9.5.7 Diesel Generator Lubricating Oil System

The diesel generator lubricating oil system (DGLS) stores and supplies the necessary clean lubricating oil to the engine bearings, crankshaft, turbocharger, and other moving parts of the engine for the operation of the EDGs. In standby mode, the system provides prelube to the diesel engine and maintains minimum lube oil temperature to facilitate quick starting, if required. Each EDG has a separate, independent engine lubricating oil system.

9.5.7.1 Design Basis

The DGLS, with the exception of the prelube and keep-warm portion, is safety related and is required to function following a DBA in order to place and maintain the plant in a safe shutdown condition.

The design basis of DGLS must meet the following:

- Provide protection from the effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and external missiles (GDC 2).
- Remain functional after an SSE and performs its intended function following the postulated hazards of internal missiles or pipe break (GDC 4).
- Provide the shared systems and components important to safety the ability to perform required safety functions (GDC 5).
- Provide a four independent division design to make sure that safety functions are performed, assuming a single active component failure coincident with the LOOP (GDC 17).
- Provide the capability for active components to be tested during plant operation. Provisions are made to allow the inservice inspection of components (GDC 45 and 46).
- To the extent practicable, the system is designed and fabricated to codes consistent with the quality group classification assigned by RG 1.26 and the seismic category assigned by RG 1.29. The power supply and control functions are in accordance with RG 1.32.
- Capability to isolate components or piping is provided to deal with leakage or malfunctions (GDC 44).
- The DGLS is designed to provide adequate lubrication and cooling for the various moving parts of the engine to permit it to be operated at continuous nameplate rating for a minimum of seven days without replenishing the system.
- The DGLS for the EDGs has a safety-related function to provide essential lubrication to the engine and turbocharger wearing parts during emergency starts

and runs and to continuously maintain the lube oil temperature within an operable range.

The non-safety-related portion of the DGLS provides prelubrication to the diesel engine to preclude dry starting (i.e., momentary lack of lubrication) and maintains the lubricating oil in a warm condition when the engine is on standby to facilitate quick starting, when required.

9.5.7.2 System Description

9.5.7.2.1 General Description

Each EDG has a separate, independent lube oil system. The lube oil system is located in the EPGB of each division and consists of the piping, instrumentation, thermostatic control valve, prelube pump, keep-warm heater, and heat exchanger. The lube oil system stores and supplies the necessary clean lubricating oil to the engine bearings, crankshaft, turbocharger, and other moving parts for the operation of the EDGs. The DGLS is shown schematically in Figure 9.5.7-1—Emergency Diesel Generator Lubricating Oil System, which shows valve arrangements to provide component isolation capabilities in the event of system leakage.

The system consists of an engine-driven lube oil pump, oil cooler, temperature control valve, electric motor-driven prelube pump, keep-warm oil heater, heat exchanger, strainers, filter, piping, valves, make-up tank, controls, and instrumentation.

During engine operation, the engine-driven pump draws oil from the engine sump and delivers it through the oil cooler and duplex lube oil filter to the main engine oil header. The header supplies oil under pressure to lubricate and cool various engine components. A pressure regulating valve on the main lube oil header maintains proper oil pressure by dumping excess oil back to the lube oil sump.

When the EDG is on standby, the electric prelube pump draws oil from the engine sump and delivers it through a lube oil standby keep-warm heater (for heating) and the lube oil filter to the main engine lubricating oil header. The keep-warm system serves the following functions:

- Maintains the oil in the sump in a warm condition to provide for a quick start capability and minimize wear during initial operation.
- Prelubricates the essential engine components to minimize wear during starting.
- Maintains oil purity by continuous filtration and straining.

A crankcase vacuum system maintains a slight negative pressure in the crankcase. The vacuum system removes oil vapor that can be ignited by an overheated component and result in a crankcase explosion. The negative pressure in the crankcase also reduces

the potential for engine oil leakage. The system consists of an exhauster, an oil separator, piping, valves, and instrumentation. The exhauster discharge is piped to the engine exhaust system.

The layout of piping and main components (i.e., strainers, pumps, valves, coolers, and filters) provides the space required to permit inspection, cleaning, maintenance, and repair of the system.

9.5.7.2.2 Component Description

The major components of the DGLS are described in the following paragraphs. Table 3.2.2-1 provides the seismic design and other design classifications for components in the DGLS.

Main Suction Strainer

A full flow duplex strainer is installed in the lube oil flow path prior to the main engine-driven lube oil pump to prevent foreign material that may have accumulated in the sump from causing damage to the pump. Each element is 100 percent capacity to enable online maintenance. The strainer is monitored for differential pressure to alert operators when a degraded condition exists and the strainer needs to be switched over and cleaned. This strainer is safety-related.

Engine-Driven Pump

The safety-related main oil pump is a positive displacement, rotary pump, driven by the engine. The pump draws oil from the engine sump and delivers it under pressure to the lubricating oil system. A relief valve at the pump discharge provides the required overpressure protection. A failure of this pump constitutes an engine failure. The pump failure is detected by low lubricating oil pressure or by a rise in the bearing temperature. Suction and discharge pressure are monitored to provide indication of and pump performance. See Section 8.3 for the details of instrumentation.

Lubricating Oil Cooler

The safety-related lube oil cooler is a single pass, counter-flow, shell and tube heat exchanger supplied by the plant ESWS. The lubricating oil heat exchanger has the capacity for cooling the total lubricating oil system flow to the required inlet temperature for engine operation at 110 percent rated load with an operating margin to allow fouling and tube plugging. The engine lube oil circulates through the shell side and the plant essential service water circulates through the tube side of the cooler.

Oil Temperature Control Valve

The safety-related lube oil temperature control valve is a motor operated three-way valve that is designed for use in engine lube oil systems. The valve directs lube oil flow

either through or around the lube oil cooler to maintain a lube oil temperature acceptable for engine operation.

The three-way bypass valve automatically positions based on the combined oil temperature being supplied to the engine. The valve can be remotely controlled from the MCR to allow valve stroking following maintenance or valve positioning if automatic control failure occurs.

The valve aligns to the full bypass position when the lube oil temperature is at or below the minimum engine lube oil inlet temperature. The valve is fully open to direct lube oil through the heat exchanger when the oil temperature is at or above the maximum lube oil temperature. At intermediate lube oil temperatures the valve will be in a mixing position to obtain an oil temperature acceptable for engine operation.

Lubricating Oil Filter

The safety-related lube oil filter is a duplex filter with each filter capable of full flow from the engine-driven lube oil pump. Filter configuration allows shifting of on-service element during operation and allows isolation of the off-service element for maintenance. Piping configuration allows refilling of the off-service element after maintenance.

The filter assembly is equipped with differential pressure instrumentation for monitoring and alarm to alert the operators of a degraded condition.

Engine Lube Oil Sump Tank

The safety-related sump collects oil from the engine. The prelube and engine-driven lube oil pumps take suction from the sump though wire mesh screens. The sump has access covers to allow periodic inspection of internal components in the engine crankcase and cleaning of the sump. The sump is equipped with relief valves to relieve pressure in the event of a crankcase explosion. The sump is also equipped with fill and drain connections and provisions to obtain a lube oil sample for lube oil analysis.

The sump is equipped with an air ejector ventilation system to remove oil vapors and gases from the engine crankcase. Compressed air from the discharge of the turbocharger is ducted to an ejector equipped oil separator that is connected to the engine sump. The vacuum created by the air passing through the ejector draws oil vapors from the engine oil sump through the separator. The oil separator system maintains a slight vacuum in the sump which also minimizes potential for oil leakage.

The crankcase pressure is monitored and the sump is equipped with level instrumentation that provides remote indication, alarms, and automatic fill from the auxiliary tank. Alarms notify operators on a low or high level that a degraded condition exists. Sump monitoring consists of a dipstick for local indication.

Auxiliary Lube Oil Tank

The safety-related auxiliary oil tank is located in the diesel room and contains an oil volume for oil consumption makeup during a seven day period of engine operation. Oil is transferred from the auxiliary tank to the engine sump by gravity through a solenoid operated valve that is actuated by a level control switch located in the engine sump. The interior of the tank is coated to prevent corrosion products from degrading the stored oil.

The tank is equipped with a low point drain for removing any accumulated water and is vented through a flame arrestor filter to prevent entry of foreign material. The fill line to the tank has an inline replaceable filter element to prevent introduction of contaminants during filling.

The auxiliary tank is equipped with level indicators and alarms for high and low level to alert operators of a degraded condition. Local indication is provided.

Keep-warm/Prelube Pump

The prelube pump is a non-safety-related, positive displacement pump driven by an electric motor. A strainer is installed in the suction piping to the pump. A relief valve is provided on the pump discharge to prevent overpressurization. The prelube pump circulates oil through an electric heater to maintain lubricating oil temperature within operating limits.

Keep-warm/Prelube Pump Suction Strainer

A full flow duplex strainer is installed in lube oil flow path prior to the keep-warm/ prelube pump to prevent foreign material from the sump from causing damage to the pump. Each element is 100 percent capacity to enable online maintenance. The duplex strainer is non-safety related.

The strainer is monitored for differential pressure to alert operators that a degraded condition exists and the strainer needs to be switched over and cleaned.

Lubricating Oil Standby Keep-warm Heater

The keep-warm heater is a non-Class 1E electric heater that provides heated oil during standby to maintain the engine in optimal condition for engine starts. The keep-warm heater has a power density that precludes coking of the engine oil during operation.

9.5.7.3 System Operation

9.5.7.3.1 Normal Operation

The EDG includes an electric motor-driven prelube pump as an integral part of the lube oil system. This pump circulates lube oil from the engine crankcase through a lube oil keep-warm heater and the lube oil filter, then into the main lube oil system and into the engine header. During engine standby, this system provides continuous prelubrication and filtering of the lube oil within the operating temperature limits. During engine operation, this system is shut down.

During diesel engine operation, the engine-driven main oil pump draws oil from the engine sump through a duplex suction strainer and delivers the oil to the engine lubricating oil header through the lube oil cooler and the main lube oil duplex filter. The oil header supplies oil under pressure to the engine components requiring lubrication and cooling. The oil then drains back to the sump.

ESWS is used to cool the lubricating oil at the cooler. The oil flow to the cooler is modulated by a temperature control valve, so that the temperature differential between the oil inlet and outlet to the engine remains at the design minimum. The temperature control valve is in the cooler bypass position during standby due to the lower oil temperatures. When the engine is started the oil continues to bypass the cooler until operating oil temperature opens the temperature control valve. This allows the lubricating oil to be brought to normal operating temperature rapidly. The valve is designed to permit the full volume of oil flow through the engine.

Oil is added to the engine through the addition of oil to the auxiliary lube oil tank. The auxiliary lube oil tank is piped to the engine sump. The system is filled using a portable pump. The quality of the oil in the sump can be checked by withdrawing samples through the drain connections provided.

During engine operation, a portion of the combustion air is used to drive an exhauster. The exhauster is designed to maintain a negative pressure in the crankcase. An oil separator is provided so that the exhauster discharge is oil free. The oil from the separator drains back to the engine sump.

The engine lube oil sump, supplemented by a makeup tank, contains sufficient lube oil to operate for seven days under the worst expected operating conditions before additional lube oil is needed.

9.5.7.3.2 Abnormal Operation

The abnormal operating conditions of the EDG lubricating oil system that could occur are as follows:

- A failure in the prelube system, which results in a lowering of the sump oil temperature. As described in Section 8.3, this condition is monitored and alarmed locally and in the MCR.

- Crankcase pressure exceeding a maximum, which sounds an alarm to alert an increase in crankcase pressure and to shut down the engine automatically. This alarm is active in all modes but the trip function is disabled in emergency mode. See Section 8.3 for instrumentation details.

- Sudden pressure surges within the crankcase will be relieved by explosion relief doors which are designed to relieve the vapors from the crankcase and prevent the entry of outside air into the crankcase.

- Excessive leakage in the main oil system decreases the system pressure and, as described in Section 8.3, the engine automatically shuts down. This trip function is active in all engine operating modes.

- Low lube oil level in the engine lube oil sump is alarmed locally and generates a common MCR alarm.

- High oil temperature will result in an alarm in all engine operating modes. Very high temperature will trip the engine in normal engine operating mode, but the trip is bypassed in emergency engine operating mode.

9.5.7.4 Safety Evaluation

- The DGLS is located in the EPGB. This building is designed to withstand the effects of earthquakes, tornadoes, hurricanes, floods, external missiles, and other natural phenomena. Sections 3.3, 3.4, 3.5, 3.7(B), and 3.8 provide the bases for the adequacy of the structural design of this building.

- The DGLS remains functional after an SSE. Sections 3.7(B).2 and 3.9(B) provide the design loading conditions that were considered. There are no high energy lines in the EPGB. Sections 3.5, 3.6, and 9.5.1 provide the hazards analyses to provide reasonable assurance that a safe shutdown, as outlined in Section 7.4, can be achieved and maintained.

- The DGLS for each diesel engine is independent of any other diesel engine's DGLS. This precludes the sharing of any safety-related systems and components that could prevent those systems or components from performing required safety functions.

- The four-division design of the EDGs provides complete redundancy; therefore a single failure of the DGLS portion will not compromise the EDG safety function. Vital power can be supplied from either the onsite or offsite power systems, as described in Chapter 8. This meets the recommendation of NUREG/CR-0660 (Reference 1).

- The U.S. EPR has four independent divisions of essential service water (ESW) that provide cooling to the EDG of their respective division. Each EDG is cooled by a

dedicated ESWS that is powered from that EDG during emergency operation. Failure of an ESW division will only affect the EDG of that same division.

- The DGLS is initially tested using the program described in Chapter 14. Periodic inservice functional testing is done in accordance with Section 9.5.7.5.
- The power supplies and control function necessary for safe function of the DGLS are Class IE, as described in Chapters 7 and 8.
- Section 9.5.7.2 describes the provisions to isolate leakage or malfunctions of the system components.
- The DGLS components provide adequate lubrication and cooling for the various moving parts of the EDG to permit operation at nameplate continuous rating for a minimum of seven days without oil replenishment from external sources.

9.5.7.5 Inspection and Testing Requirements

The DGLS will be tested during commissioning in accordance with the preoperational testing program described in Chapter 14 and Section 14.2, tests #104, 105, and 106.

The DGLS is tested periodically along with the complete diesel generator system. This test will demonstrate the performance and structural and leak tight integrity of each system component.

The DGLS is designed and located to permit inservice inspection.

9.5.7.6 Instrumentation Requirements

The DGLS instrumentation is designed to permit automatic operation and to provide continuous indication of the system parameters. Refer to Section 8.3 for a list of annunciators and engine trip functions associated with the DGLS.

Table 9.5.7-1—DGLS Indicators and Alarms lists the indicators provided for the various system parameters. All appropriate instruments, controls, sensors, and alarms for the diesel engine lube oil system are shown on Figure 9.5.7-1.

The lube oil temperatures, pressures, and levels which alarm locally and result in a common control room alarm are:

- High lube oil temperature from engine.
- High lube oil filter differential pressure.
- Low lube oil pressure to engine.
- Low lube oil sump temperature.
- Low lube oil sump level.

In addition to the local and MCR alarm for low lube oil pressure to the engine, operation of any two of the three low-low lube pressure indications initiate automatic shutdown of the engine. None of the other malfunctions shut down the engine in emergency operation or result in any effects which require immediate operator action.

Local indication is provided for lube oil temperature to and from lube oil cooler and to and from the engine, lube oil filter differential pressure, and lube oil pressure to the engine.

Instrumentation and control for the DGLS provide the following safety-related control functions:

- Cooling function – The ESWS provides a cooling function of the diesel engine lubrication oil with a heat exchanger on the cooling loop. The oil temperature control valve is the actuator used to maintain the oil temperature.

- Lube oil fill valve – The lube oil fill valve is actuated by the lube oil sump level actuation to make sure that the engine sump maintains adequate inventory for operability

Instrumentation and control for the DGLS is designed to provide the following non-safety-related control functions:

- Prelubrication pump – In stand by mode, the prelubrication pump is always actuated. The prelubrication oil pump is stopped when the engine is started and running.

- Standby heater – In stand by mode, the lube oil heater is activated to keep the engine lube oil warm to reduce the potential for component wear during engine starts. The standby heater is shut off when the engine is started and running.

- Sump oil level monitoring – The sump oil level is monitored by a level sensor and a local gauge. The level sensor actuates the oil fill valve on the auxiliary oil tank if the level in the sump falls below the minimum level. If the level falls below the low-low level setpoint an alarm is initiated to alert the operator to initiate lube oil transfer to the oil sump for continued operability of the diesel engine.

- EDG lube oil protection – When the diesel engine is running, the oil pressure is constantly monitored and, if it falls below the minimum limit for operation, the engine protective control shuts down the engine. This control is a priority protective circuit and operates using two of three logic design. It is active in all modes of operation. A low lube oil pressure also initiates a priority interlock. The actuators used to perform this function are as follows:

  – Governor shutdown solenoid.

  – Fuel shutoff valve–engine auxiliary fuel pump.

  – Generator excitation contactor.

9.5.7.7 References

1. NUREG/CR-0660, “Enhancement of Onsite Emergency Diesel Generator Reliability,” University of Dayton Research Institute for the U.S. NRC; UDR-TR-79-07; February 1979.

Table 9.5.7-1—DGLS Indicators and Alarms

Component	Indication/Alarm
Lube oil Sump level	Monitoring w/alarm and control
Make-up tank lube oil level	Monitoring w/alarm
Main Lube oil pump suction strainer differential pressure	Monitoring w/alarm
Main Lube oil pump discharge pressure	Monitoring w/alarm
Main Lube oil pump discharge temperature	Monitoring w/alarm and control
Main Lube oil pump discharge temperature	Monitoring w/alarm and control
Main Lube oil pump discharge temperature	Monitoring w/alarm and control
Lube oil cooler HX oil temperature –In	Monitoring w/alarm
Lube oil cooler HX oil pressure-In	Monitoring w/alarm
Lube oil cooler HX oil temperature-Out	Monitoring w/alarm
Lube oil cooler HX oil pressure-Out	Monitoring w/alarm
Lube oil header temperature	Monitoring w/alarm
Lube oil header pressure	Monitoring w/alarm
Lube oil filter differential pressure	Monitoring w/alarm
Engine Lube oil pressure	Monitoring w/alarm, NT, ET
Engine Lube oil temperature-In	Monitoring w/alarm
Keep-warm/Prelube pump suction strainer differential pressure	Monitoring w/alarm
Keep-warm/Prelube pump temperature-In	Monitoring w/alarm
Keep-warm/Prelube pump suction pressure	Monitoring w/alarm
Keep-warm/Prelube pump pressure out / heater pressure-In	Monitoring w/alarm
Keep-warm/Prelube pump temperature-Out / heater temperature-In	Monitoring w/alarm and control
Keep-warm heater temperature-Out	Monitoring w/alarm and control
Keep-warm heater pressure-Out	Monitoring w/alarm

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