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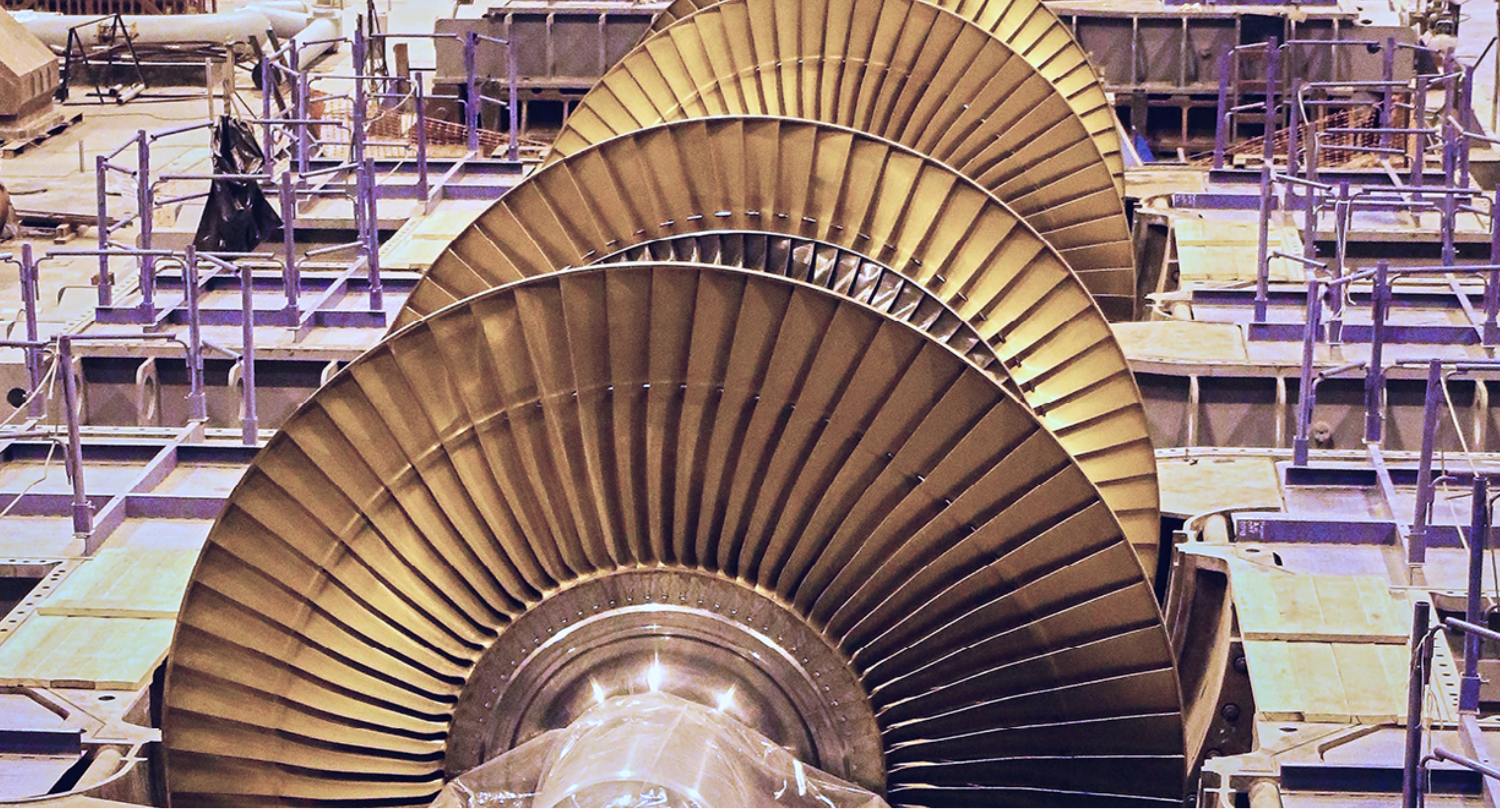
Lube oil protection

Lube oil protection systems
and common failure modes

Author
Ryan Wood
Risk Engineer



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1 Introduction

The goal of this paper is to provide an overview of the various types of lube oil systems used in steam and combustion turbines, as well as their primary protection mechanisms. The primary function of a lube oil system is to ensure a continuous supply of filtered and cooled oil to the bearings of the turbine train. This oil serves a dual purpose: lubricating the bearings and providing essential cooling.

During operation, the oil is supplied at a regulated temperature and pressure to meet the system's demands, regardless of whether the turbine is starting up, generating power, shutting down, coasting, operating on turning gear, or in an emergency mode.

Without a consistent flow of lube oil, rotating machinery is at significant risk. Bearings can quickly overheat, leading to severe damage caused by metal-to-metal contact between the rotating shaft and the bearings. Loss-of-lube-oil events often result in damaged bearings, thermally affected shafts, compromised seals, and even damage to both rotating and stationary turbine blades. These types of events occur frequently and can lead to significant property losses and business interruptions, representing substantial claims to the insurance market.

In many cases, loss-of-lube-oil events are preventable through proper testing and maintenance. While there is no universal governing code or standard for lube oil protection, the responsibility often falls to the Original Equipment Manufacturer (OEM) to develop appropriate control and protection strategies. Although OEMs may differ in their specific approaches, the physical components — such as pumps and system configurations — tend to share similar characteristics.

Thorough testing of lube oil systems and their associated protection schemes is crucial to ensure an uninterrupted oil supply. Despite appearing straightforward, these systems can be highly complex, incorporating mechanical components, electrical systems, and control instrumentation. Each element must be fail-safe and rigorously tested to ensure the overall reliability and adequacy of the system.

2 Types of lube oil pumps

2.1 Shaft drive oil pump

A shaft-driven oil pump is typically centrifugal pumps but can also be positive displacement pumps directly driven or coupled through a gear reducer/increaser to the main turbine shaft. These pumps are designed to deliver a consistent volume and pressure of oil while the turbine shaft is rotating. Positive displacement pumps should have pressure relief valves to prevent pump damage from blockages. Because they are mechanically linked to the turbine shaft, they provide a reliable supply of oil to the bearings as long as the shaft is in motion.

During normal online operation, this configuration is highly reliable and capable of delivering an uninterrupted supply of oil to the bearings. However, it does have limitations. Since these pumps depend on the turbine shaft's rotation, they may not supply sufficient oil during startup or shutdown, when the turbine is not operating at nominal speed. To address this limitation, shaft-driven pumps are typically supplemented with auxiliary pumps, which are discussed later in this document. In configurations utilizing shaft-driven pumps, the auxiliary oil pump is often critical during startup, shutdown, or emergency situations. For example, during an emergency turbine trip and subsequent shutdown, the shaft-driven oil pump continues supplying oil as the turbine coasts down. However, as the turbine speed decreases, the pump eventually becomes incapable of maintaining adequate oil flow. At this point, the auxiliary pump automatically takes over and supplies oil until the turbine has significantly cooled down.

Figure 1

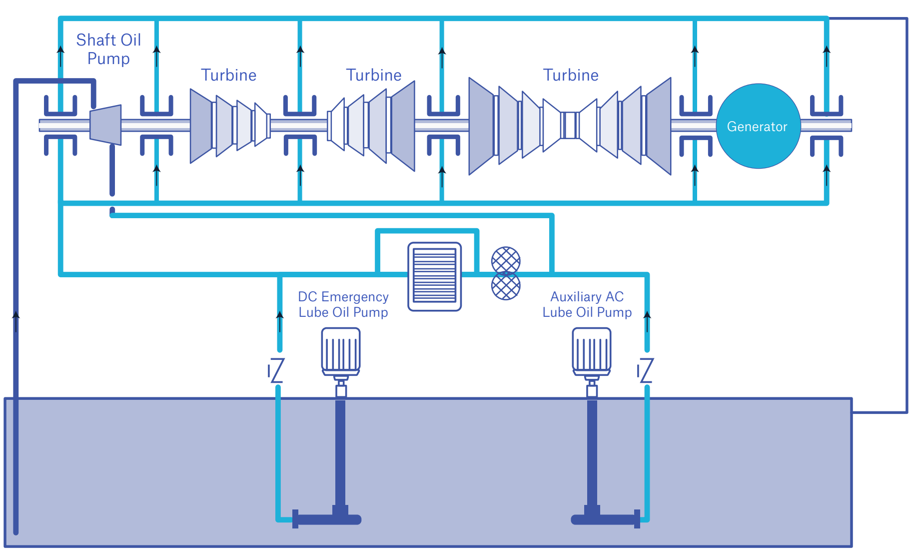

Figure 1: A turbine train, consisting of either a steam turbine or combustion turbine, typically features a shaft-driven oil pump supplemented by a DC emergency lube oil pump and an auxiliary AC lube oil pump, as illustrated in Figure 1.
This configuration, while varying slightly depending on the OEM, generally ensures uninterrupted oil flow to the turbine bearings during all operational phases, including startup, power generation, shutdown, coast down, turning gear operation, cool down, and emergency conditions.

However, this configuration can become inadequate under certain conditions. For example, if a DC lube oil pump is not available and the auxiliary AC lube oil pump lacks a reliable emergency power source, the system may fail to supply sufficient oil during critical periods. To mitigate this risk, the emergency power source — preferably an uninterrupted power supply (UPS) or battery system — must be capable of operating the system throughout the entire coast-down period, with an additional buffer to allow enough time for the unit to cool. Since the emergency oil pump serves as the last line of defense to safely run down and cool the turbine without major damage, each unit should be equipped with a dedicated and independent emergency lube oil system.

2.2 Auxiliary oil pump

As a continuation of the previous section, auxiliary oil pumps are commonly found in lube oil systems where the main oil pump is shaft driven. These pumps are typically centrifugal and are designed to supply lube oil to the turbine bearings during startup and shutdown, when the turbine is operating below nominal speed. Their role is to ensure an uninterrupted flow of oil to the bearings until the turbine rotor reaches sufficient speed for the shaft-driven oil pump to take over. The transition between the auxiliary and shaft-driven pumps is governed by fluid dynamics and occurs seamlessly without operator intervention. Auxiliary oil pumps are typically powered by an AC electrical source.

Operators typically select which of the two pumps will serve as the primary, with the other being used as the standby.

Despite their critical role, auxiliary oil pumps present specific risk exposures that must be addressed to ensure the overall system's adequacy. These pumps are often smaller in size and have a lower volume output, making them unsuitable for supplying lube oil at nominal turbine speed. However, this limitation is not an issue when the system includes a shaft-driven oil pump. In systems equipped with main AC oil pumps, auxiliary oil pumps are rarely used. Such configurations are generally adequate when there are two or more main AC oil pumps, as discussed further in this document.

Auxiliary oil pumps activate in response to a drop in pressure, typically controlled by hardwired pressure switches with electrical interlocks or through a Distributed Control System (DCS). These pumps are generally powered by an AC electric motor. If the AC power supply is backed by an uninterrupted power supply (UPS) it may qualify as an emergency standby pump. However, if the auxiliary oil pump's power supply does not meet this criteria, the pump cannot be classified as an emergency standby pump. In such cases, a DC emergency lube oil pump is required to ensure the system provides adequate protection for the turbine bearings.

2.3 Main AC oil pumps

The most common configuration for ensuring uninterrupted lube oil supply to turbine bearings consists of two AC lube oil pumps. In this setup, there are two identical, self-lubricated centrifugal pumps, each rated for 100% continuous duty: one designated as the primary pump and the other as a standby. These main AC oil pumps are responsible for delivering lube oil during all operational phases, including startup, power generation, shutdown, coast down, and turning gear operations. However, during emergency events where there is a loss of main AC power, these pumps will likely shutdown.

Operators typically select which of the two pumps will serve as the primary, with the other being used as the standby. As part of normal maintenance, these pumps are often rotated between primary and standby to ensure run time hours are roughly the same. During normal operation, the active pump supplies oil to the bearings while system pressure is continuously monitored by pressure switches or a Distributed Control System (DCS). If the system detects a pressure drop, the standby pump is triggered to start automatically, ensuring uninterrupted oil flow to the bearings.

While this configuration is widely used in the industry, it does present certain risks. Both pumps depend on a reliable AC power supply; any interruption to this power can result in a loss of lube oil. Additionally, the control system — whether using pressure switches or the DCS — is a potential single point of failure. Any malfunction in this system could lead to an interruption in oil supply. To mitigate these risks, a third DC emergency lube oil pump is often included in the system.

Powered by a DC battery bank, this pump ensures continuous oil flow in the event of a failure of both AC oil pumps. This configuration does offer advantages, particularly in terms of redundancy. Both AC pumps are fully capable of indpendently supplying the turbine with adequate lube oil. Each pump is typically powered from separate AC power sources, adding resilience to the system. Furthermore, both pumps can be started either automatically or manually by the operator, enhancing operational flexibility.

2.4 DC lube oil pump

The DC motor-driven lube oil pump is a common component in lube oil systems, providing an emergency backup supply of oil in the event of a failure of the main oil pump, whether it be a shaft-driven pump or a system with two AC pumps. Typically designed as a single-stage centrifugal pump, the DC oil pump is powered by the plant's DC battery system. It is best practice to remove the thermal overload for the DC lube oil pump and set them to alarm only. If there is a manual breaker or other primary disconnect device installed, it is recommended that the breaker be set to 150% greater than the maximum starting current. Due to the finite capacity of the batteries, the DC motor is generally smaller than the main oil pumps.

The DC emergency oil pump is specifically sized to deliver reduced bearing oil flow at the minimum pressure required to protect the bearings. This reduced flow is achievable because the oil supplied by the DC pump bypasses the cooler, filter, and pressure regulator, feeding directly into the bearing header. The battery system must be capable of supporting emergency operations long enough to safely bring the turbine to 0 RPM, with an additional buffer to allow the unit to cool.

The risks associated with the DC oil pump primarily involve its configuration and the systems controlling its activation, such as electrical interlocks or Distributed Control System (DCS) commands. As the DC oil pump is a critical emergency component, it should be tested weekly to ensure reliable operation. Since the DC oil pump is typically needed during major plant upset events, its emergency systems must function flawlessly to prevent physical damage and loss of equipment.

The DC oil pump is activated through a combination of DCS commands and electrical interlocks. Fail-safe configuration and regular testing of these systems are essential to ensure proper operation during emergencies. Electrical interlocks are often preferred over DCS commands because they are inherently redundant, reducing the risk of failure. In contrast, the DCS can present a single point of failure, making redundancy in the system's design and testing critical for reliability. As previously mentioned, the DC oil pump serves as the last line of defense, ensuring the turbine can safely coast down and cool without sustaining major damage. It is recommended that emergency lube oil pumps remain independent and dedicated to each unit to maintain reliability and effectiveness.

Figure 2

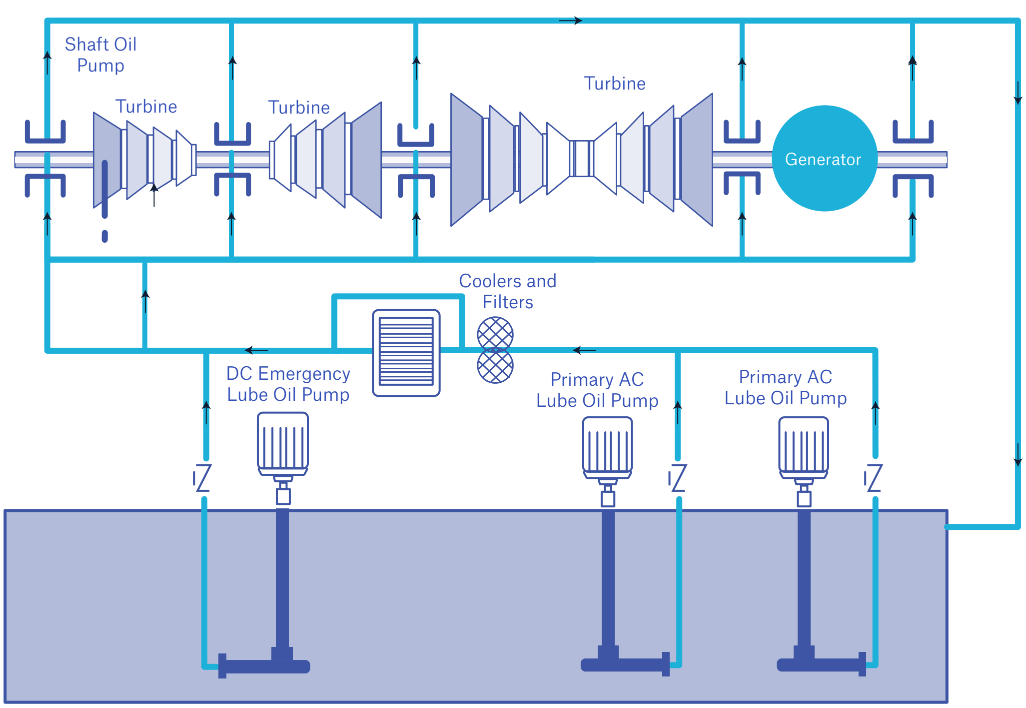

Figure 2: The image shows a typical configuration of a steam or combustion turbine with two AC lube oil pumps and an emergency DC lube oil pump. Actual system configuration may differ with OEM, but concept should be consistent.

2.5 Steam-driven oil pump

The steam-driven oil pump is typically a centrifugal pump powered by a small steam turbine. Commonly found in older steam plants, this type of pump is used in various roles, including as a main oil pump, an auxiliary oil pump for startup and shutdown, or an emergency oil pump. Historically, these pumps were prevalent in conventional steam plants, where they provided lubrication during startup and shutdown phases before the shaft-driven oil pump assumed operation. The pump operates using steam generated by the plant, making it well-suited for integration with steam-driven systems.

In modern applications, steam-driven oil pumps are most commonly used as auxiliary pumps for startup, shutdown, or emergency situations, often in conjunction with a shaft-driven oil pump. When equipped with proper safeguards, these pumps are considered an adequate and reliable option for lube oil systems.

Steam-driven pumps are known for their dependability, particularly because they often utilize mechanical regulating valves to activate the pump using steam when required. These valves make the pump nearly fail-safe. However, the main drawback is the pump's reliance on steam to operate. A critical vulnerability arises if the isolation valves supplying steam to the pump are inadvertently closed. In many older configurations, these valves were not monitored or alarmed in the control room, creating a potential point of failure.

To mitigate this risk, plants utilizing steam-driven lube oil pumps should implement position indicators and alarms for the steam isolation valves in the control room or establish physical isolations to prevent accidental valve closure.

These safeguards ensure that operators are immediately alerted if a valve is closed, reducing the likelihood of pump failure. Additional alarms should monitor steam quality, including pressure and temperature, as the operation of steam-driven oil pumps depends on these parameters. The inclusion of such alarms and/or isolations should be considered mandatory in any system employing steam-driven lube oil pumps to ensure reliability and safety.

3 Lube oil protection

3.1 Pressure switch vs. DCS

All the pumps discussed above incorporate some form of monitoring to trigger additional pumps or initiate a turbine trip in case of low oil pressure. The two most common methods employed in the industry for this purpose are pressure switches and Distributed Control System (DCS) monitoring.

Pressure switches

Pressure switches are physical devices designed to continuously monitor oil pressure and activate when a preset threshold is reached. These thresholds are configured by an instrumentation technician and require routine calibration as part of a preventive maintenance plan that conforms with OEM recommendations. Pressure switches are usually electrically interlocked with lube oil pumps using fail-safe configurations.

This ensures that in the event of a wire being cut or a power loss, the pump is automatically triggered to run. Pressure switches are considered the most reliable and desirable means of controlling lube oil pump protection due to their simplicity and dependability. Configurations are often redundant, employing 2-out-of-3 voting circuit to enhance reliability. Unlike DCS control, pressure switches operate independently, ensuring that pumps are triggered whenever oil pressure drops, regardless of whether the turbine is online or offline.

However, this straightforward approach can sometimes be a nuisance for operators, as pumps may be inadvertently activated during non-critical conditions. Despite this, the simplicity and redundancy of pressure switches make them ideal for ensuring consistent protection against oil pressure loss.

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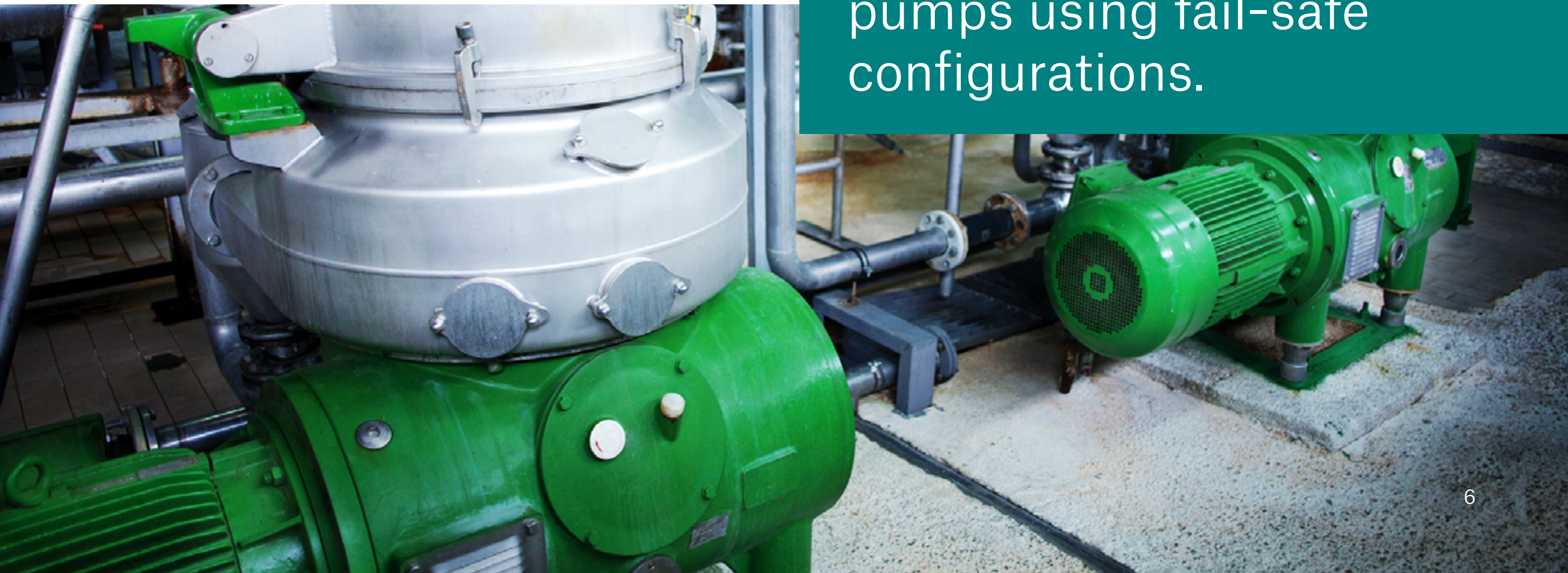


Distributed control system (DCS)

DCS-based control of lube oil pumps has become increasingly popular since 2010, with many OEMs now favoring this method. In this setup, transmitters monitor the system's oil pressure and typically use 2-out-of-3 voting logic to determine when to start a backup pump. While DCS control offers a degree of "smart" functionality — allowing for more nuanced operation and greater operator oversight — it comes with increased complexity and risks.

The primary concern with DCS-based control is its potential for failure. For the system to be reliable, it must be configured for fail-safe operation and thoroughly tested to ensure it responds appropriately during emergencies. If the DCS fails or loses communication, the lube oil pumps may not start as needed, especially during critical events like blackouts, turbine trips, or mechanical breakdowns.

DCS control also requires more sophisticated programming to account for various operating conditions, such as when the plant is online, offline, swapping pumps, or performing lube oil pump tests. While this added functionality enhances operational flexibility, it introduces additional failure points and greater risk compared to simpler pressure switch systems.

Another critical concern with DCS control of emergency oil systems arises during DCS reboots or communication faults. Computer systems are prone to freezing, locking up, or rebooting, and during these moments, the control system temporarily resets to default parameters before resuming its automated processes. Even with fail-safe logic controls, there is a risk that the system could default to an "OFF" condition during the reboot sequence, overriding the intended fail-safe state until the controls fully initialize. This vulnerability has been a factor in numerous incidents, where fail-safe logic was properly implemented but the system failed due to "first-pass values" set during the reboot.

Testing protocols should include validation of fail-safe operations through a complete DCS restart, not just a shutdown. This would confirm the system's ability to maintain protection during an unplanned reboot scenario.

Comparison of pressure switches and DCS

The key difference between these two approaches lies in their architecture and reliability.

— **Pressure Switches:** Each lube oil pump operates independently with its own set of pressure switches, providing multiple layers of protection. This decentralized approach minimizes the risk of a total system failure.

— **DCS:** By centralizing control within the DCS, a single-point failure potential is introduced. A major fault in the DCS could result in the loss of oil supply to the bearings, significantly increasing the risk of equipment damage.

While DCS control offers modern functionality and convenience, pressure switches remain the preferred method for critical protection due to their simplicity, redundancy, and fail-safe design.

The primary concern with DCS-based control is its potential for failure.

3.2 Lube oil coolers and filters

Lube oil coolers and filters are critical to the efficient and reliable operation of the lube oil system. The filters ensure a clean, particulate-free oil supply to the bearings, while the coolers remove excess heat generated during operation.

Lube oil coolers

Lube oil coolers are typically installed inline between the lube oil pump and the turbine bearings. Under normal operating conditions — such as startup, shutdown, and power generation — the oil passes through the cooler to maintain an optimal temperature, ensuring effective lubrication and heat dissipation.

During emergency events, trips, or abnormal shutdowns, where the emergency lube oil pump is engaged, the oil may bypass the cooler depending on the system's configuration. Emergency lube oil pumps are generally smaller than the main oil pumps, as they are designed to conserve energy from the limited emergency battery supply. This smaller size often limits their capacity to sustain sufficient flow through the cooler and to the bearings simultaneously.

It is therefore best practice to bypass the lube oil cooler during emergency pump operation to ensure maximum oil flow to the bearings. For systems with an inline lube oil cooler that utilizes a DCS-controlled valve for temperature regulation, it is crucial to verify the valve's behavior during emergency scenarios. Specifically, the valve should isolate the cooler to prevent added resistance in the system when the emergency pump is operating. Failure to do so could jeopardize the bearings by reducing the flow and pressure of oil during critical moments.

Lube oil filters

Lube oil filters can be configured in line with the main lube oil pumps or as part of a separate hydraulic circuit (kidney loop) operating independently of the main lube oil system. Filters ensure that the oil remains free of contaminants, protecting the bearings and other critical components.

In emergency scenarios where the emergency lube oil pump is running, the oil may bypass the filters, depending on the system configuration. This bypass typically occurs for reasons similar to bypassing the coolers — to minimize resistance and ensure the emergency pump can maintain adequate flow and pressure.

Three-way valve considerations

Lube oil coolers and filter systems often utilize three-way valve configurations to facilitate online swaps between filters or coolers. These valves are typically operated manually by turning a hand valve to select which filter or cooler is in service. To prevent operational errors, valve stops are installed to restrict the valve handle from being turned beyond its intended stopping point.

If a valve is turned past its stop, it can result in the valve being misaligned, potentially cutting off the oil supply — a critical failure that has led to significant losses in the industry.
To mitigate this risk, it is essential for operators to regularly inspect valve stops for wear or damage and verify that valve handles are functioning correctly. Proper maintenance and oversight of three-way valve systems are vital to ensure continuous and reliable operation of the lube oil system.

Considerations for emergency pump operation

As part of a robust preventive maintenance program, emergency lube oil pumps should be tested regularly to confirm their reliability during emergencies. To minimize the risks associated with testing an emergency system, all testing should be carefully planned and executed. Additionally, system safeguards must be verified to ensure long-term functionality and reliability.

3.3 Emergency power supplies

The most common power source for an emergency oil pump is a DC battery bank. Ideally, and as preferred practice, each turbine unit should have its own dedicated DC battery system complete with an associated charging system. These battery systems are designed to power critical emergency equipment, such as the lube oil pump, while also supporting the turbine's continuously operating control systems.

In some cases, an AC auxiliary oil pump powered by a UPS with a DC/AC inverter system has been employed as an alternative emergency oil pump. While this setup can suffice, it introduces additional complexity to the electrical system, increasing the potential for failures that could lead to a loss of functionality. When it comes to protection systems, simplicity and reliability often outweigh the appeal of advanced, more complex configurations.

To ensure reliability, DC battery systems should be routinely tested in accordance with IEEE Standards 450 or 1188, based on the specific battery type. These standards provide best practices for maintenance, testing, and performance evaluation to confirm that the batteries are capable of delivering power during critical moments. It is crucial to avoid performing battery system maintenance or testing while the unit is in operation, as disturbances to the DC system can pose significant risks. Such disruptions may inadvertently trigger events that could lead to severe equipment damage or operational failures, underscoring the importance of scheduling these activities during planned outages or downtime.

Battery testing methods may vary depending on the system configuration and testing capabilities. For example:

- **Modified Performance Testing:** Simulates the battery's inrush current during motor startup and measures the expected current draw based on the battery sizing document. This test ensures the battery can perform as designed.

- **Constant Discharge Testing (Load Testing):** Measures battery health by subjecting it to a constant current discharge. This test evaluates the battery's capacity and overall state of health.

The charging system plays a vital role in maintaining battery reliability. Battery chargers should include health monitoring alarms to alert operators of malfunctions. In the event of a charging system failure during operation, the battery system's energy reserve is typically limited to a few hours. If the batteries are fully depleted, the plant will trip and shut down, leaving critical emergency protection systems, such as lube oil pumps, inoperable.

Given the potential consequences of a charging system failure, diligent monitoring and maintenance of both the batteries and their charging systems are essential for ensuring the plant's safe and continuous operation.

4 Common and preferred testing methods

The following are various testing methods designed to ensure the adequacy and functionality of lube oil protection systems. When performed routinely, these tests help maintain system reliability and minimize the risk of failure. These guidelines are intended to provide readers with a general understanding of preferred testing and validation practices. It is important to note, however, that these recommendations are not meant to override or replace the original equipment manufacturers' (OEM) guidelines.

4.1 Unit pre-start test

Most turbine units include a lube oil system function test as part of the pre-startup procedure. This test is designed to confirm the operation of the DC emergency oil pump and ensure the system can maintain positive pressure. Ideally, the test simulates a low-pressure condition, triggering the DC emergency oil pump, and verifies that the pump establishes positive pressure downstream. A successful test confirms proper pump functionality, allowing the unit to proceed with the startup process.

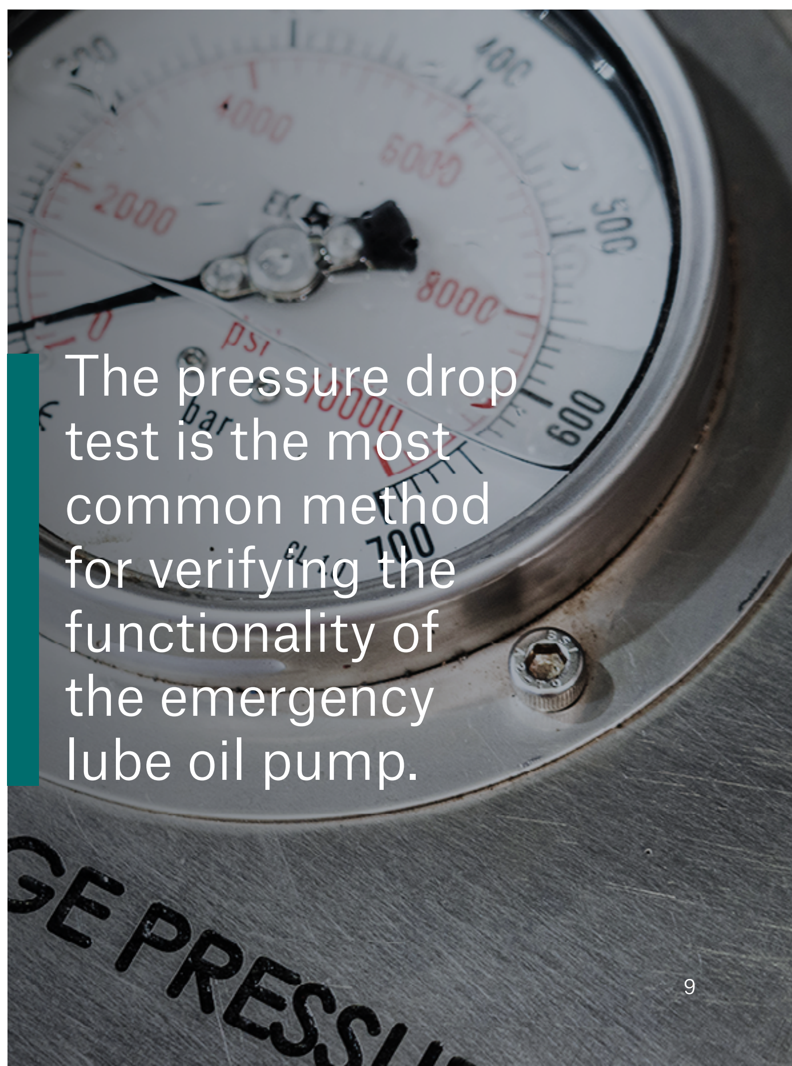
While this approach is ideal, the specific tests performed may vary depending on the unit's design and operational requirements. In some cases, the functionality of critical components, such as the pressure switch or transmitter, may not be fully validated during routine pre-startup tests. The pressure switch plays a vital role in detecting low-pressure conditions and activating the emergency oil pump, making its reliability critical for system protection. To address this gap, supplemental testing or calibration of the pressure switch should be incorporated into the maintenance schedule.

This ensures that all elements of the emergency lube oil system, including the DC pump and its activation mechanisms, are functioning correctly and can respond effectively in an actual low-pressure event.

4.2 Pressure drop test

The pressure drop test is the most common method for verifying the functionality of the emergency lube oil pump. This test is typically performed on a weekly basis to ensure the proper operation of both the emergency pump and the pressure switch or transmitter responsible for activating it. If the unit is equipped for an online pressure drop test, this procedure can often be conducted while the unit is running, minimizing operational disruptions. However, not all units are configured for this capability; in some cases, the hydraulic setup, or the activation of the DC oil pump during testing could risk tripping the turbine.

To perform the pressure drop test, the plant must be operating under normal, steady-state conditions. An operator manually drains lube oil pressure from the sensing line connected to the pressure switch or transmitter. As the pressure decreases, the emergency lube oil pump should activate before the pressure fully dissipates. A successful test confirms that the emergency lube oil pump engages as designed and discharge pressure if verified, ensuring reliable protection during low-pressure events.



The pressure drop test is the most common method for verifying the functionality of the emergency lube oil pump.

4.3 Cascade test

The lube oil cascade test is typically performed during commissioning; however, it is recommended to conduct this test annually and after any major outage or overhaul that disturbs the lube oil system or bearings. This test is primarily applicable to turbines equipped with two AC lube oil pumps and one DC emergency lube oil pump.

The cascade test is an offline procedure conducted with the turbine not in operation and off turning gear. The process involves sequentially verifying the operation of each backup pump by simulating a failure of the primary pump.

1. **Primary AC Pump Shutdown:** The test begins by manually turning off the breaker for the primary AC lube oil pump. The backup AC pump should seamlessly take over the supply of lube oil to the bearings.

2. **Secondary AC Pump Shutdown:** The breaker for the backup AC pump is then turned off, triggering the DC emergency lube oil pump to activate and supply oil.

The test is successful when the transition between the primary AC pump, secondary AC pump, and DC pump is seamless, maintaining uninterrupted oil flow throughout the process. This test provides critical insights for plant staff, including:

— **System Pressure Behavior:** The lowest pressure in the lube oil system during each pump transition is recorded by the control system, ensuring pressure remains within safe limits.

— **Redundancy Verification:** The functionality and reliability of each pump and the overall system redundancy are confirmed.

Regularly performing this test helps ensure the lube oil system operates as designed during critical events, reducing the risk of equipment damage.

4.4 Loss of control system test

Turbine lube oil systems are becoming increasingly integrated with control systems, making it essential to regularly verify their fail-safe functionality. This test applies to any lube oil system that uses control systems or pressure switches for functionality. It should be conducted whenever the lube oil system wiring, transmitters, or pressure switches are disturbed, following major outages, or after control system upgrades. The primary goal of this test is to verify the fail-safe operation of the lube oil system during a DC power disruption. Such disruptions could stem from control system failures or damage to control wiring.

Test process:
The loss of control system test is performed while the turbine unit is offline. The procedure involves cycling off the DC control system power, effectively removing control power from the circuits, transmitters, and pressure switches.

With control power removed, the system will no longer have visibility into the state of the lube oil system. This should trigger the system's fail-safe operation, activating the pumps to ensure continuous oil supply to the bearings.

Test success criteria:
The test is considered successful if all lube oil pumps are verified to run, despite the loss of control system power. This ensures that the system can still protect the bearings and prevent damage during an emergency situation when control power is unavailable.

5 Conclusions

By this point, the reader should have a solid understanding of the various types of lube oil pumps and their protection schemes. Although this paper does not cover every configuration currently in use, it addresses the most common systems found in power plants. The preferred practices outlined here are intended to provide value and insight to the reader.

Lube oil systems are complex and critical to the reliable operation of turbines. Occurrences of lube oil events are unfortunately common in the industry; these events are often among the costliest and, fortunately, the most preventable. Ensuring robust protection, regular testing, and proper maintenance of lube oil systems can significantly reduce the risk of these costly failures, safeguarding both equipment and operations.

As plant technologies evolve and new best practices emerge, it is essential to continually review and enhance lube oil system protection to keep pace with advancements. Regular maintenance, system validation, and testing protocols are key to mitigating risks such as system failure or unplanned downtime. In conclusion, prioritizing the reliability and protection of lube oil systems is not only critical for operational efficiency but also for protecting plant assets and ensuring long-term financial stability.

6 References

IEEE-450 and 1180 Recommended practice for maintenance, testing, and replacement of vented lead acid batteries for stationary applications.

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