

Nuclear Maintenance Applications Center: Reactor Coolant Pump/Reactor Recirculation Pump Motor Lubrication Oil Systems Maintenance Guide

1013456

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**Nuclear Maintenance Applications Center:
Reactor Coolant Pump/Reactor Recirculation
Pump Motor Lubrication Oil Systems
Maintenance Guide**

1013456

Technical Update, December 2006

EPRI Project Manager

D. Dobbins

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REPORT SUMMARY

Background

RCP and RRP Motor Lubrication system issues have ranked high on NMAC maintenance Issues Surveys in recent years. Problems reported have included oil leakage at power, the need for additional reservoirs to accommodate leakage, oil degradation (foaming, particulate) as well as sludge problems due to the design of the motor and some as a result of new oil formulations and other changes made by the oil suppliers.

Reactor Coolant Pumps (RCP) used in Pressurized Water Reactors and Reactor Recirculation Pumps (RRP) used in Boiling Water Reactors are used to move water through the reactor for cooling and control purposes and are required to run continuously for the duration of a fuel cycle. These components are generally inaccessible during power operation, therefore, reliability is critical for plant operation.

Objectives

To investigate industry data and member experiences with the lubrication systems used on Reactor Coolant and Reactor Recirculation Pump Motors

To investigate the nature of the problems and provide industry experiences in dealing with these issues

To identify leak paths and provide guidance on preventing common oil leakage points.

Approach

The approach for this report was to first to collect and review industry data to determine the scope and type of problems that were being experienced in the industry. Then a detailed survey was developed to solicit and gather as much information as possible from NMAC members with regard to the exact nature of the problems being experience and to compile the steps being taken to address these issues. The survey results are listed in Appendix B.

During the development of this report, the Technical Advisory Group recommended that the project be separated into two parts. The first part, which is the subject of this report, deals with the motor lubrication systems and the nature of the leaks within these systems. The second part, anticipated to be prepared and completed in 2007, will deal with the problems with the lubricants and possible causes and solutions that are available in this area.

Results

This report summarizes many of the issues and solutions that are being implemented in the industry to limit motor oil leakage. The experience from motor specialists has been collected to limit maintenance and material errors related to large motor maintenance.

EPRI Perspective

NMAC members and the industry will benefit from the information provided in this report by providing details on the problems that other utilities are facing with the Reactor Coolant and Reactor Recirculation Pump motors and providing insight from plants that have been dealing with previous oil leakage issues. Material changes and workmanship are just some of the lessons learned during this project. The number of real experts to provide this insight into how to minimize lubricating oil leakage on these large electric motors is small and it is very important to capture this knowledge into a concise and useful NMAC Guide for the Nuclear Power Industry.

Keywords

Reactor Coolant Pump Motor

Reactor Recirculation Pump Motor

Large Electric Motor

Motor Lubrication

Lubrication

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Motor Lube Oil System

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CONTENTS

1 Introduction	1-1
1.1 Purpose	1-1
1.2 Organization	1-1
2 Glossary of Terms	2-1
3 Background Information	3-1
Introduction	3-1
4 RCP/RRP Motor Lubrication Systems	4-1
5 Lubrication Oil System Leakage Remedies	5-1
6 References	6-1
A APPENDIX A	A-1
B Appendix B Survey Summary	B-1
C Translated Table of Contents	C-1

LIST OF FIGURES

Figure 4-1 Typical Westinghouse RCP Motor.....	4-2
Figure 4-2 Thrust Bearing Assembly.....	4-3
Figure 4-3 Oil Lift System.....	4-5
Figure 4-4 Motor Overview.....	4-7
Figure 4-5 Upper Motor Bearing	4-10
Figure 4-6 Upper Bearing Area.....	4-11
Figure 4-7 Upper Bearing External Oil.....	4-12
Figure 4-8 Lower Bearing Area Potential Leak Paths.....	4-13
Figure 4-9 Lower Motor Bearing Area.....	4-14
Figure 4-10 Lower Bearing Cooling Coil	4-15
Figure 4-11 Photograph of the Oil Cooler Penetration Flange Area	4-15
Figure 4-12 Lower Oil Pan	4-16
Figure 4-13 Lower Oil Pan Halves	4-17
Figure 4-14 Lower Oil Pan in Place	4-18
Figure 4-15 Lower Oil Pan in Flange “Buttered”	4-18
Figure 4-16 Lower Bearing Reservoir Drain Isolation Valve	4-19
Figure 4-17 Lower Bearing Labyrinth Seal.....	4-20
Figure 4-18 Common Leak Paths in the Oil Lift System	4-21
Figure 4-19 Ratchet Plate Shock Absorber.....	4-22
Figure 4-20 Lower Bearing Oil Damage from Low Oil Level.....	4-23
Figure 4-21 GE Motor Upper Bearing	4-25
Figure 4-22 Upper Bearing Potential Leak Paths.....	4-26
Figure 4-23 Upper Bearing Potential Leak Paths.....	4-27
Figure 4-24 Upper Bearing Potential Leak Paths.....	4-28
Figure 4-25 Upper Bearing Cooling Water Lines Oil Reservoir Penetrations	4-28
Figure 4-26 Upper Bearing Cooling Water Lines	4-29
Figure 4-27 Lower Motor Bearing Area.....	4-29
Figure 4-28 Lower Bearing Oil Level Switch.....	4-30
Figure 4-29 Lower Bearing Potential Leak Path	4-31
Figure 4-30 Lower Bearing Oil Pan Being Installed	4-32
Figure 4-31 Lower Bearing Oil Pan Being Installed	4-32

1

INTRODUCTION

Reactor Coolant Pumps (RCP) used in Pressurized Water Reactors and Reactor Recirculation Pumps (RRP) used in Boiling Water Reactors are used to move water through the reactor for cooling and control purposes and to run continuously for the duration of a fuel cycle. These components are generally inaccessible during power operation; therefore reliability is critical for the plant operation. The large motors used on these vertical pumps serve not only as the prime mover but also the support for the pump rotating elements as well. Their reliability depends on the integrity of the bearings and lubrication systems. Responses from NMAC Maintenance Issues Surveys have indicated that lubricating oil systems, system maintenance or lack of system maintenance, and the lubrication oils currently in use by members contribute too many of the operational and maintenance concerns.

1.1 PURPOSE

This report, which will be completed in two stages, will provide information on the RCP/RRP motor lubrication systems and lubricating oils currently in use today. It is intended to assist nuclear power plant maintenance personnel in maintaining and servicing the RCP/RRP motors and in making decisions regarding routine and preventive maintenance practices that should be followed. Stage One, and the contents of this report, will address the motor lubrication system and components; specifically the issues that are facing the power industry and solutions that have been implemented to combat these problems. Part Two, which will be issued in a separate report, will provide information on lubricating oils used in these motors including a discussion of common maintenance practices current in used by power plant personnel as well as information on oils that are available on the market today and some of the issues that are being experienced by end users.

Data for this guide were obtained from experience of motor specialist in industry surveys on failure reports, vendor input, and reviews of plant literature and industry documentation.

1.2 ORGANIZATION

The organization of this guide is as follows:

Section 1 is an introduction and discussion of the guide's purpose and organization.

Section 2 is a glossary of items, definitions, and acronyms used in this guide.

Section 3 provides background information (including a discussion of adverse problems from industry sources and survey results)

Section 4 provides technical description, basic discussion of lubricating systems used on RCP/RRPs including a discussion of the various leak paths that exist in two of the more common motor designs and issues facing power plant personnel.

Section 5 provides a discussion of lubrication oil system issues facing power plant personnel and solutions to these problems.

Appendix A contains a summary from INPO TR5-50 of the industry events that related to RCP/RRP lube oil/system problems.

Appendix B contains a summary of the responses from the survey of NMAC membership in support of this project.

2

GLOSSARY OF TERMS

INPO	Institute of Nuclear Power Operations
LEMUG	Large Electric Motor Users Group
OEM	Original Equipment Manufacturer
NSSS	Nuclear Steam Supply System
PdM	Predictive Maintenance
PM	Preventative Maintenance
RCP	Reactor Coolant Pump (used in Pressurized Water Reactor plants)
RRP	Reactor Recirculation Pump (used in Boiling Water Reactor plants)

3

BACKGROUND INFORMATION

INTRODUCTION

RCP and RRP Motor Lubrication system issues have ranked high on recent NMAC Maintenance Issues Surveys in recent years. Problems reported have included oil leakage, the need for additional reservoirs to accommodate leakage, oil degradation (foaming, particulate) as well as sludge problems due to the design of the motor and some as a result of new oil formulations and other changes made by the oil suppliers.

A review of INPO TR5-50, “Review of Events Impacting Power Production Involving Large Electric Motors” (Reference 1) revealed that of the 71 events identified for the period of ~~the year~~ 2000 through mid 2005 involving large motors, 13 events (18%) occurred in RCP/RRP motors. Of these 13 events, 6 (46%) were related to the lubrication system or lubricating oil. See Appendix A for a summary of these events.

In November 2006, INPO issued TR6-55 “Review of Large-Pump-Related Events Resulting in Scrams, Shutdowns, and Outage extensions (Reference 5) during the period January 2001 through December 2005. Of the 67 events cited in TR6-55, 13 of those related to lube oil issues of the driver. This report was issued late in the cycle for developing this guide and was not reviewed in sufficient depth to be included. TR6-55 specifically states that the scope did not include the drivers for the pumps. Despite that, lube oil system on large electric motors continues to present challenges for plant operations and maintenance.

To gather information for this report a survey questionnaire was developed and provided to the industry to provide specific information on the types of problems and issues that are facing plant personnel concerning RCP/RRP motor oil lubrication. The survey and the summary results are provided in Appendix B. This information reveals that many nuclear plants have experienced a number of problems with the lubrication/systems on their RCP/RRP motors.

From a systems standpoint by far the majority of the problems identified by respondents stem from leaks in the lubrication system and problems with oil level indication. In response to these problems, members have made modifications to their oil leakage collection systems, installed larger or additional oil reservoirs to accommodate leakage during the fuel cycle runs, added oil addition systems and installed new/additional oil level monitoring equipment. A number of the respondents indicated that they have the capability of adding oil to the motors while operating. These problems are the subject of this report.

With regard to the lubricating oil, a number of issues were identified in the survey responses. First of all there is a wide range of approaches with respect to oil monitoring and replenishment within the industry. Some plants are changing their lubrication oils every refueling outage and some are using monitoring techniques to extend change out cycles for as long as 10 years.

Techniques used for monitoring the oils (tests) varied greatly as well. A number of problems are being experienced with the oils in use today which include oil contamination, problems with foaming, premature oil degradation, sludge problems as well as problems with new oils and new formulations. Because of the complexities with the lubricating oils (wide varieties in use, differing maintenance practices being implemented, changes in available products, etc.) this topic will be addressed in a subsequent report.

This report will investigate many of the issues with RCP/RRP Motor Lubrication Systems and will provide a narrative of the problems involved along with how they can be dealt with. Because of the differences in operating characteristics of the various motors and lubrication systems in use, there may be some gaps remaining but the reader will be provided information that can be used to approach solving problems that may be experienced at their facility.

4

RCP/RRP MOTOR LUBRICATION SYSTEMS

Section Outline: Basic Description of Components and Lubrication Systems

- 4.1 Lubrication system descriptions for major motor types (Westinghouse, GE)
- 4.2 Description of Potential Leak paths and locations for Westinghouse and GE motors

4.1 Basic Description of RCP and RRP Motor Lubrication Components/Systems

The two most common motors used in nuclear power plants are supplied by Westinghouse and General Electric (GE). The lubrication systems used in these applications have many differences. A brief description will be provided to familiarize the reader with these components.

4.1.1 Westinghouse RCP Motors.

The motor for the reactor coolant pump is a drip-proof squirrel cage induction motor with two bearing assemblies, upper and lower. At the top of the motor are the pivoted-pad radial upper guide bearing, the flywheel, the anti-reverse rotation device, and one up-thrust and one down-thrust Kingsbury-type thrust bearing. A viscosity pump at the outer periphery of the thrust-bearing runner-circulates oil through an external oil-to-water heat exchanger to cool the upper bearing. This viscosity pump also pumps oil to the upper guide bearing which is located above normal oil level. An oil lift system applies an oil film to the thrust bearing shoes and upper guide bearing before startup and is also used for coast down of the motor. The lower radial guide bearing, a pivoted pad type is located below the rotor core. It is cooled by with an oil-to-water heat exchanger which is integral to the oil reservoir. Figure 4-1 shows a typical Westinghouse RCP motor.

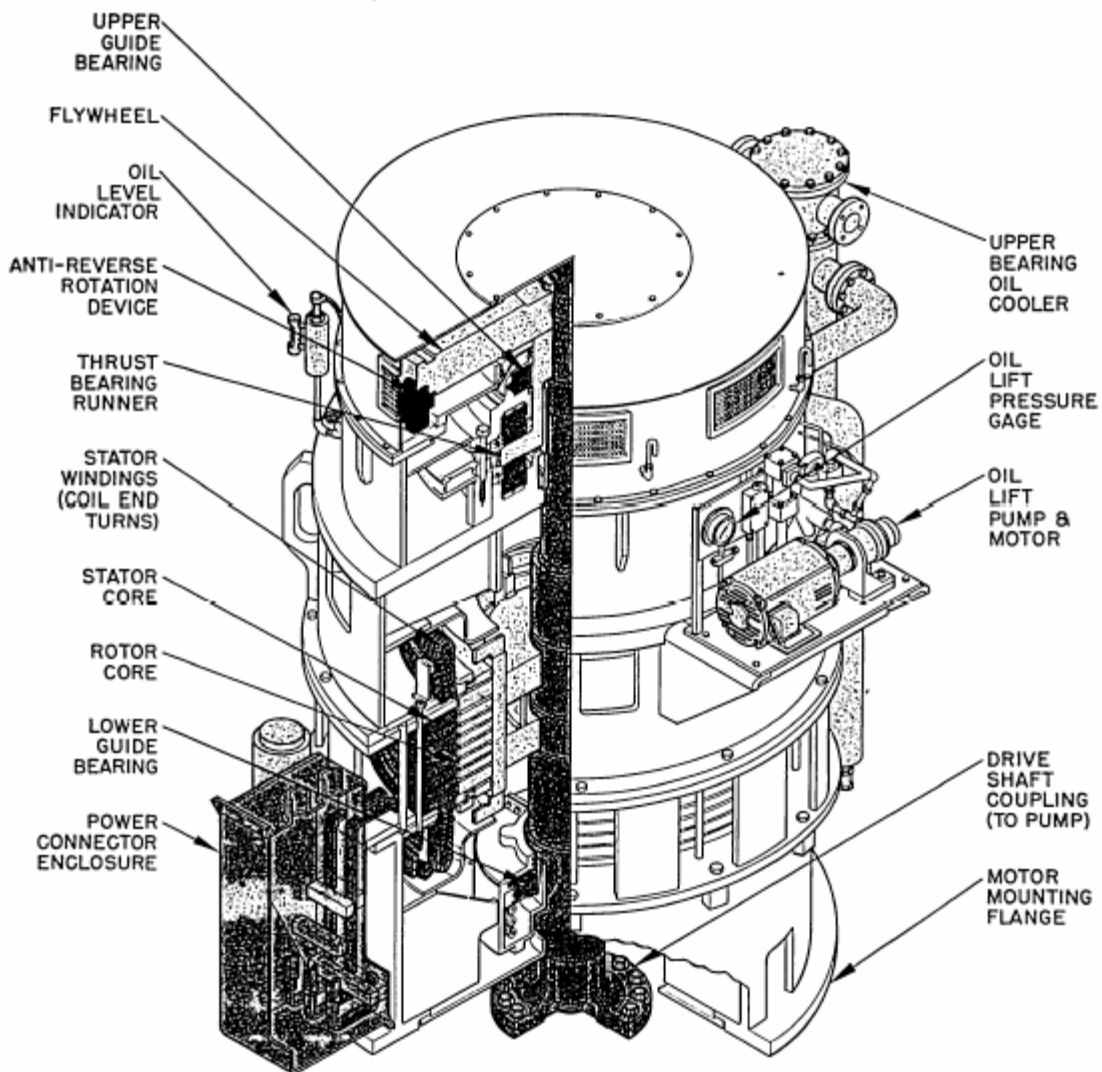


Figure 4-1 Typical Westinghouse RCP Motor

Upper Bearing Assembly

The upper bearing assembly contains two eight-shoe thrust bearings (upper and lower thrust bearings) (see Figure 4-2) and a seven-pad radial guide bearing (upper guide bearing). Kingsbury-type thrust bearing shoes are used above and below a common runner to accommodate thrust in either direction. The babbitted-steel shoes are mounted on equalizing pads which distribute the thrust load equally to all shoes. The shoes tilt and allow the oil to form a thin wedge-shaped film between them and the shaft mounted runner. An oil lift system provides the initial oil film during startup. Cooling is provided by the upper bearing oil cooler. The upper radial guide bearing consists of oil-cooled pivoted pads similar to the lower guide bearing. The guide bearing runner is an integral portion of the thrust bearing runner. Typical oil capacity for the upper bearing assembly including the external oil cooler is around 250 gallons.

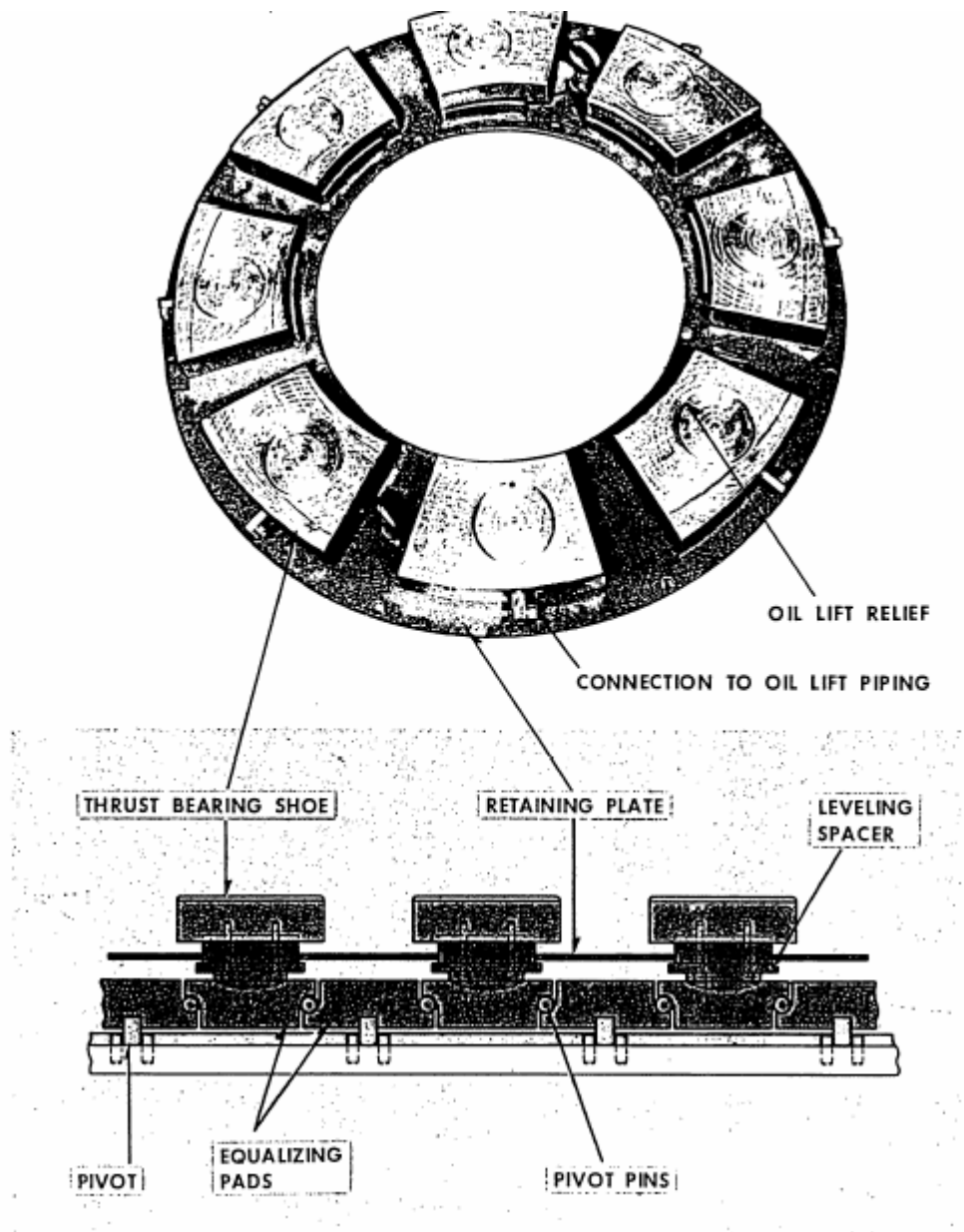


Figure 4-2 Thrust Bearing Assembly

Lower Guide Bearing

The lower radial guide bearing consists of babbitted-steel pads which are free to pivot. They are positioned by jackscrews and are held in place with lock plates. The entire lower guide bearing assembly is located in the lower oil reservoir (oil pot) which also contains an integral oil-to-water heat exchanger for cooling the bearing. This oil pot has a capacity of approximately 20 gallons (this amount may vary for certain models) and is an integral part of the lower bracket.

Oil Lift System

An external oil lift system provides lubrication to the upper bearings during motor startup. High-pressure oil is delivered simultaneously to both sets of thrust bearing shoes. The oil lift system will provide from 0.001 inch to 0.003 inch of oil film between the runner and the thrust bearing shoes, depending on the amount of pump thrust on the bearings. Thus, regardless of thrust condition (either up-thrust or down-thrust), an oil film between the shoes and runner is present. At the same time, high-pressure oil is being sprayed into the guide bearing chamber for lubricating the upper radial guide bearings. Oil lift is required only during the startup of the pump, however, it is also usually energized during shutdown due to reduced oil being pumped to the upper guide bearing as the motor coast down and the flow from the viscosity pump is reduced. Figure 4-3 provides a schematic on the oil lift system.

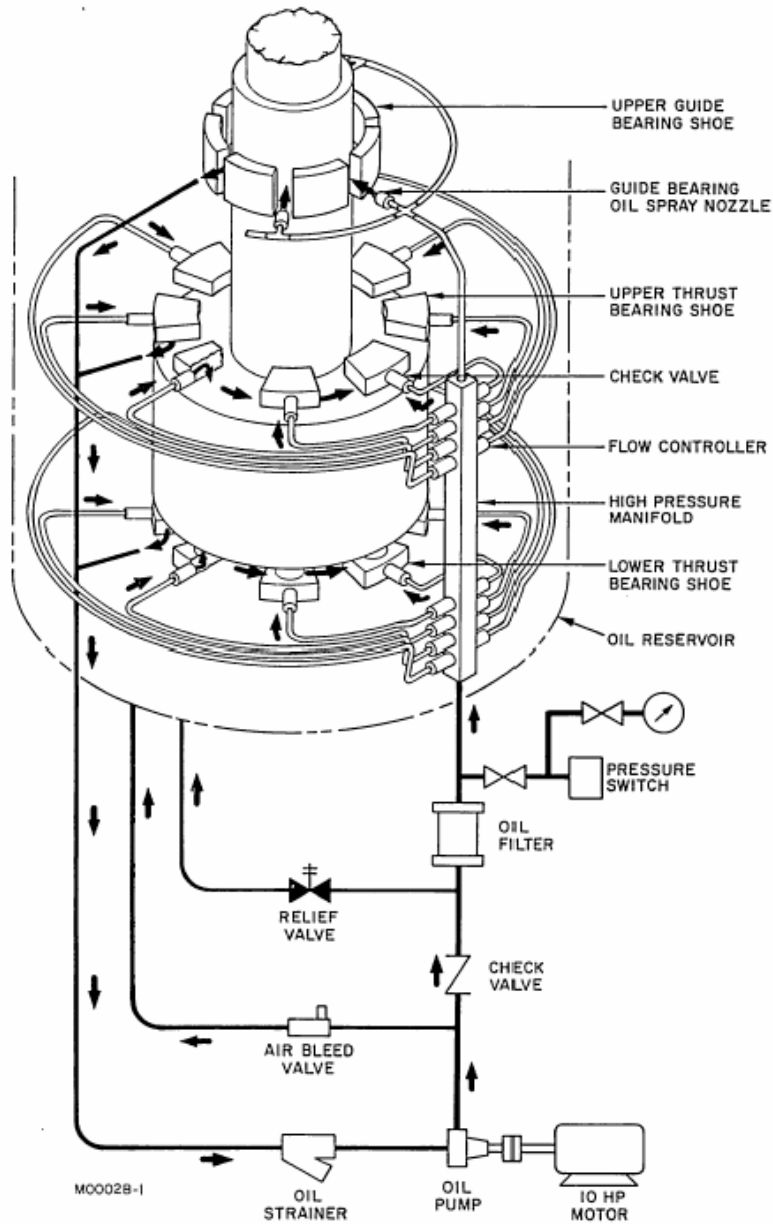


Figure 4-3 Oil Lift System

Oil Reservoirs

Each bearing has an oil reservoir. There are high and low level alarms in each of the reservoirs to alert the operators of an oil level issue.

Bearing Temperature Detectors

One shoe of each bearing (upper thrust, lower thrust, upper radial guide, and lower radial guide) is provided with a temperature detector. Leads are brought out to a conduit box on the outside of the motor.

4.1.2 General Electric RRP Motors

The motor for the RRP used in most GE BWRs (and a few RCP motors) are high horsepower variable speed induction motors (four pole, 1668 rpm at a frequency of 56 Hz). To accommodate axial thrust, the motors are equipped with one up-thrust and one down-thrust self-lubricating Kingsbury type thrust bearings. Self-lubricating guide bearings are also provided above and below the rotors. The motors have upper and lower oil reservoirs to supply oil to these bearings. Indication of high or low oil level is provided by annunciators in the Control Room. To check actual level in the reservoirs requires access to the motor in the drywell which is usually in an inert environment. The cooling of the motor oil is accomplished in two ways; the passing of cool air over the outside surface of the oil reservoirs and through the use of tube-in-tube heat exchangers that are an integral to the oil reservoirs. These coolers are cooled by the RBCCW System.

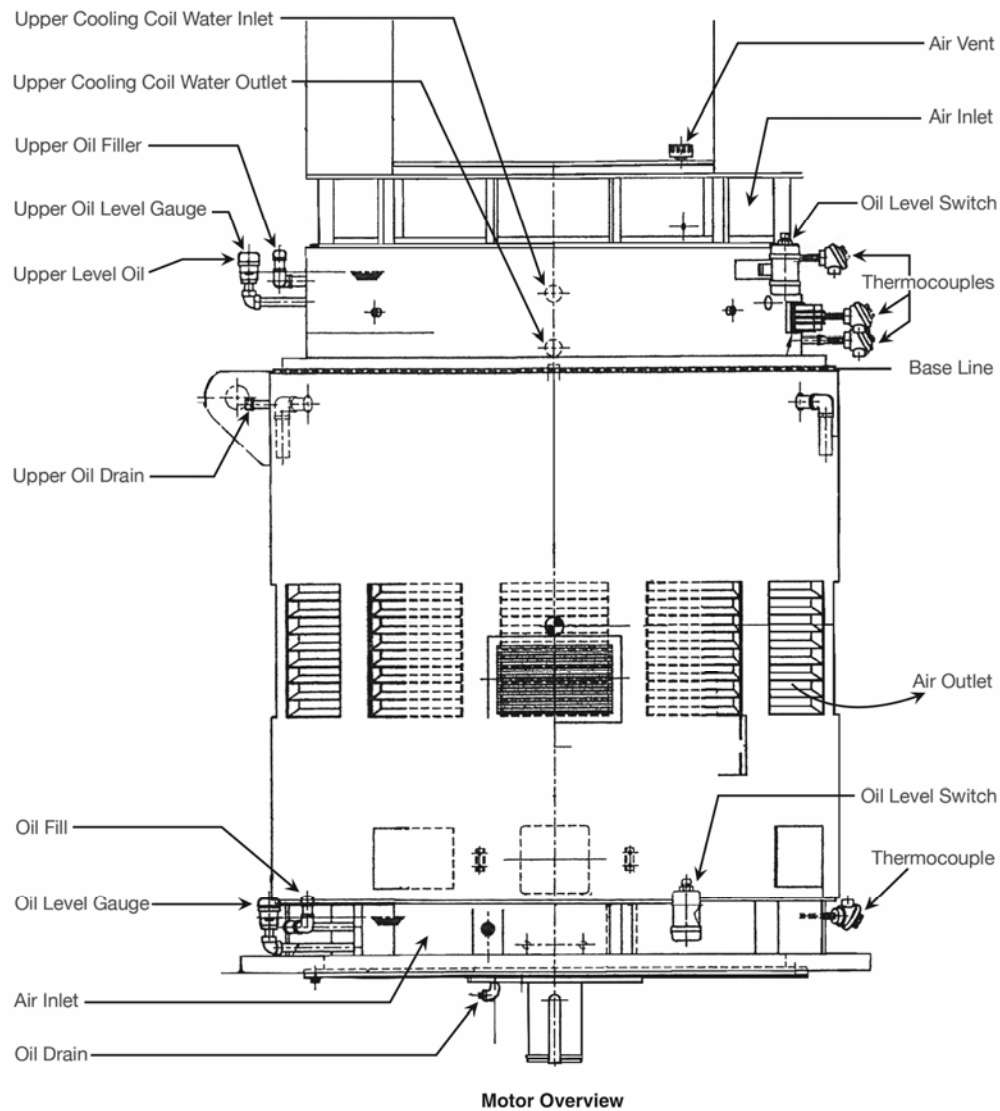


Figure 4-4

There is no oil lift system required with this design. The thrust bearings are immersed in oil and the radial guide bearings are half immersed in oil at standstill oil level. Lubrication circulation is provided by the rotation of the bearing journals and the oil grooves designed into the Babbitt of the radial guide bearings.

4.2 Motor Lubrication System Leak Paths

Motor lubrication systems on RCP/RRP motors must be reliable and generally trouble free due to their general inaccessibility during power operations. Each motor type being addressed in this guide has unique characteristics that result in potential for leakage while

the motor is in service. This section will describe the various places where leaks can occur in the lubrication systems.

The RCP/RRP motors use an oil pumping system to supply the motor with lubrication during operation. The oil systems used in the applications are generally reliable but a number of issues have been identified that cause problems for plant personnel. A majority of the problems that have been identified involve leaks within the system which can occur in the area of the bearing oil pan, standpipe, seals, the supply piping, oil reservoirs, oil coolers and oil level switches. Other problems that have occurred deal with the reliability of the oil level indication can result in incorrect information being provided to the plant operator with regard to oil supply.

In response to problems, plant personnel have implemented a number of changes to combat many of these problems which will be discussed in this section. These changes include changes to the oil system to stop the leaks or to minimize their effects and impact on plant operation. Other changes that have been made provide means for oil to be added while the plant remains at power. Some of these remedies have come from the OEMs but a number have been developed by plant personnel.

Leak paths that have been identified by the TAG as primary areas of concern for RCP/RRP motors are as follows:

- a. Leaks in the areas of:
 - Upper bearing oil reservoir
 - External oil coolers (Westinghouse)
 - Oil lift systems (Westinghouse)
 - Lower bearing oil reservoir
 - Labyrinth seals
 - External oil piping, fittings and connections
 - Oil sight glass
 - Oil level switches
 - Oil reservoir penetrations (cooling water lines, RTD, etc.)

- b. Motor Specific Issues
 - Westinghouse RCP motors
 - Split oil pan oil leaks
 - External oil cooler oil leaks (J-pipe joints)
 - GE Recirculation pump motors
 - Sight glass oil leaks
 - Oil reservoir oil pan/standpipe o-ring degradation oil leaks

4.2.1 Westinghouse RCP Motor Lubrication Leak Paths

Potential leak path locations for Westinghouse motors are as follows:

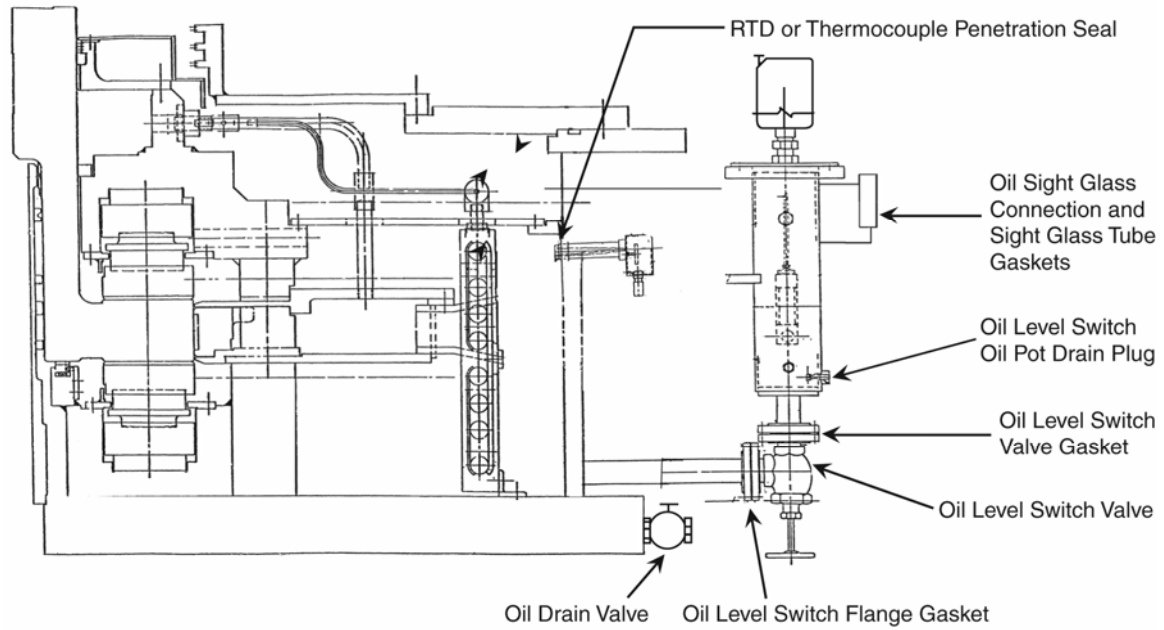
- Upper Motor Bearing Area (including oil level switch)
- Upper Motor Bearing Oil Cooler (including J-pipe)
- Lower Motor Bearing Area (including oil level switch)
- Oil Lift System

In general each of the potential leak path areas shown should be addressed during the recommended 10 year overhaul of the motor (gaskets, seals, o-rings replaced) and disconnected threaded pipe connections re-sealed. If these are not addressed during refurbishment, the potential for leaks to occur during operation is greatly increased. In addition, each of the leak path areas should be inspected each refueling outage and any leaks found should be corrected to provide increase motor reliability.

The inspections to maintain these motors are listed in the Westinghouse RCP Motor Recommended 1-Year, 5-Year, and 10-Year Inspection and Maintenance Technical Bulletin TB-04-5 (Reference 7).

Upper Motor Bearing Area

The outline of the upper bearing area of the Westinghouse RCP motor is shown in Figure 4-5. The most probably potential leak paths that can result in a lubrication oil leak are shown.



Westinghouse Motor Upper Bearing

Figure 4-5 Upper Motor Bearing

Figure 4-6 is a photograph which shows the upper bearing area including the oil sight glass, the oil level switch oil pot and the upper bearing oil drain valve.

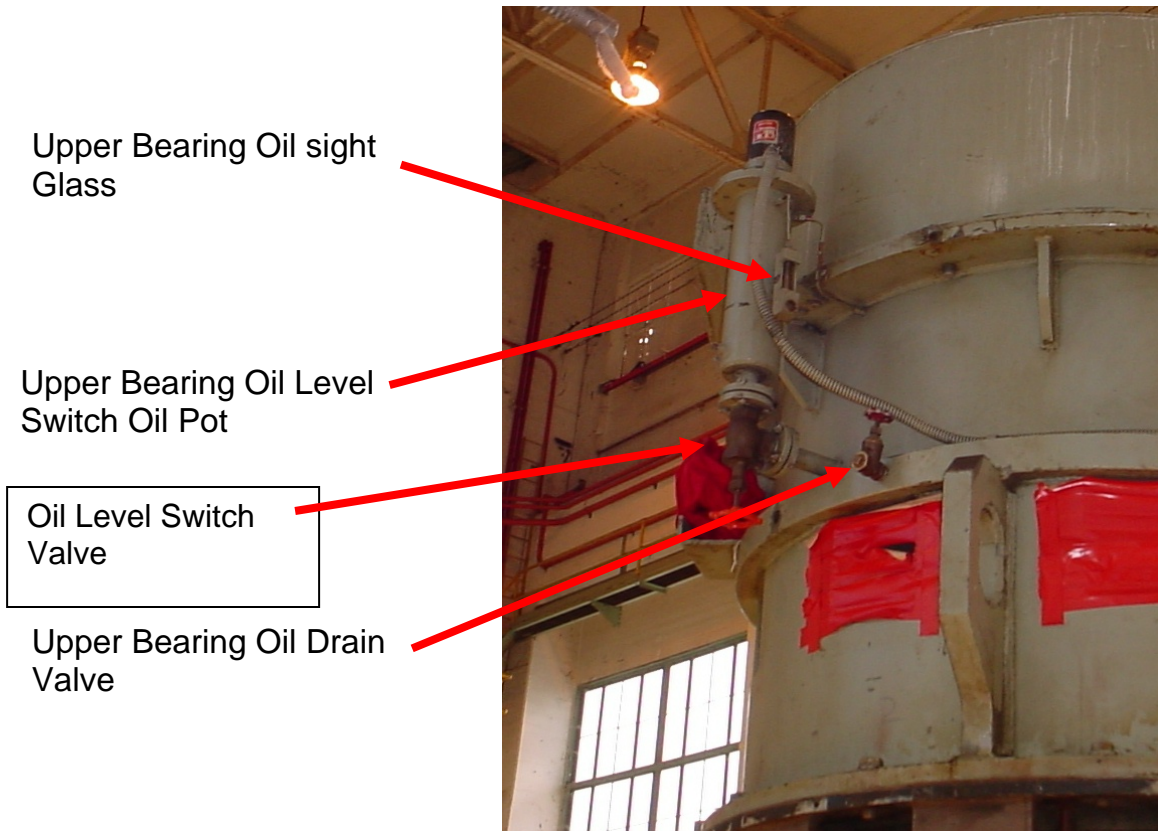
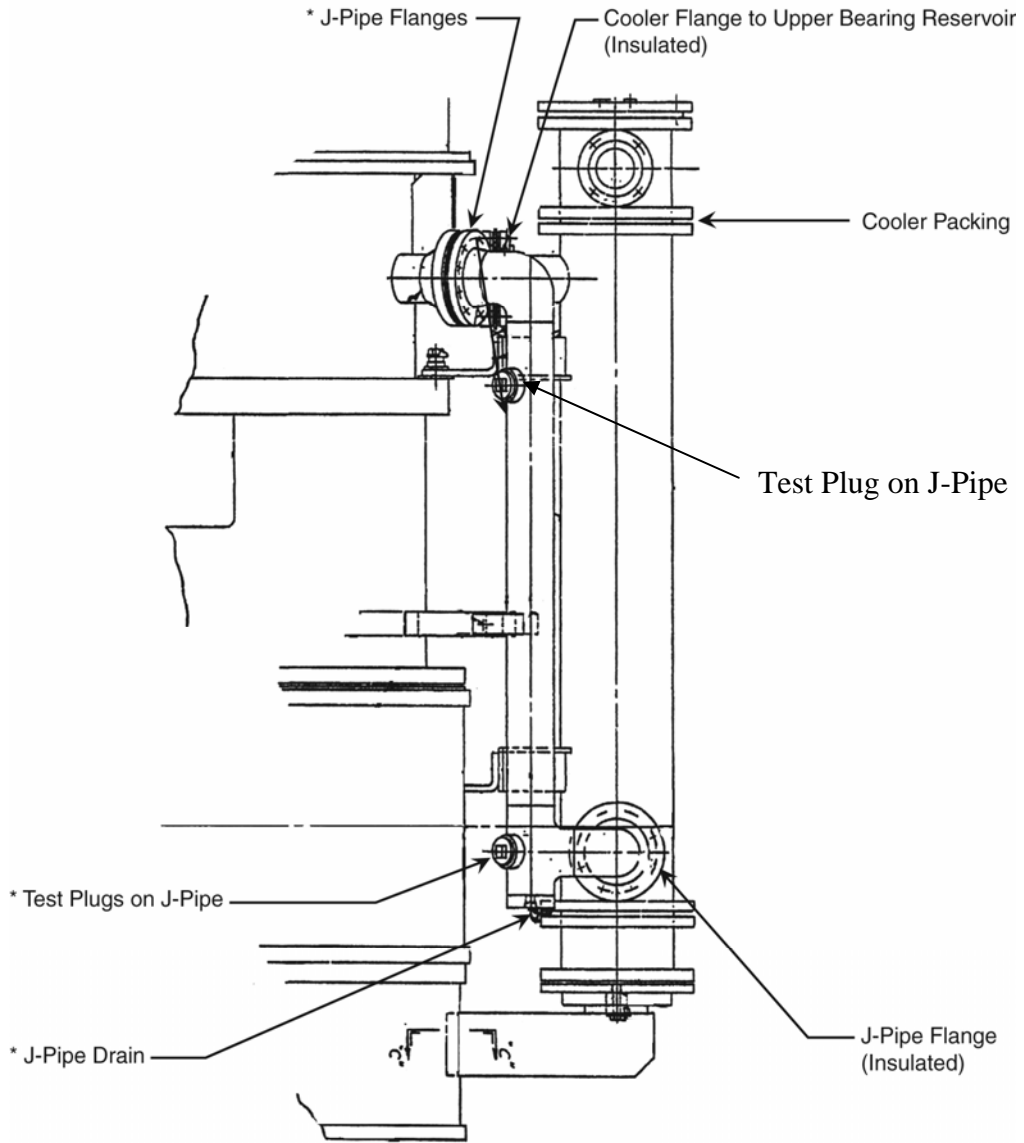


Figure 4-6 Upper Bearing Area

Upper Bearing Oil Cooler

Figure 4-7 is a drawing with shows the potential oil leak paths on the upper bearing oil cooler which is located on the outside of the motor (see figure 4-1). Oil is taken from the upper bearing oil reservoir and piped to the oil cooler and back. This piping can be the source of leakage at the flange joints. Particular attention should be placed on replacing the insulated flange joint gaskets whenever they are removed.



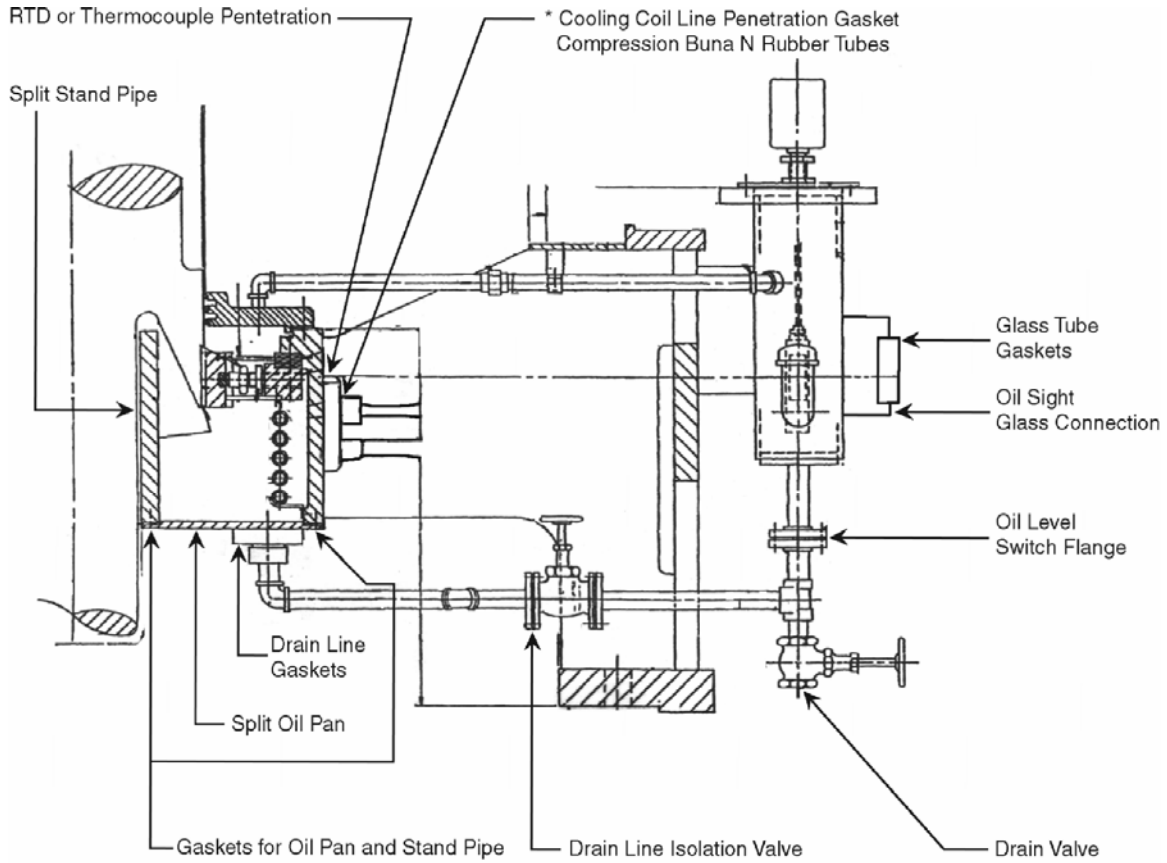
Westinghouse RCP Motor Upper Bearing External Oil Cooler

** Note: On this drawing, there is one test plug shown. The configuration varies from none to two test plugs. Other J-pipe plugs may be present.*

Figure 4-7 Upper Bearing External Oil Cooler

Lower Bearing Area

The lower bearing area is quite complex and has many potential leak paths, including threaded connections, flanges and oil pan/(segmented oil pan)/standpipe gasket areas. Figure 4-8 shows a schematic drawing of the lower bearing areas:



Westinghouse RCP Motor Lower Bearing

** Note: On some models, these inlet and outlet waterlines are soldered in place.*

Figure 4-8 Lower Bearing Area Potential Leak Paths

Figure 4-9 shows a photograph of the lower motor bearing area showing the oil level switch oil pot, the oil sight glass and the oil drain valve, all potential leak paths.

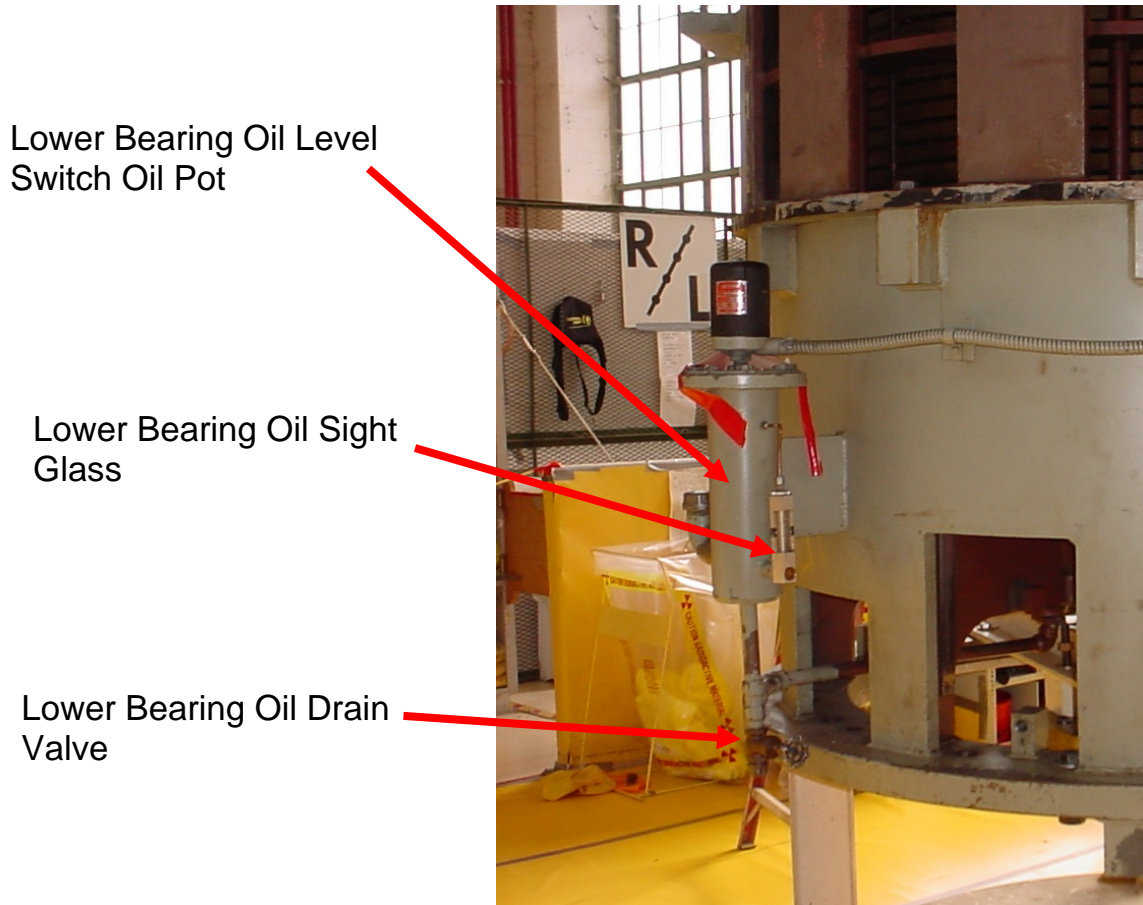
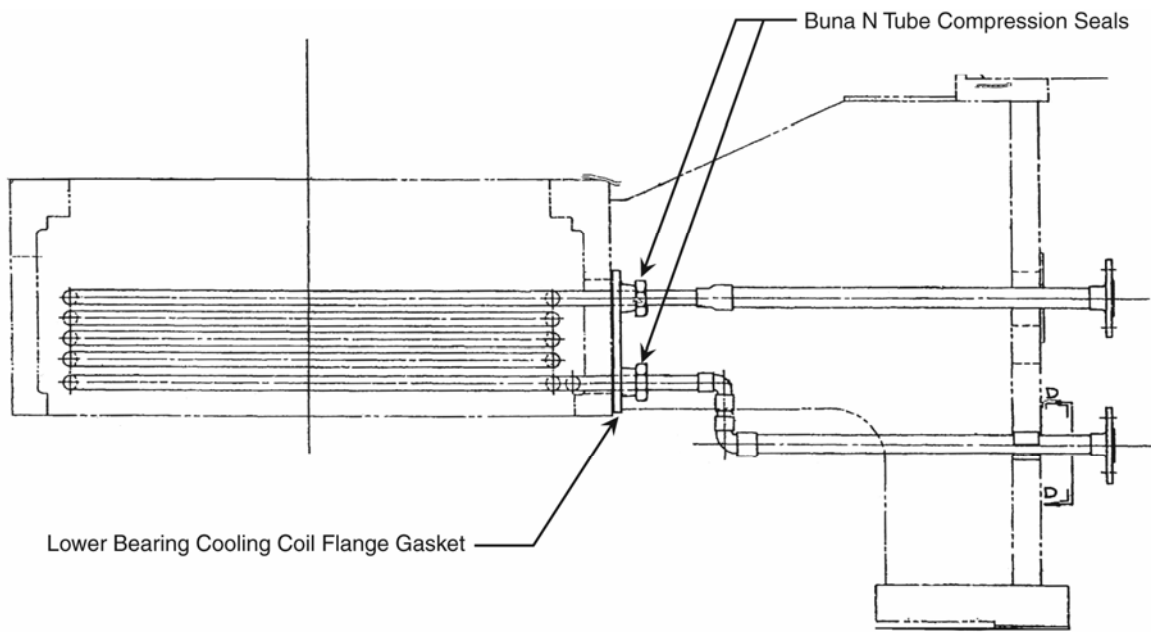


Figure 4-9 Lower Motor Bearing Area
(see also Figure 4-14)

Figure 4-10 and 4-11 shows the lower bearing cooling coil and in particular, how the cooling water lines penetrate the lower oil reservoir. Potential leak paths occur in the area of the flange where it bolts to the oil reservoir. Another common leakage area is where the cooling water line exits the flange and a Buna N compression seal (very similar to small valve packing) is used. Both of these areas should be replaced during the 10 year motor overhaul.



Lower Bearing Cooling Coil

Figure 4-10 Lower Bearing Cooling Coil

Lower Bearing Oil Cooler
Flange Gasket

Lower Bearing Oil Cooler
Compression Tube Fittings

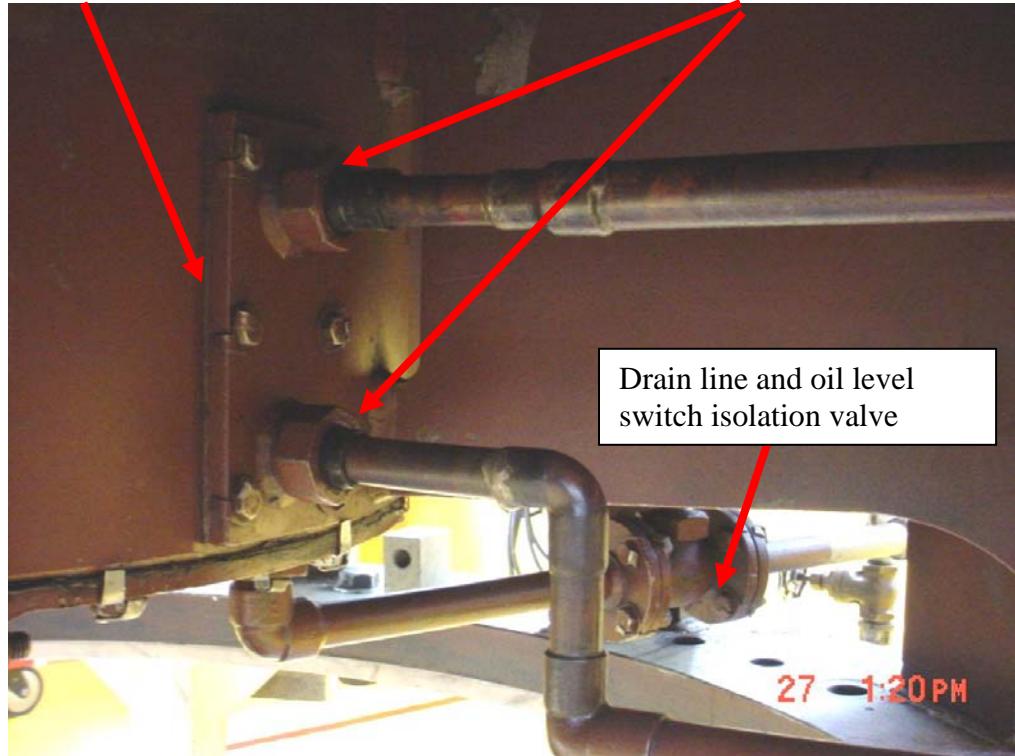


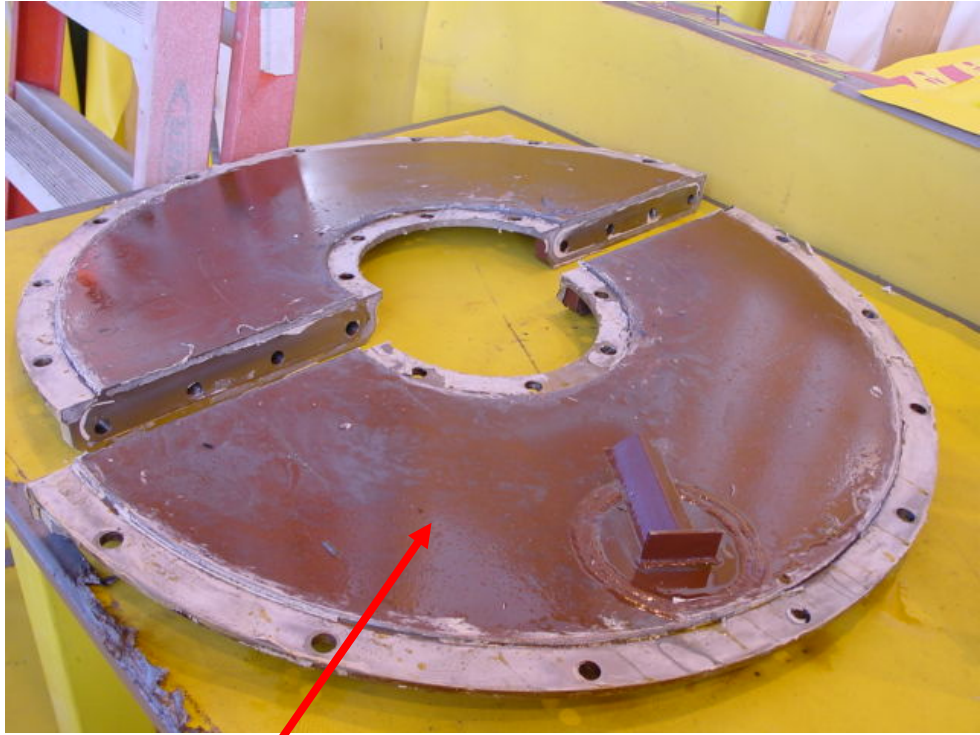
Figure 4-11 Photograph of the Oil Cooler Penetration Flange Area

Figures 4-12, 4-13 and 4-14 show the various parts of the lower oil pan and standpipe. The flange connections on these are very crucial and can leak if not properly assembled. Some Westinghouse motors have been supplied with lower oil pans made of aluminum which have a tendency to warp and leak due to the high temperatures surrounding the motor. A replacement oil pan made of steel is available which is much stiffer and not subject as susceptible to these leakage problems. Additionally, the proper size oil pan and standpipe flange bolting (in particular, length) must be utilized to obtain a good seal. One area that needs particular attention is the bolting hardware on the splits on the lower bearing oil pan. Two bolts on each split are ream bolts which act as dowels for the split alignment. If these bolts are not installed, split misalignment can occur which will create a leak path. Figure 4-14 shows the lower pan drain line which has threaded pipe connections and flanged joints which can leak if not properly installed and sealed. Figure 4-15 is a picture of the lower oil pan installed and the flange has been 'battered' with sealant which can help prevent leaks.

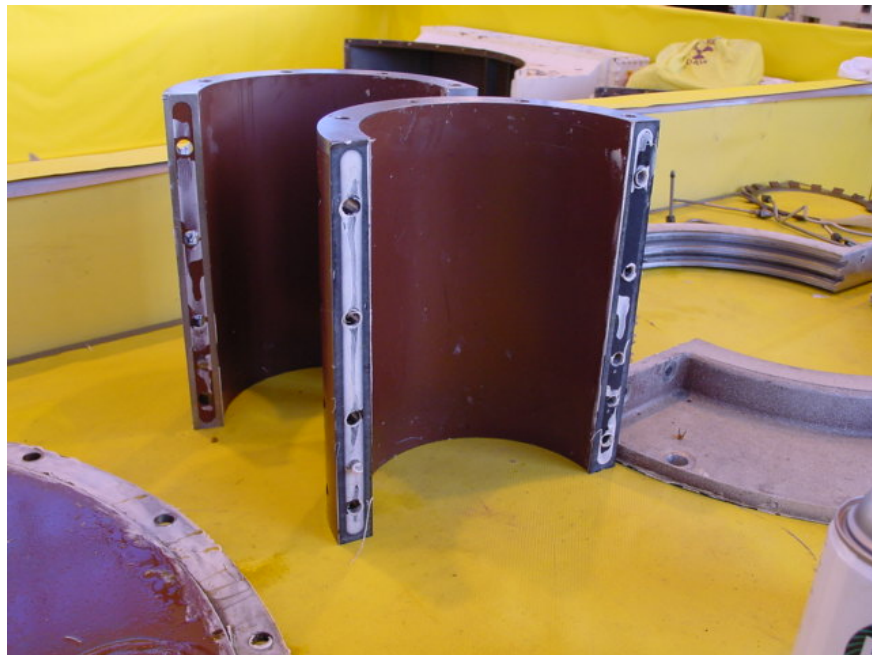
Lower Oil Pan with
Standpipe attached
Dropped Down



Figure 4-12 Lower Oil Pan



Lower Bearing Split Oil Pan



Split Oil Pan Halves
Figure 4-13 Lower Oil Pan Halves

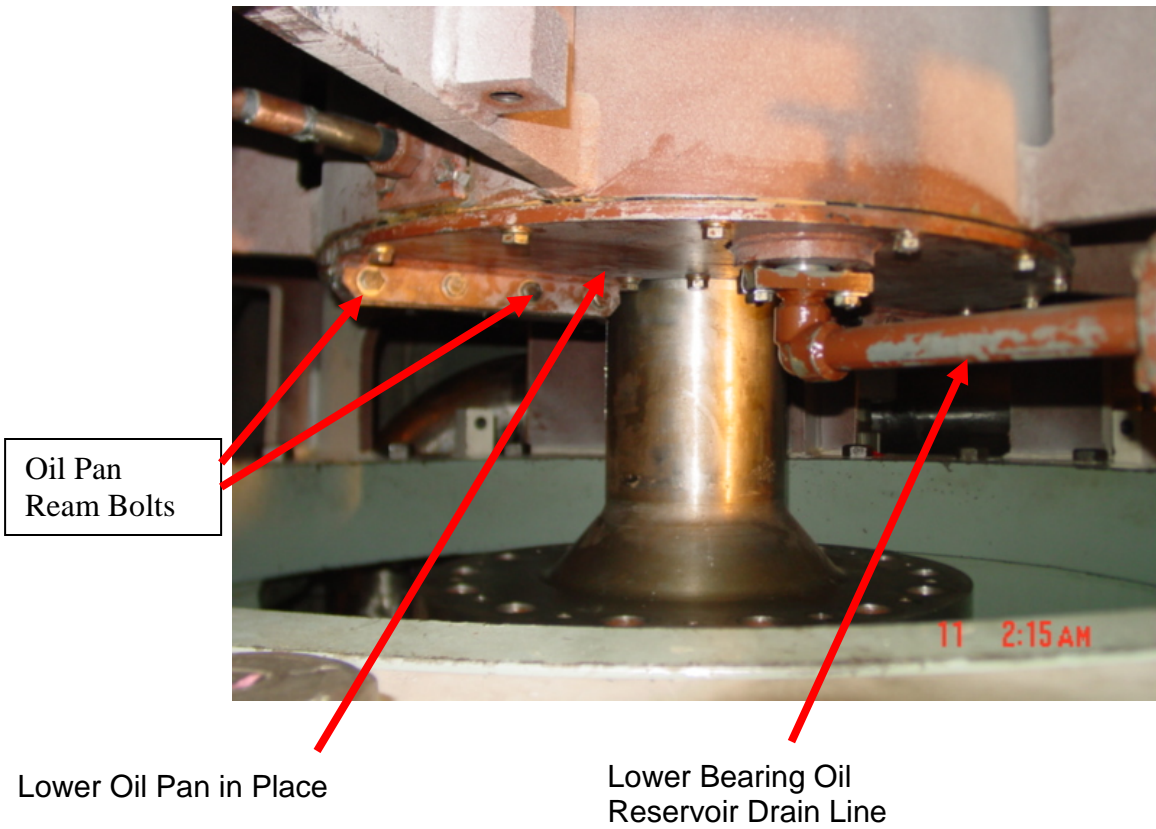


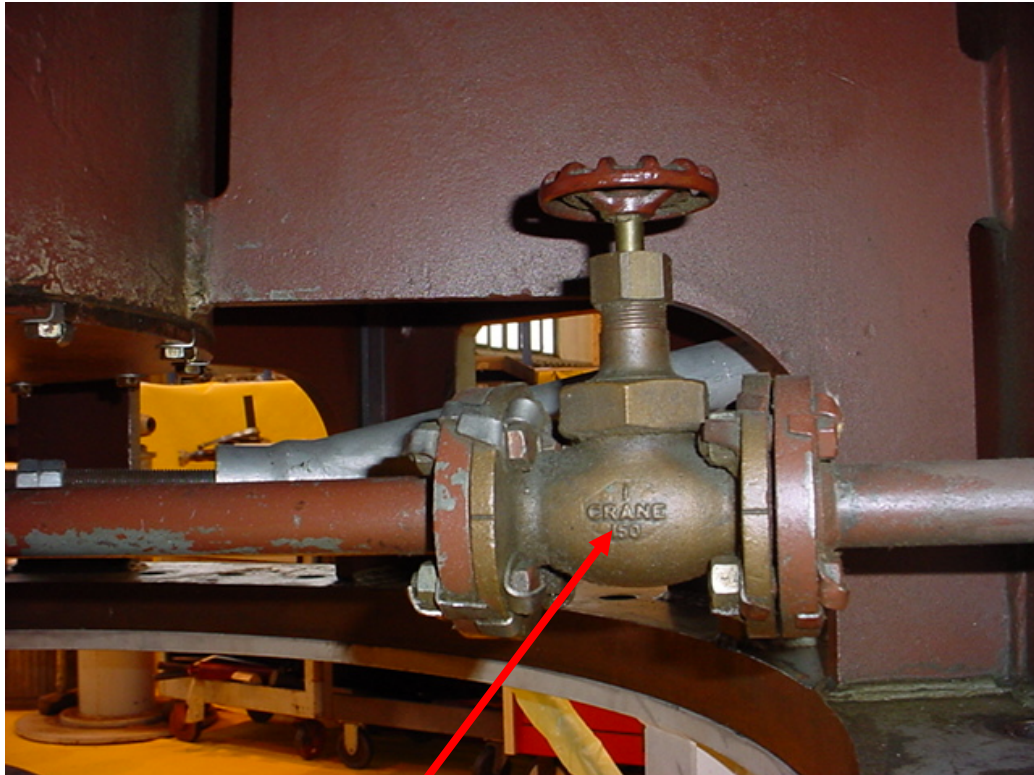
Figure 4-14 Lower Oil Pan in Place

Lower Bearing Oil Pan (showing sealant)



Figure 4-15 Lower Oil Pan Flange "Buttered"

Figure 4-16 shows the Lower Bearing Reservoir Drain Line Isolation Valve. Potential leak paths here are at the valve flanges and packing. These should also be refurbished during the recommended 10 year motor overhaul.



Lower Bearing Drain Line Isolation Valve
This line goes to the lower bearing oil level switch oil pot

Figure 4-16 Lower Bearing Reservoir Drain Isolation Valve

The lower bearing oil reservoir is topped with a two piece labyrinth seal as shown in Figure 4-17. The flange on the seal are above the oil level and do not typically cause leakage problems. However, the seals themselves can become a source of oil misting should the clearances grow too large which can result in oil accumulating external to the oil reservoir. The motors were originally supplied with aluminum seals but now a more durable copper seal is available which provides longer seal life.

Lower Bearing Labyrinth Seal, can be aluminum or copper
Can cause oil misting inside the stator if seal clearances are too large,

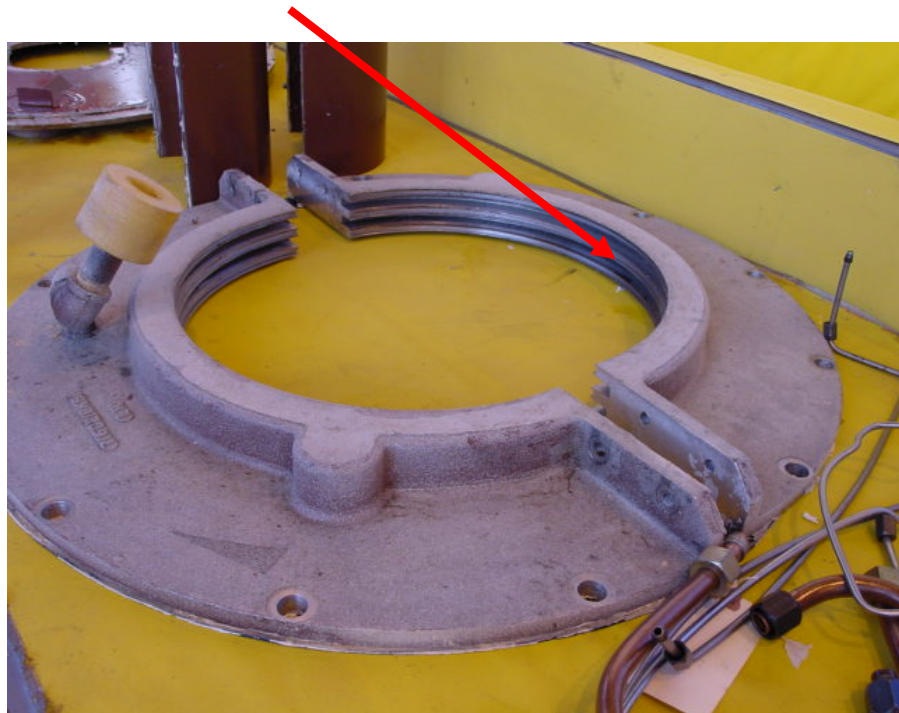
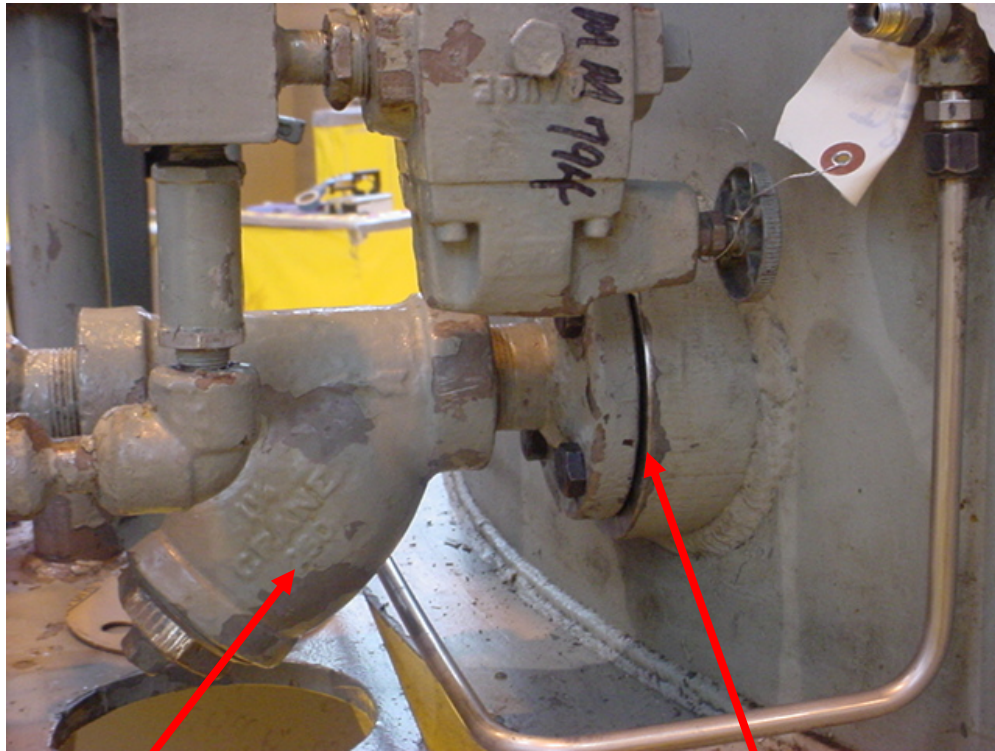


Figure 4-17 Lower Bearing Labyrinth Seal

Oil Lift System

The oil lift system (shown schematically in Figure 4-3) consists of many threaded connections which can be the source of oil leakage, especially when removed for maintenance. EPRI Report TR-111413 provides excellent guidance on preventing leaks in lube oil piping systems and can be a resource for dealing with problems in this area (as well as all threaded connections in the lube oil system). Figure 4-18 shows two common leak areas, the flange on the suction line from the bearing oil reservoir and the suction strainer, care should be taken in the installation of these items.

It should be noted that some leak paths are only present during oil lift system operation when the high pressure is applied to the oil lift system piping. Typical operating pressure is around 1200 psi.



Oil Lift System Strainer on
Suction Line

Oil Lift System Suction Line
Flange Gasket to Oil Reservoir

Figure 4-18 Common Leak Paths in the Oil Lift System

Ratchet Plate Shock Absorber

One area that is mistakenly diagnosed as indication of a lubrication system oil leak occurs in the area below the flywheel. The Anti-Rotation Ratchet Plate Shock Absorber can begin to leak oil due to o-ring aging as shown in Figure 4-19.

These shock absorbers should be replaced during the 10 year refurbishment.

Ratchet Plate Shock Absorber
O-Ring Degradation
(Potential False Bearing Oil Leak)

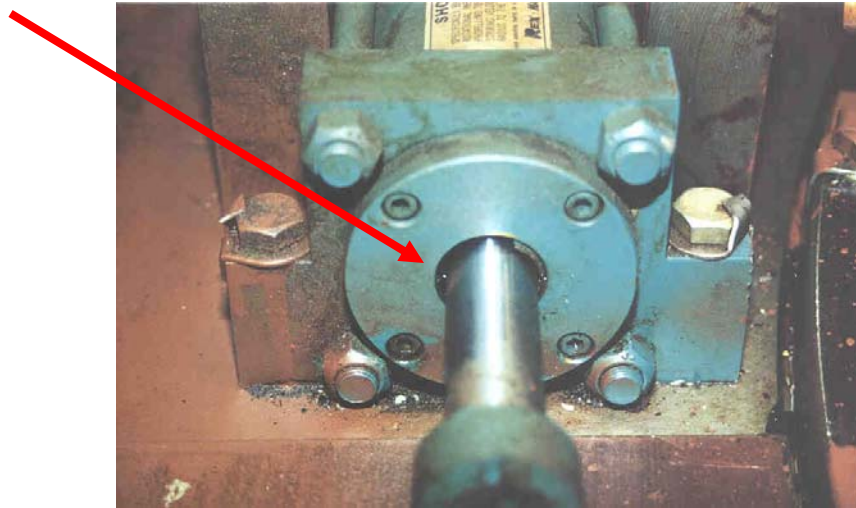


Figure 4-19 Ratchet Plate Shock Absorber

Lower Bearing Oil Level

Low oil level in the Lower Bearing Oil Reservoir can sometimes result in the ‘wiping’ of the lower bearing (shown in Figure 4-20). Often times this goes undetected and is discovered during inspection or teardown. Usually this damage is preceded by a bearing temperature spike and a sudden return to normal. Because the upper motor bearing and the hydrostatic bearing in the pump are still functioning, vibration levels remain normal as well. Inspection during a RFO should include the lower bearing if low oil levels have resulted in repetitive low oil level alarms.

Lower Bearing wiping
due to low oil level



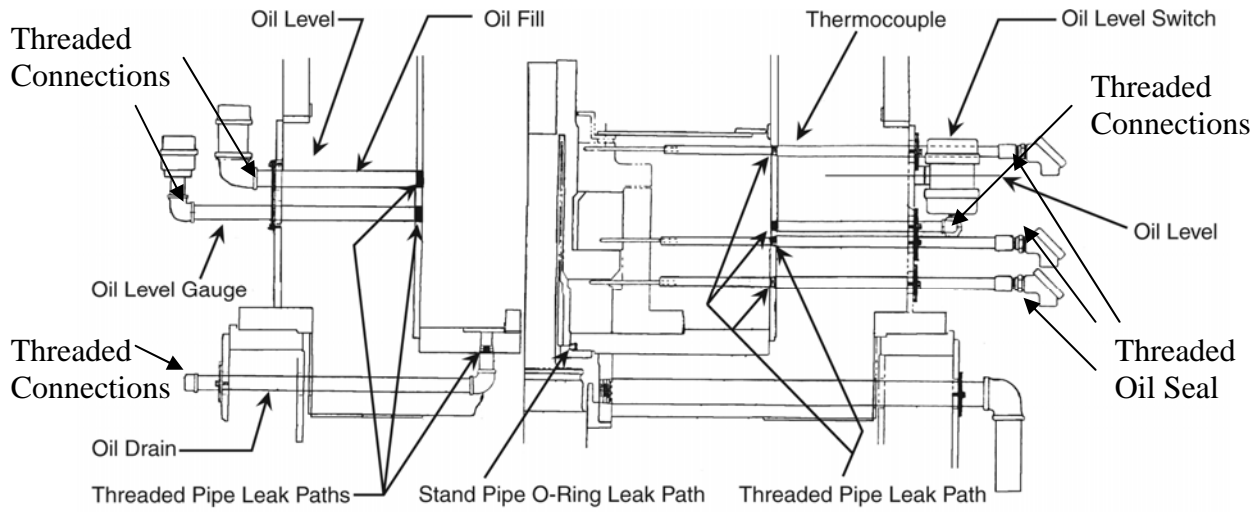
Figure 4-20 Lower Bearing Oil Damage from low oil level

4.2.2 GE RRP Motor Lubrication Leak Paths

The GE Reactor Recirculation Pump motor has fewer potential leakage paths than the Westinghouse RCP motors due to the differences in design. GE motors have more threaded pipe oil leak paths than the Westinghouse motors. GE motors typically do not use the flange joint design in their oil piping. In general, as with the Westinghouse motors, each of the leak path areas shown should be refurbished during the recommended motor overhaul of the motor (gaskets, seals, o-rings replaced) and disconnected threaded pipe connections re-sealed. In section 6 there is a discussion about GE recommendations for maintenance of the RRP Motor as recommended in SIL 0484.

Upper Motor Bearing Area

The outline of the upper bearing area of the GE RRP motor is shown in Figure 4-21. The most probable potential leak paths that can result in a lubrication oil leak are shown. Photos of these leak paths are shown in Figures 4-22, 4-23 and 4-24. As can be seen, the majority of the leak paths involve threaded connections.



GE Recirc Motor Upper Bearing
 Figure 4-21 GE Motor Upper Bearing

It should be noted that the threaded pipe connections that enter the oil reservoir are hidden from view due to the motor housing design for the air flow inlet path to the stator.

Photos of these leak paths are shown in Figures 4-22, 4-23 and 4-24.

Upper Bearing Thermocouple
(threaded pipe into oil reservoir—potential leak path)

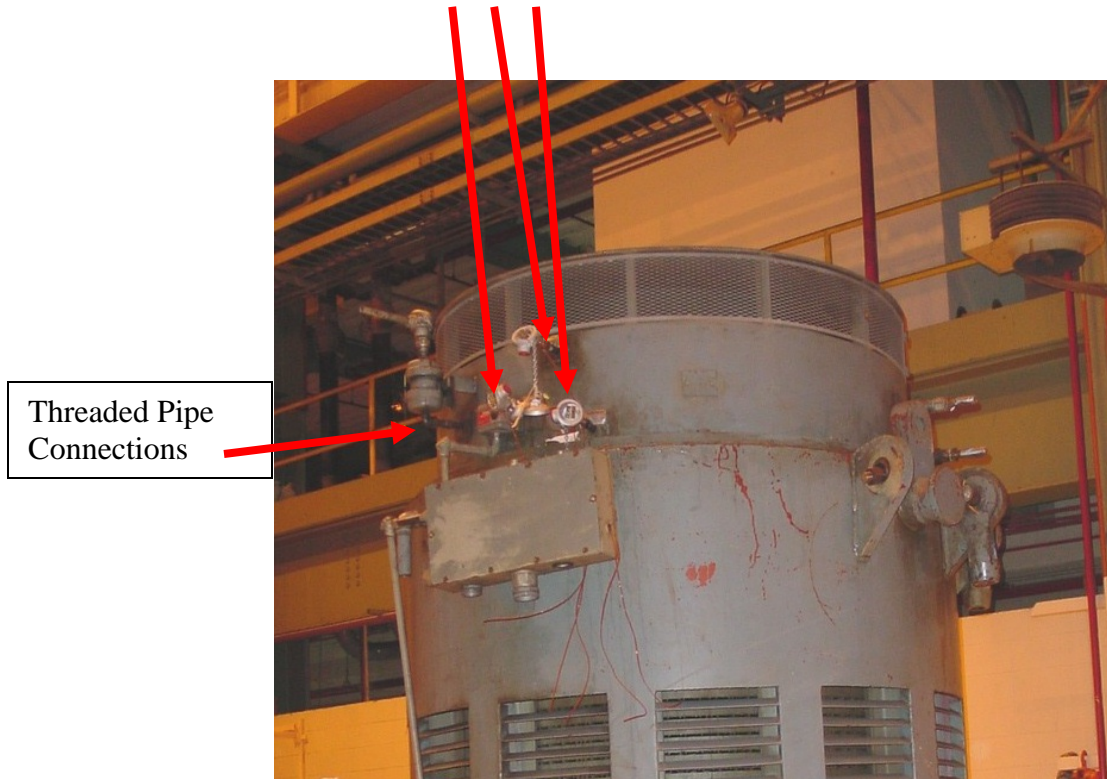
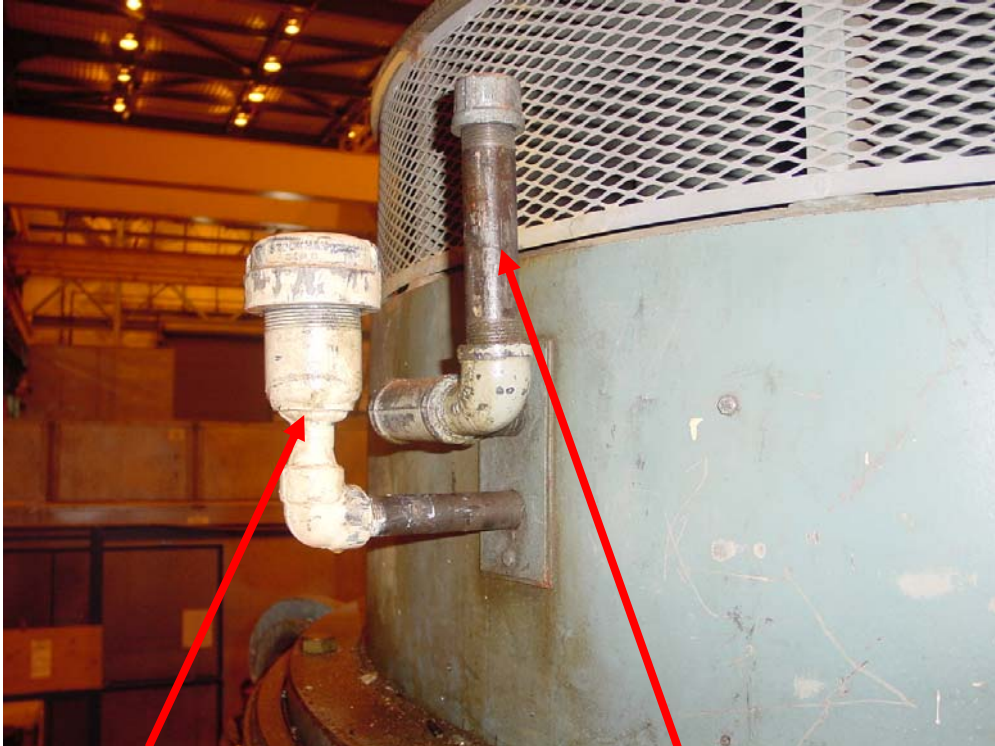


Figure 4-22 Upper Bearing Potential Leak Paths



Upper Bearing Oil Level Gauge
(some have sight glasses)

Upper Bearing Fill Line

(Both are potential leakage paths where they thread into oil reservoir and the external threaded connections)

Figure 4-23 Upper Bearing Potential Leak Paths

Upper Bearing Level Switch
Threaded pipe in oil reservoir
Potential leak path where this pipe
threads into the oil reservoir and the
external threaded connection shown
here



Figure 4-24 Upper Bearing Potential Leak Paths

A leak path that requires careful attention is the area where the upper bearing cooling water lines penetrate the upper bearing oil reservoir. The seal must be properly installed and is very similar in design to a 'stuffing box' design. See Figure 4-25 and 4-26.

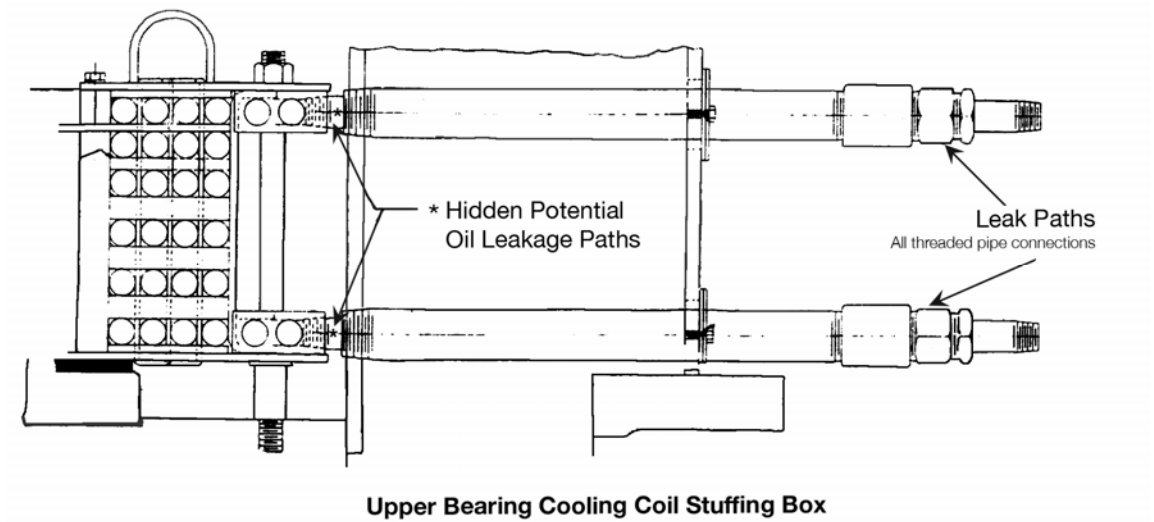


Figure 4-25 Upper Bearing Cooling Water Lines Oil Reservoir Penetrations

Upper Bearing Cooler Water Line
Stuffing Box – Oil Seal

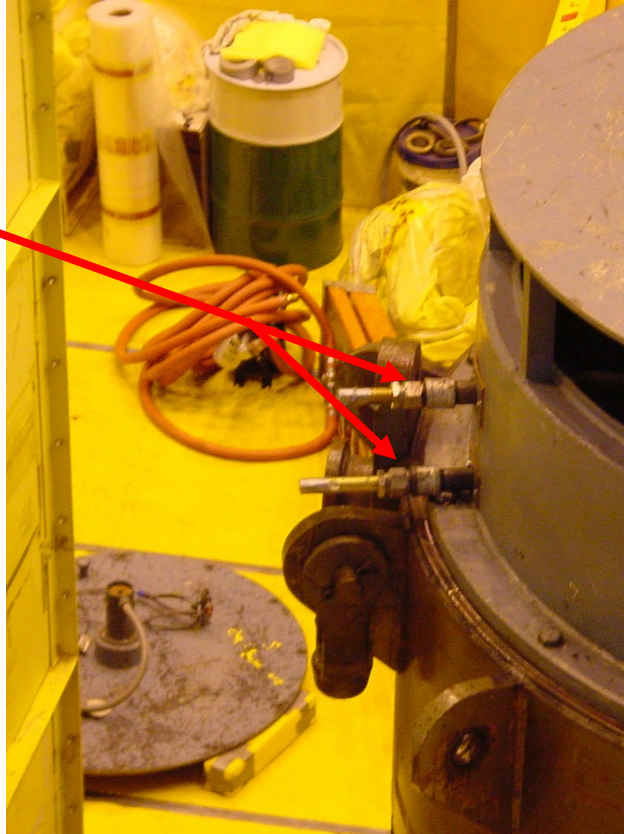
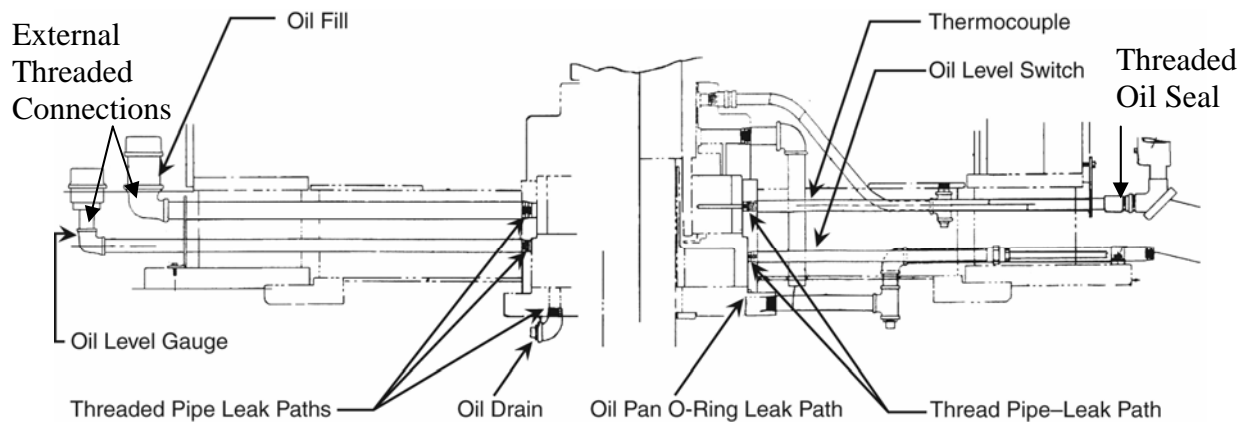


Figure 4-26 Upper Bearing Cooling Water Lines

Lower Motor Bearing Area

The outline of the lower bearing area of the GE RRP motor is shown in Figure 4-27. The most probable potential leak paths that can result in a lubrication oil leak are shown. Photos of these leak paths are shown in Figures 4-28, 4-29. The majority of the leak paths also involve threaded connections



GE Recirc Lower Bearing

Figure 4-27 Lower Motor Bearing Area

Lower Bearing Oil Level Switch-
Threaded pipe into oil reservoir
potential leakage path and external
threaded joints shown



Figure 4-28 Lower Bearing Oil Level Switch

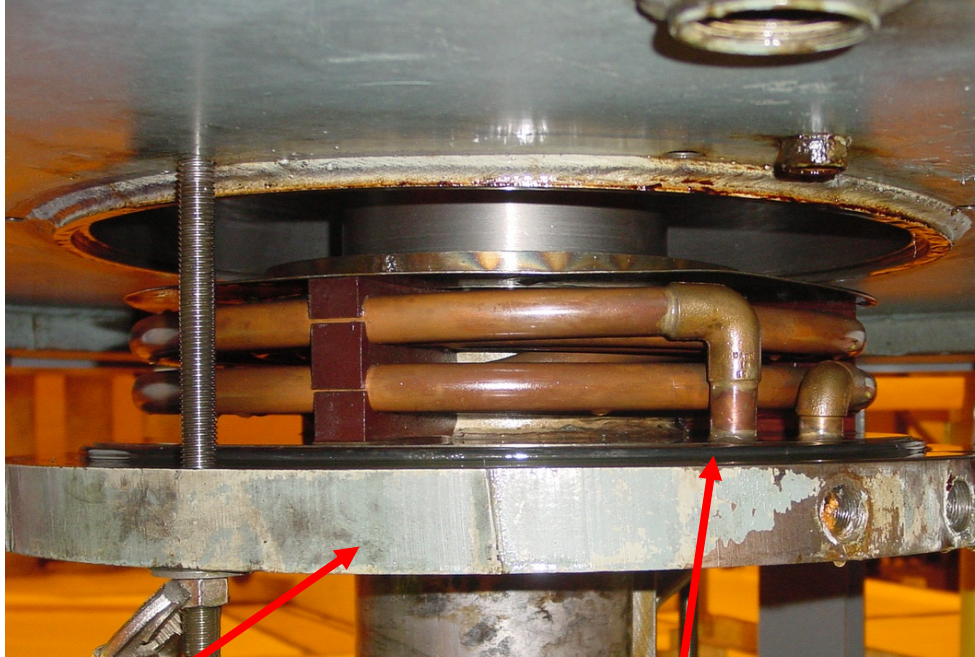
Lower Bearing Oil Level Gauge
Threaded pipe into oil reservoir
leak path and external threaded
joints shown in this photo



Lower Bearing Oil Fill Line
Threaded pipe into oil reservoir
leak path and external threaded
joints shown in this photo

Figure 4-29 Lower Bearing Potential Leak Paths

Another potential leak path is the lower bearing oil reservoir lower oil pan. This pan (Shown in Figure 4-27) is sealed with an O-ring and care must be taken for proper installation. One method of ensuring that a good seal is obtained is to use threaded rod to raise and lower the pan evenly in order to properly seal the lower oil pan as shown in Figure 4-30 and 4-31.



Lower Bearing Oil Pan

Lower Bearing Oil Pan O Ring
Leak path

Figure 4-30 Lower Bearing Oil Pan Being Installed



Lower Bearing Oil Pan

Figure 4-31 Lower Bearing Oil Pan Being Installed

5

LUBRICATION OIL SYSTEM LEAKAGE REMEDIES

5.1 Lubrication Oil System Maintenance Practices/OEM Recommendations

RCP/RRP motor manufacturers recommendations, contained in maintenance manuals and bulletins, should be adhered to at all times. Often times, oil leaks stem from a failure to adhere to these recommendations which are based on many hours of operating experience. These recommendations often contain specific guidance on lubrication systems, including periodic inspections and part replacements. Often times, gaskets and sealing systems such as o-rings, packing and seals have a limited life expectancy, especially considering the harsh environment in which these motors operate. All maintenance activities should be conducted by personnel trained and familiar with these unique motors to ensure a high quality evolution is achieved. Personnel unfamiliar with these systems should be accompanied by a more skilled and knowledgeable peer whenever possible.

Westinghouse RCP Motors

Westinghouse recommendations in their maintenance guidelines include the following:

At each refueling outage, check for oil leaks at the following locations:

- a. Flywheel seal and ratchet plate area
- b. Lower guide bearing oil pot
- c. Oil lift assembly piping
- d. Anti-reverse shock absorbers.

The frequency of cleaning the filter element depends on the operating conditions and should be established based upon the user's experience. In order to establish this experience, it is recommended that the filtering element be checked during the refueling shutdown.

Oil changes should include a cleaning of the upper and lower oil reservoirs.

A rotor and stator inspection is recommended at 5 year intervals. During this inspection, which requires removal of the rotor from the stator, the upper and lower bearing reservoirs are disassembled and the associated piping disconnected. Gaskets and insulating seals should be replaced at this time.

To get the best service from the anti-reverse shock absorbers, change the internal software items every five years.

GE RRP Motors

GE recommends in SIL 484 that the RRP motors be inspected every 10 years. This includes inspection for oil leaks within the lubrication system. (However, at every refueling outage, the lubrication system should receive a walk-down to identify any oil leaks that may have surfaced during the previous operating cycle.)

One area that should receive special attention is in the areas of the motor drain plug o-ring and the sight glass o-rings. These areas were supplied with o-rings made of low nitrile buna material that will degrade due to contact with the oil and the operating conditions that they experience. These o-rings on the motor drain plug should be replaced at every other oil change with parts that are made from medium nitrile buna-N o-rings containing at least 27% nitrile. The sight glass o-rings should be replaced with the same type of material recommended for the drain plugs whenever they are removed for maintenance or motor refurbishment.

5.2 Lubrication Oil System Remedies

In response to problems, plant personnel have implemented a number of maintenance practices and/or physical changes to combat many of these problems which will be discussed in this section. These changes include changes to the oil system to stop leaks or to minimize their effects and impact on plant operation. Some plants have made provisions to add oil while the plant remains at power. Some of these remedies have come from the motor OEMs but a number have been developed by plant personnel.

Each of these areas will be discussed in the following paragraphs including a description of the problem and what has been done to correct the issues (when available). In some cases information will be provided with regard to what was attempted with incomplete success. This information has been provided by plant personnel.

In general however, many of the problems cited in Section 4 can be discovered during periodic inspections (during Refueling Outages) and prevented by replacing all gaskets and seals during any maintenance activity and as a minimum during the motor overhauls. Threaded pipe connections (more common on GE RRP motors) and flange joint connections (common on Westinghouse RCP motors) are a frequent location of oil leaks. Guidance on these types of connections can be found in EPRI Reports Number TR-111413 , Lube Oil System Leakage Mitigation [2] and TR-10413 [3], Bolted Joint Maintenance and Applications Guide [3].

5.3 Motor Leaks

Upper bearing oil reservoir

Point Beach (PWR with Westinghouse RCP Motor)

Operating experience has identified the potential for the leakage of oil from the upper oil pot to the flywheel seal area. Westinghouse has designed a factory modification/upgrade package for minimizing oil mist in this area of the motor. These modifications/upgrades are incorporated when the utility sends their RCP motor to our facility for remanufacture services. In early vintage RCP motors, historical data indicates that oil leakage has been noted in the flywheel seal area of several motors. Leakage of oil from the oil pot to containment may constitute a fire hazard. There are four modifications/upgrades to the motor that may be performed, in conjunction with RCP motor factory remanufacture services, to significantly reduce this hazard.

FLYWHEEL SEAL UPGRADE

The flywheel seal has two functions. The primary function is to establish a blanket air pressure in the upper oil pot. This blanket pressure must be maintained in reasonable agreement with the air pressure at the oil pot standpipe. A mismatch of these two pressures would result in either oil loss over the standpipe or air ingestion into the oil pot. The secondary function of the flywheel seal is to avoid oil loss at the seal. The upgraded design seal equalizes the pressures in the flywheel seal area and the blanket pressure in the oil pot to help eliminate leakage. The airflow through the seal has been changed to help avoid oil loss at the seal.

TOP OIL POT COVER MODIFICATION

The top oil pot cover inside the upper bearing oil pot reservoir separates the upper portion of the reservoir from the lower portions. The original design of the top oil pot cover is very restrictive so that when the motor is started, it is believed that a large suction is formed under the top oil pot cover and that a combination of air and oil is sucked beneath the cover. This continues until the oil level on top of the cover is sufficient to provide an adequate supply of oil to the middle area of the oil pot. This increase in oil level results in a high dynamic oil level and air entrapment under the top oil pot cover. Eventually, this air becomes entrained in the oil and can lead to oil foaming and/or misting directly under the flywheel seal.

The existing Top Oil Pot Cover was modified to make the plate less restrictive.

Note: This factory modification is offered only in conjunction with the truncated flow chamber (as described below).

TRUNCATED FLOW CHAMBER MODIFICATION

The originally designed flow chamber is restrictive so as to limit the flow of oil between the center and lower portions of the upper oil pot. This increases the possibility of air entrainment into the oil.

The new flow chamber is designed to reduce the possibility of air being entrained into the oil through the top oil pot cover. It also allows more time for air entrained in the oil to be released and thus enhancing the life of the oil. The truncated flow chamber also will raise the pressure within the lower portion of the oil pot, which will raise the oil level in the standpipe and reduce the risk of air being sucked into the oil in that area. In addition,

the oil pot is machined to provide an o-ring groove to provide better sealing between the oil pot and ratchet plate.

VISCOSITY PUMP UPGRADE

On reactor coolant pump (RCP) motors equipped with tangential oil pumping systems for lubrication of the upper guide and thrust bearing assembly; oil life may be somewhat less than expected due to oil degradation. When this situation arises, it could cause frequent shutdowns for changing and cleaning of the oil pot. The oil degradation, which is evidenced by an acrid odor, dark color and viscosity change, will ultimately result in sludge formations and varnish-like deposits. The sludge formations and varnish-like deposits will coat bearing surfaces and will eventually clog oil lift lines. It has been determined that this phenomena results from air entrainment and high localized temperatures which result in a progressive degradation of the oil.

A viscosity pumping system has been developed which has extended oil life at sites where it is installed, and is recommended as an upgrade for the existing tangential pumping system. This modification is required as part of the Truncated Flow Chamber upgrade. This factory modification has been performed for a number of plants.

A conversion from the tangential to the viscosity pumping system requires all or some of the following modifications:

- Replacement of the existing runner with a new runner, or modification of the existing runner
- Installation of a viscosity pump
- Modification of the upper thrust support
- Modification of the stand pipe

Installation of the four modifications/upgrades designated above minimizes the amount of oil mist in the flywheel seal area.

Crystal River 3 with GE RCP Motor

In the upper guide and thrust bearing oil reservoir, the high temperature and shearing action generate an oil mist / vapor that can be seen exiting the motor torque drum / oil reservoir vents. Conventional filters (as in the currently installed Consler filter) will not prevent oil mist escape from the RCP motor torque drum / oil reservoir vents because the oil particles are too small. The type of filter needed for this application requires effective removal of visible oil mist. A coalescing filter is appropriate for this type of application as it is very efficient for a wide range of particle sizes. During the next refueling outage new oil demisters provided by Graver Technologies will be installed.

External oil coolers (Westinghouse)

Sequoyah and Watts Bar with Westinghouse RCP Motor

The upper bearing oil cooler bundle was originally Admiralty Brass but due to problems with leaks the tube material was replaced with 90/10 Copper/Nickel. Future plans are to

switch over to stainless steel material. Because of the potential for bolt torque relaxation, it is recommended that the torque bolts be checked at each outage where feasible. Additionally, periodic (8-12 years) refurbishment practices should include:

- Cooler Disassembly, Clean, and Inspect
- Perform eddy current test of tubes
- Plug tubes as required (maximum of 4 tubes can be plugged)
- Reassemble using new gaskets and packing
- Replace hardware as needed
- Pressure test tube side and shell side
- Paint

Lower bearing cooler refurbishment practices (performed at 8-12 years) include:

- Removal from oil reservoir
(requires un-soldering).
- Visual inspection.
- Chemical cleaning
- Flange replacement
- Pressure test using
nitrogen

Oil lift systems (Westinghouse)

Point Beach (PWR with Westinghouse RCP Motor)

Installed Stainless Steel lines in conjunction with the upper bearing oil reservoir modifications described above to eliminate degradation that was occurring with the existing copper lines.

Sequoyah and Watts Bar with Westinghouse RCP Motor

Broken oil lift lines were a problem with the old ring header design. The oil pump modification that Westinghouse offered re-routed the oil lift lines inside the motor which eliminated the ring header. The tangential pumping holes that were originally on the thrust runner generated excessive oil turbulence inside the upper oil reservoir. This contributed to the lines breaking. The holes were plugged with the oil pump modification.

The ermeto fitting installation process also contributed to the stress on the oil lift lines where it exits the fitting. All of the oil lift lines that TVA found cracked or broke were at the entrance to ermeto fitting just before check valves on the thrust shoes. The oil pump modification coupled with the 10 year refurbishments which replaces all of the oil lift lines, fittings, check valves, and flow valves internal to the upper oil pot has eliminated this problem.

Palisades (PWR with Allis Chalmer RCP Motors)

The external lift, backstop (anti-reverse rotation) and circulating oil systems have been completely redesigned to ease maintenance and improve reliability. The original systems

were primarily piping and flanges. The new systems are Swagelok tubing and fittings. The oil systems were reconfigured with many components being eliminated to improve system performance and reliability and to significantly reduce potential leak points. The redesigned systems have proven to be reliable and require minimal maintenance.

Crystal River (PWR with GE RCP Motor)

The internal lift oil hoses were replaced with stainless steel tubing. The AC powered Oil Lift Pump has been removed leaving only the DC powered pump.

Lower bearing oil reservoir

Plants with Westinghouse motors were originally provided with a lower bearing oil reservoir that was made of welded aluminum panels. The temperatures in the RCP motor area can get quite high; this caused stresses to increase in the aluminum which resulted in leaks from the reservoir. A common and successful solution to this problem has been to replace the lower bearing oil reservoir oil pan and standpipe with ones made of steel which is able to withstand higher temperatures and minimize flexing during torquing.

Sequoyah and Watts Bar with Westinghouse RCP Motor

A number of problems have been experienced in this are and include:

Gasket material changes

Original material was ungraphited compressed asbestos.

Material was changed to a black enamel coated compressed fiber nitrile

Present material is nitrile butadien rubber PF-4N made by Interface Solutions, Inc.

Sealant used over the gasket material

Original was Permatex #2

It was changed by Westinghouse in the mid 80's to RTV 732 and 734

The RTV did not stick to the black enamel coated gasket material (this has been tested by EPRI per TVA's request).

Permatex #2 is presently being used with the PF-4N gasket material

Loctite Right Stuff is presently being tested by EPRI as a replacement to Permatex #2

Bolt length, bolt grade, bolt type (body fit bolts, standard bolts)

Through the years bolts have been changed out during maintenance.

Original bolts were Grade 5.

Some were replaced with Grade 3. This caused bolt breakage during torquing

Some bolts were replaced with the correct size (diameter) but the bolts were too long.

The 4 body fit bolts in the oil pan splits were replaced with standard 1/2 bolts. This caused the splits to lose their alignment.

Bolt torque

Bolt torque values have varied the last 20 years.

For 1/2 inch Grade 5 Bolts - 60 - 65 lb.ft. should be used if bolting steel to steel. (Note: The specified torque is near the yield point for a Grade 5 bolt. It is strongly recommended to upgrade these bolts to grade 8 to minimize potential leakage paths over time.) If aluminum oil pans are used without stiffeners, the torque will need to be reduced.

Torque sequence on assembly is very important to minimize oil leaks. Torquing of the bolts should be within 1 hour of applying the sealant to the gaskets.

Torquing sequence

Cross pattern works best

Flange degradation

The flanges must be smooth with no gouges or nicks.

Most problems are caused by oil pan removal using a screw driver or improper protection of the flanges once the oil pan or standpipe are removed.

Improper assembly methods

Improper alignment of the splits. The standpipe splits and the oil pan splits must never line up with each other.

Lack of cleaning of the flanges. Any residual sealant can create an oil leak.

Assembly sequence steps. The standpipe is bolted together first, then the oil pan is bolted together. The standpipe is then bolted to the oil pan and then the oil pan is bolted to the oil reservoir. Sealant and gaskets are used on each split and flange.

It is important to give the sealant enough time to cure before adding oil.

Labyrinth seals

Sequoyah and Watts Bar with Westinghouse RCP Motor

Replaced aluminum lower bearing labyrinth seal with new style which is copper labyrinth style seal

External oil piping, fittings and connections

Crystal River (PWR with GE RCP Motor)

Piping connections that contain oil are either welded or flanged using Belleville washers.

Oil level switches/Oil Level Monitoring

Calvert Cliffs (PWR with Westinghouse RCP Motor)

CCNPP has oil level indication that reads out to the control room. System works on a capacitance principle (Magnatrol probes and Robert Shaw transmitters). Reliability of this system has been a problem and are looking at solutions. Some of the indication drifts with containment temperature. As temperature rises, indicated level rises, and vice versa.

In response to this, the plan has developed the capability to enter containment at power and use a boroscope to observe the motor oil sight glasses. A guide tube is permanently mounted to the motor at each sight glass. The other end of the guide tube is routed out of the pump bay and mounted to the operating deck. To take a reading, a 50 foot boroscope, mounted on a cart, is brought into containment. The boroscope is plugged in, the probe pushed down the guide tube and the sight glass reading taken. To obtain a reading takes no more than 10 minutes from the time the team (operator and HP tech) enters the air lock to when they get back to the air lock.

Point Beach (PWR with Westinghouse RCP Motor)

During the operation of the RCP motor a great deal of fluid activity occurs in both the upper and lower bearing assemblies. Specifically, one such activity is the turbulent flow experienced in both the oil and air portions of the bearing cavity. Due to this turbulence, the possibility of direct insertion of a float into the bearing oil pot, where it would be severely buffeted, is ruled out. The nebulous nature of the air-oil interface eliminates proposed methods such as ultrasonic. A reasonable approach is to monitor the oil level through use of a remotely located alarm pot reservoir. Here, the alarm pot reservoir and oil pot are interconnected with the intent that the level in the oil pot will be replicated in the alarm pot reservoir. Once the level in the alarm pot reservoir is established, it can be sensed using a float-type switch.

The concept of a remotely located oil level alarm pot was a logical design to pursue. However, an inconsistent array of problems has plagued this design. Rarely is the dynamic indicated level found to be equal to the static level. Also, the dynamic indicated level is found to change during the first ½ to 1 hour of operation as the bearing temperature stabilizes. In some machines the dynamic level is indicated to be higher, while in other machines the dynamic level is found to be lower than the static level.

Reports of high level indications and some time later low-level indications on the same machine have occurred. The inconsistencies from machine to machine and even for the same machine indicate that a very complex interaction is taking place.

The upgrade consists of a labyrinth entry vent port and a multi-port drain sump. Through incorporation of the upgrade, rather than sensing pressures in finite, limited areas, where they may differ drastically from the average or characteristic static pressures, the pressures sensed are indicative of the overall or characteristic pressures of the air and oil, respectively. Although the labyrinth entry vent port and multi-port drain sump are located independently, functionally they are dependent.

The labyrinth entry vent port system essentially eliminates the anomalous level alarms caused by the dynamic effects in the air/oil circulation patterns located above the bearing shoes. The labyrinth entry vent varies from the original design in that the vent line interconnecting the lower oil pot to the alarm pot reservoir has no distinct entry port into the lower oil pot. Rather, the vent line originating at the alarm pot reservoir is terminated in a "J" tube which is positioned near the labyrinth area of the lower bearing seal. Through this configuration, the vent line communicates with the bearing oil pot by means

of the lower bearing seal labyrinths. The seal labyrinths provide a static pressure to the vent line, which is an average static pressure indicative of the bearing oil pot air cavity.

Other advantages of the labyrinth entry vent port system are:

The reduction in alarm response time relative to an increasing oil pot liquid level caused by a ruptured cooling coil.

Elimination of the phenomena known as supersaturated percolation.

Supersaturated Percolation - This phenomenon occurs with the oil located below the float in the oil level alarm pot of the lower bearing. The physical characteristic observed is a significant off-gassing of entrained air that has the appearance of "boiling." The entrained air is not a true solution, but is a slurry of oil and extremely small air bubbles. This slurry is generated in the air void above the bearing shoes. In some motors it is carried through the vent line and into the oil level alarm pot. It then flows past the float and settles in the chamber below the float. Here, within a short period of time, the extremely small bubbles touch and join together. With this joining of the bubbles there is a significant increase in the relative air-to-oil volume ratio, which is related to the surface tension and bubble size (i.e., as the bubbles become larger, their internal pressure decreases and the specific volume of the air increases).

The multi-port drain sump varies from the original design in that the baffle located on the oil pan at the drain junction is removed. In its place is a multi-port plate, which contains an array of strategically placed penetrations. The plate surface is flush in the oil plan and is located directly above a shallow basin. Drain piping, as was used originally, interconnects the basin (lower oil pot) to the oil level alarm reservoir. The purpose of the multi-port drain sump is to generate a characteristic static pressure, which is indicative of the average pressure at or near the bottom of the oil pot. The addition of the multi-port drain sump does not significantly add to the overall mass of the oil pan, therefore, handling by maintenance personnel is not affected. The multi-port plate is removable such that it and the basin may periodically be cleaned.

St. Lucie (PWR with Allis Chalmers RCP Motors)

St. Lucie Unit 1 RCPs previously used pressure transmitters located outside of the bio-wall with sensing lines over 100 feet long to determine oil level in the reservoirs. This system proved to be unreliable. Blockage and air bubbles in the piping interfered with the indication. The system was replaced with a bubbler system where level is sensed by a dip tube in the oil reservoir. A small air flow is established through the dip tube at all times. The pressure transmitters remain outside of the bio-wall. This system is similar to the design used on St. Lucie Unit 2, which has performed well for many years.

Robinson (PWR with Westinghouse RCP Motors)

Robinson plant replaced the existing RCP oil level switches with an oil level indication system. Originally the Reactor Coolant Pumps had two oil level reservoirs, an upper and

a lower. Each reservoir has a level switch installed which provides a high and a low alarm. All of these alarm switches are wired in series to provide a single annunciator for each pump. Therefore, when an alarm is received on RCP oil level, a containment entry into the RCP bays is required to determine; 1) if the alarm is valid, 2) which reservoir is alarming. 3) whether it is a high or low alarm. At power, the RCP bays are a high dose area, so entry was not desirable unless absolutely necessary.

The plant replaced the RCP oil level switches with a system that provides trendable data outside containment. The modification installed alarm switches in each of the RCP oil reservoirs, routed new cables from the RCP bays to the containment penetrations, installed an alarm/indicator panel in the MG Set Room, routed a power cable from the R-24 skid to the new panel, and rerouted the annunciator cables to the alarm/indicator panel. It provides an electrical signal that is recordable, so that long term trends could be established.

Oil Collection Systems

St. Lucie (PWR with Allis Chalmer RCP Motors)

The plant has installed additional drip trays or extensions to the oil collection system to capture oil that the original system did not capture.

Palisades (PWR with Allis Chalmer RCP Motors)

This system was redesigned as a result of modifications to the external lift, backstop and circulating oil systems. The original system shielded only flanged joints and had drip pans to collect and route leakage. The flange spray shields were mounted directly on the piping around the flange. The redesigned oil collection system still utilizes drip pans to collect and route leakage. But, since the oil systems no longer have flanges, large spray shields have been installed to direct spray down to the collection pans.

Crystal River 3 (PWR with GE RCP Motor)T

The old sheet metal enclosures were removed and a fiberglass enclosure was added to the top of the motor

Remote oil addition capability

Because the RCP/RRPs are located within the containment building, when oil leaks result in low oil level alarms, plant personnel are faced with the difficult decision of whether to come down in power or off line to investigate and add oil to allow for continued operation of the motors or to add oil to the motors while the plant continues to operate. In most cases, this represents a significant effort for the maintenance staff due to the extreme heat and radiation environment as well as accessibility issues that often exist in plants. To alleviate the difficulties of adding oil while at power, some plants have installed, both on a temporary and on a permanent basis, provisions that allow for the addition of lubricating oil to allow for continued operation of the motor until the next refueling outage or until such time that the plant can be brought off line to address the problem. A number of different approaches have been implemented to accomplish this:

Turkey Point (PWR with Westinghouse RCP Motor)

In the late 90's PTN installed remote oil fill lines to each of the RCP lower reservoirs. The lines are 3/8" SS tubing that run from the motor to outside the bio-wall. At the same time permanently mounted cameras were also installed on each motor to monitor the lower oil level sight gauge. The output from the cameras was also routed to outside the bio-wall. These modifications were in response to numerous low oil level alarms. When an alarm is received, a containment entry is made with a TV monitor, oil and a small pump. Monitor is connected to the camera, oil level is verified and oil is added as needed. All within 10-15 minutes in a low dose area. The system has worked well when needed.

Calvert Cliffs (PWR with Westinghouse RCP Motor)

CCNPP modified the motors with a remote oil fill port to add oil to motors at power. This fill line (one for each oil pot) is a permanent run of tubing that connects between the operating deck and the oil reservoir. We have a portable oil tank (about 15 gallons) on a cart with a manual crank pump (looks like a filling station hose and nozzle) that is taken into containment and used to pump the oil into the fill port.

Crystal River (PWR with GE Motor)

Both the upper and low oil reservoirs for all of the RCP Motors have remote oil addition capability. This allows CR3 to make oil additions during full power plant operations. The connections to the reservoirs are located on the outside of the D-ring walls near the personnel hatch.

5.4 Motor Specific Issues

There are a number of issues that are specific to the more common motors being used in RCP/RRPs in nuclear plants. Some of these issues are summarized in this section

Westinghouse RCP motors

Oil leaks from lower oil pan Replacement design calls for the pans and standpipe made of steel - old style was aluminum split pan design. Temperature gradients causes aluminum to stress and crack over time resulting in leaks)

Loss of Bearing Insulation

Loss of bearing insulation can cause premature bearing failure due to electrical discharge from the shaft to the bearing. Bearing insulation has several components on the Westinghouse RCPMs.

Upper bearing insulation.

Upper bearing oil cooler.

Upper bearing insulated dowels.

Oil lift system insulated couplings.

Air cooler RTD junction box flex conduit insulated couplings.

Lower bearing support ring insulator.

Lower bearing top cover seal insulated bolts.

Lower bearing top cover seal vent line insulated coupling.

Two areas of specific concern are the Upper Bearing Insulation (stacked between the stator and upper bracket) and the Lower Bearing Insulation Ring (this ring has to be hand fitted)

Rapid Oil Degradation in the Upper Bearing

Rapid oil degradation occurred due to the original oil pumping design of the RCPMs.

- Too large of an air gap between the thrust runner and standpipe.
- Tangential pumping holes in the thrust runner.
- Thrust runner seal breaking dowel pins allowing it to rotate with the thrust runner.

The oil pump modification that Westinghouse offered corrected this problem by:

- Adding 4 rings to the standpipe to reduce the air gap between the O.D. of the standpipe and the I.D. thrust runner.
- Adding special l-shaped clips to secure the thrust runner seal.
- Plugging the pumping holes in the thrust runner and adding a viscosity pump.

GE Motors

GE issued a SIL 0484 in 1989 covering many issues on the RRP Motors including recommendations for proper maintenance of the motors. Subsequent to issue of the SIL several supplements have also been issued. The recommendation include the following on a ten- year program for lube oil system:

- ✓ Assessment of the motor conditions through monitoring of performance including bearing temperatures, oil analysis, etc.
- ✓ Assessment of the motor performance may include recommendations for full disassembly and inspection for refurbishment

The Upper Bearing Cooling Water Lines Oil Reservoir Penetrations are a common source of problems for these motors due to the unusual nature of the sealing design.

The Lower Bearing Oil Pan O ring requires careful attention during installation to ensure a proper seal is obtained. (See section 4.2.2)

The majority of the remaining lube oil system leak paths involve threaded pipe connections. EPRI Report TR-111413 provides guidance that may be of use in this area.

6

REFERENCES

1. INPO TR5-50, “Review of Events Impacting Power Production Involving Large Electric Motors”, November 2005
2. “Lube Oil System Leakage Mitigation: Sealing Technology and Plant Leakage Reduction Series”, TR-111413, August 1999
3. “Bolted Joint Maintenance and Applications Guide”, TR-10413
4. “Electric Motor Predictive and Preventative Maintenance Guide”, NP-7502, July 1992
5. INPO TR3-23, “Pressurized Water Reactor, Reactor Coolant Pump Operating Experience, Information and Insights”, 2003
6. INPO TR6-55, “Review of Large-Pump-Related Events Resulting in Scrams, Shutdowns, and Outage Extensions”, November 2006
7. Westinghouse RCP Motor Recommended 1-Year, 5-Year, and 10-Year Inspection and Maintenance Technical Bulletin VTD-WEST-1004
8. SIL 0484 1989 GE Recirculation Pump Motor Maintenance Program

A

APPENDIX A

Summary of RCP/RRP Motor Oil/System Related Problems Identified In INPO TR5-50, "Review of Events Impacting Power Production Involving Large Pump Motors"

	EPIX Report No. ¹	PED Report No. ¹	Event Date	Unit	PED Report Title	Motor Application	Plant Impact	Problem Component	Problem Description
12	None	368-040206-1	2/6/2004	ANO-2	Manual Shutdown Due To Long Term Increasing Trends On Reactor Coolant Pump Motor Bearing Temperatures	Reactor coolant pump	Shutdown	Bearing	Rise in temperature attributed to an increase in D/P across the lube oil strainer due to clogging / material found in strainer element appeared to be fibrous in nature and may have been residual left from the oil change during prior refueling outage
13	567	None	3/3/2004	Crystal River 3	Oil leak from Oil Fill Cap for Motor Lower Reservoir	Reactor coolant pump	Shutdown	Oil Leak	Oil leak from oil fill cap for motor lower reservoir
39	1025	280-030114-1	1/14/2003	Surry 1	Manual Reactor Trip as a Result of Elevated Shaft Vibrations on a Reactor Coolant Pump	Reactor coolant pump	Manual scram	Bearing	Motor experienced elevate shaft vibrations / all six bearing shoes were found damaged (wiped) / attributed to slow loss of lubrication over operating cycle
44	745	317-020724-1	7/24/2002	Calvert Cliffs 1	OE14329 - Preliminary Notification - Unit 1 Manual Scram Due to a Crack in the Vendor Supplied Flange to Pipe Weld for the 11A Reactor Coolant Pump	Reactor coolant pump	Manual scram	Oil Leak	Leak from failed butt weld on the oil return line from the oil cooler / attributed to high cycle fatigue and the lack of full penetration in the weld / weld not inspected after similar failure of a butt weld on Unit 2 in 2001
56	119	None	12/19/2001	Perry	Reactor Recirculation A Motor Cooler Leakage High	Reactor Recirculation Pump	Delayed startup	Switch / water leak	Annunciator for "Recirc A Motor Cooler Leakage Hi" alarmed / pump shutdown and alarm cleared 5 hours later / attributed to switch problem

	EPIX Report No.¹	PED Report No.¹	Event Date	Unit	PED Report Title	Motor Application	Plant Impact	Problem Component	Problem Description
71	339	313-000108-2	1/8/2000	ANO-1	Reactor Coolant Pump Oil Leak	Reactor coolant pump	Shutdown	Lube oil / anti-rotation device	Unit shutdown to inspect for oil leak on motor / fragmented parts of the antirotation device (ARD) found in upper oil reservoir / attributed to inadequate design of ARD and inadequate foreign material exclusion (FME) requirements for the upper oil reservoir which clogged nozzles

B

APPENDIX B SURVEY SUMMARY

Has your plant experienced any adverse problems with your RCP/RRP oil lubricating system (not including the lubrication itself) in the past 5 years?

Yes-28 No-8

Question 5: If yes, were the adverse problems related to:

Causes	Number			Causes/Comments	
	W	GE	Other		
Oil Leaks	10	6	5	21	All have been in the lower bearing area; Cracked RTD insulator Small oil leaks due to age of equipment Lower bearing design problems Minor oil leakage (< 1 gallon) in cont. basement
Oil System Level Indication Outages;		6	7	14	High oil level alarms following Refueling Spurious alarms; Drex1 brook level indication is poor
Oil Quality		2		2	
Oil Collection Systems			1	1	
Oil Cooler Leaks		2	1	3	
Piping Cracks/Leaks		1		1	
Other	2			2	oil misting problems Loss of oil lift pressure

Within the last 10 years has your plant had to come off line or reduce power to address an RCP/RRP motor lubrication problem? - If yes, please provide details

Lower bearing oil pan/standpipe leaks caused lower bearing wear. The addition of the lower bearing online fill system has minimize this problem. This system is installed at our Sequoyah plant only. **W**

4 years ago plant power was reduced to add oil to a lower reservoir. A cracked RTD insulator was leaking. The insulator was cracked due to over tightening. **Allis Chalmers**

Have reduced power to add oil to RR motor due to an oil leak. We schedule this activity with normal down power for control rod pattern changes. We have added oil approximately 4 times on line. **GE**

Cracked oil pipe cause manual trip in 2002. **W**

Leak caused plant to come off line. **Jeumont**

No. However, we have had to top-off oil level due to minor leaks during forced outages caused by unrelated causes. **GE**

Weld crack on lube oil piping in 1996 - U1 shutdown to repair RCP oil leak - 2000 - U1 U2 - 2004 shutdown to clean oil strainers. **Allis Chalmers**

before installing remote fill/monitoring system, plant was shutdown to inspect/add oil **W**

Reduced power at least three times in the past 10-11 years to add oil due to leakage. Origins of leakage were the lower reservoir drain isolation valve, fittings in the oil lift system, and the lower reservoir sight glass (2006). Replacement of a couple of cracked RTD insulators were required due to finding leakage during RFO, but did not require ramp down. **W**

Has your plant experienced any problems with the lubricating oil used in your RCP/RRPs as described below?

		<u>Brand</u>
Premature oil degradation	3	Chevron, Imperial, Shell
Oil contamination	6	Texaco, Mobil SHC (3),
Terresso 68, Shell		
Oil foaming	4	Shell (2), Texaco, Chevron GST
Oil sludge problems	2	Chevron (2)
Problems with oil additives	1	Texaco
Increased degradation from past experiences	1	Imperial
For new oil, poor oil quality	1	Texaco
Problems with new oil	2	Texaco, Mobil DTE
Problems switching to a new brand or type of oil	3	Texaco, Mobil SHC, Mobil
DTE		
Bearing failures attributed to lube oil issues	0	
Other (please explain):	3	Found oil oxidation @ 3 yrs, so change
@ 2 yr		micro-dieseling of oil passing beneath
thrust shoe		
fills		Short life of oil compared to original

Please describe your Predictive and Preventative Maintenance program for the RCP/RRP motor at your plant with respect to the lube oil system (i.e. periodic inspections of the systems, oil sampling program including test and frequencies.

Oil changed every refuel outage (2 years). On pump shutdown, the oil is sampled immediately (within 15 minutes). Sample sent offsite for analysis to determine bearing condition and motor / pump condition for possible work scope increases. **Mobil DTE**

Oil sampling determines oil change out intervals. Synthetic oil is used and sampled during refueling and forced outage conditions. Our oil normally will last 4 operating cycles of 18 months each. Oil is filtered when installed and base line samples are taken to start the trending process. **Mobil SHC**

The following is performed every outage. Oil systems are inspected for damage, leaks, loose fittings, etc. Dye that glows when exposed to UV light is used to quickly and accurately identify even the most minute leak. Backstop oil filters are replaced every outage. Oil lift filters are replaced every third outage. Oil is sampled and tested (RBOT, particle, viscosity, element, infrared, acid number). Replacement is based on test results (oil is typically used for >10years). Pressure and level instruments are calibrated. Oil lift system pressure is checked. **Mobil DTE**

All that my group handles is the testing of the oil, which is tested every outage. There are inspection pms for the motors themselves and to the best of my knowledge they are performed each refueling outage. **Mobil DTE**

take oil samples and change out oil every refuel outage. Dresden is on a 24 month fuel cycle.

Mobil DTE

oil samples are taken every refueling outage. Samples are taken from the upper and lower motor bearings right after shutdown. The oil is then filter pressed Beta(5-micron)>1000. filter press. The oil is then sampled again (post-sample). Test slate consist of Specto-chemical analysis, Acid Number, water by Karl Fischer, viscosity at 40C, Particle count, RPVOT on upper bearing reservoir only. Lower motor oil (24 gallons) is typically disposed. **Mobil SHC**

Oil sampling each refueling outage. Sampling includes RVBOT and is consistent with Westinghouse 1995 Oil Samples are analyzed/tested at Herguth Lab. Oil replacement every 4 R.

Texaco R&O

Every outage: Oil analysis (ferrography, viscosity, moisture, appearance); Oil changed; Reservoirs cleaned as needed; Internals inspected and cleaned thru access covers; Air vents cleaned if needed. Otherwise, considering a motor current analysis task. **Mobil DTE**

Motor overhaul every 10 years. Includes cleaning of pots and setup of the lift system. Change oil every 4 years (just started). used to do every 2 years (CCNPP on 2 year RFO frequency). **Texaco R&O**

Test and inspect the oil lift system at each refueling. **Shell R&O**

oil sample PMs performed at 18 month intervals. **Chevron**

RCP oil sampling is performed on refueling frequency. An EOC representative sample is taken from the J-pipe drain during plant shutdown (mode 3 or below). The oil is sent off-site for analysis. Lower bearing oil is discarded and replaced with new. Upper bearing oil is polished (filtered) and re-used for up to 5-cycles. A BOC representative sample is taken during plant start-up and sent off –site for analysis. Lower bearing test package includes viscosity, TAN, filter residue, spectroscopy (metals), particle count, ferrography, and water. Upper bearing test package is the same as the lower bearing test package except that the EOC sample has these additional tests; OIT by PDSC, RULER, and FTIR Acceptance criteria is based on WEMD 6665 limits. **Mobil SHC**

WE SAMPLE ALL 3 MOTORS EARLY IN EACH OUTAGE TO HAVE OIL ANALYZED. WE'VE HAD NO PROMBLEMS AS OF LATE **Texaco R&O**

Predictive: 1) oil sampling every 3 months (water, color, Ruler, particle count, viscosity).

Preventive: 1) jacking oil RV set-point test every 10 years, 2) calibration of jacking oil filter DP switches every 4 years. **Imperial**

Every 24 months the set-points for the oil level switches are checked/adjusted. **Mobil DTE**

Renew oil every second refueling outage (cycle =18 months)

Engen Turbine 46

We conduct the inspections of the lube oil systems according to O/H schedule which is achieved per 12 months **Texaco R&O**

Sampling is performed every outage (18 months). Major inspections are performed every 10 years with minor inspections every outage. These minor inspections consist mostly of visual inspections and checks on the oil lift system. Oil is replaced based on the results of the oil analysis. **Mobil DTE**

-oil sample upper and lower bearings and reservoirs (viscosity, neutralization number and particle checks); **Texaco R&O**

Samples are collected and analyzed on a 2-year frequency. If the samples are not contaminated (radiological), they are sent to our off-site fluid analysis lab. If they are contaminated, they are evaluated on-site using CSI's Oilview. **Gulf Harmony**

The pump and motor are located in containment. Therefore access to motor bearing oils is available every second year. Oil samples have been taken from each bearing housing and analyze for Acid Number, Water Content (by Karl Fischer titration), ISO Cleanliness level, ASTM Color, Trace Element, Viscosity at 40C, Appearance. The intention is to predict oil deterioration rate and schedule oil change during the next outage in two years. Unfortunately, there are examples of oil change request immediately after sampling and analysis. Typical oil life is 4 to 6 years. Longer intervals cause greater increase in oil acidity. **Exxon Terresso 46**

Oil is sampled every RFO, tests include vis, TAN, Moisture, Particle count, metals **Mobil SHC**

2-year inspection/sampling/testing frequency for the upper and lower motor bearings **Mobil SHC**

Take oil samples each 18 months. Due to type oil used, am changing the oil each 18 months. Although oil quality is trended, more interested in machine condition at this point. **Mobil DTE**

The upper and lower oil reservoirs are sampled every 18 months. RCP Motor Oil Tests: * Acid Number (Colormetric), ASTM D974 * Viscosity Kinematic, cST @ 40°C, ASTM D445 * Water by Karl Fischer, ASTM D1533 * Filter Residue, HL-1116 * Metals by ICP (18 elements), HL-1158 * Oxidation Stability (RBOT), ASTM D2272 **Shell Turbo**

Oil sampling each refueling outage. **Mobil**

Biannual oil sampling for TAN, RBOT, particle count, viscosity, moisture, color, elements. **Exxon Terresso 46**

The RCP oil is sampled and analyzed every refueling outage in time for feedback on any indication of an adverse problem that has to be addressed during the refueling outage. **Mobil SHC**

complete lube oil collection system and indication system each outage, oil sampling each outage. Sample and analyze every 18 months. Change lower motor oil every outage, change upper per analysis results. test include: wear metals, containment metals, additive metals, viscosity, TAN, particle count, Karl Fischer (water), rust, RBOT, foam, ISO code. **Chevron GST**

Lube Oil Analysis Bearing Temperatures **Mobil DTE**

We inspect the systems for leaks and change the oil filter at every outage. **Mobil SHC**
oil sampled every 18 months, oil replaced based on sample results **Shell**

Upper and Lower reservoirs are sampled at the beginning of each outage (18 months). Sample results determine if oil and oil filter / strainer is to be replaced. An 18 month PM is performed every outage and consists of oil replacement if necessary, oil lift system adjustments, oil level switch test / adjustments, and visual inspections for oil leakage and physical damage. A 10 year PM replaces one motor with the refurbished spare. Ten year refurbishment is a detailed inspection / cleaning of all major components including the lube oil system. **Shell**

Please describe your Predictive and Preventative Maintenance program for the RCP/RRP motor at your plant with respect to the lube oil sample frequency.

Every refuel outage (2 years).
See answer to question number 7.
See 7 above.
As stated above sampling is performed every refueling outage.
Oil is sampled every refuel outage and then replaced. Dresden is on a 24 month fuel cycle.
see question 7.
Oil samples are taken during refueling outages, every 18 months.
Oil sampling each refueling outage (18 month interval).
Take samples from oil drains during outages (now every 2 years).
Sample lube oil every RFO (2 years)
Oil sample at each refueling
18 month PM
See Question 7
ONLY SAMPLED EVERY 18 MONTHS
Sample frequency is 3 months. Not sure what is required to answer this question.
Every 24 months a sample is obtained.
Sample oil every refueling outage (18 months).
At the every O/H per 12months
The results of the 18 month sample could cause us to replace a motor sooner than planned.
52 weeks
2-year frequency - BWR refueling outage
During planned outages every second year (approximately every 24 months).
Every RFO
2-year inspection/sampling/testing frequency for the upper and lower motor bearings
See above
Every 18 months
Sample every 18 months. Change oil every 36 months.
See previous answer in (7)
2 years
Sample and analyze every 18 months. Change lower motor oil every outage, change upper per analysis results.
Sample is taken once per cycle during RFO
Sampling is carried out at every outage.
every 18 months
Both reservoirs are sampled every outage.

Please describe your Predictive and Preventative Maintenance program for the RCP/RRP motor at your plant with respect to the lube oil system

Every refuel outage (2 years).
See answer to question number 7
See 7 above.
Inspected for leaks every refuel outage
Every 18 months check for leaks, replace the lift pump filter, and check discharge pressure of the lift pump every

If contaminants (dust, oil oxidation by-products, wear) found in oil, additional inspection or reservoir cleaning is done.

Inspect for leaks every 2 years (every RFO). Internals parts of lube oil system inspected every motor overhaul which is 10 years.

Inspection for leakage at exchange refueling

3 year

See Question 7

EVERY OUTAGE WE DO AT LEAST A 18 MONTH PM ON EACH MOTOR

We have not been doing internal inspections of the oil systems routinely. These would be driven by oil sample results. However, we have been replacing all the upper brg Cu/Ni brg coolers over the last few years with SS ones and have found the condition of the upper brg reservoirs to be good. The only exception is two hydraulic hoses used to connect the two jacking oil pumps to the two ring headers on the brg. These were in poor condition, ie hardened and cracked. These hoses have been installed approximately 15 years and have been subjected to the heat, oil mist, and possibly ozone, inherent in a brg housing. It looks like we should be opening up the upper brg to replace them every 10 years.

Every 24 months the set-points for the oil level switches are checked/adjusted.

Inspect every refueling outage (18 months).

At the every O/H per 12months

The 18 month lube oil system inspection would only indicate failures. The 10 year inspection is a rebuild. This question does not apply to our plant.

once per day (gauge glass oil level check)

Motors are inspected every 2-years for oil leaks (internal and external). Oil levels are verified during forced/refueling outages.

On-line vibration sensor provide continous monitoring capability on the overall vibration level. In addition, every 13 weeks vibration spectrum is taken using the same probe and saved in vibration database. In addition, bearing temperature are continuously monitored and each bearing housing has oil max and min oil level alarms. There are other parameters, which can indirectly provide additional info on condition of lubrication system.

Lube oil system is only inspected during motor overhaul every 10 years

2-year inspection/sampling/testing frequency for the upper and lower motor bearings

Visual examination performed each 18 months.

Every 18 months.

The lube oil system is inspected during every refueling outage.

2years

Inspected during refueling outages

Inspection is performed at every outage.

every 18 months

Externally inspected every outage for leakage and physical damage.

Please describe your Predictive and Preventative Maintenance program for the RCP/RRP motor at your plant with respect to acceptance criteria for lube oil

Acceptance criteria is defined in a corporate procedure. Testing includes Viscosity, Acid Number, Karl Fisher Water, Wear metal (Spectroscopy and WPC) and additives.

The oil is tested for viscosity, oil and water, sediment, neutralization number, and ferrography is performed on particles found to determine type. Acceptance criteria will be based on the type of oil used, however the condeming limits listed in ASTM D6224-02 are used as guidance basis.

Per vendor recommendations and company guidelines.

RPVOT>25% of new, Particulate count better than ISO 18/15, Acid Number: >1.0 (alert), >2.0 (alarm), Viscosity: +/- 10% of baseline, water >135 ppm (alert), > 240 ppm (alarm), Spectrochemical: B>5 ppm (alert), >18 ppm (alarm); Si> 22 ppm (alert), >63 ppm (alarm); Pb>6 ppm (alert), >18 ppm (alarm); Sn>4 ppm (alert), > 10 ppm (alarm); Cu>2 ppm (alert), >6 ppm (alarm); Fe>2 ppm (alert), > 3 ppm (alarm). Note these variances are from baseline results.

RBOT, TAN/TBN, visc, water, spectro,part count

1995 Westinghouse RCP Motor Oil Report / Applicable ASTM standards

No strict acceptance criteria. Compare analysis results to previous results.

Moisture, wear products, additives

15% deviation from RPVOT baseline

See Question 7

ALL OIL SAMPLES ARE SENT OF SITE AND ANALYZED, RESULTS ARE THEN SENT BACK TO ENG. REVEIW

We use the following action limits on the Teresso 32 lube oil. Note, these are action limits, not condemning limits. 1) no visible cloudiness, water, or sediment, 2) relative humidity >10% above ambient, 3) particle count >ISO 18/16/14, 4) RBOT <200 mins, 5) Ruler # <30%, 6) Tan >0.25, 7) viscosity >110% nominal or <90% nominal.

Perform Viscosity, Neutralization (TAN) Number, Moisture, Water and Sediment, Metal Analysis, ISO Particle Count

Moisture, wear products, viscosity.

Total acid value : less than 0.4mg KOH/g Viscosity : 182.7~223.3sus Kinematic Viscosity : 39.1~47.8cst Humidity : less than 0.03%

See 8.

-viscosity +/- 10%; -neutralisation number 0.5

For off-site analysis, we rely on ASTM D6224-02 and SSES empirical data. Summary: Visc ±10%; TAN >0.2 above baseline; metals >15-ppm except for AW additives (CA, P & Zn) which are ±50% from baseline; water 500-ppm; Foaming Tendency >450-ml; Foaming Stability >10-ml. For on-site Oilview screening, we use changes (>0.02) in the Dielectric value from the baseline and/or deviation in the Chemical, Contamination or Ferrous indices of 5 or more.

The primary criteria are oil test results taken every two years. In general, acid number warning is set at 0.25 mg KOH/g and alarm (oil replacement) at 0.35 mg KOH/g. Kinematic viscosity at 40 C warning limits is +/-10% of oil ISO grade (we are using 68 VG R&O oil)and +/-15% for oil replacment. ISO Cleanliness warning level is set at 15/17 and oil replacement 17/19 (for 6 and 14 microns. We do not monitor 4 micron size particles). Dissolved and suspended water content warning level is set at 50 mg/kg and oil replacment at 100 mg/kg. ASTM Colour is warning level is set at 4.5 and oil replacement at 6 ASTM colour scale. Trace element warning level is set at 5 mg/kg and alarm (investigation level) at 10 mg/kg. We are also using RULER method to monitor oxidation characteristics of the oil. Current OPEX is not very clear what the trends indicate.

Vis @ 100c - 4.9 - 7.0 Moisture 135 ppm Particle count 18/15 TAN 1.49 Boron 40 ppm Silicon 22 ppm Lead 6 ppm Tin 4 ppm Copper 12 ppm Iron 4 ppm

Acceptance Criteria is governed by a corporate procedure, MA-AA-736-230-1001, Oil Analysis Interpretation Guideline for the types of oil in the motor bearings.

Acceptance criteria per Westinghouse recommendations.

See # 7 testing listed above

Sampling includes RVBOT for the remainder of usefully life. Oils are analyzed/tested at Herguth Lab.

Quality level oil dedicated by external contractor, acceptance criteria are defined in commercial grade dedication plan.

Our lube oil acceptance criterion is based upon the Westinghouse Owners Group RCP motor oil evaluation guidelines.

Remaining useful life within acceptable range considering 18 month run, Water <.1, Viscosity within 10 percent normal range, TAN, wear metals, contaminants trended.

Established guidelines for all oil properties ie viscosity, acid number

Oil must be within allowable limits for viscosity, water content, TAN, sediment content, trace metal spectrometry and ferrography.

per the Westinghouse/WOG report

Marginal – ISO particle count 19/16, Viscosity at 40oC ? ± 10%, TAN ? 0.16 mg KOH/g,

Spectroscopy (ppm) – Si > 22, Fe > 2, Cu > 2, Pb > 6, Sn > 4, B > 5, Water ? 140 ppm, Rotary

Pressure Vessel Oxidation Test ? 400 minutes, Insoluble Filter Residue (5 micron) ? 2.4

mg/100ml. Unacceptable – ISO particle count 20/17, Viscosity ? ± 13%, TAN ? 0.20 mg KOH/g,

Spectroscopy (ppm) – Si > 63, Fe > 3, Cu > 6, Pb > 18, Sn > 10, B > 18, Water ? 240 ppm,

Rotary Pressure Vessel Oxidation Test ? 320 minutes, Insoluble Filter Residue (5 micron) ? 3.3 mg/100ml.

Please describe your Predictive and Preventative Maintenance program for the RCP/RRP motor at your plant with respect to the lube oil supply system. (i.e. piping, coolers, strainers, supports inspections, testing, NDE, etc

N/A

All external oil systems (external oil coolers, oil lift system, oil sight glasses, oil level switches, oil drain lines and associated valves, and all gasketed areas) are inspected each refueling outage.

Any oil leaks found are corrected at that time. All of these components are completely refurbished every 8 to 12 years when the motor is removed and refurbished.

See 7 above. Oil coolers replaced during major overhaul (30 years)

I have no knowledge of this part.

Inspected every refuel outage.

The cooler is inspected and hydro'd during the ten year motor overhaul.

Lower bearing pot is static oil volume(25 gallons) lubricating the bearings and cooled by a pancake coil heat exchanger installed in the oil reservoir. CCW flows through the cooling coils.

No strainer. Upper oil reservoir contains 175 gallons/225 gallons of oil. The oil volume is circulating by the viscosity pump turning at motor rpm speed. The oil circulates through an attached but external vertical heat exchanger. CCW provides the heat removal medium. The Motor is also designed with a high pressure oil lift system external to the RCP Motor. This system uses a self contained 10HP motor and dynex pump to service the upper bearing assembly. The piping arrangement includes a strainer/filter assembly.

Coolers visually inspected and cleaned during outages if needed.

Lift pump suction strainer and discharge filter are cleaned/ replaced every 4 years. Oil cooler is cleaned/ inspected/ pressure tested every 10 years with motor overhaul. Lift system bearing flow tested every 10 years with motor overhaul.

Self contained with flow to coolers maintained by pressure differential in the thrust bearing.

3 year

See Question 7

OIL SYSTEM IS LOOKED AT IF ALARMS HAVE COME IN OR ARE LOCKED IN.

OTHERWISE WE LOOK AT ENTIRE SYSTEM DURING PM

Both upper and lower brgs run in an oil bath with immersed coolers so there is no external piping except for jacking oil on the upper brg. The only routine PM mtce we do is change the jacking oil RV's and calibrate the jacking oil filter DP switches. We do no routine piping or

support inspections. We have switched all upper brg coolers to stainless steel coolers and have no plans to routinely inspect these. (They are inside the bearing housing.) We are planning to change all the Cu/Ni lower brg coolers but this is much more difficult and is proceeding slowly. We do no routine NDE.

N/A

Every refueling outage (18 months) inspect and clean strainers, inspect for leaks and check level. We conduct the inspections of the lube oil supply system including piping, coolers, strainers, supports inspections, testing, NDE, etc for period of O/H which is achieved per 12months

See 9.

-Check the lifting system at 52 weeks

Replaced cooling supply piping to the lower motor bearings due to leaks.

I will provide this info later.

Every RFO piping is inspected for leaks

Oil reservoir - (bath)

No additional PM performed other than visual inspection each 18 months.

Every 18 months the RCP motors are inspected for oil leaks in and around oil coolers, oil filters are changed oil levels alarms are checked in the control room, the oil lift system is leak checked and set to the proper pressure.

Electrical maintenance.

Visual inspection during hot shutdown and startup. leaks, abnormal conditions

None

We clean and test the oil coolers at the 10 year inspection. Valves, piping, strainer, pump and motor are serviced at the 10 year inspection. Pressure switch and gauge are calibrated at every outage. Oil filter is changed at every outage.

external inspection every 18 months, internal inspection every 10-12 years

Visually inspected for leakage every outage including oil coolers, under flywheel, oil lift system, and upper and lower oil pots. Strainers are replaced if oil replacement is necessary after sample results.

Do you filter or clean the new oil before adding?

Yes – 29 No – 7

Additional comments:

New oil is sampled and then run through a 5 micron filter prior to filling motor.

See question 7 for filter rating.

We send it through a filter.

Use a two filter arrangement particulate (10 and 50 micron) and moisture filtering skid.

Filter @ 5 micron

New oil is polished (filtered) prior to use. During outages in-service oil is polished for upper bearing.

WE HAVE A IN-LINE FILTER ON PUMP CART FOR NEW OIL.

We use 5 um filters.

Particle filter 10 microns

Oil is processed through a portable Y2K filtration (5-micron) unit to remove moisture and particulate during transfer between the barrel and the motor.

Solid particle contamination is an issue and we tried to implement in-situ cleaning process using a portable filtration system but we are not successful in this approach. We are still working on this.

The new oil is filtered thru a 1 micron system.

We will start in fall of 2006.
Started this recently.
3 micro mesh

Do you sample new oil?

Yes – 30 No – 6

Comments

During receipt inspection and again when we put it into the motor.
Recommended. This is how we found an additive concern and did not install new oil.
To ensure it is the correct oil.
QA performs dedication testing upon receipt. PdM tests for water and particulate prior to use.
EACH BARREL IS SAMPLED PRIOR TO USE
As part of the receipt inspection process for new oil.
New oil is sampled and dedicated for Safety-related applications. In addition, our PdM group will periodically sample new oil and send it off-site for analysis. These results are used to identify formulation changes and to update our Oilview baseline reference.
We do have a specification for this oil and we do have procedure to verify quality of fresh oil.
There is however more work to do in this area.
Yes , every new oil drum is sampled prior to use.
Batch testing only.
Per Commercial Grade Dedication process.
Receipt acceptance test for new. Sample sent to PdMA for analysis to determine correct oil and properties.
Generally not, unless adverse trends are recognized.

What modifications have been made to your plant to address RCP/RRP motor lube oil system problems?

Additional oil reservoirs in containment to accommodate leakage during fuel cycle run
4
Oil leakage collection systems
18
Oil level monitoring
12
Oil addition systems
7
Oil strainers/filters/coolers
3
Add oil while operating?
Yes 10

Comments

Complete redesign of backstop and HP lift systems.
truncated flow chamber / viscosity pump
OUR CANNING SYSTEM IS MANDATORY
Considering on-line oil addition capability

Possibly on-line oil monitoring sensors.
Oil level alarms - 'low' and 'high'
All of our drain lines are channeled to a drain pan
changing over to new collection design (fiberglass)

Describe in detail any modifications you have performed on your lube oil system.

The upper oil pump system was modified with Westinghouse's oil pump modification which added a viscosity pump system and several other changes in the upper bearing oil reservoir. Also changed the aluminum split oil pan/standpipe components to steel. We use Armstrong PF-4N gaskets material and Permatex #2 sealant on the lower oil pan gasketed areas.

External lift, backstop and circulating (cooling) oil systems completely redesigned. New system utilizes stainless steel tubing and Swagelok fittings.

That is outside of my knowledge

Revised low oil level switch height location. Lowered the alarm band for oil level.

Temporary tygon hose and funnel have been attached to oil fill connection on motor while shutdown to allow adding oil from low dose area.

Replaced Magnetrol float level switches with "reed/column" style Switches.

Can add oil at power. have level indication but it is erratic. Have ability to boroscope the siteglass at power.

Changed level indication system from static head system to bubbler system.

recently upgraded during last remanufacture period for each motor

NONE, WE SAMPLE NOW INSTEAD OF CHANGING OUT EVERY 18 MONTHS.

We have performed no modifications.

We have a maintenance to separate the status of oil level alarm monitoring two part.

The oil leakage collection system was originally installed before startup. The oil level monitoring system was change from a simple High or Low alarm--the operator could not tell which--to a remote level indication system.

We intent to modify the upper bearing tube oil in order eliminate the leakage during 2006 outage for one motor.

We have introduced oil sampling ports to both the upper and lower bearing housing. This allows us to obtain more representative samples. It would be beneficial to have access to on-line filter oil.

Oil collection system is only modification performed.

Oil addition system for adding oil from outside of the RCP vaults.

We have added an oil level monitoring system and an oil addition system where we can add oil to a RCP without entering the high radiation area of the motor and pump.

changing over to new collection design (fiberglass enclosure, dc lift oil only)

Normal upkeep and maintenance

Added filtration to the systems

remote fill system for the lower reservoir

Oil collection system per Appendix R requirements is all that I'm aware of.

What manufacture/type of lubricating oil do you utilize in your RCP/RRP motor?

MobilExxon DTE Heavy Medium (ISO 68)

Mobil SHC 824

Mobil DTE Heavy Medium in A-C, DTE Medium in West

Mobile - DTE-797 lower reservoirs and

Upper bear-Mobil DTE Heavy Med., lower bear-797
Mobil SHC 626
Mobile DTE Medium
Texaco R&O 46 turbine grade oil
Mobil DTE types, ISO 10 lower, ISO 20 upper
R&O 46
Shell R&O 32
Chevron
Mobil SHC 824
R & O 46
Imperial Oil in Canada (Exxon in US) Teresso 32
Upper: Mobil DTE Heavy Medium; Lower: Mobil DTE 797
Engen turbine 46
Regal RO46
Mobil DTE Medium
Texaco Regal oil EP 32 Premium
Gulf Harmony 68 AW
We are using steam turbine oil type Teresso 68.
Mobil SHC 824
Mobil SHC 626 - upper bearing and SHC 624 - lower
Mobil DTE 25
Shell Turbo T 46
Mobil
ESSO Teresso 32 and 46
Mobil SHC 824
CHEVRON GST 68 and 32
Texaco R&O 68
Mobil DTE-26 drive end, Mobil DTE-797 opposite dri
Mobil SHC 824
Shell Turbo T 46
Shell

Have you always used this lubricant?

Yes – 27 No – 9

If not, when were the changes made and for what reason?

We changed to this lubricant in the early 1980s due to the original design of our motors being designed with an upper bearing oil pump system that was too efficient causing air entrapment in the oil. This resulted in rapid oil degradation. The oil pump modification stated in question #15 resolved the rapid oil degradation and we decided to stay with the synthetic oil to increase time between oil change outs.

Do not know when changes were made.

Mobil SHC 825 was used at one time in the past.

Yes, but we now know that oil companies have formulated new based stock oil since companies have merged

Previous suppliers (Gulf, BP) no longer available in area.

originally used Amoco Amacon until they went out of business and could not supply Mobil was previously used but withdrew from our country and then had to switch to alternative manufacturer.

Initially we used Gulf Harmony 68 R&O oil. Then through a lubrication consolidation effort, we switched to Gulf Harmony 68 AW. We are in the process of evaluating switching to an Exxon/Mobil product in the future.

In the early 80's, to enhance oxidation inhibition

Texaco R&O 46, merger of manufacturers

Texaco. Unsure of time but it was due to a merger.

If you have changed lubricants, what results have been experienced from these changes? (good/bad/etc)

Longer run times between oil changes. Cleaner oil reservoirs have been observed during refurbishments. Another good finding during the refurbishments was minimum bearing wear. Mobil SHC 626 has shown good results.

No change known.

began to have sludging/varnishing problems when switched to the Chevron GST oil - this is because motors were not equipped with the truncated flow chamber design feature.

Mobil SHC 824 was recently reformulated. Currently Unit 1 has old formula and Unit 2 has new formula.

No difference

No.

None

excellent

none

No change known.

If you have experienced a problem with the quality of your lubrication, please describe in detail.

this problem has caused high breakaway torque characteristics for some motors and also reduces the desired axial end play

Post 10 year inspection particle counts are elevated. Polishing oil insitu is effective only when motor is operating.

The original fill of Teresso 32 lasted 10-15 years (based on TAN). However, the second fills have had much shorter lives, the worst being 2 years. We suspect formulation changes but Imperial Oil denies this. We have done extensive testing to determine the cause of this short life and so has Imperial Oil but the testing has been inconclusive. WE are now considering changing to a different type of oil. Another possible cause recently suggested is ozone build up in the brg housings, especially the upper ones which have the shortest life. The motors are 13.8 kV and it is possible we have increasing partial discharge creating ozone.

There two areas of concern: oxidation and contamination. With regard to oxidation of concern is increasing acidity and ASTM Colour. With regard to contamination of concern is water (from oil coolers) and solid particles.

Particle Count issues at the end of a 2-year cycle

No actual problems other than worried about RBOT testing results if extend oil replacement frequency past 18 months.

How often do you upgrade your RCP/RRP motor lube oil with additive packages?

We do not add additives.
Never.
Never
Never to the best of my knowledge
no additives, just change oil every refuel outage
Never
N/A
Based on Sampling
we do not add additives to oil
never
NO ADDITIVES ARE ADDED
Never. We just change it.
Not done at BFN
Never
We do not upgrade the oil with additives.
Never...we change oil based upon test results
We are not adding additives but replacing oil
Never
2-yrs
Never
NEVER
N/A
Never
Oil is changed out when indication of degradation
when needed
Change lowers e/18/m Uppers per analysis results
Never
don't do that
none
Never

What is your criterion for adding additive package to the lube oil?

Based on Sampling
Oxidation stability : more than 100min Anti-emulsification factor : less than 40
We are adding additive package only to steam turbine lubrication system. We believe that it is more cost effective to change the whole oil charge rather than add additive package.

How often do you replace the RCP/RRP motor lube oil?

Every 72 months or 4 operating cycles.
10 years
Not in three outages at least based on condition
4 RO cycles (7.5 years), but moving to cond. based
We change oil during 10 year motor overhaul.
Every fourth refueling

4 years. Replaced oil at 2 years until last year.

Based on sampling

have been changing oil every outage on those motor

Lower bearing every outage, upper bearing 5 years.

DEPENDING ON THE REPORT

As required by oil sampling. But see 19 above.

Every second refueling outage (cycle = 18 months)

Based on oil analysis. Typically 3-6 years.

Depending on the results of the oil analysis.

Condition based

Usually every four to six years.

Changed based on oil analysis

we have motors with as much as 5 cycles on the upp

Not sure, many years service.

as needed based on sample

Condition Based change

after every overhaul or if oil properties degrade.

dependent on sample results

Only replace upon sample analysis results.

cont. from question 22, due to sludging problems experienced, we have been changing oil every outage on those motors not yet equipped with the truncated flow chamber design. Positive results from this upgrade should allow greater than 3 cycles of operation to occur on a single batch of oil.

C

TRANSLATED TABLE OF CONTENTS

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Electric Power Research Institute (EPRI)

内容

I简介.....	1-1
1.1目的.....	1-1
1.2组织.....	1-1
2术语词汇表.....	2-1
3背景信息.....	3-1
简介.....	3-1
4RCP/RRP马达润滑油系统.....	4-1
5润滑油系统泻落补救措施.....	5-1
6参考文献.....	6-1
A附录A.....	A-1
B附录B调查汇总.....	B-1

图列表

图4-1典型的西屋电器RCP电机	4-2
图4-2推力轴承装置.....	4-3
图4-3油压支承系统.....	4-5
图4-4电机概览.....	4-7
图4-5上部电机轴承.....	4-10
图4-6上部的承压面积	4-11
图4-7上部轴承的外部轴承油	4-12
图4-8下部承压区域的潜在泄漏路径	4-13
图4-9下部电机承压面积	4-14
图4-10下部轴承冷却管	4-15
图4-11油冷却器渗透耳轮缘区域的照片	4-15
图4-12下部油底盘	4-16
图4-13下部油底盘的一半	4-17
图4-14就位的下部油底盘	4-18
图4-15在耳轮缘“涂了黄油”的下部油底盘	4-18
图4-16下部轴承储油罐放泻隔离阀	4-19
图4-17 下部轴承的曲径汽封.....	4-20
图4-18油压支承系统中的常见泄漏路径.....	4-21
图4-19棘轮板的缓冲器	4-22
图4-20由于低油面引起的下部轴承油故障	4-23
图4-21 GE电机的上部轴承.....	4-25
图4-22上部轴承的潜在泄漏路径.....	4-26
图4-23上部轴承的潜在泄漏路径.....	4-27
图4-24上部轴承的潜在泄漏路径.....	4-28

图4-25上部轴承冷却水线储油罐渗漏	4-28
图4-26上部轴承冷却水线	4-29
图4-27下部电机的承压面积	4-29
图4-28上部轴承油面的切换	4-30
图4-29上部轴承潜在泄漏路径	4-31
图4-30上部轴承油底盘的安装	4-32
图4-31上部轴承油底盘的安装	4-32

TABLE DES MATIERES

1 introduction	1-1
1.1 Objectif	1-1
1.2 Organisation	1-1
Glossaire	2-1
L'information du contextes	3-1
Introduction	3-1
Systèmes de lubrification des moteurs de RCP/RRP	4-1
remèdes du système d'huile de fuite de graissage	5-1
références	6-1
ANNEXE A	A-1
Résumé d'enquête de l'annexe B.....	B-1

LISTE DE FIGURES

Le schéma moteur type de RCP Westinghouse	4-2
Le schéma palier de butée.....	4-3
Le schéma système de levage d'huile	4-5
Le schéma vue d'ensemble de moteur	4-7
Le schéma roulement supérieur de moteur	4-10
Le schéma section de roulement supérieure	4-11
Le schéma pétrole externe de roulement supérieur	4-12
Le schéma circuits inférieurs de fuite de section de roulement	4-13
Le schéma section de roulement inférieure de moteur.....	4-14
Le schéma serpentin de refroidissement de roulement inférieur	4-15
Le schéma photo de la région de bride de pénétration de radiateur d'huile	4-15
Le schéma carter d'huile inférieur	4-16
Le schéma moitiés inférieures de carter d'huile	4-17
Le schéma carter d'huile inférieur en place	4-18
Le schéma carter d'huile inférieur en bride « beurrée »	4-18
Le schéma soupape d'isolement inférieure de drain de réservoir de roulement.....	4-19
Le schéma joint inférieur de labyrinthe de roulement	4-20
Le schéma circuits courants de fuite dans le système de levage d'huile.....	4-21
Le schéma amortisseur de plaque de rochet de.....	4-22
Le schéma les dégâts inférieurs d'huile de roulement du niveau d'huile inférieur	4-23
Le schéma roulement supérieur de moteur	4-25
Le schéma circuits potentiels de fuite de roulement supérieur	4-26
Le schéma circuits potentiels de fuite de roulement supérieur	4-27
Le schéma circuits potentiels de fuite de roulement supérieur	4-28
Le schéma lignes de flottaison supérieures de refroidissement de roulement pénétrations de réservoir d'huile.....	4-28
Le schéma lignes de flottaison supérieures de refroidissement de roulement	4-29
Le schéma section de roulement inférieure de moteur.....	4-29
Le schéma contact inférieur de niveau d'huile de roulement.....	4-30
Le schéma circuit potentiel de fuite de roulement inférieur.....	4-31
Le schéma carter d'huile inférieur de roulement étant monté	4-32
Le schéma carter d'huile inférieur de roulement étant monté	4-32

目次

1	はじめに	1-1
	1.1目的	1-1
	1.2構成	1-1
2	用語集	2-1
3	背景情報	3-1
	はじめに	3-1
4	RCP / RRPモーターの潤滑油システム	4-1
5	潤滑油システムの漏えい修理	5-1
6	参照	6-1
A	付録A	A-1
B	付録B サーベイ要約	B-1

図のリスト

図4-1	一般的なWestinghouse社製RCPモータ	4-2
図4-2	スラストベアリング・アセンブリ	4-3
図4-3	オイルリフト・システム	4-5
図4-4	モータ概観	4-7
図4-5	上部モータベアリング	4-10
図4-6	上部ベアリング部	4-11
図4-7	上部ベアリング外部オイル	4-12
図4-8	下部ベアリング部の潜在漏えい経路	4-13
図4-9	下部モータベアリング部	4-14
図4-10	下部ベアリング冷却コイル	4-15
図4-11	オイルクーラ貫通フランジ部の写真	4-15
図4-12	下部オイルパン	4-16
図4-13	下部オイルパン	4-17
図4-14	下部オイルパンの設置	4-18
図4-15	“ Buttered” フランジの下部オイルパン	4-18
図4-16	下部ベアリング・リザーバードレン隔離弁	4-19
図4-17	下部ベアリング・ラビリンスシール	4-20
図4-18	オイルリフト・システムの共通漏えい経路	4-21
図4-19	ラチェット・プレートのショックアブソーバー	4-22
図4-20	オイルレベル低による下部ベアリングオイルのダメージ	4-23
図4-21	GE社製モーターの上部ベアリング	4-25
図4-22	上部ベアリングの潜在漏えい経路	4-26
図4-23	上部ベアリングの潜在漏えい経路	4-27

図4-24	上部ベアリングの潜在漏えい経路.....	4-28
図4-25	上部ベアリング冷却水ラインのオイルリザーバー貫通部.....	4-28
図4-26	上部ベアリング冷却水ライン.....	4-29
図4-27	下部モータベアリング部.....	4-29
図4-28	下部ベアリングのオイルレベルスイッチ.....	4-30
図4-29	下部ベアリングの潜在漏えい経路.....	4-31
図4-30	設置されている下部ベアリング・オイルパン.....	4-32
図4-31	設置されている下部ベアリング・オイルパン.....	4-32

CONTENIDO

1	Introducción	1-1
1.1	Propósito	1-1
1.2	Organización	1-1
2	Glosario de términos	2-1
3	Información previa	3-1
	Introducción	3-1
4	Sistemas de lubricación de motores de la RRP/RCP	4-1
5	Soluciones a las fugas de aceite de lubricación	5-1
6	Referencias	6-1
A	APÉNDICE A	A-1
B	Resumen del estudio del apéndice B	B-1

LISTA DE FIGURAS

Figura 4-1 Motor típico de una RCP de Westinghouse	4-2
Figura 4-2 Montaje del cojinete axial	4-3
Figura 4-3 Sistema de elevación de aceite	4-5
Figura 4-4 Visión general del motor.....	4-7
Figura 4-5 Cojinete superior del motor	4-10
Figura 4-6 Sección superior del cojinete	4-11
Figura 4-7 Aceite externo del cojinete superior	4-12
Figura 4-8 Posibles vías de fuga de la sección inferior del cojinete	4-13
Figura 4-9 Sección inferior del motor del cojinete	4-14
Figura 4-10 Serpentin de refrigeración del cojinete inferior.....	4-15
Figura 4-11 Fotografía de la zona de la brida de penetración del enfriador de aceite	4-15
Figura 4-12 Colector inferior de aceite	4-16
Figura 4-13 Mitades del colector inferior de aceite	4-17
Figura 4-14 Colector inferior de aceite (instalado)	4-18
Figura 4-15 Colector inferior de aceite en la brida “untada” con pasta sellante	4-18
Figura 4-16 Válvula de aislamiento inferior del desagüe del depósito del cojinete ...	4-19
Figura 4-17 Sello de laberinto inferior del cojinete	4-20
Figura 4-18 Vías de fuga comunes en el sistema de elevación de aceite	4-21
Figura 4-19 Amortiguador de la placa de trinquete.....	4-22
Figura 4-20 Daños por aceite en la parte inferior del cojinete debido a bajo nivel de aceite	4-23
Figura 4-21 Cojinete superior del motor de GE	4-25
Figura 4-22 Vías de fuga comunes del cojinete superior	4-26
Figura 4-23 Vías de fuga comunes del cojinete superior	4-27
Figura 4-24 Vías de fuga comunes del cojinete superior	4-28
Figura 4-25 Penetraciones del depósito de aceite de las líneas de agua superiores de enfriamiento del cojinete	4-28
Figura 4-26 Líneas de agua superiores de enfriamiento del cojinete	4-29
Figura 4-27 Sección inferior del motor del cojinete.....	4-29
Figura 4-28 Interruptor de nivel de aceite del cojinete inferior	4-30
Figura 4-29 Vías de fuga comunes del cojinete inferior.....	4-31
Figura 4-30 Colector de aceite del cojinete inferior (instalado).....	4-32
Figura 4-31 Colector de aceite del cojinete inferior (instalado)	4-32

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