
Liquid Fuel Requirements for GE AeroDerivative Gas Turbines

This document lists specifications and describes application guidelines for liquid fuels that can be fired satisfactorily in GE AeroDerivative gas turbines. It is recommended that a complete specification analysis of all liquid fuels proposed for use in GE AeroDerivative gas turbines be reviewed by GE prior to use.

1.0 Fuel Specifications

Fuels conforming to the following military and industry specifications are acceptable for use in GE gas turbines in industrial and shipboard applications, except as noted below, and provided they also meet the additional criteria described in 2.0. However, their use should be reviewed against applicable safety and regulatory requirements.

D50TF2 - *GEAE Aviation Fuel Specification*

ISO 8217 - *ISO-F-DMA (MGO)*

MIL-DTL-5624 - *Grades JP-4¹, JP-5 (NATO F-40, 44)*

MIL-DTL-83133 - *Grade JP-8 (NATO F34/F35)*

ASTM D975 - *Diesel Fuel Oil, Grades 1-D, 2-D, 1-D Low Sulfur, and 2-D Low Sulfur*

ASTM D1655 - *Aviation Turbine Fuels (Jet-A, Jet-A1, and Jet-B¹)*

MIL-F-16884 - *Fuel Oil - Diesel Marine*

¹ Highly volatile wide-cut fuels (such as MIL-DTL-5624 JP-4, ASTM D1665 Jet-B, and ASTM D2880 Grade No. 0-GT) are generally acceptable for industrial, but not shipboard applications.

(NATO F-75, F-76)

VV-F-800 - *Fuel Oil - Diesel, Grades DF-A, DF-1, and DF-2 (NATO F-54)*

ASTM D396 - *Grades No. 1, 2, 4, and 4 (Light)*

ASTM D2880 - *Gas Turbine Fuel Oils, Grades No. 0-GT^{1,2}, No. 1-GT, No. 2-GT*

Other:

The pure hydrocarbon combustibles² [e.g. propane (C₂H₈) and butane (C₄H₁₀), both normal and iso], are acceptable either alone or in various mixtures with other liquid fuels, providing that fuel manifold pressures are sufficient to maintain the fuel in the liquid state. Alternate fuels may be required for starting and low-power operation. Contact GE for specific applications.

Light distillate fuels², such as Naphtha (C10 down to C4 hydrocarbons), gasoline (C7 to C5 hydrocarbons) and D2880 Grade No. 0-GT, are acceptable as fuels in GE AeroDerivative gas turbines provided fuel manifold pressures are sufficient to maintain fuel as a liquid, especially in hot climates. Alternative fuels may be necessary for starting the engines and low power operation. Contact GE for specific applications.

² Liquefied gas fuels, light distillates, and alcohols may have inadequate *lubricity*, requiring the use of a fuel pump/system specifically designed to handle these types of fuels. See paragraph 2.3.

Various alcohols², [e.g. hydroxyl derivatives of hydrocarbons, such as methanol (CH₃OH) and ethanol (C₂H₅OH)], can burn in GE aero-derivative gas turbines. Contact GE for specific applications.

2.0 Additional Requirements

The following requirements supplement and supersede, where there is a conflict, the specifications listed in 1.0. However, if the specification requirement is more restrictive, it applies.

2.1 Composition

The fuel shall consist of hydrocarbon compounds only and must be compatible between brands and batches.

While there is no specific requirement or limit on the amount of fuel-bound nitrogen (FBN) contained in a liquid fuel, it is recommended that the amount of liquid fuel FBN be understood for those applications that are sensitive to levels of oxides of nitrogen (NO_x) in the gas turbine exhaust. FBN is the amount of nitrogen in the fuel that is chemically bound. During the combustion process, the FBN is converted, at least partially, to NO_x (called organic NO_x) and adds to the total amount of NO_x that is contained in the gas turbine exhaust. GE emissions data provided for liquid fuels assumes a FBN content of less than 0.015 percent by weight unless otherwise noted.

2.2 Additives

The use of any dyes or additives requires approval of GE, unless such additives are specifically approved in the fuel specifications (1.0) or, they conform to MIL-S-53021A.

The purchaser may refer to the Qualified Parts List (QPL-53021) for a summary of approved stabilizer additives used in the long-term storage of diesel and distillate fuels. This publication is periodically revised, and is available from the U.S. Government Printing Office.

2.3 Viscosity

The viscosity of the fuel as supplied to the inlet connection on the gas turbine shall be a minimum of 0.5 centistokes³ and shall be up to 6.0 centistokes maximum for starting and 12.0 centistokes maximum during operation. The fuel may be heated to meet this requirement.

2.4 Wax

Wax can be present in fuel oil, especially the distillates with higher pour points. It may be necessary to determine the percent of wax and its melting point and to provide a suitable method to keep the wax dissolved at all times.

2.5 Fuel Temperature Requirements

The minimum temperature of liquid fuel supplied to the gas turbine shall be the greater of:

- (a) 20°F (11°C) above the wax point temperature of the fuel.

or

- (b) The temperature required to remain within maximum fuel viscosity requirements, or 35°F (2°C).

³ Required for adequate GE aeroderivative gas turbine fuel pump lubrication and to prevent pump cavitation when using light fuels.

The maximum temperature of liquid fuel supplied to the gas turbine should not exceed 150°F (65.6°C). For liquid fuels with high vapor pressure constituents (naphtha, NGL, etc.) the fuel temperature in the manifold should be at least 100°F (55.6°C) below the bubble point temperature of the lightest component at high pressure compressor discharge static pressure (PS3).

3.0 Property Requirements

Property requirements are listed in Table 1. Contaminant limits apply to fuel samples taken at the gas turbine fuel manifold flange. It cannot be assumed that specification fuel supplied by a refinery still meets those specifications once it is delivered to the gas turbine.

4.0 Fuel Handling

True distillate fuel as refined has low water, dirt, and trace metal contaminant levels that can be maintained with careful transportation, handling, and storage methods. Most contamination occurs during transportation of fuel.

Since fuel can be contaminated during transportation from the refinery to the site, auxiliary fuel cleanup equipment should be available to restore the fuel quality. Available purification equipment includes centrifuges and electrostatic dehydrators. In addition to potential hot corrosion from salt in the water, water accumulated in the bottom of a storage tank can also cause problems. Microorganisms tend to grow at the water/fuel interface, generating both chemicals corrosive to metals in the fuel system and also slime that can plug fuel filters. In marine applications, shipboard systems that allow recycling fuel from the service tanks through the centrifugal purifiers are recommended.

When liquid fuel is supplied by barges or other

bulk modes of transportation, it should be pumped directly into raw fuel storage tanks, and must be conditioned/treated before being placed in one of two clean fuel day storage tanks from which gas turbine will be supplied. Redundant, clean day fuel storage tanks are recommended to provide a primary *settled* fuel supply and to allow tank repair and/or cleaning with minimum downtime. Storage tanks must be constructed of corrosion-resistant materials or appropriately lined to minimize internally formed contaminants. Fuel shall not be transported, stored, or handled in system components containing copper, e.g. ships that have copper heating coils, or storage tanks coated with zinc. Neither copper or zinc are normally found in refined fuels such as diesel and naphtha, but should they be present, they can cause fuel degradation and additional engine maintenance. No fuel should be used that contains detectable amounts of copper or zinc.

Duplex, primary strainers (150-200 microns absolute) should be located between the off-loading facility and the raw fuel storage tanks. Duplex, secondary filters (50-100 microns absolute) should be located between the raw fuel storage tanks and the final fuel treatment system. All fuel storage tanks must have inlets at the bottom of the tank. All fuel day storage tanks should be provided with a floating suction. The distance between the inlet and outlet should be maximized.

After filling any tank or adding fuel to it, a settling time of 24 hours should be allowed before taking fuel from that tank. Initially, water and sludge should be drained from all storage tanks on a daily basis. After experience is gained with a given fuel and fuel source, the frequency of draining may be adjusted by the customer.

5.0 Fuel Sampling

A well thought out fuel sampling protocol will ensure that quality fuel is delivered to the engine. For each delivery, fuel samples should be taken and analyzed at the following locations:

- At the refinery before loading
- At the port where the fuel is delivered before unloading
- From the pipeline just upstream of the raw fuel storage tanks as the fuel is being added to the tanks

After the fuel is treated/conditioned, samples should be taken and analyzed at both the inlet and outlet of the fuel treatment system. Fuel exiting the system must meet the fuel specification. This should be confirmed before the fuel is placed in clean fuel day storage tanks. Fuel samples should be taken and analyzed to ensure that the fuel discharged from these

tanks and at a practical location at, or just upstream of, the gas turbine fuel manifold flange meets the specification.

For all fuel sampling, sufficient samples (a minimum of three) must be taken to assure that a representative sample is obtained. Samples should be taken at different levels in large volume tanks and at equally spaced time intervals during fuel delivery or fuel treatment. To avoid contamination, all samples should be obtained in clean plastic bottles. Fuel samples taken should be analyzed to meet all GE liquid fuel requirements. If fuel samples taken after the above recommendations have been implemented indicate that the fuel system does not provide fuel per the requirements, the customer must change his fuel source or modify the fuel treatment system. The end user is responsible for ensuring that the fuel meets the requirements.

Table 1 Liquid Fuel Property Requirements

Property	Limit	ASTM Method
Ash, %, maximum	0.01	D482
Sulfur, %, maximum	1.0 ^a	D129 ^b
Vanadium, ppm, maximum	0.2	D3605
Sodium, Potassium and Lithium, ppm, maximum	0.2 ^{c, d}	D3605 ^e
Lead, ppm, maximum	1.0	D3605
Calcium, ppm, maximum	2.0	D3605
Hydrogen content, %, minimum	12.7 ^{f, k}	D1018, D3701
Demulsification, minutes, maximum	20.0	D1401 and Note 3 therein
Carbon residue, %, maximum (100% sample)	1.0	D524
Carbon residue, %, maximum (10% Ramsbottoms)	0.25	D524
Particulates, mg/gal., maximum	10.0 ^g	D2276
Water and Sediment, volume %, maximum	0.10 ^h	D2709
Flash Point, oF, maximum	See i Below	D93
Copper corrosion, maximum	No. 1 ^j	D130
Asphaltenes, %, maximum	None Detectable	D6560

Notes

- a. Fuels with a higher sulfur content can be burned. Impact on HSRI (Hot Section Repair Interval) will be dependent upon alkali metals present in the fuel, inlet air, and injected water and upon engine operating temperature. Consult GE for review of higher sulfur fuels.
- b. The following alternate methods are acceptable: ASTM D1552, ASTM D2622, and ASTM D1266.
- c. This limit is considered to include all alkali metals, e.g. potassium and lithium as well as sodium. Experience, however, has shown that sodium is generally the predominant alkali metal.

This limit also assumes zero alkali metals in the inlet air or injected water or steam. When actual levels are above zero, the maximum allowable sodium content of the fuel must be reduced in accordance with the following relationship:

$$\begin{aligned} &\text{ppm Na in Inlet Air} \times \text{Air/Fuel Ratio} \\ &+ \text{ppm Na in Water or Steam} \times \text{Water or Steam/Fuel Ratio} \\ &+ \text{ppm Na in Fuel} \end{aligned}$$

Total fuel equivalence for sodium from all sources not to exceed 0.2 ppm
- d. For nonmarinized engines (except for LM6000), the total amount of alkali metals from all sources shall not exceed 0.1 ppm.
- e. To achieve the level of sensitivity for detection of sodium to the level required, an atomic absorption spectrometer or a rotating disc spectrometer may be necessary.
- f. Care must be taken with the more viscous fuels to ensure that the minimum hydrogen content is met.
- g. Maximum particle size, 20 micrometers.
- h. For marine gas turbines using a hydromechanical main fuel control, the limit is 40 ppm.
- i. Legal limits and applicable safety regulations must be met; however, it should be noted that use of fuels having a flash point in excess of 200°F (93.3°C) may result in unsatisfactory starting characteristics. Blending for enhancement of spark ignition or use of alternate fuels may be required for starting.
- j. Copper corrosion test conditions are 2 hours at 212°F (100°C).
- k. Fuels with Hydrogen content lower than 12.7% have been approved for use in certain applications with specific restrictions. These fuels require a development test program for the applicable engine model before approval would be considered.