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An American National Standard

Standard Practice for
Design of Gas Turbine Generator Lubricating Oil Systems[1]

This standard is issued under the fixed designation D 4241; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This practice has resulted from a culmination of the experiences of the turbine builders, the erectors, the oil suppliers, and the operators. Out of necessity, it is a generalized and minimal standard. Previous issues of this practice have been used in specifications to aid in obtaining satisfactory performance of the lubricating oil system.

1. Scope

1.1 This practice covers the design of lubricating oil systems for gas turbine driven generator units 1000 kW and larger.

1.1.1 The lubricating oil system is defined as that assembly which utilizes and circulates the turbine generator lubricating oil and furnishes pressurized oil for control and seal functions.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ISO Standard:*

ISO 4572 Hydraulic fluid power-fillers-multi-pass method for evaluating filtration performance[2]

3. Significance and Use

3.1 This practice establishes minimum recommended design practices for gas turbine generator lubricating oil systems to ensure that:

3.1.1 Lubrication, control, and seal functions will be performed satisfactorily by the oil mutually acceptable to the parties concerned.

3.1.2 Installation, cleaning, and flushing will be facilitated.

3.1.3 Satisfactory system cleanliness can be maintained.

3.1.4 Safe practices are observed.

4. System

4.1 The operation of the gas turbine generator depends upon a satisfactory supply of lubricating oil at the proper places. Thus, a highly reliable system must be supplied.

4.2 The system flow requirements include the summation of the individual requirements for lubrication of all the bearings, gear meshes, couplings supplied by the system, and the steady state and transient control oil requirements. A margin should be added for flow changes with use.

4.3 The system pressure must be sufficient to overcome piping and equipment pressure drop, overcome elevation head difference, provide margin for regulation, and ensure proper distribution of lube oil to the required areas of the machinery.

4.3.1 The control and seal oil function may require higher pressure levels than the lubrication. For these cases, the total system pressures may increase to where reasonable or separate control or seal oil pumps, or both, can be required.

4.4 The designer should specify the maximum allowable oil viscosity for cold start. With reduced temperatures the increased lube oil viscosity can have a significant affect upon the reliable distribution of the oil throughout the system and upon the reliable operation of the controls.

4.5 Heat is rejected from a number of sources to the lubricating oil.

4.5.1 Bearing shearing and pumping losses are transferred to the lubricating oil.

4.5.2 When accessory or load gearing are used, a major portion of their losses is transferred to the lubricating oil.

4.5.3 Lubricated couplings add heat to the oil.

4.5.4 Because of the proximity of hot gas turbine parts, some heat is transferred to the lube oil. This is especially true with buried bearings.

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[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.C0 on Turbine Oils.

All previous recommended practices have been published by ASME as joint ASTM-ASME-NEMA standards. With the issuance of this document all standards under the auspices of Technical Division C of ASTM Committee D02 will be published by ASTM, solely as ASTM standards. This standard replaces ASME Standard No. 120.

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[2] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

4.5.5 Pumping and throttling result in heat being added to the oil.

4.6 Failure of the system to distribute lubricating oil to the required areas can result in significant damage to machinery. Annunciating or machine tripping, or both, should be provided for the following:

4.6.1 Trip with low lube oil pressure.

4.6.2 Alarm for high oil temperature at the bearing header.

4.6.3 Alarm for high- or low-reservoir level, or both, depending upon the system design.

5. Materials

5.1 Exposed devices and piping containing pressurized lubricating oil should be of rugged construction and made of high melting point materials.

5.1.1 Steel piping, tubing, valve bodies, fittings, and fabrications are acceptable and recommended. Valve and pump bodies of cast iron can be used within the oil tank.

5.2 The use of copper, cadmium, zinc, and lead in systems should be avoided due to the poor resistance to corrosion by oil oxidation products. In addition, these metals can serve as catalysts for accelerating oil oxidation processes.

5.2.1 Make sleeve bearing linings of high-tin base babbitt with a minimum of 80 % tin.

5.3 All materials used in system construction, including gaskets, seals, diaphragms, interior surface coatings, and hoses, should be resistant to turbine lube oils and maintain adequate physical and chemical properties at maximum and minimum expected operating temperatures.

5.4 Interior surfaces of steel reservoirs and major fabrications should be coated for rust protection with a material impervious to oil and water at the maximum expected temperature. If corrosion resistant materials are used, no coating is needed.

6. Oil Reservoirs

6.1 The lubricating oil is stored in the reservoir. The several components frequently mount from or within the reservoir. Oil distribution and return piping originate and terminate respectively from this assembly.

6.2 The capacity of the reservoir is affected by the necessary dwell time and the total system capacity.

6.2.1 To allow for the separation of entrained air, the normal operating oil volume should not be less than four times the flow per minute to the bearings. The exposed oil surface and oil depth affect the air separation.

6.2.1.1 As an alternative, air separation may also be accomplished through incorporation of mechanical separators, mounted internally to the reservoir, on each return connection. Reservoir size shall then be determined by the separator space requirements and flow paths to limit short circuiting flow, together with the provisions of 6.2.2.

6.2.2 The capacity of the reservoir should be sufficient to hold the operating oil level volume, plus the volume that will drain from the remainder of the system when the gas turbine generator unit is shut down.

6.3 Numerous factors contribute to the arrangement of the reservoir, including the following:

6.3.1 The entire inside of the reservoir should be accessible.

6.3.2 All connections and openings should be sealed to minimize air leakage and the entrance of atmospheric contaminants into the reservoir.

6.3.3 Access openings and device mounting pads on horizontal surfaces should be raised from the normal surface to reduce the entrance of contaminants into the reservoir.

6.3.4 Flanged submerged connections should be kept to a minimum.

6.3.5 Oil reservoir connections for major drain lines from bearings should be as far from the pump suction as practical or baffled to prevent return oil from flowing directly to pump suction, thereby providing a maximum oil rest period. Drains should be arranged to provide for maximum deaeration and minimum oil agitation.

6.3.6 The discharge of relief or regulating valves should be arranged to minimize air entrainment by discharge below oil level or over a deaeration tray.

6.3.7 The reservoir and the oil system should be arranged such that the entire system can be drained.

6.4 The reservoir should be drainable.

6.4.1 The bottom of the reservoir should slope towards the drain connections. For rectangular reservoirs, the slope should be 20 mm/m (¼ in./ft) or greater. Small easily cleanable reservoirs may not need the sloping bottom.

6.4.2 Drain connections should be provided at the reservoir low points. Precautions must be taken to prevent accidental draining of the oil. If drain valves are used, they should be locked closed or have blanks in the drain lines immediately downstream.

6.4.3 If connections for an external oil purification system are provided, they must be arranged and located so that siphoning of the reservoir below a safe level is not possible.

6.5 Forced ventilation of the lube oil system vapor space should be provided.

6.5.1 One method produces a vacuum for removal of gases and vapors. This may use a vapor extractor or an air–operated eductor. Internal baffles should have openings above the oil level to equalize the vacuum within the reservoir. The vacuum produced in the bearing housing should not average more than approximately 0.5 KPa (2 in. water) to minimize the entrance of atmospheric contaminants into the oil system.

6.5.2 Another method uses air pressurized seals in the bearing housings. This air circulates through the vapor spaces of the oil system and discharges through a vent.

6.5.3 The reservoir extractor or vent connection should be located to minimize oil vapor entrainment.

6.5.4 Care must be taken in location of the reservoir ventilation discharge so that any oil vapors do not become entrained with the gas turbine inlet air.

6.5.5 The external vent outlet should be screened and covered.

6.5.6 For hydrogen cooled generator application, the reservoir should contain an explosion door or blowout diaphragm capable of maintaining the reservoir internal pressure at a safe level at all times.

7. Pumps

7.1 Pumps must circulate lubricating oil from the reservoir to the bearings, controls, and other points of use. The pressure level must be high enough to ensure proper distribution and satisfy control functions.

7.1.1 Satisfactory circulation and pressure levels must be provided for start-up, operation, and shut down.

7.2 Several commonly used pumps are defined as follows:

7.2.1 *Main Pump* normally supplies the oil circulation and pressure for the gas turbine generator operation.

7.2.2 *Auxiliary Pump* is sized to permit continued operation if the main pump fails.

7.2.3 *Emergency Pump* is of reduced capacity. Its function is to provide last resort lubrication for coastdown, should the other pumping fail.

7.3 Many combinations of pumps can be satisfactory. As a minimum these should be two pumps driven from two independent and different power sources. Thus, no single incident or equipment failure can cause loss of pumping.

7.3.1 An exception may be made to the two pump recommendation if the turbine generator can survive shut-downs without oil circulation.

7.3.2 Examples of these pump drive combinations are listed in the following table:

Main	Auxiliary	Emergency
shaft	ac motor	dc motor
shaft	none	ac/dc motor
shaft	ac motor	turbine
ac motor	none	dc motor

7.3.3 The auxiliary and emergency pump drivers shall be sized for adequate capacity when operating with the oil viscosity corresponding to the minimum temperature for start-up.

7.4 Control of the auxiliary and emergency pump drivers can significantly affect reliability.

7.4.1 The auxiliary and emergency pump drive controls shall provide for automatic starting and in-service testing.

7.4.2 The pump motor overloads shall not trip the motor breaker. The overload shall only provide a warning.

7.5 Several application requirements must be considered for proper pump functioning.

7.5.1 The main shaft driven pump must have adequate suction conditions to provide uninterrupted supply of oil. Centrifugal pumps shall be provided with a positive suction.

7.5.2 Pump suctions shall be below the minimum reservoir operating level. The exact submergence will be determined by the pump suction requirements including the consideration of air entrainment in the pump suction. In many cases the pump suction is at least 150 mm (6 in.) below the minimum reservoir operating level.

7.5.3 The auxiliary and emergency pumps shall be submerged with their suction at least below the minimum reservoir operating level.

7.5.4 The emergency pump suction shall be lower than other pumps so that with the loss of oil in the reservoir, shut down oil would still be available.

7.5.5 Coarse strainers should be provided in the suction system of all pumps.

7.5.6 Pump suctions should be at least 150 mm (6 in.) from the bottom of the reservoir.

7.5.7 The pump suction is defined as starting at the solid fluid conveyance to the pump inlet. Normally this begins at attachment of the suction strainer to the pump inlet or to the pump suction pipe.

8. Coolers

8.1 Since one of the important functions of the circulating oil is cooling of bearings and gearing, it is necessary to dissipate this heat to maintain a reasonable oil temperature level.

8.2 The cooler needs to be sized considering the following:

8.2.1 Total heat rejection to the lube oil.

8.2.2 Extreme temperature ranges of the cooling medium.

8.2.3 Allowable range of lube oil temperatures.

8.2.4 Adequate fouling margin for reasonable cooler maintenance. As a guide, refer to Standards of Tubular Exchanger Manufacturers Association.[3]

8.2.5 Velocities and pressure drops must be compatible with systems and heat exchanger design.

8.3 The following recommendations apply:

8.3.1 The heat exchange surface should be located and arranged so that it can be removed for maintenance or replacement.

8.3.2 Provide means for draining both sides of the cooler during shutdown. (**Warning—**These drains need to be protected from draining the reservoir during operation.)

8.3.3 Vent connections should be provided on the cooler to permit continual air removal.

8.3.4 When dual coolers are used, the three-way changeover valve should be designed so that oil flow will not be interrupted when transferring from one cooler to the other.

8.3.5 When liquid coolant is used, the design should minimize the chance of the lube oil being contaminated.

8.3.5.1 The coolant pressure should be less than the lube oil pressure at all times.

8.3.5.2 Separate seals or gaskets should be provided for the coolant and the lube oil sealing. The space between the seals should be open to the ambient.

9. Filters

9.1 Circulating oil contains contaminants. Filtration is recommended to reduce the contamination level of the lubricating oil system.

9.1.1 Full flow filtration should be used so that all the circulated oil is filtered on each pass through the machine.

9.2 The filter shall be designed compatible with the lube oil system requirements including the operating pressure and temperature.

9.2.1 A filter element with a $\beta_{10} \geq 200$ rating, or finer, is recommended. The beta rating, β_x, represents a ratio of particles of a given size $_x$ (in microns) that enter a filter to those that leave the filter as determined in a filtration performance test carried out in accordance with ISO 4572.

9.2.2 The element pressure drop shall not significantly increase with as much as 10 % water in the oil.

[3] Available from Tubular Exchange Manufacturer's Assoc., Inc., 53 Park Place, New York, NY.

NOTE 1—Do not interpret this as condoning unit operation with this much water in the oil.

9.2.3 Filter pressure drop with the start-up viscosity shall be within the system capabilities.

9.3 Filter applications to the lube oil system encompasses several recommendations:

9.3.1 Schematically the filter should be located as close to the point of use as practical. As a minimum it should be downstream of the cooler.

9.3.2 Lube system low-pressure alarm should be arranged so that if abnormal filter pressure drop occurs it will give a signal.

9.3.3 Filter housing drains should be provided.

9.3.4 Provisions should be made for removing air that may be trapped in the filter.

9.3.5 When dual filters are used, the three-way changeover valve should be designed so that oil flow will not be interrupted when transferring from one filter to the other.

9.3.6 Use of mechanical indicators or electrical pressure switches, or both, is recommended to provide indication that the filter element(s) should be changed.

10. Regulation

10.1 With positive displacement pumps, discharge relief valves are required to protect the pump and its driver from overloading.

10.2 Bearing header pressure regulation is frequently required to handle the flow and pressure drop variations.

10.2.1 The header regulation should be arranged so that regulator malfunction will not shut off the flow of oil.

11. Instrumentation

11.1 Provision should be made for determining the significant operating pressures of the lube oil system. These include pump discharge, bearing header, filter differential pressure.

11.2 Provisions should be made as desired for oil temperature measurements at the oil reservoir, at the bearing header and at each bearing or major component discharge.

11.3 A method for reservoir oil level determination should be provided.

11.4 Bearing oil drains should be provided with an oil flow observation point if feasible.

12. Piping

12.1 Welded or flanged and bolted joint construction should generally be used for oil piping. For small diameter lines tube construction may be used. When tapered pipe threads larger than ¾ –in. pipe are used, they should be guarded within a housing or pipe or seal welded. Straight thread connectors with appropriate seals can be used.

12.2 Pipe joints, field welds, and field bends should be minimized commensurate with shipping, erection, and cleaning requirements.

12.3 When butt welds are made with backing rings, the rings should be carefully fitted to minimize the gap between the ring and pipe. If butt welds are made without backing rings, care must be taken to minimize the weld spatter on the inside of the pipe. If necessary to assure a clean weld, the inside of the pipe should be ground or back welded.

12.4 The inside surface of all pressure and drain piping should be cleaned and coated with an oil soluble rust preventive unless corrosion resistant materials are used.

12.5 When drain lines are used for system ventilation, they should be sized and pitched to maintain adequate air space above the normal steady state oil level at all points. If low loops cannot be avoided in the piping drain system, supplementary vents and means for drainage during shutdown should be provided.

12.6 For hydrogen cooled generator application, the generator drain piping system should be separate from the turbine drain system and main oil reservoir by a loop seal to minimize the system volume subject to possible hydrogen contamination. A vent to atmosphere should be provided on the generator side of the loop seal.

12.7 The piping system should be designed to:

12.7.1 Minimize local heating from external sources such as turbine shells or casing steam pipes, and induced heating from bus ducts.

12.7.2 Withstand vibration by adequate bracing and contain adequate flexibility to account for the thermal expansion of the unit.

12.7.3 Minimize potential fire hazards by providing guards or baffles to prevent oil from contacting high temperature surfaces.

12.8 Welded or threaded and seal welded thermometer and thermocouple wells should be used if located in pressure lines or below the oil level in drain lines.

12.9 Gage lines should be provided with shut-off valves.

12.10 All valves capable of draining the oil system should be locked or blanked downstream when not in use.

12.11 All flange joint bolting should be secured with an appropriate locking means.

13. Keywords

13.1 coolers; filters; gas turbines; lubricating oil system; lubrication; oil systems; piping; pumps; reservoirs; strainers