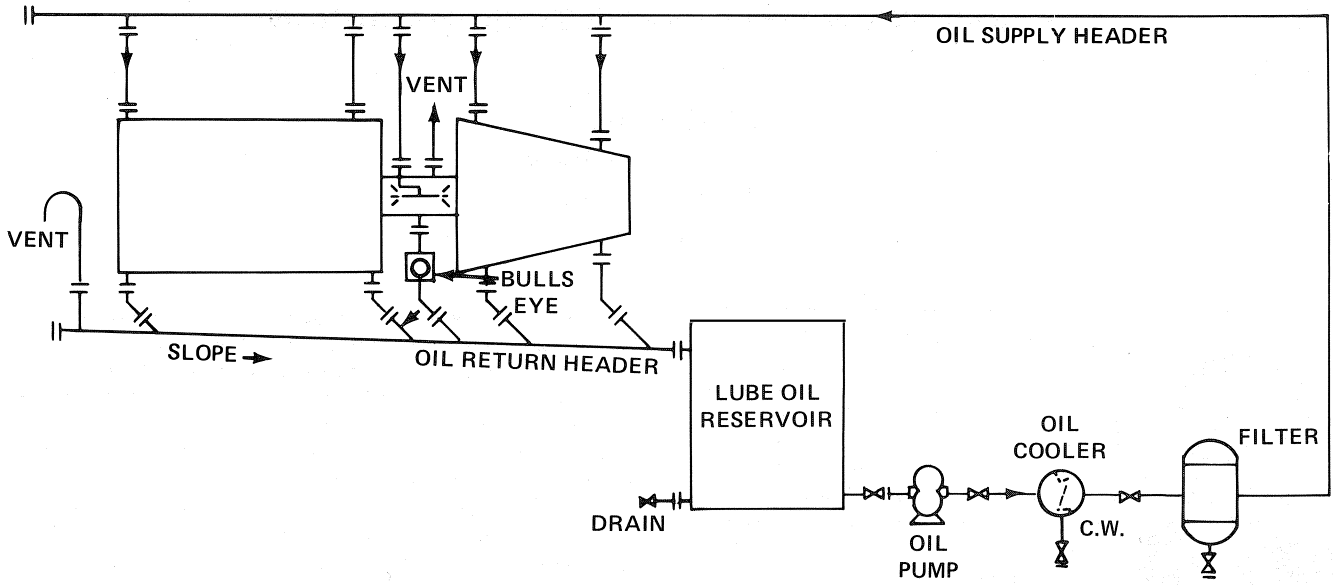

Figure 1. Circulating Lube Oil System.

need for a spare cooler is considered by some to be an option of the user.

Every effort should be made to maintain the temperature of the oil at all points in the circulating system below 150°F. For every 18°F above 180°F the deterioration rate of the oil doubles. Optimum reservoir temperature for circulating systems using ASTM/ISO 32 grade oils is 120-130°F. Water separation is less effective below 120°F and higher temperatures than 130°F may result in higher than desirable bearing temperatures.

Filters. It is rather unfortunate that there are essentially no universal standards for evaluating the effectiveness of cartridge filters designed for liquid service [4, 5]. Nevertheless the use of reputable brands of nominal 5 to 10 micron resin impregnated pleated paper filters in central lubricating oil systems can provide reliable performance in keeping the oil clean [1]. This type of filter provides a large surface area in a small volume, has a high solids holding capacity, small pressure drop change with increase in oil viscosity, and appropriate elements do not plug from water in the lube oil.

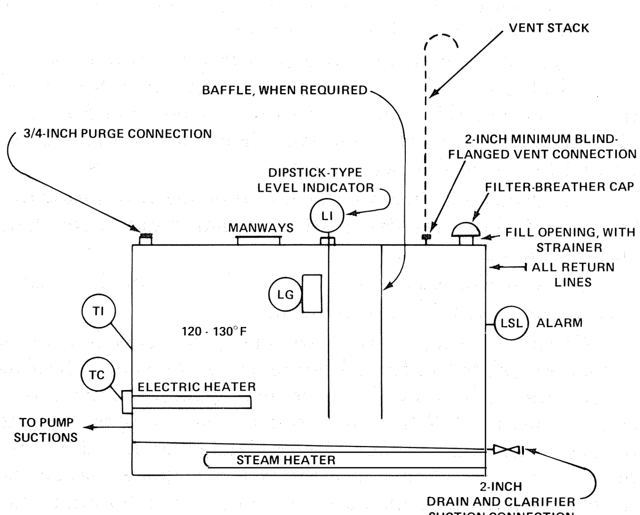

Figure 2. Lube Oil Reservoir (API STD 614).

The lubricating oil in many systems can be satisfactorily cleaned with 10 micron elements. However, nominal 5 micron is considered to be required in systems on machinery with oil lubricated couplings. A coupling performs like a centrifuge and any foreign material heavier than the oil such as solids and water, is separated out of the oil in the coupling. The material fills the outer area where the gear teeth are located and prevents their lubrication, resulting in coupling failure. To obtain satisfactory operation for periods exceeding one year, it may be necessary to use, in addition to the 5 micron system filter, a 0.5 micron separate filter on the stream to the coupling or provide nitrogen blanketing of the reservoir.

Full flow dual oil filters, as shown in Figure 3, should be provided and located downstream of the cooler [1]. Continuous flow transfer valves and a differential pressure indicator with alarm should be provided. By-pass and relief valves should not be used since they will permit unfiltered oil to reach the bearings, governors, etc.

Piping. All piping used in the system should be made from steel. The use of copper and zinc should be held to a minimum, since both act as catalysts to promote oxidation and degradation of the oil. Copper and copper alloy tubes are generally used in heat exchangers to minimize water fouling problems and for more efficient heat transfer [6]. The temperatures, normally below 150°F, encountered in turbomachinery equipment do not usually cause copper to have an appreciable catalytic effect on the oil.

Oil drain piping should be sized to operate no more than half full to ensure good drainage despite possible foaming [2]. Horizontal runs should slope continuously toward the reservoir and the angle of the slope should be a minimum of ½ inch per foot. Tie-ins to the main drain header should be at a 45 degree angle in the direction of slope as shown in Figure 4. The main header should be provided with a suitable vent.

Drain piping is exposed to vapors including air and moisture. This piping should be made of stainless steel or coated internally with corrosion and oil resistant paint.

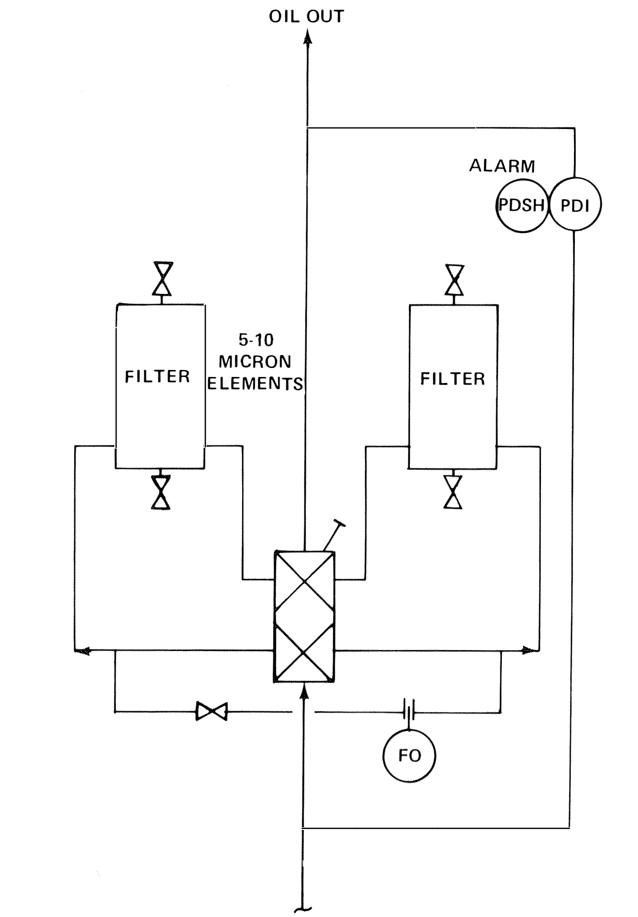

Figure 3. Dual Filters with Continuous Flow Transfer Valves (API STD 614).

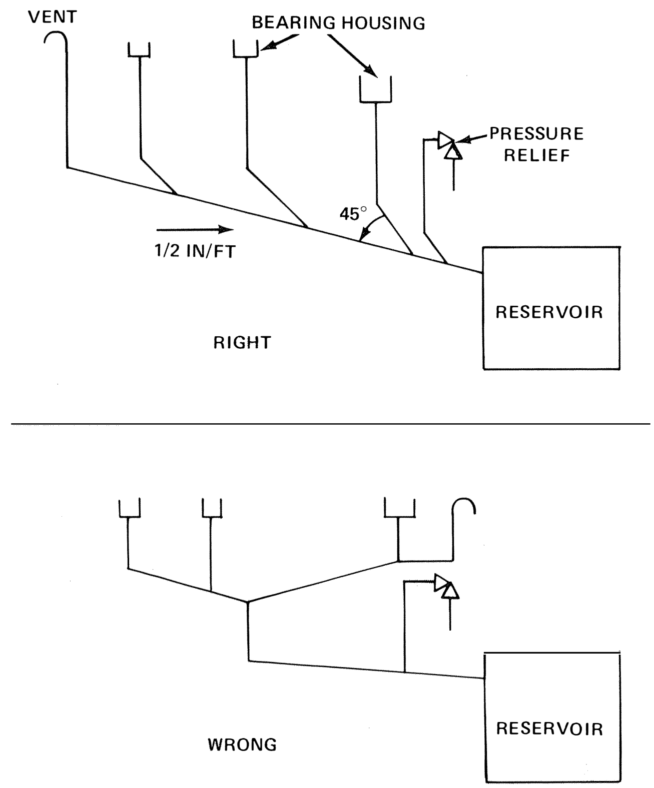

Figure 4. Oil Return Line Routing.

COMMISSIONING NEW EQUIPMENT

Establishing a clean lubrication system at commissioning is extremely important. Improper cleaning of the new system prior to operating will result in continuing problems for years. Many good procedures for cleaning central lube oil systems have been published [7, 8, 9, 10].

There are certain factors which should be emphasized. Rust preservatives used by manufacturers, and which are incompatible with lube oil, must be removed. Many rust preservatives contain petrolatum (wax) and/or calcium/sodium detergent type wetting agents. As much as 30-50 ppm of a calcium detergent contaminant will promote emulsions with water. Detergent contamination must be reduced to below 10 ppm calcium (or sodium) to prevent emulsion formations and obtain good water separation characteristics with the oil.

Sandblasting and pickling procedures should be avoided if at all possible since these add contaminants to the system which are as difficult to remove as rust, preservatives, dirt, etc.

Agitation is required during flushing to break loose materials adhering to pipe walls, etc. High flow velocities and high temperatures (160-170°F) are required. Mechanical vibration of pipes, etc., and injection of nitrogen downstream of the pump can be beneficial in breaking loose materials that tend to cling to internal sufaces.

Laboratory tests can be performed on the oil after the flushing and cleaning procedures to determine if the system is in satisfactory condition. Two methods have been suggested [1], ASTM F-312 Microscopic Sizing and Counting Particles from Aerospace Fluids on Membrane Filters and ASTM D-2276 Patriculate Contaminant in Aviation Turbine Fuels. The particle size method ASTM F-312 is time consuming and not readily adaptable to routine use. The latter, ASTM D-2276 or alternatively ASTM F-313 for hydraulic fluids is preferred. If the contamination level of the oil is below 100 ppm by ASTM D-2276 or F-313 using a 5 micron Millipore filter, the system can usually be considered to be in satisfactory condition.

OPERATION AND MAINTENANCE

The oil in a turbomachinery lubrication system can be contaminated from many sources. Steam leaks across the labyrinths result in water in the oil. Breathing of the reservoir will allow moisture, dirt and various other contaminants such as acid gases, chemicals, etc., to contaminate the oil. Products handled by the driven element can contaminate the oil by leakage across the seal system. The rate will vary depending on design conditions, types of seals and age of the equipment. Precautions should be taken during operation to maintain the oil in good condition. Periodic inspections can be of great assistance in preventing oil deterioration and subsequent equipment failure.

The type of oil used should be a high quality rust and oxidation (R&O) inhibited turbine quality mineral oil with good water demulsibility. Oils of this type used in a properly designed and properly operated system will stay clean and clear. Oils with detergent and/or antiwear additives should not be used. Visual inspection of a sample of the oil at a specific interval, such as once per week, is the only routine test required on the oil. Any change in the oil due to water or dirt contamination or darkening in color will be readily perceptible. Significant changes observed visually may be determined quantitatively by lab tests. Viscosity, total acid number, insolubles and water are usually all that are necessary to determine the condition of the oil. Any rapid, significant changes in the oil require remedial action.

The bottom of the reservoir should be checked daily for water and drained when necessary. Log sheets should be maintained to record pressures and temperatures about the system.

If the lube oil in a particular system is being unduly contaminated with water or gases (particularly H_2S or acid gases) because of excessive leakage across seals, additional facilities should be engaged to maintain the oil in good condition until the equipment can be shut down for repairs. A vacuum dehydration/degasification unit can be very effective for removing both water and contaminating gases [11, 12, 13]. This type unit can also be used for purification of compressor waste seal oil for recycling to the lube oil system.

A centrifuge can be used to remove water and solids from the oil and nitrogen sparging [14] in the reservoir can be used to reduce gas contamination.

CONCLUSIONS

There are various types of materials which can contaminate a turbomachinery lube oil system resulting in equipment failure. Reservoirs should be designed to provide adequate residence time and proper flow to maximize separation of water and gases. Return oil lines should be sized and routed properly to eliminate flow restrictions. Filters should be selected and used to effectively remove solids from the oil. The system must be made clean during commissioning and must be maintained clean during operation. Procedures should be selected to obtain the best performance practical.

REFERENCES

1. Smith, A. N. "Clean Oil Systems for Heavy Duty Gas Turbines," ASTM Symposium Boston, Massachusetts, June 1967.
2. API Standard 614, "Lubrication, Shaft-Sealing and Control Oil Systems for Special Purpose Applications," September 1973.
3. Booser, E. R. and Smeaton, D. A., "Circulating-Oil-System Design," *Standard Handbook of Lubrication Engineering*, ASLE, 1968.
4. Soules, W. J. "Chemical Engineering Progress," pg. 43-45, December 1974.
5. Nickolaus, N. "Filtration Engineering," pg. 8-9 May/June 1975.
6. ASME Standard No. LOS-5D1 "Recommended Practices for the Design of Oil Systems for Lubrication and Control of Hydroelectric Equipment," 1972.
7. Morrow, A. S. "Cleaning Lubrication Systems" ASLE New York Section Meeting, May 6, 1952.
8. Peterson, F. S. "Large Industrial Circulating Oil Systems — Cleaning and Maintenance," *Lubrication Engineering* Vol. 29, 12, pg. 534-538, December 1973.
9. ASME Standard No. LOS-4C1 "Recommended Practices for the Flushing and Cleaning of Gas Turbine Generator Lubricating Oil Systems" 1971. (Also ASME Standards 113, 114, LOS-2C1, LOS-5C1)
10. Kure-Jensen, J. "Cleanliness of Large Steam Turbine Oil Systems," *Lubrication Engineering*, August 1972.
11. "A Low-Cost Answer to Oil Recycling" *Factory Management* pg. 32-33, January 1977.
12. Baronowski, L. B. "Compressor Seal Oil Recycling," Baron & Associates, Inc., Cookeville, Tennessee.
13. Steele, F. M. "Filtration and Reclamation of Turbine Oils," *Lubrication Engineering*, Vol. 34, pp. 252-257, May 1978.
14. Bloch, Heinz P. "Reclaim Compressor Seal Oil," pg. 115-118, *Hydrocarbon Processing*, October 1974.