GEK 32568f
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GE Power Systems
Gas Turbine

Lubricating Oil Recommendations for Gas Turbines with Bearing Ambients Above 500°F (260°C)

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I. GENERAL

These instructions contain information intended to help the purchaser of a General Electric gas turbine and the lubricant supplier to select the proper grade and quality of lubricating oil for the turbine application. For phosphate ester fire resistant lubricants refer to GEK 28136, "Phosphate Ester Based, Fire-Resistant Recommendations for Gas Turbines."

These recommendations apply to General Electric's Heavy Duty Gas Turbines only. For lubrication recommendations for equipment other than General Electric, refer to the instructions provided by the manufacturer of that equipment.

The successful operation of the gas turbine and its driven equipment is vitally dependent upon the lubrication system. Therefore, it is necessary that all factors contributing to correct lubrication be present and that the entire system be maintained in good order.

The life of the apparatus depends upon a continuous supply of lubricant of proper quality, quantity, temperature, and pressure.

This being the case, the life and quality of the lubricant is of prime importance to the user. Experience has shown that certain fluid monitoring and condition maintenance is required. Hence, the following recommendations are made.

II. RECOMMENDED PHYSICAL PROPERTIES

The lubricating oil intended for this service is a rust and oxidation inhibiting petroleum lubricating oil or synthetic hydrocarbon with greater high temperature oxidation stability than conventional lubricating oils. Operating experience has shown the antioxident of the di-tertiary butyl-para-cresol (DBPC) type is not adequate for this service. The inhibitors must be of the non-volatile type.

A listing of recommended properties of new oil is shown in Table 1. Included with this listing is the ASTM test method and the recommended value. The reader should refer to these methods for details of the tests. The oil is an International Standards Organization Viscosity Grade 32 (ISO VG 32) oil. The properties listed are rather typical of turbine lubricating oils except for the oxidation test requirements. Note that the values in Table 1 are only recommended values. An oil that has been shown to perform successfully in the field may still be used even if all values in Table 1 have not been satisfied.

For several years there have been investigations to decide on appropriate laboratory tests which could distinguish between fluids which gave satisfactory service in a turbine and those which did not. To date, there has not been complete correlation between laboratory testing and field experience.

There are three methods recognized by the ASTM for determining carbon residue. They are D-524, "Ramsbottom Carbon Residue of Petroleum Products", D-4530, "Determination of Carbon Residue (Micro Method)" and D-189, "Conradson Carbon Residue of Petroleum Products". Although these methods are similar in concept, they do not provide identical results. Each method contains a graph that can be used to convert the results for comparison to the other methods. Although Table 1 only contains acceptance criteria for D-524, either of the other two methods can be used instead provided the results obtained are equivalent to the value contained in Table 1 for D-524.

Two oxidation tests are listed in Table 1. The ASTM D-943 (Oxidation Characteristics of Inhibited Steam-Turbine Oils) minimum value must be satisfied for this service. In addition, both of the Oxidation Stability by Rotating Bomb tests described below must be satisfied.

ASTM D-2272, Standard Test Method for Oxidation Stability of Steam Turbine Oils by Rotating Bomb, presently shows the best correlation with service experience but it is not absolute. It has been found that the volatility of the inhibitor can have a significant effect on the results of this test. As stated above, these inhibitors need to be non-volatile.

The ASTM D-2272 test should be run in the normal way and a second test run on oil which has been treated to remove volatiles. This pretreatment is done by putting the oil to be tested in a test tube 38 mm ID× 300 mm L. (This is the same tube used for the International Harvester BT-10 oxidation test.) This tube is immersed in a bath maintained at 250°F (l21°C). Clean, dry nitrogen is then bubbled through the heated oil for 48 hours at the rate of 3 liters per hour. The treated oil is then tested per ASTM D-2272.

The value obtained in the test of the treated oil should be no less than 85% of that obtained for the untreated.

When applying a new lubricating oil it is recommended that laboratory test comparisons be made with a known successful oil.

Table 1. Recommended Properties High Temperature Lubricating Oil for Gas Turbines (for New Oil)

ASTM Test Method No.	Test	Recommended Value
D-287	Gravity (°API)	29-33.5
D-1500	Color	2.0 (max.)
D-97	Pour Point (°F/°C)	+10/-12 (max.)
D-445	Viscosity 40°C (centistokes)	28.8-35.2
D-974	Neutralization No. (mg KOH/g)	0.20 (max.)
D-665	Rust prevention — B	Pass
D-92	Flash point (COC) (°F/°C)	420/215 (min.)
D-130	Copper corrosion	1B (max.)
D-524 (or equivalent)	Carbon residue ramsbottom	0.10% (max.) (or equivalent)
D-892	Foam	50/0 (max.) 50/0 (max.) 50/0 (max.)
D-943	Turbine oil oxidation test (hrs)	3,000 (min.)
D-2272	Oxidation Stability by Rotating Bomb (minutes)	500 (min.)
D-2272	Oxidation Stability by Rotating Bomb (modified)	85% (min.) of time in unmodified test
D-3427	Air Release	5 (max.)
D-2270	Viscosity Index (VI)	95 (min.)

III. LUBRICATION SYSTEM

The lubrication system is designed to provide an ample supply of filtered lubricating oil at the proper temperature and pressure for operation of the turbine and its associated equipment.

Protective devices are incorporated into those systems where it is necessary to protect the equipment against low lube oil supply, low lube oil pressure, and high lube oil temperature. The protective devices sound a warning or shut down the unit if any of these conditions occur.

The particular arrangement of the system, the protective devices, and the system settings are shown on the schematic piping diagram for the specific gas turbine. Other information on the Lubrication System is found in the service manual and includes the system's operation, maintenance, and instructions for the various pieces of equipment used in the system.

IV. OPERATING TEMPERATURES

Lubricating oil is exposed to a range of temperatures as it is circulated through the gas turbine. For reliable circulation of oil before starting, the oil temperature should be 70°F (21°C) to obtain the appropriate viscosity.

The normal bearing inlet oil temperature is 130°F (54°C). However, because of customer requirements or because of ambient conditions and/or coolant temperatures, the actual operating conditions may be different.

The lubricating system cooling equipment is designed to maintain the nominal 130°F (54°C) bearing inlet oil temperature when raw water is available for cooling. However, when radiator systems are involved, the sizing is such that for the maximum recorded ambient temperature at the site, the bearing header temperature may be 160°F (71°C). The minimum recommended oil inlet temperature is 90°F (32°C). The gas turbine bearings are designed to operate satisfactorily at these inlet oil temperatures. With radiator systems, the nominal 130°F (54°C) bearing header will be maintained for a high percentage of the operating time. In special cases, other design header temperatures are used as dictated by the load devices.

Operating bearing temperature rises are discussed in appropriate sections of the service manual. Typically, the lubricant temperature rise from inlet to drain is in the 25°F to 60°F (14°C to 33°C) range. If a reduction gear is involved, this temperature rise may be 60°F (33°C).

Some gas turbines have bearings that are in an ambient of high temperature. This ambient and the sealing air may be over 500°F (260°C). The bearing housing is sealed with labyrinths and airflow such that the bearing drain spaces are at approximately atmospheric pressure. A portion of the lubricating fluid will be mixed with a small quantity of hot air and will wash metal surfaces between the bearing housing ambient and the oil drain temperature.

The lubricant temperature in the tank will be 25°F to 40°F (14°C to 22°C) above the bearing header. Thus, the bulk temperature will be 155°F to 200°F (68°C to 93°C) during operation.

V. CORROSION — PREVENTATIVE MATERIALS

Manufacturing procedures provide for corrosion protection by cleaning and treating all metal surfaces which will be in contact with the lubricating oil in the lubrication system.

The inside walls of the lubricating oil tank are processed at the factory using an oil-resistant paint.

The inner surfaces of all lubricating oil piping, bearings, hydraulic control devices, and other apparatus whose surfaces will be in contact with the turbine lubricating oil are coated with a vapor space rust-inhibited (VSI) lubricating oil which is used as a combination test and shipping oil.

In addition, 50 gallons of this oil is put in the reservoir at shipment and the system openings are closed. The oil and its vapors provide corrosion protection during shipment and installation.

At installation this oil should be removed and the reservoir manually cleaned. The remaining VSI oil should be removed with a displacement flush.

VI. CLEANING REQUIRED AT INSTALLATION

The reliable operation of controls and machine bearings is dependent upon the cleanliness of the lubricating oil system. During manufacture, considerable care has been taken in processing, cleaning, and flushing this system to maintain the cleanliness. Further, full flow filters are included in the system thereby filtering all of the fluid before its use.

For assistance in flushing and cleaning, refer to ASTM Standard D 6439 “Standard Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems.” Most of the General Electric Company gas turbines are package power plants that require a minimum of flushing and cleaning at installation. This ASTM standard should be followed.

If the installation is of a non-package type requiring field pipe fabrication of intricate shapes, then complete cleaning and flushing is required.

From this ASTM standard for a package power plant the minimum practices include the following:

1. Upon arrival of the equipment at the site, a general visual inspection should be made to become familiar with the equipment, to observe any shipment damage, and to determine that the lubrication and control systems are sealed from contamination. Take corrective action as necessary from these observations. It is important that the systems subject to contamination or corrosion remain sealed as much as possible during the installation period.

2. The field interconnections of the piping must be clean at installation. This piping is of simple configuration to permit visual inspection and manual cleaning.

3. During the installation, any soft or hard film temporary corrosion protective material must be manually removed.

4. A displacement flush should be performed. Install and circulate the operating lubricant for a 24- to 36-hour period at a temperature of 130°F to 150°F (54°C to 66°C). The auxiliary lubricant oil pump may be used. Remove and dispose of this displacement fluid.

5. After satisfying the above items, the reservoir should be manually cleaned. The parties involved should be satisfied that the operating lubricant is clean and free of water and that it meets the manufacturer’s recommendations. The actual fill should be made through a suitable strainer, as a precaution against the accidental ingress of solid foreign objects.

6. After filling, circulate the lubricant through the system to confirm that satisfactory flow has been established. Also, check for system leaks.

VII. RESPONSIBILITY OF OPERATOR

After the unit is installed, and prior to its initial starting, the operator should take all precautions to ensure that:

1. The lubricating system has been thoroughly flushed and/or is clean.
2. The supply of turbine oil is ample for operation of the unit.
3. The type of oil is in accordance with this instruction.

During operation of the unit, the operator should establish a routine inspection procedure to ensure that:

1. The temperature and pressure levels of the lubrication system are within the limits specified by the service manual and the piping schematic diagrams.
2. The oil purity is maintained by checking for water leaks, by draining tank bottoms, and by adhering closely to the recommendations set forth by the oil vendor for sampling, purifying, and replenishing the lube oil supply or inhibitors.

VIII. RESPONSIBILITY OF OIL VENDOR

It is generally recognized that turbine lubricating fluid should be a petroleum derivative or synthetic hydrocarbon free from water, sediment, inorganic acids, or any material which, in the service specified, would be injurious to the oil or the equipment. There should be no tendency toward permanent emulsification or rapid oxidation with the formation of sludge.

The responsibility of supplying the proper oil for the lubricating system to meet this instruction rests with the oil vendor and the turbine operator. The oil vendor is expected to make recommendations to the turbine operator concerning compatibility with the VSI oil and operational sampling and testing. Further, he is expected to cooperate with the manufacturer and the operator by providing the support necessary to ensure satisfactory performance of the lubricant, such as examination of oil samples and recommendations for corrective action, if required.

IX. MONITORING

Lubricant condition must be monitored for reliable operation of the gas turbine. ASTM Standard D-4378, “In-Service Monitoring of Mineral Turbine Oils for Steam and Gas Turbines" provides guidance for selecting sampling and testing schedules. This document recommends sampling the oil after 24 hours of service and then suggests nominal intervals depending on hours of operation.

The sampling and testing schedule should be adjusted to account for severity of service and oil condition. ASTM Standard D-4378 provides information that can be useful in making this determination.

A. Sampling

The proper sampling techniques are important when taking lubricant samples. A sample to be representative must be obtained either from an *agitated tank* or a *free flowing line.* The preferable sampling method is:

***Dipping from the Tank*:**

Lubricant fluid sample should be taken by dipping from the tank. Lubricant should be thoroughly circulated (with one or more lube oil pumps) before the sample is taken.

Secondary sampling methods are:

***Sampling from a Line*:**

The line should contain lubricating fluid which is free flowing and not dead-headed. For instance, the lines in the bearing header, the active filter and active heat exchanger are free flowing; the lines to the gauge cabinet are deadheaded. In a machine with dual filters or heat exchangers, the inactive filters or heat exchangers do not have flowing fluid and, therefore, are not suitable sampling points.

When using a sampling line, make sure that the line has been thoroughly flushed before taking a sample. Adequate amount of flushing will depend on sampling line dimensions, length and diameter.

***Tapping from a Reservoir*:**

As described above, the lubricant fluid must be thoroughly agitated in the reservoir and the tap line flushed before a sample can be taken.

A fluid sample is probably not representative if:

1. The fluid in the system is hot while the sample is cold.
2. The fluid in the system is one color or clarity in a sight glass while the sample is a different color or clarity.
3. The viscosity of the reservoir fluid is different than the sample when both are at the same temperature.

It should be noted that on occasion a sample may be requested which will not be representative. At that time, sampling instructions, as specified by the requestor, must be followed. For example, a sample might be taken off the top or the bottom of a tank to check for contamination. In such a case the sampling point should be marked on the sample container.

Samples should be taken in a “suitable” container. To be “suitable” the container should be:

1. Clean. If in doubt about its cleanliness, use another container. If this is not possible, flush it out with the fluid to be sampled.
2. Resistant to the material being sampled. For instance, the fire resistant phosphate ester fluids and some fuels will dissolve certain plastics. This includes the liner in bottle caps. To verify the container’s resistance, if time permits, allow the sample to sit in container and observe its effects. Aluminum foil makes a good, resistant cap liner.
3. Appropriate for whatever handling is required. Containers with leaking tops and glass containers improperly protected are not suitable for shipment. Note that stringent packaging requirements must be followed if shipment is to be made by air.
4. Of sufficient size. An extensive chemical analysis, if that is why a sample is required, cannot be done on the contents of a container that is too small. Normally one pint is sufficient unless a larger quantity is requested.

Lubricant suppliers provide sample containers which meet the above mentioned requirements. These should be used whenever possible. If frequent samples are taken, an adequate supply of containers should be kept.

A sample should be properly marked. Markings should include at least the following information:

Customer name

Site

Location

Turbine serial number

Turbine fired hours

Date sample taken

Type of fluid sampled

Sampling point

Samples from the initial fill should be forwarded to the lubricant supplier for extensive tests. The amount of testing of the other samples depends upon the service and interests of the parties involved. Sufficient tests and sample intervals are necessary to establish trends and to prevent significant lubricant operational problems. Sharing the test results among the user, oil supplier, and the General Electric Company Gas Turbine Division can be helpful.

Tests that are indicative of fluid condition include:

1. *Viscosity* — ASTM D-445, Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity).

2. *Total Acid Number* — ASTM D-974, Neutralization Number by Color Indicator Titration.

3. *Oxidation Life Remaining* — ASTM 2272, Oxidation Stability of Steam Turbine Oils by Rotating Bomb (RBOT).

NOTE

Some oil suppliers have alternate tests for this purpose.

4. *Oxidation Inhibitor Level* — Oil suppliers have methods of determining oxidation inhibitor content of in-service oils.

   This information can be important on its own or when combined with the other data.

5. *Water Content* — The presence of water in the lubricating fluid is not indicative of decomposition. Water can, however, promote decomposition of the lubricating oil by reacting with additives in the oil. This reaction may also cause filter plugging. Also, the presence of water indicates a

problem with the turbine system such as a leaking heat exchanger. The source of water should be determined and corrected.

X. USE LIMITS

The lubricant supplier will have recommended use limits. However, the General Electric Company also has recommendations that are stated in this section. The object of the use limits is to prompt action before turbine operational problems develop because of the condition of the oil. Oil oxidation can produce sludges, varnishes, and light flammables that have caused fires and explosions.

Recommended use limits are given in Table 2 and discussed below.

Table 2. Recommended Use Limits

Viscosity at 40°C (104°F)	41 centistokes (max.) 25 centistokes (min.)
Total Acid Number	0.4 mg KOH/gm (max.)
Rotating Bomb Oxidation Test (RBOT)	25% (min.) of value for new oil

The viscosity limits provided above are consistent with the guidelines presented in ASTM D-4378. High viscosity is most likely the result of oil oxidation. Low viscosity is probably the result of contamination with fuel or water.

Total Acid Number is an indication of the lubricant condition. With oxidation the total acid number increases. The oil should be changed before a total acid number of 0.4 mg KOH/g is reached.

The remaining oxidation life of the oil can be measured by ASTM D-2272, Oxidation Stability of Rotating Bomb (RBOT). The RBOT values and limits vary with the various oil formulations; however, with a RBOT of 25 percent of the oil's initial value, its life is gone.

As stated above, the oil supplier may have other tests to determine oil conditions. These tests and any associated limits should be included in the oil monitoring program.

With any one of these measurements out of limits, the lubricating oil needs to be changed. The steps for such a change include draining the old oil, manually mopping out the tanks, filling and displacement flush (see section 6), draining flush oil, manually mopping out the tank, and filling with the new charge of oil.

XI. COMMENTS

As the turbine manufacturer, the following comments are offered.

A. Oil Purifying System

External oil purification systems are not recommended. Since full-flow filtration is included in the lubrication system, a bypass filter for dirt removal is superfluous.

Water removal systems have not normally been installed with gas turbines. Water contamination is limited to condensation and cooler leaks. It is recommended that the cooling water pressure be below lube fluid pressure to minimize the chance of water leakage into the lubrication system. An operating gas turbine is an excellent dehydrator. Centrifuges are not recommended because of their potential for removing oil additives.

Clay filters are not recommended for cleaning of the inhibited turbine oils meeting these instructions.

B. Use of Additives

The customer should not incorporate any additives into the fluid except at the request of or with the approval of the fluid supplier. This prohibition particularly refers to the use of "oiliness additives," "oil dopes," preservative oils, and engine oils which have been used in the past during installation and maintenance. If oiling the bearing is required to facilitate rolling of the shaft, the oil from the lubricant oil tank should be used.

C. Diagnostics Programs

Diagnostic programs such as wear metal analysis, Spectrographic Oil Analysis Program (SOAP) or others may be used as part of oil sampling and analysis. General Electric makes no recommendation with regard to use of these programs. There are, however, several reservations. These programs are useful only for establishing trends; a single point in time value is not meaningful. Unlike aircraft jet engines and piston engines, there have not been and are not any studies correlating the results of these programs with performance of a gas turbine. With the type of bearings used in a gas turbine, impending bearing failure is most likely to be predicted by analysis of mechanical vibration.

XII. APPENDIX A — TEST METHOD

A. Discussion of Test Methods

For detailed information concerning the various test methods, please refer to the parent published documents. The discussions below will help explain these various tests and properties.

1. Viscosity

The viscosity of a fluid is its resistance to flow. Viscosity is commonly reported in stokes which has the units of cm/sec. Centistokes (one hundredth of one stoke) are most commonly used for convenience. The viscosity in centistokes is also called the kinematic viscosity. The absolute or dynamic viscosity is expressed in poise (more commonly centipoise). It is the kinematic viscosity in stokes (or centistokes) at a given temperature multiplied by the density of the fluid at this temperature expressed in grams/cm^3.

The viscosity in centistokes is determined per ASTM D-445, "Viscosity of Transparent and Opaque Liquids (Kinematic and Dynamic Viscosities)." The viscosity is calculated from the time required for a fixed volume of fluid at a given temperature to flow through a calibrated glass capillary instrument using gravity flow. Centistoke viscosities can be converted to Saybolt and vice-versa using the tables and formulas given in ASTM 2161 "Conversion of Kinematic Viscosity to Saybolt Universal Seconds."

2. Pour Point

The pour point is the lowest temperature at which a fluid is observed to flow. It is reported in increments of 5°F and is determined as the temperature at which fluid, contained in a tube with an inside diameter of 30 to 33.5 mm, will not flow within five seconds of rotating the tube 90 degrees from the vertical to the horizontal position.

The pour point is reported more as a matter of information. Of practical concern in the design of lubrication systems is the viscosity at which the lubricant fluid becomes too viscous to be pumped. For General Electric gas turbines the viscosity should be less than 173 centistokes for proper circulation of the fluid before starting.

3. Total Acid Number

The total acid number is the milligrams of potassium hydroxide (KOH) required to neutralize the acidic constituents in a gram of sample. It is determined per ASTM D-974, “Neutralization Number by Color lndicator Titration.” The total acid number (TAN) is sometimes called the neutralization number (NN) or neut number and also the acid number (AN).

4. Flash and Fire Point

Flash and Fire Points are determined per ASTM D-92, “Flash and Fire Point by Cleveland Open Cup.” Flash point is the temperature at which the fluid contained in a test cup and heated at a constant rate will flash but not burn when a flame is passed over the cup.

Fire point is the temperature at which the fluid contained in a test cup and heated at a constant rate will burn for at least 5 seconds when a flame is passed over the cup.

Flash and Fire Points are an indirect measure of both the volatility of the fluid and the flammability of these volatiles. Since there are more accurate ways of determining these, as an example: distillation to determine volatiles, this test is mainly of value as a quality control test.

5. Autogenous Ignition Temperature

The autogenous ignition temperature of a fluid is the temperature of a fluid at which it will ignite due to heat alone, that is, without a flame or other ignition source being used. It is determined per ASTM D-2155, “Autoignition Temperature of Liquid Petroleum Products.” It consists of injecting a small amount of fluid into a 200 milliliter flask at elevated temperature. The lowest temperature at which a fire occurs within five minutes of injecting the fluid is reported.

The autogenous ignition temperature (AIT) is sometimes called spontaneous ignition temperature (SIT). This test does not necessarily indicate ignition temperature in a “hardware” situation.

6. Oxidation Tests

The ASTM D-943, “Oxidation Characteristics of Inhibited Steam-Turbine Oils" is the traditional oxidation test for turbine oils. In this test, a sample of oil is placed in a container of water along with pieces of steel and copper wire that have been coiled together. The container is maintained at a temperature of 95°C (203°F) and oxygen is passed through it. The test measures the time in hours for the acidity to reach 2.0 milligrams of potassium hydroxide per gram of sample.

This test is used primarily to determine the life of the oxidation inhibitor and does not necessarily indicate the stability of the base oil.

The ASTM D-2272, "Oxidation Stability of Steam-Turbine Oils by Rotating Bomb" is an oxygen absorption test. The test oil, water, and copper catalyst coil, contained in a covered glass container, are placed in a bomb equipped with a pressure gauge. The bomb is charged with oxygen to a pressure of 90 psi (620 kPa), placed in a constant temperature oil bath set at 150°C, and rotated axially at 100 rpm at an angle of 30 degrees from the horizontal. The time for the test oil to react with a given volume of oxygen is measured, with completion of the time being indicated by a specific drop in pressure. This test is normally used for quality control of particular new oil formulation.

Recent work shows it to be an excellent in-service monitoring test. Some studies show it to be a good indicator of performance.

7. Foaming Tendency

The ASTM method specifies three sequences of bubbling air through oil. First, it is done at 75°F; second, it is done with a new sample of oil at 200°F; and third, the oil from the second sequence is used but operated at 75°F.

8. Rust Prevention

The rust prevention characteristics of the lubricant are determined per ASTM D-665. A mixture of 300 ml of lubricant and 30 ml of distilled water (Procedure A) is stirred while held at a temperature of 140°F. A carbon steel rod conforming to ASTM specification A108, Grade 1018, is immersed in the oil for a period of 24 hours then examined for rust.

9. Air Release

ASTM Test Method D-3427 describes the method for determining air release properties of petroleum oils. Compressed air is blown through oil heated to a specified temperature. The length of time required for the air entrained in the oil to reduce to 0.2% is recorded as the air release time. Air release provides a measure of the oil's performance in hydraulic systems because entrained air can lead to sponginess.

10. Viscosity Index (VI)

Viscosity Index (VI) is an arbitrary number used to characterize the variation of kinematic viscosity with temperature. A higher VI indicates a smaller decrease in kinematic viscosity with increasing temperature.

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