



Property Risk Consulting Guidelines

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PRC.6.1.1.0.5

STEAM TURBINE LUBRICATING OIL SYSTEMS

INTRODUCTION

This section discusses reliability requirements and protective features for steam turbine lubricating oil systems. PRC.17.12 and PRC.17.12.1 provide fire protection guidelines for all steam turbine units. Additional fire protection may be necessary for units driving equipment other than electric generators.

PRC.6.1.1.0.1 describes steam turbine construction and component parts. API 614 contains additional information on lubricating and other oil systems, including sample diagrams.

Lubricating oil systems generally serve the turbine and its driven object in ways other than supplying oil to the bearings. Most turbines have hydraulic control systems that use lubricating oil as the working fluid and lubricating system pressure as the actuating force. The lubrication system may also supply seal oil to the driven machine, however, this arrangement may increase the fire hazard.

Steam turbines cannot operate without lubrication. Therefore, turbine lubricating oil systems must be designed, operated and maintained for extreme reliability.

POSITION

Lubricating oil systems affect overall facility loss prevention more than most mechanical systems. They contain combustible liquid under pressure. System design should minimize the fire hazard presented. Under most circumstances, good fire protection design would also include shutting off the oil supply if a fire starts. Since shutting off the oil supply could cause the mechanical destruction of the turbine unit, the design of the associated fire protection system must reflect the fact that lubricating oil system operation must continue until the turbine unit coasts down.

Each steam turbine unit should have oil systems that are independent of any other unit.

A steam turbine lubricating oil system should be designed to supply clean oil at the correct temperature and pressure to all bearings, control equipment and seals, under the reasonably adverse condition that results in the largest drop in system pressure. The following conditions should be considered:

- Failure of any single bearing.
- Rupture of any external line or component in the control oil system.
- Failure of any single seal.

Preventing these events from causing serious additional damage may require limited line sizes, orifice plates or needle valves to distribute flow in service and to limit the system pressure drop produced by a component failure.

The system reservoir should be large enough to supply oil to bearings under any of the above conditions for at least twice the unit coastdown time from its maximum operating speed.

Pump capacity should be the largest of:

- Flow required to maintain pressure under the worst reasonably adverse condition.
- 120% of normal flow.
- Normal flow plus 10 gpm (37.8 L/min).

Turbines subject to damage from coastdown without lubrication require a backup or emergency lubrication source. The backup source should:

- Start automatically if the normal source fails.
- Provide oil to the bearings in case of a crash shutdown.
- Continue to operate for at least 150% of the coastdown time from the maximum operating speed.
- Operate independently of the normal facility electrical supply.

Turbines larger than 10,000 hp (7460 kW) require at least two independently-powered backup oil sources. At least one source must operate independently of the normal facility power supply.

Turbine units may be subject to damage from residual heat if lubricating oil flow stops. The backup or emergency oil source for these machines should be capable of supplying oil for the cool down period if that period is longer than the coastdown time.

Seal oil provided by lubrication systems should not return to the main oil reservoir. If seal oil must return to the main oil reservoir:

- Gas disengaging equipment is necessary.
- Hazard analysis must consider the consequences of returning gas-laden oil to the reservoir.
- Maintenance programs must be arranged to detect and correct any contamination of the oil or deterioration of its properties.
- Equipment location, venting, gas detection and fixed fire protection may be necessary to control the hazard.

Also, the minimum duration of supply for the backup or emergency oil source may require further extension to include the time necessary to isolate and depressurize the machine after shutdown.

Turbine units with forced lubrication systems require the following features:

- Low lubrication pressure alarm and unit shutdown.
- High lubrication temperature alarm(s).
- Oil reservoir low level alarm.
- Low seal oil pressure alarm and shutdown for hydrogen-cooled generators and gas compressors.
- Backup and emergency lubrication source running alarms.
- High oil filter differential alarm.
- Locked or plugged oil reservoir drains.

Low lubrication pressure shutdowns on all machines and low seal oil pressure shutdowns on machines handling flammable or otherwise hazardous gases are critical systems. Therefore, for important machines, install redundant systems. Do not permit machine operation if critical systems are out of service.

Protective features should be designed to be calibrated and tested while the turbine unit is on line. Test procedures should simulate improper values of the measured parameter as realistically as possible. Any bypass switch should be the "dead man" type.

Operation and maintenance of the turbine lubrication system should be covered by the management programs written for the turbine unit. On-line oil purification or reclamation and servicing of oil filters and strainers are potentially hazardous operations requiring written procedures and operator training.

All protective features should be tested weekly. Pressure and temperature sensing devices should be calibrated at least annually. All maintenance and testing activities should be part of a managed maintenance program.

DISCUSSION

Steam turbine lubricating oil systems present unusual fire protection problems. For years, it was thought that aggressively attacking an oil fire on a steam turbine using sprinklers or deluge systems would cause catastrophic turbine failure. Loss experience and subsequent tests have demonstrated this result to be unlikely.

Unfortunately, turbine fire protection systems still must be designed to control a fire being fed by a system that must stay in service. Controlling a turbine room fire by shutting down oil systems is not effective loss control if destroying the major piece of equipment being protected is the result. The lubricating system must be kept in service until the machine coasts down. If the turbine drives a hydrogen cooled generator or a compressor which handles a flammable or hazardous material, the seal oil system must remain in service until all flammable or hazardous materials contained in the driven object are contained.

Some small steam turbines contain ring-lubricated bearings, however, most have simple lubrication systems consisting of a shaft-driven pump, an oil cooler and a filter or strainer. Coastdown time and bearing loading are not sufficient to result in damage when the machine coasts down. The amount of rotation after the shaft-driven pump becomes ineffective and after the lubrication film breaks down is insignificant.

Larger turbines require more complex lubrication systems. Coastdown times may exceed 30 minutes and bearing loads are much higher. If a large turbine unit coasts down from operating speed without lubrication, the bearings are likely to be destroyed, possibly to the extent the turbine rotating parts rub destructively against the stationary parts.

The oil reservoir for a large turbine unit may incorporate the following features:

- Level indication and alarms.
- Heaters to assist contaminant settling and moisture elimination and to preheat the oil for startup.
- Connections for an oil-conditioning or purifying system.
- Devices for foaming and static electricity control.

Oil reservoir drain valves should be locked shut, or plugs should be installed in the drain lines during normal operation to prevent inadvertent or easily accomplished draining of the system.

Oil systems for larger machines also include:

- Pumps and their prime movers.
- Oil coolers and filters with associated transfer and control valves.
- Pressure control devices, including relief valves and accumulators.
- Flow-indicating devices, such as bull's eyes, and control devices, such as needle valves or orifice plates.
- Alarms and other protective devices.
- Gas disengaging equipment if a seal oil system is incorporated.

Figure 1 is a simplified turbine lubricating oil system showing the relationship of major components. The system provides a high pressure discharge to the control system and a low pressure discharge to the bearings. The main oil supply is a turbine shaft-driven pump whose discharge is augmented at

lower speeds by a steam turbine-driven auxiliary pump. Electric backup and battery-powered emergency pumps are also provided. Orifice plates are used to balance system flows and limit flows in case a bearing fails or a control system line ruptures. The figure does not show equipment that even a simple system would include. For example, an actual system would have thermometers and pressure gauges. System controls are also not shown. These would include the interlocks necessary to operate the proper number of pumps at the correct speed and in the correct sequence.

Turbines subject to damage from coastdown without lubrication must have a backup source of lubrication. Seal oil systems for machines handling flammable or otherwise hazardous fluids also need backup. In either case, the backup source may be a gravity head tank or a fluid accumulator of sufficient capacity to provide lubrication for the required time period. A backup pump which is powered by a source other than the normal utility power may also be provided. Possible sources of power for such a pump include:

- A reliable source of steam with the backup pump maintained in a warm condition or slow roll.
- Air or other compressed gas, preferably from a dedicated receiver.
- Electricity from a highly reliable independent source, such as a dedicated battery bank or an emergency generator.

Testing backup systems should include testing the sensing element wherever possible. For pressure-sensing systems, this is easily accomplished by installing an orifice in the supply line to the pressure switch and a drain valve to dump oil pressure from the pressure switch back to the oil reservoir.

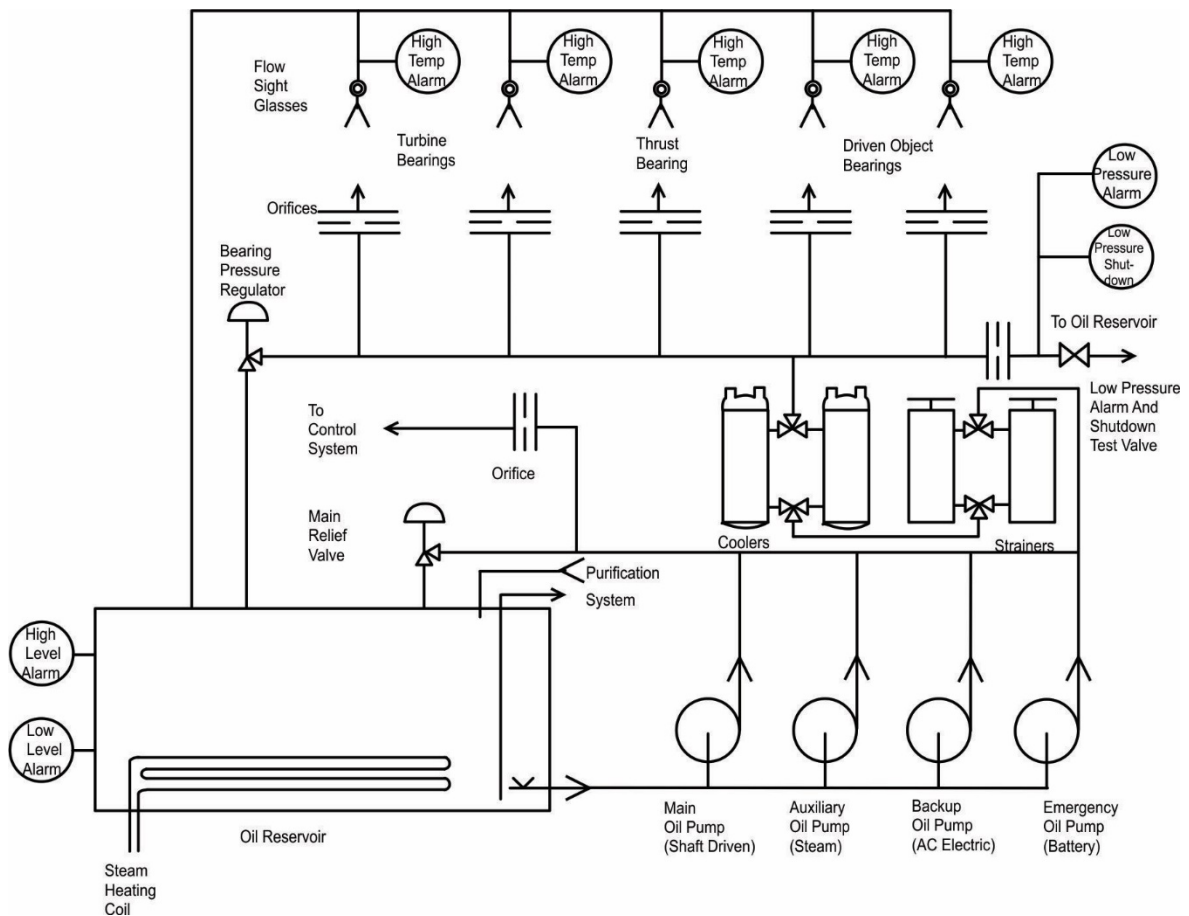


Figure 1. Simplified Steam Turbine Lubricating Oil System.