PROPOSAL

Presented To:

Electricidad de Caracas

For

1 x LM2500PE

Prepared By

DERWICK

DERWICK ASSOCIATES S.A.

Proposal No. 709-2905-1

November 17, 2009

Table of Contents

1.0 Introduction

Derwick Associates ("Derwick") is pleased to provide this proposal to Electricidad de Caracas("EDC") for one of (1) GE LM2500PE Gas Turbine.

The GE LM2500PE is highly reliable, mid-sized packaged power plant developed for either 50 or 60 hertz applications with design emphasis placed on energy efficiency, availability, performance and maintainability.

2.0 Gas Turbine Generator Set Scope of Supply

We are offering one refurbished dual fueled gas turbines generator set a LM2500PE ISO Rated at 22 MW which includes the following scope of supply:
:

LM2500PE

- LM2500PE gas turbine completely refurbished and configured for both natural gas and liquid fuel operation
- Coupling for direct drive at 3600 rpm, 60hz operation
- Weatherproof acoustic enclosure for gas turbine and electric generator
- "Single lift" I bean base plate to support turbine and 23.4 MW Brush generator (13.8KV)
- New or similar Air inlet filtration system for GT combustion air, generator cooling air and compartment ventilation systems.
- Separate lube oil systems for turbine and generator including fin-fan coolers
- Electro hydraulic starting system
- Fire detection and extinguishing system
- New or Refurbished Electronic control panel for gas turbine & generator including 24v control batteries and charger
- Gas turbine water wash system
- Neutral and line side cubicles mounted including CT's and lightning arrestors (Derwick's electrical scope ends at these cubicles)
- One modular control room with Turbine Control Panel, Generator Control Panel, GTG MCC's, batteries and chargers.

2.1 Exclusions

Derwick has excluded the items listed below from our offering. Any other equipment or service not described in our proposal is also excluded.

- Balance of plant and energy optimization controls
- Buildings, foundations, anchor bolts, embedments and grouting
- Bus bars and bus duct beyond generator lineside and neutral enclosures
- Distributed plant control
- Filter house support structure – other than standard
- Turbine exhaust system including industrial grade silencer and stack
- Field Supervision
- Fuel, fluids and chemicals
- Fuel storage tanks, forwarding equipment and primary fuel filter
- Gas compression, filtration and separation or regulation equipment
- High voltage transformer(s), cables, switchgear and associated equipment
- Interconnecting piping, conduit, and wiring between equipment modules (site layout is unknown at this time)
- Plant utilities
- Power plant calibration tools and ordinary hand tools
- Spare parts (quoted separately)
- All Transportation to job site loading and off loading of equipment
- Water injection pressurization equipment
- Water treatment and purification equipment
- Yard light and fences

3.0 Pricing

Pricing references the scope of equipment and service work described in this proposal:

- One (1) GE Gas Turbine LM2500PE gas turbine generator
- New or refurbished GT Controls
- Overhauled and tested gas turbine to GE Standards

Equipment is subject to prior sale until down payment is received.

3.1 Equipment Pricing

- Total **US$ 15,500,000.00**

3.2 Payment

This proposal and pricing is based upon receipt of the progress payments shown below:

- Down Payment: USD $1,550,000.00 to take the units off the market.
- **Non-refundable**
- Balance: USD $13,950,000.00 upon notice of readiness to ship.

Instrucciones para transferencias:	
Intermediary Bank:	Beneficiario:
Citibank, N.A.	International Union Bank, S.A.
ABA: 021000089	Cuenta: 36246731
Sucursal: New York	Dirección:
Dirección:	Ave. Samuel Lewis, Edif. Omega Piso 5,
111 Wall Street, New York, NY 10043	Apartado 0391 Wtc Panamá, Republica de Panamá
	FFC: Davos International Bank/000767-224-001 Ref: Derwick Associates/ 13102362

3.3 Taxes, Duties and Fees

No sales or use taxes have been included in this quotation. These prices quoted exclude any federal, state or local taxes or fees which may be associated with the export, import or purchase of equipment and/or services.

4.0 Schedule

Derwick expects to prepare the equipment for shipment at site within Thirty (30) days after receipt of down payment.

5.0 Warranty

Derwick will provide a one (1) year warranty on the entire gas turbine generator package and any other balance of plant equipment provided.

6.0 Terms & Conditions

This proposal shall be valid for thirty (30) days; provided, however, the obligation to treat this proposal as confidential, and that it cannot be shared with any third party without the prior written consent of Derwick shall survive.

Derwick and EDC will negotiate in good faith to establish general terms and conditions that are usual and customary of the sale of used equipment.

7.0 Site Services

Derwick would be pleased to also provide a proposal for the installation, startup and commissioning of the facility. This would include providing construction supervision as well as startup engineers for all equipment provided.

Derwick can also provide an experienced service representative to assist the operating personnel during the first two (2) months after the equipment goes online.

8.0 Follow Up

Please contact the following person at Derwick for information regarding this proposal:

Pedro Trebbau
Director
ptrebbau@derwickassociates.com
Cellular: +58 (412)3007470

Attachment A
LM2500PE
BASIC (Typical) SCOPE OF SUPPLY

Gas Turbine

General Electric LM2500 - PE-MG gas turbine, ISO rated at 31,235 HP for continuous duty, with a heat rate of 6772 Btu/HP-hr (LHV). Suitable for base load or peaking, designed for simple cycle, combined cycle or cogeneration service. Turbine is shock mounted and shipped in position, ready to run. Turbine is complete with "last chance" inlet screen and bellmouth seal for protection against foreign object damage.

Generator

Air-cooled generator B.E.M. Model 167ESS (or equal) with brushless excitation, suitable for Class 1, Group D, Division 2 areas, rated at 35,412 KVA @ 0.85 pf, 59ºF cooling air, 13,800 volts, 60 Hz. The generator can handle the full continuous power of the gas turbine at any ambient temperature throughout the operating range. Filtered air from the inlet air filter is used to cool the generator. A cooling water loop and its associated fans and pumps are not required. The generator is a utility grade, 2-pole, synchronous design and includes a brushless excitation system with permanent magnet generator. Neutral and lineside cubicles and voltage regulator are also included.

Coupling

The LM2500 gas turbine drives the generator with a dry, flexible-diaphragm coupling that bolts directly to the forged generator hub and the turbine output hub. No gearbox is required. The coupling transmits the full turbine load torque at all operation conditions. The coupling spacer is removed for shipment and is reinstalled at the jobsite by Derwick.

Enclosure

Both gas turbine and generator are fully covered by a weatherproof acoustic enclosure. The enclosure is completely assembled and mounted over the equipment prior to testing and shipment. Both turbine and generator compartments are fully ventilated with redundant fans. Explosion-proof AC lighting and DC emergency lighting are provided in both compartments. A bridge crane in the turbine enclosure simplifies engine removal and maintenance.

Baseplate

Full length I-beams are used to support the gas turbine, generator, and air inlet system. This provides single lift capability for the total equipment package. Dowelling of baseplate sections in the field is not required. Lifting spools are incorporated in the baseplate design. A spreader bar and rigging are provided at no charge if returned prepaid to Derwick within 8 weeks of shipment. The rigidity of the baseplate is suitable for UBC earthquake Zone 4 installations.

Inlet Air System

Derwick furnishes a modular, multi-stage filtration system consisting of weatherhoods and inlet screens, a pre-filter and a final barrier filter. All air for ventilation systems is filtered to the same level as turbine combustion air. Optional anti-ice system, evaporative cooling system and combustion air heating or chilling system are available. Filtered air is silenced before entering the turbine plenum. This compact arrangement eliminates the need for customer-supplied inlet ducting when the standard design is utilized. Internal lighting of the filter house is provided for inspection and service. Internal and external ladders and platforms for servicing the filter are included.

Exhaust System

The LM2500 package includes a thermally insulated exhaust collector to direct the turbine exhaust gases to an 80"h x 55"w rectangular flange in the side of the main enclosure. Customer furnished expansion joint, ducting; ducting supports and mounting hardware are required for heat recovery applications. For simple cycle, an exhaust silencer assembly may be ordered as an option. Right-hand exhaust, as viewed from the exciter end, is standard. Left-hand exhaust may be ordered as an option.

Piping System

Stainless Steel throughout. Lube Oil, Water and Fuel piping and fittings are Type 304 Stainless Steel. Steam piping and fittings are Type 321 Stainless Steel, and all piping is fabricated in accordance with ANSI B31.1 Power Piping Code requirements. Pipe spools are hydrostatically tested at 1.5 time's maximum working pressure. Fuel, steam and high pressure hydraulic piping welds are 100% x-ray inspected. Lube oil piping welds are randomly x-rayed. Turbine and Generator Lube Oil Reservoirs are Type 304 Stainless Steel. The pressure vessels on the turbine baseplate (Water Wash Tanks, Generator Lube Oil Rundown Tanks) are also Type 304 Stainless Steel and are ASME Code stamped.

Fuel System

A natural gas fuel system using an electronically controlled fuel-metering valve is supplied in the basic package. For full-load operation, the gaseous fuel must be supplied to the baseplate at 375 psig ± 20 psig (lower starting pressures available Liquid fuel or dual fuel systems are available as factory options. Fuel specifications are included in Section 12. All necessary shutoff valves, piping and instruments between the baseplate connection and the engine are included.

Lube Oil Systems

Two systems - mineral oil for the generator, synthetic oil for the gas turbine. Each lube oil system includes duplex full-flow filters, stainless steel piping and reservoirs and stainless steel trimmed valves. The oil from both systems is cooled by dualcore fin-fan coolers mounted on the enclosure roof. All interconnecting piping is included. The coolers are 100% redundant and either can handle the cooling load. The full-flow oil filters can be serviced during operation. An optional water-cooled design is available utilizing duplex shell and tube coolers for customer installation on a separate foundation.

Electro-Hydraulic Starting Module

Rotates turbine for starting and water washing. The starting system includes a 200 HP electric motor, hydraulic pump, filters, cooler and controls mounted on a separate baseplate. The pump powers a hydraulic starting motor mounted on the turbine auxiliary gearbox. Customer furnishes interconnecting hydraulic piping between hydraulic start module and rotating equipment module.

Digital Control System

The Derwick control system provides operating, safety and sequencing controls for the gas turbine and generator. The unit panel is suitable for mounting indoors in a non-hazardous, air-conditioned control room. The panel contains a Woodward programmable, microprocessor-based controller for fuel management and sequencing. Also included are a Bently-Nevada vibration monitor, a manual/auto voltage regulator, a color CRT, and meters and switches for starting, synchronizing, and loading. CRT annunciates alarms and shutdowns, status, analog valves (pressure, temp. etc.), with RS-232 interface to customer DCS. Baseplate mounted equipment includes pressure, level, flow, speed and temperature sensors, plus valves and actuators. 24V DC Nickel-Cadmium batteries and dual battery chargers for control system power are included.

Fire Protection System

The fire and gas detection and extinguishing system includes optical flame detection, hydrocarbon sensing and thermal detectors; complete with factory installed piping and nozzles in both generator and engine compartments. The fire protection system includes cylinders of CO_2 extinguishant mounted on the side of the generator set enclosure. Derwick furnishes a dedicated 24V DC battery and charger to power the fire protection system. Fire system alarms and shutdowns are annunciated at the turbine control panel. An alarm sounds at the turbine enclosure and unit control panel if the gas detectors sense high gas levels, or if the system is

preparing to release the extinguishant. When activated, the primary extinguishant cylinders discharge into both the turbine and generator compartments via multiple nozzles, and ventilation dampers close automatically. After a time delay, the reserve supply of extinguishant is discharged, if required.

“On Line" Cleaning and Soak Wash System

For baseload application, an "on-line" cleaning system is included which allow customers to clean the compressor section of the engine during full power operation. The same system reservoir and piping are utilized for off-line soak washing. Baseplate connections are provided for customer supplied purified water at 15-85 psig and air at 85-120 psig filtered to 20 microns.

Component Testing and Package Full Load Test

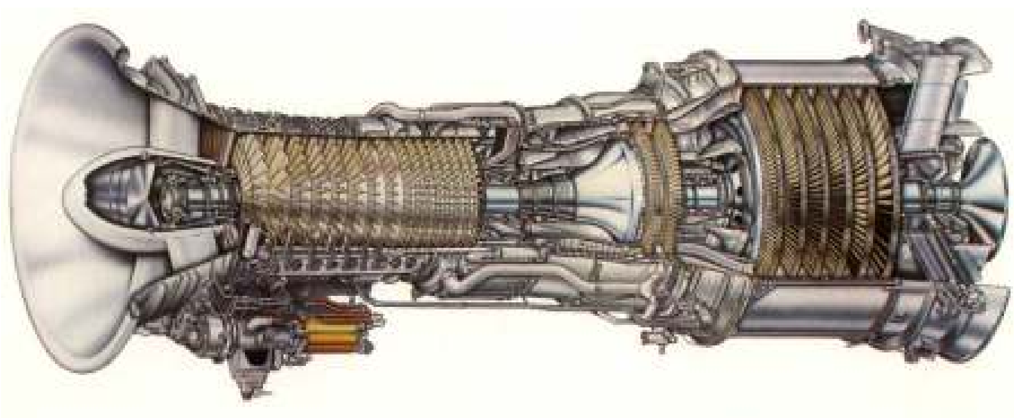
The generator is tested to IEEE 115 or IEC 34.3 standards at its factory of manufacture. The gas turbine is performance tested at the G.E. Aircraft Division factory. The entire assembled generator set is then tested at Derwick's factory to verify performance guarantees. A full KW load string test of the turbine generator set is performed using the contract controls and auxiliary systems. Water and steam systems are functionally proven but normally not operated during the full load test.

Drawings, Documentation and Manuals

The basic equipment package is supplied with a customer drawing package, which includes general arrangement drawings, flow and instrument diagrams, electrical one-line drawings and a conduit interconnection plan. Additional electrical interconnect and logic drawings are provided for record. Maintenance manuals are provided, printed in the English language, using standard English engineering units. The manuals cover operating concepts for power generating equipment, guides to troubleshooting, and basic information on components and equipment within the turbine generator set.

Training (Optional)

Hands-on training for 10 customer's operators and supervisors. Experienced instructors, using specially developed training materials, provide a firm groundwork of basic theory, plus advanced concepts with classroom and hands-on training.



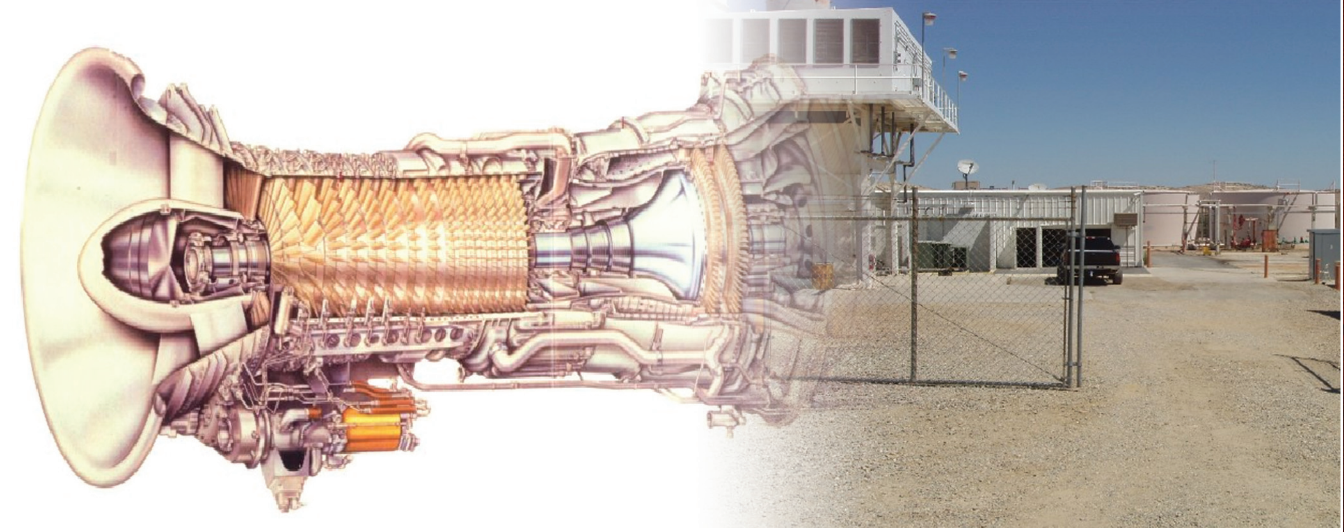
General Electric LM2500 Gas Turbine

Attachment C
LM2500 PERFORMANCE RATINGS

60 Hertz LM Gas Turbine Generator Sets PERFORMANCE RATINGS

	Base KW(e)	Btu/kWh, Lhv(kJ/kWh)		No. Shafts	Turbine Shaft Speed, rpm	Exhaust Flow, lb/sec (kg/sec)		Exhaust Gas Temp °F (°C)	
LM1600	13,794	9,593	(10,121)	3	7,000	100.0	(45.4)	909	(487)
LM2500	21,960	9,550	(10,075)	2	3,000	148.0	(67.1)	1,008	(542)
LM2500+	28,540	9,150	(9,653)	2	3,000	188.0	(85.3)	969	(520)
LM2500 STIG 50	27,020	8,620	(9,094)	2	3,000	168.0	(76.2)	941	(505)
LM5000	34,500	9,290	(9,801)	3	3,000	275.0	(124.7)	811	(433)
LM5000 STIG 80	46,360	8,340	(8,799)	3	3,000	330.0	(149.7)	767	(408)
LM5000 STIG 120	49,600	8,110	(8,556)	3	3,000	344.0	(156.0)	752	(400)
LM6000	43,076	8,247	(8,701)	2	3,600	279.0	(127.0)	842	(450)

Specifications subject to change without notice.
Ratings at 59°F (15°C), sea level, no inlet/exhaust losses, natural gas fuel.
Includes Generator and Gearbox losses.



STANDARD 60Hz LM2500 GENERATOR PACKAGE

Gas Turbine

16 Stage Axial Compressor
- 1st 6 stages have variable station
- Horizontal Split Casing
- 20:1 Compression Ratio
- 150 lb/s Nominal Inlet Mass Flow

Annular Combustor
- 30 Nozzles Gas Fuel, Water Injection for NOx Control

6 Stage Power Turbine

Generator

Continuous Duty 13.8kV, 0.85 PF
2 Pole, 3 Phase Brushless Exciter
WPII Weather Protected
Voltage Regulator/Neutral Side Protection CT's
NEMA Class F Insulation & B Temperature Rise

Package

24V and 125V DC Batteries
90dBA Near Field Design
Barrier Inlet Air Filters
Electro-Hydraulic Start System
Class I Div 2 Group D Class Electrical System
Digital Control System with a Human Machine Interface (HMI)
Turbine and Generator Lube Oil System with Simplex Shell and Tube Coolers
On/Off-line Water Wash

MMG Tower
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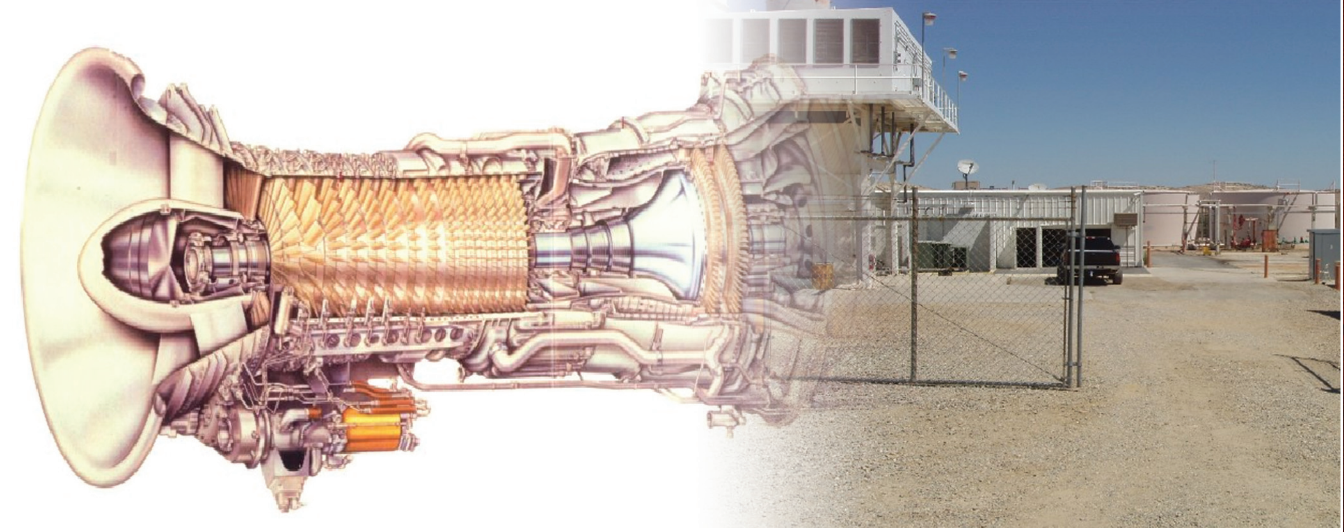
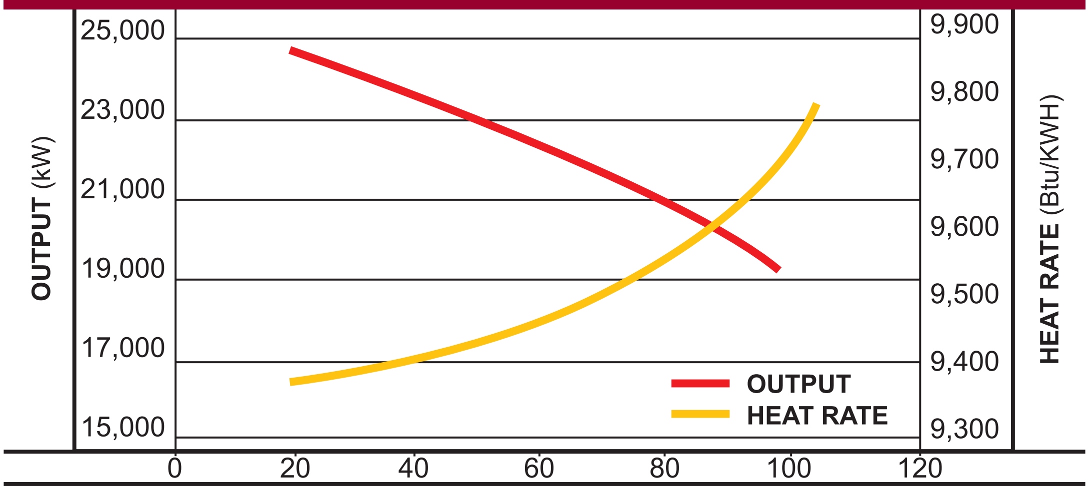


LM2500 FACT SHEET

LM2500 60Hz Output and Heat Rate



0 ft. 60% RH, 4/6 in H20 inlet/exhaust loss on natural gas with water injection to 25ppmvd NOx water inj.

AMBIENT (^{0}F)

Turbine

	LM2500
Power Output (kWe)	18,400
Heat Rate LHV (Btu/kWe-Hr)	9,900
Exhaust Flow (lbs/sec)	143
Exhaust Temperature (^{o}F)	860
Emissions (ppmvd)	NOx/CO
Gas-DLE	25/25
Gas or Liquid-Water	25/75, 42/55
Gas-Steam	25/74
Power Turbine Speed (rpm)	3,600
No. of Compressor Stages	16
No. of Turbine Stages	6

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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 ship-board 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-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-A1, 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[2] [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, 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 fuels[2], 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.

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 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 alcohols[2], [e.g. hydroxyl derivatives of hydrocarbons, such as methanol (CH_3OH) and ethanol (C_2H_5OH)], can burn in GE aeroderivative 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 (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.

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 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.

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^oF (65.6^oC). For liquid fuels with high vapor pressure constituents (naphtha, NGL, etc.) the fuel temperature in the manifold should be at least 100^oF (55.6^oC) 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
Asphaltines, %, 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:

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 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 absorp tion 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.

g

GE Energy

Process Specification
Fuel Gases For Combustion In AeroDerivative Gas Turbines

TABLE OF CONTENTS

LIST OF TABLES

1 GENERAL

GE AeroDerivative gas turbines have the ability to burn a wide range of gaseous fuels as shown in Table 1. These gases 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.

Table 2 identifies the acceptable test methods to be used in determining gas fuel properties.

TABLE 1
FUEL GAS USABLILITY

Fuel Type	**LHV Btu/SCF (kJ/NM^3)**	Wobbe Number	Major Components	Operational Comments	Applicability SAC	DLE
Pipeline Natural Gas	850-1200 (33383-47128)	45-60	Methane	No Restrictions	Yes	Yes
Medium BTU Natural Gas	400 - 850 (15709-33838)	20-45	Methane, Hydrocarbons (HC), carbon dioxide, Nitrogen	Requires > 700 BTU/scf (27492 kJ/NM^3) for starting. May require modified fuel nozzles. Contact GE	Yes	No, See Note 8.
Liquefied Petroleum Gas (LPG)	2300-3200 (90330-125676)	70-75	Propane, Butane	May require specific fuel nozzles. Contact GE	Yes	No
Gasification Gases						
- Air Blown	150-200 (5891-7855)	6-8	Carbon monoxide, Hydrogen, HC, Nitrogen, Water Vapor	Contact GE	Yes	No
- Oxygen Blown	200- 400 (7855-15709)	8-20	Carbon monoxide, Hydrogen, HC, Water Vapor	Contact GE	Yes	No
Process Gases	300-1000 (11782-39274)	15-50	Methane, Hydrogen, Carbon monoxide, Carbon dioxide	Requires >700 BTU/scf (27492 kJ/NM^3) for starting. Restricted transient operation.	Yes	See Note 8
Refinery Gases	1000-1300 (39274-51056	45-60	Methane, Hydrogen, Carbon monoxide, Ethylene, Propylene, Butylene	No restrictions. Hydrogen content should be reviewed by GE.	Yes	See Note 8

Notes:

1. When considering the use of alternate fuels, provide details of the fuel constituents, fuel temperature, and expected engine usage conditions and operating characteristics to GE for evaluation and recommendations.

2. Values and limits apply at the inlet of the gas fuel control module.

3. Heating value ranges shown are provided as guidelines. Specific fuel analysis must be furnished to GE for evaluation. The standard configured single annular combustor (SAC) gas turbines require a fuel with a LHV no less than of 6500 BTU/pound. The Dry Low Emissions (DLE) combustion system requires a minimum LHV of 18000 BTU/pound. (Reference Section 3.1)

4. The quantity of sulfur in gas fuels is not limited by this specification. Experience has shown that oxidation/corrosion rates are not significantly affected by fuel sulfur levels up to 1.3% sulfur. Hot corrosion of hot gas path parts is affected by the presence of the specified trace metals. Sulfur levels shall be considered when addressing HRSG Corrosion, selective catalytic reduction (SCR) deposition, exhaust emissions, system material requirements, elemental sulfur deposition and iron sulfide. (Reference Section 4.3)

5. The fuel gas supply shall be 100% free of liquids. Admission of liquids can result in combustion and/or hot gas path component damage. (Reference Section 3.3)

6. Wobbe Number, or Modified Wobbe Number Index, is described in 3.2.

7. Gases with Wobbe Number Index greater than 40 may be applicable for DLE. Contact GE.

8. Process and refinery gases with <5% hydrogen content and low CO and CO2 content may be acceptable for DLE application. Contact GE.

NM^3 is at 0°C, 101.325kPa (sea level)

TABLE 2
TEST METHODS FOR GASEOUS FUELS

PROPERTY	**ASTM METHOD**
Gas Composition to C6+	D1945 - Standard method for constituents of gases by gas chromatography
Heating Value	D3588 - Procedure for calculating calorific value and specific gravity of gaseous fuels
Specific Gravity	D3588 - Procedure for calculating calorific value and specific gravity of gaseous fuels
Compressibility Factor	D3588 - Procedure for calculating calorific value and specific gravity of gaseous fuels
Dew Point (see note 1)	D1142 - Water vapor content of gaseous fuels by measurement of dew point temperature
Sulfur	D1072 - Test for total sulfur in fuel gases (see note 2) D3246 - Test for total sulfur in fuel gases
Chemical Composition	D2650 - Standard method for chemical composition of gases by mass spectrography

Notes:

1. Hydrocarbon and water dew points shall be determined by direct dew point measurement (Chilled Mirror Device). If dew point cannot be measured, an extended gas analysis, which identifies hydrocarbon components from C1 through C14, shall be performed. This analysis must provide an accuracy of greater

than 10 ppmv. A standard gas analysis to C6+ is normally not acceptable for dew point calculation unless it is known that heavier hydrocarbons are not present, as is most often the case with liquefied natural gases.

2. This test method will *not* detect the presence of condensable sulfur vapor. Specialized filtration equipment is required to measure sulfur at concentrations present in vapor form. Contact GE for more information.

2 FUEL GAS CLASSIFICATION

2.1 Natural and Liquefied Petroleum Gas (LPG)

Natural gases are predominantly methane with much smaller quantities of the slightly heavier hydrocarbons such as ethane, propane and butane. Liquefied petroleum gas is propane and/or butane with traces of heavier hydrocarbons.

2.1.1 Pipeline Natural Gas

Natural gases normally fall within the calorific heating value range of 850 to 1200 Btu/SCF (33383-47128 kJ/NM^3) (LHV). Actual calorific heating values are dependent on the percentages of hydrocarbons and inert gases contained in the gas.

2.1.2 Medium BTU Natural Gas

Natural gases are found in and extracted from underground reservoirs. These “raw gases” may contain varying degrees of nitrogen, carbon dioxide, hydrogen sulfide, and contain contaminants such as salt water, sand and dirt. Processing by the gas supplier normally reduces and/or removes these constituents and contaminants prior to use in the gas turbine. A gas analysis must be performed to ensure that the fuel supply to the gas turbine meets the requirements of this specification.

2.1.3 Liquefied Petroleum Gases

The heating values of Liquefied Petroleum Gases (LPGs) normally fall between 2300 and 3200 Btu/SCF (90330-125676 kJ/NM^3) (LHV). Based on their high commercial value, these fuels are normally utilized as a back–up fuel to the primary gas fuel for gas turbines. Since LPGs are normally stored in a liquid state, it is critical that the vaporization process and gas supply system maintains the fuel at a temperature above the minimum required superheat value. Fuel heating and heat tracing is required to ensure this.

2.2 Gasification Fuels

Other gases that may be utilized as gas turbine fuel are those formed by the gasification of coal, petroleum coke or heavy liquids. In general, the heating values of gasification fuel are substantially lower than other fuel gases. These lower heating value fuels require that the fuel nozzle gas flow passages be larger than those utilized for fuels of higher heating values.

Gasification fuels are produced by either an Oxygen Blown or Air Blown gasification process.

2.2.1 Oxygen Blown Gasification

The heating values of gases produced by oxygen blown gasification fall in the range of 200 to 400 Btu/SCF (7855-15709 kJ/NM^3). The Hydrogen (H_2) content of these fuels is normally above 30% by volume and have H_2/CO mole ratio between 0.5 to 0.8. Oxygen blown gasification fuels are often mixed with steam for thermal NOx control, cycle efficiency improvement and/or power augmentation. When utilized, the steam is injected into the combustor by an independent passage. The current guideline for Hydrogen plus CO constituent is limited to 75% by volume for LM6000 and to 85% for the other AeroDerivative gas turbines. Due to high hydrogen content of these fuels, oxygen blown gasification fuels are normally not suitable for Dry Low Emissions (DLE) applications, for which the Hydrogen content is limited to 5% by volume.. The high flame speeds resulting from high hydrogen fuels can result in flashback or primary zone re–ignition on DLE pre–mixed combustion systems. Utilization of these fuels shall be reviewed by GE.

2.2.2 Air Blown Gasification

Gases produced by air blown gasification normally have heating values between 150 and 200 BTU/ SCF (5891-7855 kJ/NM^3) LHV. The Hydrogen (H_2) content of these fuels can range from 8% to 20% by volume and have a H_2/CO mole ratio 0.3 to 3:1. The use and treatment of these fuels are similar to that identified for oxygen blown gasification.

For Gasification fuels a significant part of the total turbine flow comes from the fuel. In addition, for oxygen blown fuels there is a diluent addition for NOx control. Careful integration of the gas turbine with the gasification plant is required to assure an operable system. Due to the low volumetric heating value of both oxygen an air blown gases, special fuel system and fuel nozzles are required.

2.3 Process Gases

Many chemical processes generate surplus gases that may be utilized as fuel for gas turbines. (i.e. tail or refinery gases). These gases often consisting of methane, hydrogen, carbon monoxide, and carbon dioxide that are normally byproducts of petrochemical processes. Due to the hydrogen and carbon monoxide content, these fuels have large rich to lean flammability limits. These types of fuels often require inerting and purging of the gas turbine gas fuel system upon unit shutdown or a transfer to a more conventional fuel. When process gas fuels have extreme flammability limits such that the fuel will auto ignite at turbine exhaust conditions, a more “conventional” start–up fuel, such as methane, is required.

Additional process gases utilized as gas turbine fuels are those which are byproducts of steel production. These are:

2.3.1 Blast Furnace Gases (BFGs)

Blast Furnace Gases (BFGs), alone, have heating values below minimal allowable limits. These gases must be blended with other fuel to raise the heating value to above the required limit. Coke Oven and/or Natural Gases or hydrocarbons such as propane or butane can be utilized to accomplish this.

2.3.2 Coke Oven Gases

Coke oven gases are high in H_2 and H_4C and may be used as fuel for single annular combustion (SAC) systems, but are not suitable for Dry Low Emissions (DLE) combustion applications. These fuels often contain trace amounts of heavy hydrocarbons, which when burned could lead to carbon buildup on the fuel nozzles. The heavy hydrocarbons must be “scrubbed” or removed from the fuel prior to delivery to the gas turbine.

2.3.3 COREX Gases

COREX gases are similar to oxygen blown gasified fuels, and may be treated as such. They are usually lower in H_2 content and have lower heating values than oxygen blown gasified fuels. Further combustion related guidelines could be found in Bureau of Mines Circulars 503 and 622.

2.3.4 Hydrogen

The presence of gaseous hydrogen in the fuel can present special problems due to the high flame speed and high temperatures associated with combustion, and the very wide flammability limits of this gas. Treatment of fuels containing hydrogen are separated into three categories, less than 5% by volume, 6% to 30% by volume and over 30%. If the hydrogen fuel content is 5% or less, no special precautions are necessary and starting on this fuel mixture can be permissible, assuming there are no other restrictive substances in the mix.

For fuels containing more than 5%, but 30% or less hydrogen, an alternative starting fuel may be required by local safety codes and a special exhaust system purge cycle is incorporated into the gas turbine start sequence to eliminate accumulated fuels from an aborted start. In addition, special high point venting is required for both the fuel gas and turbine compartments since the fuel constituents are normally lighter than air. The vents hold the compartment at a slight vacuum relative to local ambient. Special precautions must also be taken to completely seal the fuel delivery system from leaks. Consult the local authorities for specific local safety codes.

If the fuel contains more than 30% hydrogen, electrical devices used in the fuel gas and turbine compartments should be certified for use in Group B (explosive) atmospheres. Consult the local authorities for specific local safety codes.

2.4 Refinery Gases

Many hydrocarbon fuels contain olefin hydrocarbon compounds which have been thought to prohibit their use in aeroderivative gas turbines.

Fuel temperature is also a consideration in order to use standard fuel nozzles and to avoid the possibilities of fuel polymerization. Maximum fuel temperature of 125°F (52°C) is recommended. It may be possible to go as high as 190°F (88°C), but this may require non-standard fuel nozzle sizing and should be considered on a case by case basis. Please contact GE for assistance.

Because refinery gas fuels usually have significant higher hydrocarbon and olefin content the combustor flame temperatures are typically higher, resulting in higher than normal (high methane gas) NOx emissions. Contact GE for effect on emissions.

3 FUEL PROPERTIES

3.1 Heating Value

A fuel’s heat of combustion, or heating value, is the amount of energy, expressed in Btu (British thermal unit), generated by the complete combustion, or oxidation, of a unit weight of fuel. The amount of heat generated by complete combustion is a constant for a given combination of combustible elements and compounds.

For most gaseous fuels, the heating value is determined by using a constant pressure, continuous type calorimeter. This is the industry standard. In these units, combustible substances are burned with oxygen under essentially constant pressure conditions. In all fuels that contain hydrogen, water vapor is a product of combustion, which impacts the heating value. In a bomb calorimeter, the products of combustion are cooled to the initial temperature and all of the water vapor formed during combustion is condensed. The result is the HHV, or higher heating value, which includes the heat of vaporization of water. The LHV, or lower heating value, assumes all products of combustion including water remain in the gaseous state, and the water heat of vaporization is not available.

3.2 Modified Wobbe Index Range

While gas turbines can operate with gases having a very wide range of heating values, the amount of variation that a single specific fuel system can accommodate is much less. Variation in heating value as it affects gas turbine operation is expressed in a term identified as modified Wobbe Index (Natural Gas, E. N. Tiratsoo, Scientific Press Ltd., Beaconsfield, England, 1972). This term is a measurement of volumetric energy and is calculated using the Lower Heating Value (LHV) of the fuel, specific gravity of the fuel with respect to air at ISO conditions, and the fuel temperature, as delivered to the gas turbine. The mathematical definition is as follows:

Modified Wobbe Index $= LHV/(SG_{gas} \times T)^{1/2}$

This is equivalent to:

Modified Wobbe Index $= LHV/[(MW_{gas}/28.96) \times T]^{1/2}$

Where:

LHV	=	Lower Heating Value of the Gas Fuel (Btu/scf)
SGgas	=	Specific Gravity of the Gas Fuel relative to Air
MWgas	=	Molecular Weight of the Gas Fuel
T	=	Absolute Temperature of the Gas Fuel (Rankine)
28.96	=	Molecular Weight of Dry Air

The allowable modified Wobbe Index range is established to ensure that required fuel nozzle pressure ratios be maintained during all combustion/turbine modes of operation. When multiple gas fuels are supplied and/or if variable fuel temperatures result in a Modified Wobbe Index that exceed the ±10% limitation, independent fuel gas trains, which could include control valves, manifolds and fuel nozzles, may be required for standard combustion systems. For DLE applications the Wobbe Index range must be between 40 and 60. An accurate analysis of all gas fuels, along with fuel gas temperature profiles shall be submitted to GE for proper evaluation.

3.3 Superheat Requirement

The superheat requirement is established to ensure that the fuel gas supplied to the gas turbine is 100% free of liquids. Dependent on its constituents, gas entrained liquids could cause degradation of gas fuel nozzles, and for DLE applications, premixed flame flashbacks or re-ignitions. A minimum of 50°F (28°C) of superheat is required and is specified to provide enough margin to compensate for temperature reduction due to pressure drop across the gas fuel control valves.

3.4 Flammability Ratio

Fuel gases containing hydrogen and/or carbon monoxide will have a ratio of rich to lean flammability limits that is significantly larger than that of natural gas. Typically, gases with greater than 5% hydrogen by volume fall into this range and require a separate startup fuel. Consult the local authorities for specific local safety codes.

Fuel gases with large percentage of an inert gas such as nitrogen or carbon dioxide will have a ratio of rich–to–lean flammability limits less than that of pure natural gas. Flammability ratios of less than 2.2 to 1 as based on volume at ISO conditions (14.696 psia and 59°F (101.325 kPa and 15°C)), may experience problems maintaining stable combustion over the full operating range of the turbine.

3.5 Gas Constituent Limits

Gas constituents are not specifically limited except to the extent described in Fuel Gas Classification. These limitations are set forth to assure stable combustion through all gas turbine loads and modes of operation. Limitations are more stringent for DLE combustion systems where “premixed” combustion is utilized. A detailed gas analysis shall be furnished to GE for proper evaluation.

3.6 Gas Fuel Supply Pressure

Gas fuel supply pressure requirements are dependent on the gas turbine model and combustion design, the fuel gas analysis and unit specific site conditions. Minimum and maximum supply pressure requirements can be determined by GE for specific applications.

4 CONTAMINANTS

Dependent on the type of fuel gas, the geographical location and the forwarding means there is the potential for the “raw” gas supply to contain one or more of the following contaminants:

1. Tar, lamp black, coke
2. Water, salt water
3. Sand, clay
4. Rust
5. Iron sulfide
6. Scrubber oil or liquid
7. Compressor Lube oil
8. Naphthalene
9. Gas Hydrates

It is critical that the fuel gas is properly conditioned prior to being utilized as gas turbine fuel. This conditioning can be performed by a variety of methods. These include but are not limited to media filtration, inertial separation, coalescing and fuel heating. Trace metal, particulate and liquid contamination limits are given below. These limits are given in parts per million by weight (ppmw) corrected to the actual heating value of the fuel. It is critical that fuel gas conditioning equipment be designed and sized so that these limits are not exceeded.

4.1 Particulate

Contamination limits for particulates are established to prevent fouling and excessive erosion of hot gas path parts, erosion and plugging of combustion fuel nozzles and erosion of the gas fuel system control valves. The utilization of gas filtration or inertial separation is required. The filtration level should be a beta ratio of 200 minimum (efficiency of 99.5%) at 5μ or less. The total particulate should not exceed 30 ppm by weight. GE requires the use of stainless steel piping downstream of this last level of filtration.

4.2 Liquids

No liquids are allowed in the gas turbine fuel gas supply. Liquids contained in the fuel can result in nuisance and/or hardware damaging conditions. These include rapid excursions in firing temperature and gas turbine load, primary zone re-ignition and flashback of premixed flames, and when liquids carry over past the combustion system, melting of hot gas path components. When liquids are identified in the gas supply, separation and heating is employed to achieve the required superheat level.

4.3 Sulfur

There is no specific limit on natural gas fuel sulfur content if the engine is used in an application where both the fuel and environment are free of alkali metals. There are several concerns relative to the levels of sulfur contained in the fuel gas supply. Many of these are not directly related to the gas turbine but to associated equipment and emissions requirements. These concerns include but are not limited to:

4.3.1 Hot Gas Path Corrosion

Typically, use of sulfur bearing fuels will not be limited by concerns for corrosion in the turbine hot gas path unless alkali metals are present. Sodium, potassium and other alkali metals are not normally found in natural gas fuels, but are typically found to be introduced in the compressor inlet air in marine environments, as well as in certain adverse industrial environments. The total amount of sulfur and alkali metals from all sources shall be limited to form the equivalent of 0.6 ppm of alkali metal sulfates in the fuel. Unless sulfur levels are extremely low, alkali levels are usually limiting in determining hot corrosion of hot gas path materials. For low Btu gases, the fuel contribution of alkali metals at the turbine inlet is increased over that for natural gas and the alkali limit in the fuel is therefore decreased. The total amount of alkali metals [(a)] in gas fuels used with engines having marinized (corrosion-resistant) coatings on the high pressure turbine blading shall not exceed 0.2 ppm [(b)].

(a) Sodium, potassium, and lithium. Experience has shown that sodium is by far the preponderant alkali metal, if any, found in gaseous fuels.

(b) This limit 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 sodium inlet air x Air/Fuel Ratio	=	
ppm sodium in water or steam x $\frac{\text{Water or Steam}}{\text{Fuel}}$ ratio	=	
ppm sodium in fuel	=	
Total fuel equivalence for sodium from all sources not to exceed		0.2 ppm

4.3.2 HRSG Corrosion

If heat recovery equipment is used, the concentration of sulfur in the fuel gas must be known so that the appropriate design for the equipment can be specified. Severe corrosion from condensed sulfuric acid results if a heat recovery steam generator (HRSG) has metal temperatures below the sulfuric acid dew point. Contact the HSRG supplier for additional information.

4.3.3 Selective Catalytic Reduction (SCR) Deposition

Units utilizing ammonia injection downstream of the gas turbine for NOx control can experience the formation of deposits containing ammonium sulfate and bisulfate on low temperature evaporator and economizer tubes. Such deposits are quite acidic and therefore corrosive. These deposits, and the corrosion that they cause, may also decrease HRSG performance and increase backpressure on the gas turbine. Deposition rates of ammonium sulfate and bisulfate are determined by the sulfur content of the fuel, ammonia content in the exhaust gas, tube temperature and boiler design. Fuels having sulfur levels above those used as odorants for natural gas should be reported to GE . In addition, the presence of minute quantities of chlorides in the inlet air may result in cracking of AISI 300 series stainless steels in the hot gas path. Contact the SCR supplier for additional information.

4.3.4 Exhaust Emissions

Sulfur burns mostly to sulfur dioxide, but 5% to 10% oxidizes to sulfur trioxide. The latter can result in sulfate formation, and may be counted as particulate matter in some jurisdictions. The remainder will be discharged as sulfur dioxide. To limit the discharge of acid gas, some localities may restrict the allowable concentration of sulfur in the fuel.

4.3.5 Elemental Sulfur Deposition

Solid elemental sulfur deposits can occur in gas fuel systems downstream of pressure reducing stations or gas control valves under certain conditions. These conditions may be present if the gas fuel contains elemental sulfur vapor, even when the concentration of the vapor is a few parts per billion by weight. Concentrations of this magnitude cannot be measured by commercially available instrumentation and deposition cannot therefore be anticipated based on a standard gas analysis. Should deposition take place, fuel heating will be required to maintain the sulfur in vapor phase and avoid deposition. A gas temperature of 130°F (54°C) or higher may be required at the inlet to the gas control valves to avoid deposition, depending on the sulfur vapor concentration. The sulfur vapor concentration can be measured by specialized filtering equipment. If required, GE can provide further information on this subject.

APPENDIX 1 – DEFINITIONS

Dew Point

This is the temperature at which the first liquid droplet will form as the gas temperature is reduced. Common liquids found in gas fuel are hydrocarbons, water and glycol. Each has a separate and measurable dew point. The dew point varies considerably with pressure and both temperature and pressure must be stated to properly define the gas property. Typically, the hydrocarbon dew point will peak in the 300 to 600 psia (2068 to 4137 kPa) range.

Dry Saturated Conditions

The gas temperature is at, but not below or above, the dew point temperature. No free liquids are present

Gas Hydrates

Gas hydrates are semi–solid materials that can cause deposits that plug instrumentation lines, control valves and filters. They are formed when free water combines with one or more of the C1 through C4 hydrocarbons. Typically the formation will take place downstream of a pressure reducing station where the temperature drop is sufficient to cause moisture condensation in a region of high turbulence. Because hydrates can cause major problems in the gas distribution network, the moisture content is usually controlled upstream at a dehydration process station.

Gas Hydrate Formation Line

This is similar to the dew point line except the temperature variation with pressure is much less. The hydrate line is always below or at the moisture dew point line as free water must exist in order for hydrates to form. Maintaining 50°F of superheat above the moisture dew point will eliminate hydrate formation problems.

Glycol

Glycol is not a natural constituent of natural gas but is introduced during the dehydration process. Various forms of glycol are used, diethylene and triethylene glycol being two most common. In some cases glycol is injected into the pipeline as a preservative. In most cases, glycol may only be a problem during commissioning of a new pipeline or if an upset has taken place at an upstream dehydration station.

Superheat

This is defined as the difference between the gas temperature minus the liquid dew point. The difference is always positive or zero. A negative value implies that the value is being measured at two differing states of pressure and temperature and is not valid. A measured gas temperature below the theoretical dew point means that the gas is in a wet saturated state with free liquids present.

Saturation Line

This is the same as the dew point line.

Wet Saturated Conditions

A point where a mixture consists of both vapor and liquids.