NOTES & REFERENCES

Module 234-10

THE TURBINE LUBRICATING OIL SYSTEM

OBJECTIVES:

After completing this module you will be able to:

10.1 a) Explain how the bearing inlet oil pressure is controlled when the oil is supplied by each of the following pumps: *⇔ Page 3*

i) Main oil pump;

ii) Auxiliary oil pump;

iii) Emergency oil pump;

iv) Jacking oil pumps.

b) Describe the adverse consequences/operating concerns caused by the following upsets: *⇔ Pages 3-5*

i) Lube oil pressure too low (3);

ii) Jacking oil pressure too low (2);

iii) Lube/Jacking oil pressure too high (2).

c) State four protective actions initiated by dropping bearing inlet oil pressure. *⇔ Page 5*

d) State three features used in the turbine lube oil system to protect it against overpressure. *⇔ Pages 5-6*

10.2 Describe the adverse consequences/operating concerns caused by each of the following upsets:

a) Bearing inlet oil temperature too low (3); *⇔ Page 7*

b) Bearing inlet oil temperature too high (2). *⇔ Page 8*

10.3 a) For each of the typical lube oil impurities listed in the table on the next page, describe the indicated number of: *⇔ Page 9-14*

i) Sources;

ii) Adverse consequences/operating concerns caused by its presence in the oil;

iii) Means of its removal.

NOTES & REFERENCES

Impurity	Number of Source	Number of Consequences	Number of Means of removal
Water	4	2	3
Oxidation products	2	3	3
Gases	3	3	3
Abrasive particles	4	1	3

Pages 9-11 ⇔ *Pages 11-12* ⇔ *Pages 12-13* ⇔ *Pages 13-14* ⇔

Pages 14- 15 ⇔

b) Describe two general operating practices used to ensure satisfactory purity of the turbine lube oil.

10.4 For the lube oil tank level, describe:

Pages 15- 16 ⇔

a) One adverse consequence/operating concern caused by this level being:

i) Too low;

ii) Too high;

Page 16 ⇔

b) Examples of the causes of a low level alarm (1) and high level alarm (3).

* * *

INSTRUCTIONAL TEXT

INTRODUCTION

In the previous turbine courses, the function, major components and operation of the turbine lubricating oil system were described. Based on this general information, this module covers the following topics:

- Lube oil pressure control, upsets and protective actions;
- Abnormal lube oil temperature;
- Lube oil impurities;
- Lube oil tank level upsets.

For easy reference, a simplified pullout diagram of a typical turbine lubricating oil system is attached to the module end. Due to numerous station specific differences, the names, numbers and/or locations of the system components shown in this diagram may differ somewhat from those in your station. Some pumps that are specific to only one station are left out.

A few, slightly different names of this system are used in different stations. For the purpose of this course, the name *turbine lubricating oil system* has been chosen.

NOTES & REFERENCES

LUBE OIL PRESSURE CONTROL, UPSETS AND PROTECTIVE ACTIONS

Control

⇔ *Obj. 10.1 a)*

When oil is supplied by the **main oil pump**, the bearing inlet oil pressure is **controlled by the lube oil relief valve**. The valve operates by spilling the surplus oil back to the lube oil tank when the oil pressure exceeds a preset level. The same valve **also** provides **overpressure protection**.

In some stations, the **same valve controls** the bearing inlet oil pressure when the oil is supplied by **the auxiliary oil pump**. In the other stations, this pump has **its own regulator**. The regulator operates the same way as the lube oil relief valve: when the pump discharge pressure is too high, the regulator spills the surplus oil back to the lube oil tank. Typically, the pressure setpoint of this regulator is below that of the lube oil relief valve such that the latter remains closed.

The **emergency oil pump** is sized to supply bearing oil at a pressure of only about 40-60% of its normal value. At such low pressure, the lube oil relief valve is closed, of course. Note that under the emergency circumstances when this pump is used, the fact that the **bearing inlet oil pressure is not controlled** is unimportant. What really counts is that all the oil circulated by the pump is supplied to the turbine generator bearings in an attempt to maintain their inlet oil pressure at a safe level. In practice, in order to minimize chances for bearing damage, the turbine would be tripped, and the pump would maintain adequate bearing lubrication and cooling to allow safe shutdown.

The **jacking** (lifting) **oil pressure** at the bearing inlet is also **not controlled**. Recall that the jacking oil pumps are positive displacement type, and for such pumps, their discharge pressure depends only on the discharge line resistance to flow (assuming that the pump and its driver are strong enough). Hence, the jacking oil pressure rises until the turbine generator rotor is lifted enough to allow oil to flow through the bearings at the rate forced by the pumps. As in any other positive displacement pump, the maximum discharge pressure is limited – for overpressure protection purposes – by a pressure relief valve installed in the discharge line of each jacking oil pump.

Upsets

⇔ *Obj. 10.1 b)*

Maintenance of proper oil pressure at the bearing inlet is extremely important for safe and trouble-free operation of the turbine generator. Discussed below are three cases of improper oil pressure.

NOTES & REFERENCES

Too low pressure of the lubricating oil:

1. **May cause turbine generator damage** as follows:

   a) The **bearing(s)** whose inlet oil pressure is too low **may get damaged** due to inadequate cooling and lubrication.

      When the bearing inlet oil pressure decreases, so does the oil flow through the bearing. This impairs bearing cooling and formation of the oil wedge in the bearing. The resultant overheating and possible rubbing can damage the bearing babbitt lining. More information on the damage mechanisms is provided in module 234-14.

   b) The whole machine may suffer a **large scale damage** if loss of oil has damaged many bearings.

      Severe damage to many bearings can cause large vibration of the turbine generator rotor. This can lead to rubbing damage to turbine seals and possibly blades, further amplifying the vibration. The generator hydrogen seals can also fail (even if seal oil is available), if the generator bearings are destroyed. This may result in a generator hydrogen fire.

2. **Should cause a turbine trip** to prevent, or at least minimize, turbine generator damage.

   This action, although absolutely necessary, results in **loss of production.**

In turn, **too low jacking oil pressure:**

1. **May damage the affected turbine generator bearing(s)** due to inadequate lubrication.

   This can happen when turbine speed is too low for adequate hydrodynamic lubrication of the bearings. The resultant rubbing in the bearing(s) can wipe out the babbitt lining.

2. **May result in unavailability of the turning gear.**

   When jacking oil pressure is too low, the turning gear may become unavailable due to:

   – an interlock in the turning gear motor control circuit disconnecting power supply to the motor, or

   – the motor tripping on overload as loss of jacking oil makes turning the turbine generator rotor more difficult.

   Recall that unavailability of the turning gear causes certain adverse consequences and operating concerns. For example, it can lead to excessive rotor hogging while shutting down the turbine. Or, it can force a delay during turbine startup, resulting in loss of production. It must be stressed that these consequences, as much as they are unwelcome, are far more preferable than the very likely damage to poorly lubricated bearing(s).

The major concern caused by **too high pressure of lubricating or jacking oil** is that it **increases the risk of system overpressure failure** if the relief valve(s) failed to operate. The resultant oil leak causes operating concerns such as:

- A fire hazard if the oil comes in contact with a hot turbine casing or steam pipeline;
- Loss of oil pressure if the leak is large enough;
- An environmental hazard as the leaking oil can contaminate (via floor sumps) the station effluent.

Protective actions

⇔ *Obj. 10.1 c)*

From the above, you can see that some of these consequences can be quite serious. This applies particularly to loss of lube oil pressure. To reduce the risk of possible equipment damage, proper **protective actions** (shown in Fig. 10.1) are performed automatically **upon dropping bearing inlet oil pressure.** Due to station specific differences, the diagram is simplified, and therefore the sequence and the type of the protective actions in your station may differ somewhat.

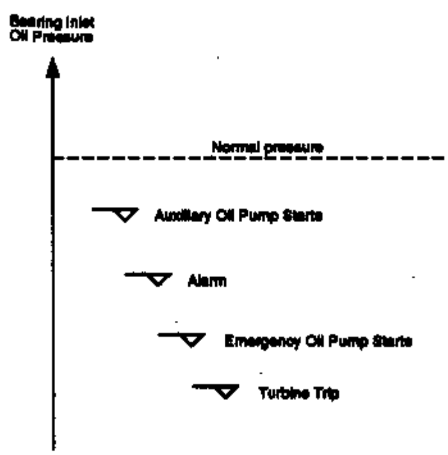

Fig. 10.1. Major automatic protective actions on dropping bearing inlet oil pressure.

Overpressure protection

⇔ *Obj. 10.1 d)*

The following features are employed in the turbine lube oil system for overpressure protection:

1. **A lube oil relief valve** installed in the common discharge piping of the oil pumps.

   This protection is particularly important in those units where the main oil pump is a positive displacement type. However, even when the main oil pump is centrifugal, it can produce excessive oil pressure in the event of abnormally high turbine overspeed*.

* Recall that discharge pressure of a centrifugal pump increases quickly with rising pump speed.

NOTES & REFERENCES

2. One pressure **relief valve in each jacking oil line.**

   This protection is necessary because the jacking oil pumps, being positive displacement type, can generate excessive discharge pressure when the oil line is blocked.

3. **The explosion door(s)** in the lube oil tank cover.

   This feature protects the tank against damage due to an explosion of the atmosphere inside*.

* More information is provided on page 12.

SUMMARY OF THE KEY CONCEPTS

- When oil is supplied by the main oil pump, the bearing inlet oil pressure is controlled by the lube oil relief valve. The valve operates by spilling the surplus oil back to the tank when the pressure reaches a certain level.
- When oil is supplied by the auxiliary oil pump, the bearing inlet oil pressure is also controlled by spilling the surplus oil to the tank. Depending on the station, this is performed either by the lube oil relief valve or by the auxiliary oil pump regulator.
- When the emergency oil pump supplies oil, its pressure at the bearing inlet is not controlled because it is well below the setpoint of the lube oil relief valve. Under emergency conditions, it is important to supply all available oil to the bearings in an attempt to maintain their oil pressure as high as possible.
- The jacking oil pressure at the bearing inlet is not controlled. As the oil is supplied by a positive displacement pump, its pressure rises until the bearing resistance to the oil flow is overcome. This happens when the turbine generator rotor is lifted off the bearings.
- Low lube oil pressure can damage turbine generator bearings due to inadequate cooling and lubrication. When many bearings have failed, other parts of the turbine generator can also suffer damage due to high vibration and rubbing. An automatic turbine trip should occur to prevent/minimize damage.
- Low jacking oil pressure can damage turbine generator bearings when turbine speed is too low for adequate hydrodynamic lubrication. Also the turning gear may become unavailable.
- Too high oil pressure increases the risk of overpressure failure in the lube oil system.
- The following protective actions (listed in the order of dropping pressure) should occur in response to low bearing inlet oil pressure: the auxiliary oil pump is started up, an annunciation is given, the emergency oil pump is started up, and finally, the turbine is tripped.

NOTES & REFERENCES

- General overpressure protection in the system is provided by the lube oil relief valve. Each jacking oil line is protected by its own pressure relief valve. In addition, explosion doors in the lube oil tank cover prevent rupture of the tank, should the atmosphere inside explode.

ABNORMAL LUBE OIL TEMPERATURE

In the previous turbine courses, you learned how the required bearing inlet oil temperature is controlled. This section describes the adverse consequences/operating concerns caused by this temperature being out of the normal operating range*.

* Typically, about 35-40°C.

⇔ *Obj. 10.2 a)*

When bearings are supplied with **lubricating oil that is too cool**, the following adverse consequences/operating concerns result:

1. **Increased risk of** heavy vibration of the turbine generator due to a phenomenon referred to as **oil whip or oil whirl.**

   Here is a simplified description of this phenomenon. With decreasing temperature, oil viscosity increases. As a result, oil in the bearing exhibits a stronger and stronger tendency to cling to the shaft surface, and thus be dragged around the bearing. When the oil temperature decreases excessively, so much oil is driven around the bearing that the oil wedge in the bearing looses its stability, and its thickness pulsates. Needless to say, the unstable oil wedge excites high vibration of the turbine generator rotor*.

   * How such vibration can damage the machine is described in the final module.

2. **Increased risk of bearing overheating.**

   Admittedly, it sounds strange that cool oil can result in bearing overheating. However, this can be easily explained. Since oil viscosity increases with decreasing temperature, the resistance to flow through the bearing oil supply piping increases. In most stations, this reduces the oil flow rate because the main, auxiliary and emergency oil pumps are of the centrifugal type (recall that for centrifugal pumps, their capacity is sensitive to system head). The reduced oil flow may be too small for adequate bearing cooling, resulting in bearing overheating.

3. **Loss of production due to forced protective actions.**

   To prevent damage due to oil whip or bearing overheating, certain protective actions are taken when bearing vibration or metal temperature is too high*. For example, the turbine generator may have to be unloaded or tripped. While these actions are absolutely necessary for equipment protection, they result in loss of production for which poor oil temperature control may be responsible.

   * These actions are described in the final module.

NOTES & REFERENCES

Obj. 10.2 b) ⇔

When the **bearing inlet oil is too hot**, the following adverse consequences and operating concerns result:

1. **Increased risk of bearing damage** due to:

   - Overheating – as the hot oil cannot keep the bearing metal temperature at the safe level;
   - Metal-to-metal contact between the shaft and the bearing lining;
   - Increased vibration levels.

   The last two effects are caused by reduced oil viscosity (due to increased temperature) resulting in a thinner oil wedge in the bearing. To understand it, note that it is the viscosity forces between the oil and the spinning shaft surface which force the oil into the wedge gap underneath the shaft. Without these forces, no oil wedge would be formed. Thus, when these forces decrease, so does the oil wedge. Obviously, its reduced thickness increases the risk of rubbing between the shaft and the bearing lining. It also reduces dampening of rotor vibration which leads to increased vibration levels. Note that the bearing oil wedge is one of the most significant sources of rotor vibration dampening. This is achieved much the same way as hydraulic shock absorbers dampen vibration of the car suspension.

2. **Loss of production due to forced protective actions.**

   As mentioned above, high bearing metal temperature or vibration can force turbine unloading or a trip, resulting in a loss of production which can be attributed to inadequate oil temperature control.

SUMMARY OF THE KEY CONCEPTS

- When temperature decreases too much, oil in the bearing becomes so viscous that it clings to the shaft surface which drags it around the bearing. This makes the oil wedge in the bearing lose its stability. The pulsating wedge excites high rotor vibration referred to as oil whip or oil whirl.
- Too low temperature – and hence, too large viscosity – of the bearing inlet oil causes the bearing oil flow to decrease due to increased friction in the oil supply piping. The reduced oil flow may be too small for adequate cooling, causing bearing overheating and possible damage.
- When bearing oil is too hot, it cannot maintain the bearing metal temperature within its safe range. Bearing damage due to overheating may result.
- Reduced viscosity of hot oil impairs the formation of an oil wedge in the bearing. As the wedge becomes thinner, turbine vibration levels may rise due to reduced dampening, and the risk of rubbing in the bearing increases.

NOTES & REFERENCES

- Through high bearing vibration or metal temperature, improper bearing inlet oil temperature may force protective actions, resulting in a loss of production.

You can now work on **assignment questions 1-5.** *⇔ Pages 17-19*

LUBE OIL IMPURITIES

In this section, you will learn about the four major impurities of turbine lubricating oil: water, oxidation products, gases, and abrasive particles. The adverse consequences/operating concerns, major sources and means of removal of each of these impurities are described. Two general operating practices used to ensure the proper purity of the oil are also discussed.

WATER

⇔ Obj. 10.3 a)

Sources

1. **Absorption of atmospheric moisture.**

   During turbine operation, atmospheric air – which always contains some water vapour – enters the oil system via the bearing oil seals. The inleakage happens because:

   – The shaft surface velocity is too large to allow for contact between the shaft and the seal. Thus, a leak path is open.

   – Slightly subatmospheric pressure is maintained inside the bearing housing and its drain line by the vapour extraction fans installed on the lube oil tank cover. Why is this pressure maintained? First, to prevent oil mist from escaping past the bearing oil seals into the turbine hall. Second, to prevent accumulation of hydrogen and oil vapour in the lube oil tank atmosphere, which could create an explosion hazard.

   Some other possible leak paths include poorly fitting or missing gaskets in the drain lines or lube oil tank cover.

   During turbine shutdown, the oil tank may be open for inspection, resulting in a large contact area between the oil in the tank and the humid air in the turbine hall. Because during shutdown, the oil in the tank can be relatively cool, condensation of moisture is promoted.

2. **A leaking turbine gland seal.**

   When a gland seal is leaking steam, the humidity of the surrounding air is increased. The humid air enters the adjacent bearing, as described above. This is promoted by a very small distance between turbine bearings and the adjacent gland seals.

NOTES & REFERENCES

3. **A leaking oil cooler.**

   Since water is used for oil cooling, a leaking cooler may result in contamination of oil with water. In most stations, this is prevented during normal operation by maintaining the oil pressure above the cooling water pressure. However, even in these stations, water in-leakage can occur during a turbine shutdown when the oil is not pressurized.

   Note that this arrangement – where during normal operation, oil pressure is maintained above cooling water pressure – can result in oil leak into the cooling water, and with it into the environment. To minimize pollution, prompt actions must be taken to locate and stop the leak. Details are left for the station specific training.

4. **Makeup additions of contaminated oil.**

Adverse consequences and operating concerns

The typical adverse consequences/operating concerns caused by the presence of water in lube oil are:

1. **Degraded oil properties** due to:
   - Formation of emulsions whose lubricative properties are lower than those of pure oil;
   - Washing out of special oil additives, eg. rust inhibitor;
   - Accelerated oxidation of the oil and its additives.
2. **Promoted corrosion and scale formation** in the equipment to which the oil is supplied.

These consequences result in **accelerated wear of equipment** such as bearings and generator hydrogen seals. Eventually, bearing or seal **failure may occur**, forcing a unit outage. The potential for serious damage is increased in the units where turbine oil is used as a hydraulic fluid in the turbine governing system. Recall from module 234-7 that poor quality of this fluid can cause massive destruction of the turbine generator and the nearby equipment if the turbine valves failed to operate as required upon a load rejection or turbine trip.

Removal

Water is **removed from the oil by:**

1. **The lube oil purifier.**

   Depending on the station, the purifier is of either the centrifugal or the vacuum treatment type. The former removes free water (due to the difference between the oil and water densities), but cannot separate emulsified or dissolved water. Vacuum purifiers, available in new stations, do not have these limitations.

NOTES & REFERENCES

2. **The vapour extraction fans.**

   The fans, installed in the lube oil tank cover, remove water vapour that is released from the surface of the hot oil in the tank.

3. **Drainage from the bottom of the oil tank.**

   This can be done during a long outage when water, being heavier than oil, collects at the tank bottom.

SUMMARY OF THE KEY CONCEPTS

- Water gets into turbine lube oil due to absorption of humid air. A leaking turbine gland seal or oil cooler, or makeup addition of contaminated oil can be other sources.
- Water degrades oil properties as it forms emulsions, washes out oil additives and accelerates oxidation. Water also promotes corrosion and scale formation in the equipment through which the oil is circulated. Accelerated equipment wear and possible failure may result.
- During normal operation, water is removed from the oil by the oil purifier and the vapour extraction fans. During a long outage, water can also be drained from the bottom of the lube oil tank.

OXIDATION PRODUCTS

⇔ *Obj. 10.3 a) continued*

Sources

Normally, oxidation products are **formed in the oil** itself due to complex chemical reactions between the oil, air, water and metals. The rate of oxidation increases quickly with rising temperature. Water and some metals (like copper) are also known to accelerate oil oxidation. The final products are resins, sludge and organic acids.

Oxidation products can also be **added to the system** when contaminated makeup oil is used.

Adverse consequences and operating concerns

The presence of oxidation products in the oil results in the following adverse consequences/operating concerns:

1. **Degradation of the oil lubricative properties** by sludge and resins.
2. **Accelerated corrosion of the system components** mainly by acidic compounds.

NOTES & REFERENCES

3. **Accumulation of sludge** in the bearing oil passages, coolers, filters, valves, etc. This can result in many problems such as impaired bearing cooling (due to reduced oil flow) or valve sticking.

Ultimately, accelerated equipment wear and possible failure can result, as described on page 10.

Removal

Oxidation products are removed mainly **by the oil purifier**. Thick sludge and resins are also removed by the oil **filters and strainers**.

SUMMARY OF THE KEY CONCEPTS

- Oxidation products (sludge, resins and organic acids) are formed in the oil due to complex chemical reactions between the oil, air, water and metals. Additions of deteriorated oil are another possible source of these impurities.
- Oil oxidation degrades its lubricative properties and accelerates corrosion of the system components. Accumulation of sludge can result in bearing overheating or valve sticking.
- Oxidation products are removed from the oil mainly by the oil purifier. Oil filters and strainers also contribute to their removal.

Obj. 10.3. a) ⇔ continued

GASES

Sources

They can enter or be produced in the lube oil system as follows:

1. **Air** – enters the system through bearing oil seals or lube oil tank cover gaskets as described earlier;
2. **Hydrogen and carbon dioxide** – are absorbed by the oil when it flows through the generator hydrogen seals*;
3. **Oil vapour** – is produced in the lube oil tank and bearing drain lines filled only partially with hot oil.

* Recall that the same oil which is used in the turbine lube oil system is also used in the generator seal oil system. The generator atmosphere contains not only hydrogen, but also some carbon dioxide. The latter is used to prevent mixing of hydrogen and air during filling and emptying of the generator.

Adverse consequences and operating concerns

The presence of these gases in the oil causes the following adverse consequences/operating concerns:

1. **Explosion and fire hazard** due to the presence of a mixture of hydrogen, oil vapour and air in the oil tank atmosphere. A safety hazard and equipment damage could result.

NOTES & REFERENCES

2. **Accelerated oil oxidation and system corrosion** due to the presence of air and carbon dioxide*.
3. Possible **oil foaming** which worsens the lubricating and cooling properties of the oil and may impair pump performance, to name a few possible consequences.

* Recall that carbon dioxid – when combined with w: ter – creates corrosive ca bonic acid.

As described in the previous sections, accelerated corrosion and degraded oil properties result in faster equipment wear and possibly failure.

Removal

Gases are removed from the oil by:

1. **The vapour extraction fans** which continuously vent the oil tank to atmosphere and maintain slightly subatmospheric pressure in the tank;
2. **The hydrogen detraining tanks** and, in some stations, **the seal oil vacuum treatment plant in the generator seal oil system;**
3. **The oil purifier** if it is **of the vacuum treatment type.** Here, degassing occurs when the solubility of gases in the oil is greatly reduced by a combined effect of high vacuum and elevated temperature*.

* About 5-10 kPa(a) and 70-80°C.

SUMMARY OF THE KEY CONCEPTS

- Air enters the lube oil system due to slightly subatmospheric pressure in the lube oil tank. Hydrogen and carbon dioxide dissolve in the oil flowing through the generator hydrogen seals. Oil vapour is produced in the oil tank and bearing drain lines which are only partially filled with hot oil.
- A mixture of hydrogen, oil vapour and air in the oil tank atmosphere creates an explosion and fire hazard. Air and carbon dioxide in the oil result in accelerated oil oxidation and system corrosion. Gases in the oil can cause foaming.
- Gases are removed from the oil by the vapour extraction fans, hydrogen detraining tanks and (where installed) the seal oil vacuum treatment plant in the generator seal oil system.

ABRASIVE PARTICLES

⇔ *Obj. 10.3 a)* *continued*

Sources

Typical sources of abrasive particles in lube oil include:

1. **Normal equipment wear and corrosion** which generate tiny metal particles, fibres from the gaskets in the system, flakes of paint and rust, etc. **Equipment breakdown** (eg. failure of the main oil pump impeller) can also produce larger debris.

NOTES & REFERENCES

2. **Dirt in the air** which is sucked into the subatmospheric part of the system as described earlier.
3. **Leftovers after maintenance** under dirty conditions followed by inadequate system flushing.
4. **Makeup additions of dirty oil.**

Adverse consequence

The major adverse consequence caused by abrasive particles in the oil is that it **accelerates wear and promotes failure** of the equipment served by the oil. For instance, the bearing babbitt surfaces, shaft journals and generator hydrogen seals can get scratched by large particles. Very fine particles can, over relatively long periods of time, lap journals, causing waviness. If the oil is used in the turbine governing system, abrasive particles can cause system malfunction and possibly catastrophic failure, as described in module 234-7.

Removal

Abrasive particles are **removed by strainers, filters and the oil purifier**.

SUMMARY OF THE KEY CONCEPTS

- Abrasive particles are formed in the oil system due to normal equipment wear and corrosion, and occasionally – due to equipment failure. They can be brought into the system with the air leaking into the subatmospheric part of the system. Poor maintenance workmanship and makeup additions of dirty oil are other possible sources.
- Particles in the oil accelerate wear and promote failure of the equipment served by the oil.
- Particles are removed from the oil by strainers, filters and the oil purifier.

Obj. 10.3 b) ⇔

GENERAL OPERATING PRACTICES USED TO ENSURE SATISFACTORY PURITY OF LUBRICATION OIL

1. **Proper operation of the oil purification equipment** as required or recommended in the operating manual. For example:
   - The oil purifier should be used continuously. Even during turbine shutdown, the purifier should not be down for more than one week, unless the lube oil system is in the drained state. Otherwise, absorption of atmospheric moisture can result in excessive water content in the oil. For best results, purifier operation should be monitored.

For instance, proper vacuum and temperature should be maintained in the vacuum treatment type purifier.

- The pressure drop (Δp) across filters should be monitored, and the cartridges changed when the Δp is too high (cartridge plugged) or too low (cartridge ruptured or missing).
- Proper vacuum should be maintained in the oil tank to prevent accumulation of water and gases.

2. **Routine analyses of the oil** and, appropriate **corrective actions** if necessary. Important points are:
   - Strict adherence to the oil sampling procedure is extremely important, because improper sampling yields misleading results which can lead to serious operational problems;
   - Proper corrective actions must be taken when the analysis results indicate abnormal levels of impurities. For instance, turbine gland seals and oil coolers should be checked for leaks when high water content in the oil has been found.

In recent years, gaining popularity are wear-particle analyses. Performed in addition to the traditional chemical analyses, they monitor the quantity, size and type of particles in the oil. This valuable tool of preventive maintenance can provide an early warning of upcoming failure, and usually can pinpoint the location(s) of abnormal wear. Typically, these analyses are done by off-site specialized laboratories.

SUMMARY OF THE KEY CONCEPTS

- To ensure satisfactory quality of turbine oil, the purification equipment must be operated properly. In addition, oil purity is monitored by taking routine samples for analyses. Strict adherence to the sampling procedure is very important to avoid misleading analysis results.

OIL TANK LEVEL UPSETS

Adverse consequences and operating concerns

⇔ Obj. 10.4 a)

The major adverse consequence/operating concern caused by **too low tank level** is **impaired pump performance** due to cavitation and possibly vapourlocking or gaslocking.

The lower the oil level, the smaller the suction head of the pumps in the tank. Pump **cavitation** and eventually **vapourlocking** can result. The lowered level can also lead to ingress of gases from the tank atmosphere into the pump suction piping, and then the pump itself. An excessive **accu-**

NOTES & REFERENCES

mulation of gases in the pump can decrease its capacity, and finally result in pump **gaslocking.**

Severe pump cavitation and entrainment of gases (not to mention vapour- and gas-locking) **accelerate pump wear and may result in failure.** When the pump performance is severely impaired, the **bearing inlet oil pressure is decreased.** The attendant adverse consequences and operating concerns have been described earlier in this module.

Too high tank level increases the risk of tank overfill. The resultant oil spill has its own adverse consequences such as an environmental hazard.

Obj. 10.4 b) ⇔

Causes

Under the assumption that the level instrumentation is fine, typical causes of oil tank level alarms are as follows:

1. A **low level** alarm can be caused by an **oil leak,** eg. through a bearing seal or in a cooler.
2. A **high level** alarm may result from:
   - **Excessive addition of makeup oil;**
   - **Large water in-leakage in an oil cooler;**
   - Large quantities of **oil descending into the tank** from other parts of the system when it is being shut down.

SUMMARY OF THE KEY CONCEPTS

- Too low lube oil tank level can result in impaired performance and accelerated wear of the operating oil pumps, possibly leading to loss of oil pressure. The upset can be caused by an oil leak in the system.
- Too high oil tank level increases the risk of oil spill due to tank overfill. This level upset can be caused by excessive additions of makeup oil or large water in-leakage in a cooler. Drainage of oil into the tank when the system is being shut down is another possible cause.

Pages 19-22 ⇔

You can now work on **assignment questions 6-10.**

ASSIGNMENT

1. When bearing oil is supplied by each of the following pumps, its pressure at the bearing inlet is controlled as follows:

   a) Main oil pump:

   ____

   ____

   ____

   b) Auxiliary oil pump:

   ____

   ____

   ____

   c) Emergency oil pump:

   ____

   d) Jacking oil pumps:

   ____

2. a) When the bearing lubricating oil pressure is too low, the following adverse consequences/operating concerns result:

   i) ______________________________

   ____

   ____

   ii) ______________________________

   ____

   ____

   b) Too low jacking oil pressure, causes the following adverse consequences/operating concerns:

   i) ______________________________

   ____

   ii) ______________________________

   ____

NOTES & REFERENCES

c) The major operating concern caused by too high oil pressure is

____

____

____

3. a) Dropping bearing inlet oil pressure results in the following automatic protective actions, listed in the order of decreasing oil pressure:

   i) ______________________________

   ii) ______________________________

   iii) ______________________________

   iv) ______________________________

   b) The turbine lubricating oil system is protected against overpressure by:

   i) ______________________________

   ____

   ii) ______________________________

   ____

   iii) ______________________________

   ____

4. If no action is taken and operation is continued, improper bearing inlet oil temperature can result in equipment damage as follows:

   a) If the oil is too cool, damage can occur due to:

   i) ______________________________

   ii) ______________________________

   b) Too hot oil can cause damage through:

   i) ______________________________

   ii) ______________________________

   iii) ______________________________

5. a) When temperature rises, oil viscosity (decreases / increases).

   b) Oil whip refers to flow pulsations in the lube oil system due to poor pump performance. (False / true)

NOTES & REFERENCES

c) Too low bearing inlet oil temperature can result in very high vibration of the turbine generator referred to as ______________ ______________ The vibration is generated as follows:

____

____

____

____

____

d) Excessively cool oil at the bearing inlet can cause bearing overheating due to ______________

____

____

____

e) Too hot oil at the bearing inlet impairs its lubrication because

____

____

____

f) If the bearing oil is too hot, turbine generator vibration can increase

because ______________

____

____

6. Typical sources of lube oil impurities are as follows:

a) Water:

i) ______________

ii) ______________

iii) ______________

iv) ______________

b) Oxidation products:

i) ______________

ii) ______________

c) Gases:

i) ______

ii) ______

iii) ______

d) Abrasive particles:

i) ______

ii) ______

iii) ______

iv) ______

6. The presence of impurities in lube oil causes the following adverse consequences/operating concerns:

a) Water:

i) ______

ii) ______

b) Oxidation products:

i) ______

ii) ______

iii) ______

c) Gases:

i) ______

ii) ______

iii) ______

d) Abrasive particles:

______

8. Lube oil impurities are removed by the following means:

a) Water:

i) ______

ii) ______

iii) ______

b) Oxidation products:

i) ______

ii) ______

iii) ______

c) Gases:

i) ______

ii) ______

iii) ______

d) Abrasive particles:

i) ______

ii) ______

iii) ______

9\. a) To ensure satisfactory purity of lube oil, the following general operating practices are used:

i) ______

______

ii) ______

______

b) During a turbine shutdown, there is no need to use the oil purifier. (False / true)

c) An oil filter cartridge may have to be replaced when the pressure drop across the filter is abnormally low. (False / true)

d) Strict adherence to the oil sampling procedure is very important because ______

______

10\. a) Too low lube oil tank level can impair pump performance due to

______

The resultant adverse consequences/operating concerns are:

i) ______

ii) ______

b) This upset can be caused by ______

NOTES & REFERENCES

c) Abnormally high tank level can result in ____________________

____

d) A high lube oil tank level can be caused by:

i) ____

ii) ____

iii) ____

Before you move on to the next module, **review the objectives** and make sure that you can meet their requirements.

Prepared by: J. Jung, ENTD

Revised by: J. Jung, ENTD

Revision date: June, 1994

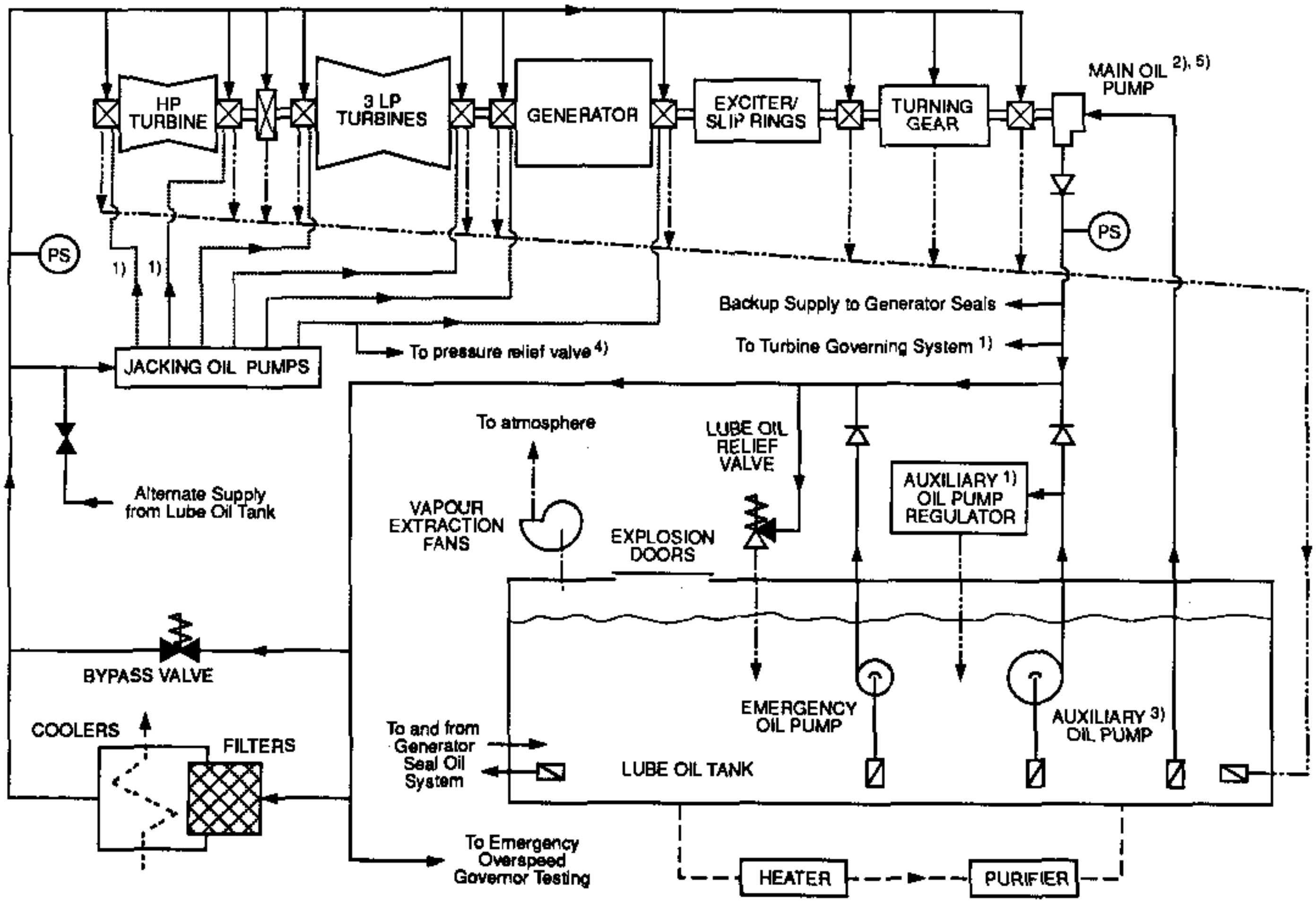

Fig. 10.2. Simplified turbine lubricating oil system:

——— Main oil supply ——— Jacking oil —·—— Drains
– – – – Purifier circuit —·—— Vapours and gases ·· ·· ·· Cooling water

Notes:

1) *Not in all stations;*
2) *In some stations, the main oil pump is located at the other end of the turbine generator;*
3) *In some stations, this pump is called "Turning gear oil pump";*
4) *Applies also to the other jacking oil lines;*
5) *For simplicity, the booster oil pump is not shown.*