LM2X LIQUID FUEL SYSTEM - SYSTEM DESCRIPTION

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LIQUID FUEL SYSTEM

The LM2500 turbine can be equipped to operate on a liquid fuel system that includes a boost pump skid. The liquid fuel system delivers customer-supplied liquid fuel to the turbine combustor through primary and secondary liquid fuel manifolds, which are connected to the 30 dual-fuel nozzles. On the main skid, liquid fuel is filtered and metered through the primary and secondary headers and the fuel nozzles. Liquid fuel must meet General Electric fuel quality requirements.

Fuel viscosity must be a minimum of 0.5 centistoke (cSt) at the supply connection. The maximum viscosity of the fuel is 6.0 cSt for starting and 12.0 cSt during operation. Acceptable fuels shall contain < 10 mg of solid contaminants per gallon and < 1000 ppm of entrained water. Maximum contaminant size shall be 5 µ. A partial list of acceptable fuels and controlling specifications appears in the table below.

SPECIFICATION	FUEL TYPE
MIL-T-5624	Grades JP-4, JP-5
ASTM D975	Diesel Fuel Oil, Grades 1-D, 2-D
ASTM D1655	Aviation Turbine Fuel
MIL-F-16884	Fuel Oil-Diesel Marine
VV-F-800A	Fuel Oil-Diesel, Grades DF-A, DF-1, DF-2
ASTM D2880	Gas Turbine Fuel Oil, Grades 0-GT, 1-GT, 2-GT
ASTM D396	Grades 1 and 2

Liquid Fuel Boost Pump

The liquid fuel system includes the fuel boost pump skid and interconnecting piping to the main turbine skid. The boost skid increases fuel pressure and filters the fuel before delivering it to the main skid. Refer to F&ID drawing *xxx260 Fuel System* to review the liquid fuel pump system. This section provides an overview of the liquid fuel pump system.

Liquid fuel is supplied to the liquid boost pump skid at customer connection [65] at 37 gpm at a pressure of 20-40 psig and pre-filtered by the customer to 5 µ. The fuel passes through a pump suction isolation valve, strained through a 10-µ basket strainer, passes through the pump assembly, and cleaned through the filter assembly before entering the main skid. Pressure transmitter PT-2021 provides a fuel inlet pressure signal to the control system. Software-based pressure alarm PAL-2021 is activated if fuel pressure drops to 10 psig. Alarm PALL-2021 activates a FSWM shutdown if fuel pressure decreases to 5 psig. Alarm PAHH-2021 activates a FSWM shutdown if fuel pressure increases to 60 psig. Each instrument can be isolated by instrument isolation valves.

The pump assembly is driven by a 40-hp, 460-VAC, 3ø, 60-Hz motor. The pump is designed to deliver 45 gpm of liquid fuel at 1100 psig. Pump discharge pressure is limited by relief valve PSV-2023, which is set at 1200 psig. Relief fuel from PSV-2023 is routed back to the liquid fuel reservoir through return connector [67]. Temperature element TE-2024 monitors the temperature at the pump assembly and activates alarm TAH-2024 if the temperature increases to 140 °F. Alarm TAHH-2024 activates a STI shutdown if the temperature at the pump assembly increases to 160 °F.

The duplex filter assembly cleans the liquid fuel to 9.7 µ before it enters the main skid. Pressure differential transmitter PDT-2020 monitors the filter assembly and activates an alarm if the pressure increases to 25 psid. The assembly has a manually operated transfer valve for shifting the fuel flow between the two filter elements, permitting either element to be serviced or replaced without disrupting system operation. A balance valve equalizes pressure across the gauges. Both gauges can be isolated from the system by instrument isolation valves. Liquid fuel passes through a pump isolation valve that is locked open during normal operation before leaving the pump skid at customer connection [8A] and entering the main skid at connection [8]. Return fuel from the main skid is routed back to the pump skid through customer piping at connection [9] on the main skid to connection [9A] on the pump skid.

Main Skid

Three valves control fuel flow to the engine fuel manifolds: *(1)* fuel shutoff valve SOV-2012, *(2)* fuel-metering valve FCV-2018, and *(3)* shutoff valve SOV-2018. Electrically actuated fuel flow control valve FCV-2018 meters fuel flow to the turbine according to turbine command signals, which are generated in response to changes in load demands on the turbine engine. According to the valve position, a portion of the pressurized fuel is used for turbine operation and the remainder is returned to the liquid fuel return. At shutdown, a bypass solenoid valve opens, opening the bypass valve in FCV-2018 so that fuel flow to the turbine is shut off and all liquid fuel flows to the liquid fuel return line.

During startups, the turbine-generator first opens shutoff valves SOV-2012 and SOV-2018, then modulates metering valve FCV-2018 in pre-set increments, as controlled by the TCP. During normal shutdowns, the TCP first closes metering valve FCV-2018 in pre-set increments to allow for turbine engine cooling. When valve FCV-2018 is fully closed, the control system closes the shutoff valves. These fail-close valves are either fully open to allow fuel flow or fully closed to prevent fuel flow. At shutdown and during coastdown following fuel valve closure, the control system opens fuel manifold drain valves SOV-2009 and SOV-2010 to drain any fuel from the headers to the exhaust collector. In emergency shutdowns, the control system initiates the immediate closure of FCV-2018, SOV-2012, and SOV-2018.

Manifolds

The primary manifold (header) can be used to start the turbine with liquid fuel. Liquid fuel provides a more precise metered fuel flow, which ensures a proper fuel-air mixture for proper ignition and burning to prevent over-temperature problems and flameout. A secondary manifold (header) provides fuel during operation at normal power settings. There is an off-engine, base-mounted, flow divider valve to switch between the two liquid fuel manifolds. Check valves prevent liquid fuel backflow.

Metering Valve

Flow control valve FCV-2018 is installed with an electrically controlled, proportional Woodward LQ25 actuator that is controlled by signals from the control system. Because each Woodward metering valve has precise valve positioning data and the pressure transmitters are monitoring the pressures of the fuel lines, the amount of fuel can be calculated. Refer to the Woodward Governor Company manual located in Chapter 5 of this manual for details on the valve operation.

The fuel-metering valve is a rotary sleeve-and-shoe throttling valve. The metering port area is determined by input shaft positioning from the actuator. The valve is spring-loaded to the *minimum fuel* direction, so that loss of signal and loss of power situations will cause a fuel shutdown. **The valve is capable of metering 50–40,000 pph of liquid fuel.**

The fuel-metering valve actuator is an electro-hydraulic proportional device. In the actuator, a torque motor servovalve is energized by the electric control system (from the TCP) to generate a pressure differential applied to operate the spool valve. Supply pressure is regulated by the spool valve to move a double-acting servopiston and provide terminal shaft output. Internal mechanical feedback is standard; GE Energy also uses the electrical position feedback transducer for fail-safe operation.

Flow Measurement

Flow transmitter FT-2002 monitors total fuel flow from FCV-2018 and applies the output signal to a flow totalizer. The totalizer displays the net amount at the TCP.

Temperature Monitoring

Temperature elements TE-2034 and TE-2035 monitor fuel temperature at the manifold inputs. If the fuel temperature at the manifold increases to 400 °F, the control system initiates an alarm; if the temperature increases to 700 °F, the control system initiates a CDLO shutdown.

Pressure Monitoring

Surface-mounted pressure transmitter PT-2070 measures liquid fuel supply pressure as it enters the main skid piping and sends this information to the control system. Software-based pressure alarm PAL-2070 is activated if fuel pressure increases to 1200 psig. Alarm PALL-2070 activates a FSWM shutdown if fuel pressure increases to 1250 psig. Each instrument can be isolated by instrument isolation valves. The gauge is scaled 0–1300 psig and holds the 50 psig start transfer permissive.

From metering valve FCV-2018 and shutoff valve SOV-2018, the liquid fuel flow is divided into the primary and secondary fuel supply. Pressure transmitters PT-2029 and PT-2030, located at the divider outputs, monitor manifold input pressures for the control system. Both pressure transducers are panel mounted and can be isolated from the system by instrument isolation valves.

Exhaust Collector Drain

Significant amounts of flammable and water wash liquids may accumulate in the turbine exhaust collector. The exhaust collector drain system eliminates these accumulations to ensure safe starts. A flexible drain line routes accumulations from the collector to the fuel drain line through pneumatically operated, normally open flow control valve FCV-2005. Air pressure to close FCV-2005 during operation comes from the 8th-stage bleed-air manifold. As the turbine speed increases, positive pressure developed in the exhaust collector forces the condensate accumulations out through FCV-2005, the check valve, and the fuel drain valve. Any fluid from the exhaust collector is routed off-skid through a fuel drain at customer connection [7]. As the turbine speed continues to increase, 8th-stage bleed air increases. When the pressure rises to 50 psig, FCV-2005 closes. The collector drain remains closed during normal operation.

Appendix A4
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 the complete specification analysis of all liquid fuels proposed for use in GE aeroderivative gas turbines be reviewed by GE prior to use.

A4.1 APPLICABLE DOCUMENTS

Fuels conforming to the following military and industry specifications are acceptable for use in GE aeroderivative gas turbines in industrial and shipboard applications, except as noted below, and provided they also meet criteria described in paragraph A4.2. 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-4[1], 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-A[1], and Jet-B[1])*
MIL-F-16884	*Fuel Oil - Diesel Marine (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 combustibles [e.g., propane (C_2H_8) and butane (C_4H_{10}), both normal and iso] are acceptable either alone or in various mixtures with other liquid fuels, provided that fuel manifold pressures are sufficient to maintain the fuel in the liquid state[2]. Alternate fuels may be required for starting and low-power operation. Contact GE for specific applications.

Light distillate fuels 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[2]. Alternative fuels may be necessary for starting the engines and low-power operation. Contact GE for specific applications.

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.

2. Liquefied gas, 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 section A4.2.3.

Various alcohols, [e.g. hydroxyl derivatives of hydrocarbons, such as methanol (CH_3OH) and ethanol (C_2H_5OH)], can be burned in the GE aeroderivative gas turbines[2]. Contact GE for specific applications.

A4.2 ADDITIONAL REQUIRMENTS

The following requirements supplement and supersede, where there is a conflict, the specifications listed in Paragraph A4.1. However, if the specification requirement is more restrictive, it applies.

A4.2.1 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 (NOx) 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 NOx (called organic NOx) and adds to the total amount of NOx 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.

A4.2.2 Additives

The use of any dyes or additives requires approval of GE, unless such additives are specifically approved in the fuel specifications (A4.1) 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.

A4.2.3 Viscosity

The viscosity of the fuel as supplied to the inlet connection on the gas turbine shall be a minimum of 0.5 centistokes[3] 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.

A4.2.4 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.

A4.2.5 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 pre-vent 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).

A4.3 PROPERTY REQUIREMENTS

Property requirements are listed in Table A3. 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.

A4.4 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 nor 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.

A4.5 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 A3 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 c. 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, °F, maximum	See i Below	D93
Copper corrosion, maximum	No. 1[j]	D130

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:

ppm Na in Inlet Air x Air/Fuel Ratio

\+ ppm Na in Water or Steam x Water or Steam/Fuel Ratio

\+ ppm Na in Fuel

Total fuel equivalence for sodium from all sources not to exceed0.2 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).

Purpose

The purpose of this procedure is to provide instructions for taking liquid fuel samples in order to ensure clean, quality fuel is delivered to the engine.

Scope

Turbine Liquid Fuel System, LM2X Gas Turbine Generator Package.

DANGER	
DANGER	SOME LIQUID FUELS MAY BE TOXIC TO SKIN, EYES AND RESPIRATORY TRACT. SKIN AND EYE PROTECTION IS REQUIRED. AVOID REPEATED OR PROLONGED CONTACT. ENSURE AREA IS WELL VENTILATED. REFERENCE MSDS FOR SPECIFIC LIQUID FUEL.

CAUTION	
CAUTION	CARE MUST BE TAKEN NOT TO ALLOW CONTAMINATION OF THE LIQUID FUEL OIL SYSTEM PRIOR TO, DURING, OR AFTER COMPLETION OF SAMPLING. COVER ALL OPENINGS TO PREVENT ENTRY OF FOREIGN DEBRIS AND OBJECTS.

NOTICE	
NOTICE	DO NOT TAKE LIQUID FUEL OIL SAMPLES FROM LOW POINT DRAINS. LOW POINT DRAINS CAN CONTAIN HEAVY SEDIMENTS AND PROVIDE INCORRECT INDICATIONS.

FUEL SPECIFICATIONS

Fuels must conform to the attached GE specifications document Liquid Fuel Requirements for GE Aero-Derivative (*MID-TD-0000-2)*. Reference this documentation for fuel specifics to ensure proper fuel is used.

GE Industrial Aero Derivative gas turbines have the ability to burn a wide range of gaseous fuels as shown in the specifications document. These fuels present a broad spectrum of properties due to both active and inert components. This specification is designed to define guidelines that must be followed in order to burn these fuels in an efficient, trouble-free manner, while protecting the gas turbine and supporting hardware.

LIQUID FUEL SAMPLING

1. For each delivery, fuel samples should be taken and analyzed at the following locations:
   - Refinery, prior to loading
   - Port where fuel is delivered, prior to unloading
   - Pipeline, just upstream of raw fuel storage tanks, as fuel is added to tanks

2. 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.

3. Once fuel is treated/conditioned, samples should be taken and analyzed at both inlet and outlet of fuel treatment system. Fuel exiting the system must meet fuel specifications. This should be confirmed prior to placing the fuel into a clean-fuel day storage tank(s).

4. Fuel samples should also be taken at a practical location at, or just upstream of the gas turbine fuel manifold flange. Fuel will be analyzed to ensure fuel discharged from the clean-fuel day storage tank(s) meets GE specifications. If there is no sampling point downstream of the customer's filtering system, it is GE's recommendation to manufacture a sampling point as near the package as possible. Label and submit sample for analysis.

5. 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.

NOTICE	
NOTICE	THE END USER IS RESPONSIBLE FOR ENSURING THAT THE FUEL MEETS THE REQUIREMENTS.