

# PROPOSAL

Presented To:

**CVG**

for

2 x LM6000

2 x Frame 7EA

1 x 7FA Gas Turbine Equipment

*Prepared By*

**DERWICK**

DERWICK ASSOCIATES CORP.



Proposal No. 709-2485A

December 28, 2009

**This document is privileged and contains confidential information intended for use only by CVG.**

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## **1.0 INTRODUCTION**

Derwick ("DC") is pleased to provide this proposal to Corporacion Venezolana de Guyana ("CVG") for Two (2) GE LM6000 PC Gas Turbines. (1) One Refurbished and (1) Never Used. Two (2) x GE Frame 7EA with less than 200 Hrs & One (1) GE Frame 7FA, new.

## **GE LM6000**

The GE LM6000 PC is a 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 SCOPE OF SUPPLY**

### **2.1 Basic Scope Description**

#### **2.1.1 *Gas Turbine***

General Electric gas turbine model LM6000 is a two-shaft/two-spool engine consisting of a five-stage low pressure compressor, a fourteen-stage high pressure compressor, a two-stage high pressure turbine, and a five-stage low pressure turbine. The engine is equipped with a stainless steel mesh screen in the inlet air stream for "last chance" protection against foreign object damage. The engine is shock mounted and shipped in position, with the exception of the coupling spacer, which is removed and shipped in a separate container.

#### **2.1.2 *Generator***

Air cooled, 2-pole generator operating at 13.8 kV, 60 Hz. Generator is capable of handling Purchaser power requirement throughout a wide ambient temperature range. A cooling water loop and its associated fans and pumps are not required. The generator includes a brushless excitation system with permanent magnet generator. Neutral and line side cubicles are included.

#### **2.1.3 *Unit Enclosure***

The basic equipment package is supplied with weatherproof acoustic enclosures with sound attenuation to an average of 85 dB(A) at 3ft 3 in (1 m) from the face of the equipment at 4 ft 11 in (1.5 m) above ground. The enclosures are completely

assembled and mounted over the equipment prior to testing and shipment. The turbine and generator compartment is fully ventilated with belt driven fans. Explosion-proof lighting is provided in both compartments.

#### *2.1.4 Gas Turbine / Generator Baseplate*

The basic equipment package is supplied with the support structures for the gas turbine generator set consisting of a two-piece skid assembly, which is sectioned between the gas turbine and the generator. The full depth, bolted section is designed to provide the full structural properties of the wide flange I-beams. Full depth crossmembers are utilized to provide for a rigid design that is suitable for installation in earthquake areas (U.S. Seismic Zone 4) as well as providing a convenient structure for transportation. The baseplate support system is enhanced by the installation of a heavy-duty, welded superstructure, which utilize structural tubing for wall columns and roof beams.

#### *2.1.5 Air Inlet System*

The basic equipment package is supplied with a modular, multi-stage filtration system consisting of inlet screens, a prefilter and a final barrier filter. All air for ventilation systems is filtered to the same level as turbine combustion air. An evaporative cooling system is included in the basic equipment package scope. Filtered air is silenced before entering the turbine plenum. This design results in a compact arrangement and eliminates the need for Purchaser supplied inlet ducting when the standard design is utilized. Internal lighting of the filter house is provided to facilitate inspection and service.

Package is also supplied with platforms and ladders to service the inlet filter. These items are packaged separately for shipment. Ladders, platforms and stairways to service other portions of the gas turbine generator enclosure are not included. Special or customized filter arrangements can be supplied, and they are quoted on an individual basis.

#### *2.1.6 Turbine Exhaust*

The basic equipment package is supplied with a circular, axial exhaust outlet with connection flange to facilitate in-line mounting of an HRSG or simple cycle exhaust stack.

#### *2.1.7 Fuel System*

The basic equipment package is supplied with a natural gas fuel system using an electronically controlled fuel-metering valve. All necessary shutoff valves, piping

and instruments between the auxiliary skid connection and the turbine are included. For full-load operation, the gaseous fuel must be supplied to the baseplate at 675 psig $\pm$ 20 (4,658  $\pm$ 138 kPag). All necessary shutoff valves, piping and instruments between the baseplate connection and the turbine are included. Gas fuel must meet General Electric specification MID-TD-0000-1.

#### *2.1.8 Lube Oil Systems*

The basic equipment package is supplied with two separate lube oil systems: one for the gas turbine (synthetic oil) and one for the generator (mineral oil). The oil reservoirs and piping are all stainless steel, and the lube oil system valves have stainless steel trim. Each lube oil system has duplex filters, duplex shell and tube coolers, and thermostatically-controlled electric heaters. The coolers, oil reservoir, and filters for each system are mounted on an auxiliary equipment module located next to the gas turbine baseplate. The auxiliary equipment module provides simplified piping connections and reduces Purchaser's installation time and costs. Purchaser must supply cooling water to the shell and tube coolers. Turbine lube oil must meet MID-TD-0000-6.

#### *2.1.9 Electro-Hydraulic Start System*

The basic equipment package is supplied with an electric motor driven hydraulic pump assembly, filters, cooler and controls, mounted on the auxiliary equipment module. A hydraulic motor is also mounted on the gas turbine accessory gearbox. Hydraulic hoses are furnished to connect the auxiliary equipment module and the main baseplate.

#### *2.1.10 Fire Protection System*

The basic equipment package is supplied with a factory installed fire protection system complete with optical flame detection, hydrocarbon sensing and thermal detectors, piping and nozzles in both generator and engine compartments. The fire protection system includes cylinders containing CO<sub>2</sub> mounted on a separate skid. A 24 V DC battery and charger to power the fire protection system is also included. All alarms and shutdowns are annunciated at the turbine control panel (TCP). An alarm sounds at the turbine if the gas detectors detect high gas levels, or if the system is preparing to release the CO<sub>2</sub>. When the system is activated, the package shuts down, and the primary CO<sub>2</sub> cylinders are discharged into the turbine and generator compartments via multiple nozzles, and the ventilation dampers automatically close. After a time delay and if required, the reserve supply of CO<sub>2</sub> is discharged.

### *2.1.11 Digital Control System*

The basic equipment package is supplied with a free-standing control panel suitable for mounting in an indoor, non-hazardous area. The control system features an integrated Woodward MicroNet Plus turbine control system, vibration monitor, digital meter, digital generator protective relay module and an HMI (human machine interface) display of key discrete and analog data. The operator selects HMI displays with convenient touch screen control. Alarm and shutdown events are displayed on the HMI automatically. An Ethernet TCP/IP EGD or RS485 Modbus Port is provided to transmit unit conditions (status, pressures, temperature, etc.) to the Purchaser's distributed control system. Power for the control panel is provided by a dedicated 24V DC battery system with dual 100% capacity chargers, which are shipped separately for installation by others.

### *2.1.12 Generator Protective Relays*

The basic equipment package is supplied with a microprocessor-based generator protective relay module, mounted in the TCP. The protective relay system includes functions necessary for protection of the generator.

### *2.1.13 Soak Wash System*

The basic equipment package is supplied with a turbine cleaning system, which allows Purchasers to clean the compressor section of the turbine during full power operation. The same system reservoir and piping are utilized for off-line soak washing. Auxiliary skid connections are provided for Purchaser supplied purified water at a maximum of 50 psig (345 kPag) and air at 100 – 120 psig (689 – 827 kPag). Purchaser is required to provide purified water meeting MID-TD-0000-4, detergent meeting MID-TD-0000-5 (See Attachment 16), and air filtered to ISA S7.3 standards.

### *2.1.14 Component Testing and Package Full Load Test*

Every new gas turbine is performance tested under load in a GE Test Cell, using procedures developed for flight turbine reliability. The generator is tested to ANSI C50.14 or IEC 34.3 standards at its factory of manufacture.

All gas turbine generator sets receive a rigorous 400-point static test including:

- Switch State (N.O. or N.C., actuation, wiring, and setpoint)
- Temperature element output, and wiring
- Transmitter range, output, and wiring
- Solenoid operation

- Control valve torque motor, excitation, and return signal
- Fire system continuity, and device actuation
- System flushing verification
- Tubing integrity

#### *2.1.15 Drawings, Data and Manuals*

The basic equipment package is supplied with a Purchaser drawing package that includes general arrangement drawings, flow and instrument diagrams, electrical one-line drawings and interconnection plan drawings. Additional electrical schematic diagrams and logic drawings are provided for record.

Maintenance manuals are provided and are printed in English. The manuals cover operating concepts for power generating equipment, guides to troubleshooting, basic information on components, and equipment within the turbine generator set.

#### *2.1.16 Training (Optional)*

The base scope of supply includes hands-on training for up to 10 operators and supervisors, where students are assumed to have at least a journeyman's knowledge of electrical generating plant operation and to be proficient in reading piping flow and instrument drawings, mechanical drawings, and have a working knowledge of electrical generators, and gas turbines. The course is designed around an eight-hour day, five consecutive day schedule with an hour lunch break and fifteen-minute breaks every one and one half hours. Experienced instructors, using specially developed training materials, provide a firm groundwork of basic theory, plus advanced concepts with classroom and hands-on training. Training includes Gas Turbine Familiarization plus System Design & Operations and Maintenance.

#### *2.1.17 Improvements and Changes*

It is understood that the Seller has the right to make changes in product design and add improvements to products or services at any time without incurring any obligations to install the same on or in connection with the Equipment or Services provided hereunder.

### 2.2 Optional Equipment and Services Checklist and Descriptions

- (I) *included in base offer at prices indicated in Article 3*

### 2.2.1 Factory Options

I	Option A	SPRINT® Power Augmentation
I	Option B	NO <sub>x</sub> Control - Water Injection System
I	Option C	Inlet Air Cooling – Evaporative Cooling
I	Option D	Lube Oil Cooler - Fin/Fan
I	Option E	Left-handed Piping Connections
I	Option F	Left-handed Line side Cubicle
I	Option G	Line side Cubicle Entry Configuration Options
I	Option H	DC Backup Lighting
I	N/A	Auxiliary Skid Enclosure

### 2.2.2 Factory Options Descriptions

#### **Option A      SPRINT® Power Augmentation**

SPRINT® boosts engine performance using a demineralized water spray intercooling design that significantly increases the mass flow by cooling the air during the compression process. The system is based on an atomized water spray injected through spray nozzles placed at two locations, one between the high pressure and low-pressure compressors, and the second at inlet bellmouth. Water is atomized using high-pressure air taken off of the eighth stage bleed. The water flow rate is metered, using the appropriate engine control schedules and at the inlet bellmouth. Bellmouth and inter-stage portions on SPRINT® alternate operation based on turbine inlet temperature. Purchaser supplies 30 gpm (114 lpm) of demineralized water to the connection on the unit. Water must meet GE specification MID-TD-0000-3 (See Attachment 16)

#### **Option B      NO<sub>x</sub> Control - Water Injection System**

A water injection system for control of NO<sub>x</sub> emissions shall be provided. The demineralized water injection system consists of inlet strainer, pump, valves, piping and controls for use with a gaseous fuel, liquid fuel or dual fuel system. Water injection shall reduce NO<sub>x</sub> emissions to 25 ppm (51 mg/N m<sup>3</sup>) (Ref. 15% O<sub>2</sub>) on gaseous fuel. For gaseous fuel applications, Purchaser must provide a



demineralized water supply of up to 55 gpm (208 lpm) and at 20-40 psig (138-276 kPag). Water must meet GE specification MID-TD-0000-3 (See Attachment 16). The minimum Purchaser supplied pressure and temperature is determined by the water injection rate required and the type of fuel nozzle utilized.

### **Option C      Inlet Air Cooling – Evaporative Cooling**

Evaporative cooling shall be utilized in the inlet air cooling system to lower the dry bulb temperature of the inlet ambient air, thus increasing power output of the LM6000 equipment.

This system is designed for recirculation of evaporative cooling water from a sump in the bottom of the inlet air filter. A recirculation pump, a conductivity probe, blowdown and make-up valves, piping and wiring shall be provided. Purchaser must supply filtered, potable water to a flanged connection on the filter house and must dispose of wastewater from the blowdown valve. Flow rates will vary based on blow down. Water must meet GE specification GEK 107158.

### **Option D      Lube Oil Cooler - Fin/Fan**

This replaces the standard simplex shell and tube coolers for the lube oil systems. A simplex core fin-fan cooler complete with changeover valve mounted on a separate base plate with dual fans is installed on a separate foundation.

### **Option E      Left-handed Piping Connections**

The Seller shall furnish one (1) right hand (standard) configuration and one (1) left hand configuration LM6000 Unit. The left hand Unit shall be built with the Purchaser's piping connections on the left side, as viewed from the exciter. The turbine removal door is placed on the side opposite the piping connections.

### **Option F      Left-handed Lineside Cubicle**

For the left hand Unit, the generator line-side cubicle shall be located on the left-hand side and the neutral cubicle shall be located on the right-hand side. However, the termination box for generator instrument and control wiring box, (MGTB) must remain on the right-hand side, and the turbine main terminal box (MTTB) must remain on the left.

### **Option G      Lineside Cubicle Entry Configuration Options**

#### ***Top Bus Duct Entry***

The standard lineside cubicle is configured for bottom cable entry. With this option, the lineside cubicle is configured for top bus duct entry.

### ***Top Cable Entry***

The standard lineside cubicle is configured for bottom cable entry. With this option, the lineside cubicle is configured for top cable entry.

### **NOTE for Option E, Option F, Option G:**

Purchaser has elected to choose quantity one (1) Unit to be “Left-hand” configuration and one (1) Unit to be “Right-hand” configuration as described above. Configurations and delivery sequence to be finalized at the Order Definition Meeting. If the configuration or delivery sequence is changed after the Order Definition Meeting, Seller reserves the right to adjust Contract price and schedule accordingly.

### **Option H      DC Backup Lighting**

Seller shall furnish DC backup lighting in the turbine and generator enclosures as an option. The DC lights turn on anytime the normal AC power fails.

### **Option I      Combustion Air Cooling – Chiller Coil**

Lowering the combustion air inlet temperature can increase the power output of the LM6000 generator set. When specified, GE Energy can furnish high performance inlet air chilling coils as an integral part of the air inlet system. Purchaser provides adequate quantities of chilled water and interconnecting piping to GE Energy furnished chilling coils at the filter house. The same coils can be used for anti-icing.

### **(Optional)    Transportation Services**

Seller arranges for shipment on behalf of the Buyer. The Buyer pays the Seller for all fees and expenses including, but not limited to, those covering preparation of consular documents, freight, loading fees at storage, storage, transit insurance and warehouse-to-warehouse insurance.

### **3.0 LIMITS OF SELLER SCOPE & EXCLUSIONS**

#### **3.1 Limits of Seller Scope**

Listed below are the limits/exclusions to the Seller standard Scope of Supply. All piping, wiring, cables, ducts, etc. connecting to these points is furnished by Purchaser (others) unless modified by specification agreement.

Equipment System	Limits of Seller Scope
All piping, including Fuel Gas, Fuel Oil, Steam, Cooling Water, Heating Water, Demineralized Water, Lube Oil, Compressed Air, Instrument Air, Hydraulic Start Oil	Flanged or threaded connection on Seller baseplate.
Inlet Air-to-Filter	Atmosphere (non-standard duct by others)
Turbine Package Ventilation/Cooling Air	Atmosphere (non-standard duct by others)
Turbine Exhaust	Exhaust flange on main baseplate
Instruments on Seller's Baseplate	Terminal box on baseplate
Instrument wiring in Turbine Control Panel	Wiring Terminal block in Turbine Control Panel
High Voltage Connections	Bus bar in Seller Lineside cubicle
Generator Ground Connections	Seller Neutral cubicle
Electric Motors	Terminal box on individual motor
Ladders and Platforms for Air Filter	Ladders and Platforms for Inlet Air Filter maintenance only
24 V DC Batteries and Chargers for Control System and Fire and Gas Systems	Battery terminals to baseplate (if supplied loose)

### 3.2 Exclusions

- Civil engineering design of any kind
- Building and civil works
- Site facilities
- Drains and/or vent piping from the gas turbine package to a remote point
- Fuel storage, treatment and forwarding system
- Site grounding
- Lightning protection
- Power system studies

- Sensing and metering voltage transformers
- Machine power transformers, and associated protection
- Grid failure detection equipment
- Off-loading, transportation and storage
- Off-skid cabling, and design of off-skid cable routing
- Balance of plant and energy optimization controls
- Anchor bolts, embedments, and grouting (quoted separately)
- Distributed plant control
- Purchaser's remote control
- Field supervision (quoted separately)
- High voltage transformer(s), cables, and associated equipment
- Interconnecting piping, conduit, and wiring between equipment modules
- Plant utilities, including compressed air supply and off-skid piping
- Battery containment
- Lube oil measurement other than that defined in the scope of supply
- Additional lube oil breather ducting other than that defined in the scope of supply
- Fuel transfer pump
- Off-skid fuel block and vent valves
- Fuel supply pipework beyond the scope of supply
- Generator controls other than that defined in the scope of supply
- Load sharing control
- Balance of plant controls
- Field Performance Testing
- Site Labor
- Ladders, Stairs, and Platforms for equipment beyond the gas turbine

#### 4.0 **SCHEDULED DATE(S)**

Reference	Equipment Description	Scheduled Date
Unit 1	LM6000PC Generating Set (Never Used)	30 Days From Contract
Unit 2	LM6000PC Generating Set (Refurbished)	30 Days From Contract

## 5.0 FUEL SPECIFICATIONS

GE Aero Derivative 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 1**  
**Fuel Gas Usability**

Fuel Type	LHV Btu/SCF (kJ/NM <sup>3</sup> )	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 <sup>3</sup> ) for starting. May require modified fuel nozzles. Contact	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 - Oxygen Blown	150-200 (5891-7855) 200- 400 (7855-15709)	6-8  8-20	Carbon monoxide, Hydrogen, HC, Nitrogen, Water Vapor Carbon monoxide, Hydrogen, HC, Water Vapor	Contact GE  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 <sup>3</sup> ) for starting. Restricted transient operation.	Yes	See Note 8
Refinery Gases	1000- 1300 (39274-51056)	45-60	Methane, Hydrogen, Carbon monoxide, Ethylene,	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.

**6.0 DESIGN CRITERIA**

The following table outlines the criteria conditions at the proposed jobsite for the design of the equipment:

Location	TBD
Elevation	TBD
Design Point Ambient Temperature / Relative Humidity	TBD
Primary Fuel Source	TBD
Secondary Fuel Source	TBD
Seismic Design Criteria (BOP Equipment)	TBD
Maximum Wind Speed (Wind Load), MPH	TBD
Near Field Noise at 3 ft horizontal and 5 ft vertical, dBA NOTE 1	TBD
Far Field Noise, dBA NOTE 1	TBD at 400 ft / TBD at 700 ft

**NOTE:**

1. Far field noise is based on single-unit only operation. Multiple units operating at the same time will have an impact on both near and far field noise levels.

## **7.0 COMMERCIAL TERMS**

### **7.1 Validity**

This proposal is valid until December 30 2009. Subject to prior Sale.

### **7.2 Taxes**

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.

### **7.3 Price TBD**

### **7.4 Payment Schedule**

### **7.5 TBD**

On the Notice of Readiness to Ship Milestone, payment must be received at least 5 days before shipment, [depending on terms] from notification of Readiness to Ship.

### **7.6 Warranty**

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

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

## **8.0 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 as an option an experienced service representative to assist the operating personnel during the first two (2) months after the equipment goes online.

## **9.0 FOLLOW UP**

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

**Pedro Trebbau**  
**Derwick Corp.**  
**0412-3007470**  
**[ptrabbau@derwickassociates.com](mailto:ptrabbau@derwickassociates.com)**



**ATTACHMENT A**  
**GENERAL ARRANGEMENT**

**SYMBOL LEGEND:**

- 1

LM-6000 GAS TURBINE GENERATOR.
- 2

EXHAUST STACK.
- 3

AUXILIARY SKID.
- 4

TURBINE REMOVAL.
- 5

GENERATOR REMOVAL.
- 6

15 KV BREAKER.
- 7

OVERHEAD CABLE TRAY.
- 8

LM-6000 CONTROL MODULE.
- 9

WATER TREATMENT/ELECTRICAL BUILDING.
- 10

BATTERY ROOM.
- 11

DEMIN FORWARDING PUMPS.
- 12

RO WATER PUMP SKID
- 13

RO WATER UNITS.
- 14

ACTIVATED CARBON FILTER.
- 15

FIRE WATER SKID.
- 16

MULTI-MEDIA SKID.
- 17

PORTABLE DEIONIZER.
- 18

AIR COMPRESSOR TANK AND DRYER.
- 19

AIR COMPRESSOR SKID.
- 20

RAW WATER FORWARDING PUMPS.
- 21

LIQUID FUEL STORAGE TANK (500,000 GALS).
- 22

LIQUID FUEL TRANSFER PUMP.
- 23

DAY STORAGE TANK (21,000 GALS).
- 24

LIQUID FUEL FORWARDING PUMPS.
- 25

LIQUID FUEL FILTER SKID.
- 26

LIQUID FUEL BOOST SKID.
- 27

BLACK START GENERATOR.
- 28

MCC/SWITCHGEAR ROOM.
- 29

DEMIN WATER TANK (250,000 GALS).
- 30

RAW/FIRE WATER TANK (500,000 GALS).
- 31

OILY WATER SEPARATOR.
- 32

OILY WASTE TANK.
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OILY WASTE OFF LOAD PUMP.
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AUXILIARY TRANSFORMER (4.16 KV).
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AUXILIARY TRANSFORMER (480 V).
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GAS COMPRESSORS WITH SHED.
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GAS COMPRESSOR FIN FANS.
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MCC ROOM.
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ROAD.
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PARKING AREA.
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LIQUID FUEL OFF ROAD AREA.
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LIQUID FUEL FORWARDING PUMPS.
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LIQUID FUEL OFF LOAD PUMPS.
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LIGHTING POLES.
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GUARD HOUSE.
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GATE.
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PLANT FENCE.
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GSU TRANSFORMER.
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DISCONNECT SWITCH.
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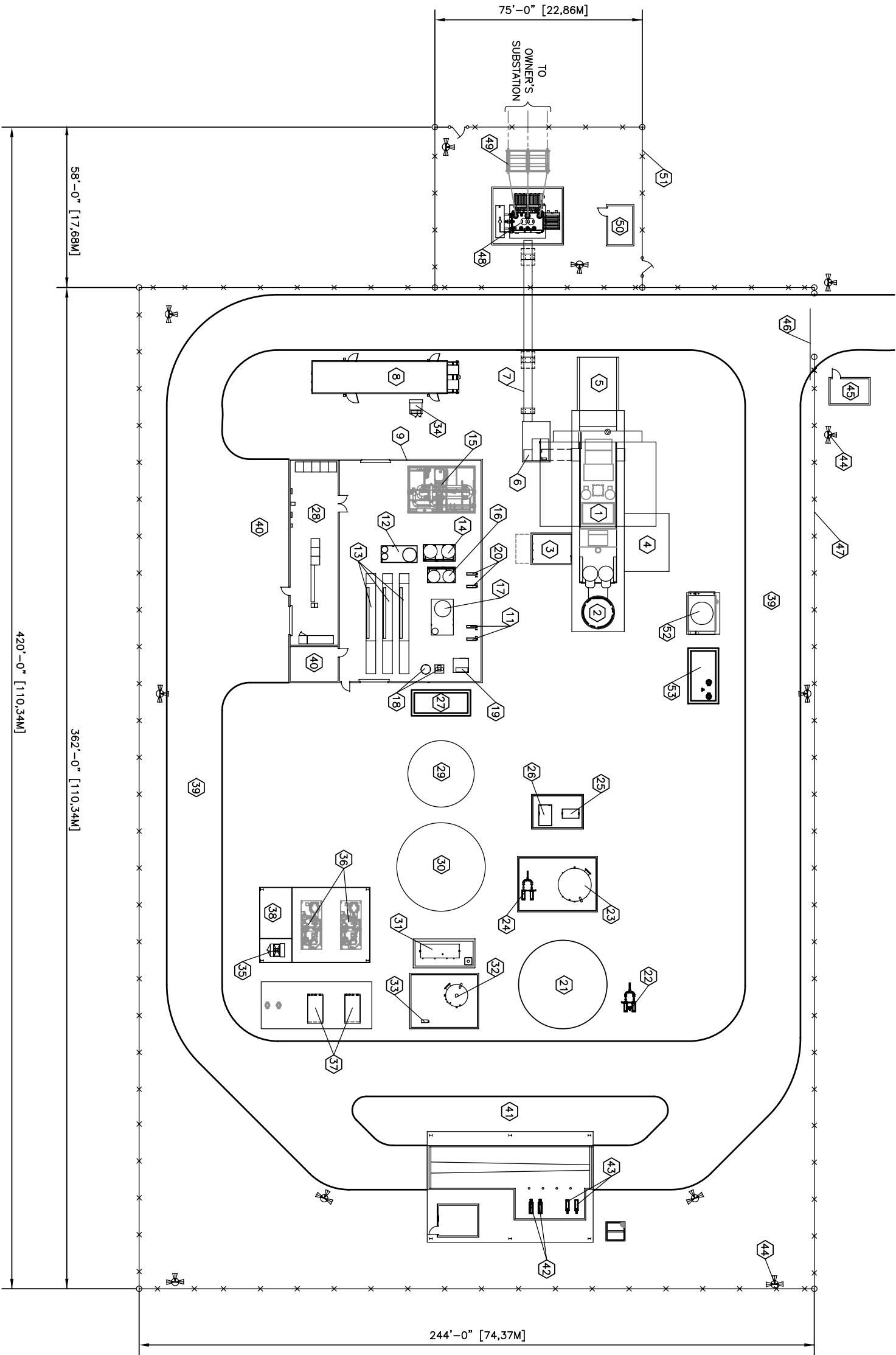
SUBSTATION CONTROL HOUSE.
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SUBSTATION FENCE.

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LUBE OIL FIN FAN.

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FUEL GAS REGULATOR/FILTER SKID.

GRAPHIC SCALE

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**ATTACHMENT B  
FUEL GAS SPECIFICATION**

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**GE Energy**

## **Process Specification Fuel Gases For Combustion In AeroDerivative Gas Turbines**

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*These instructions do not purport to cover all details or variations in equipment or to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes the matter should be referred to the GE Company.*

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## 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.

<b>TABLE 1</b> <b>FUEL GAS USABILITY</b>						
<b>Fuel Type</b>	<b>LHV Btu/SCF (kJ/NM<sup>3</sup>)</b>	<b>Wobbe Number</b>	<b>Major Components</b>	<b>Operational Comments</b>	<b>Applicability SAC    DLE</b>	
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 <sup>3</sup> ) 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 <sup>3</sup> ) 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 CO<sub>2</sub> content may be acceptable for DLE application. Contact GE.

NM<sup>3</sup> 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<sup>3</sup>) (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<sup>3</sup>) (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<sup>3</sup>). The Hydrogen (H<sub>2</sub>) content of these fuels is normally above 30% by volume and have H<sub>2</sub>/CO mole ratio between 0.5 to 0.8. Oxygen blown gasification fuels are often mixed with steam for thermal NO<sub>x</sub> 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<sup>3</sup>) LHV. The Hydrogen (H<sub>2</sub>) content of these fuels can range from 8% to 20% by volume and have a H<sub>2</sub>/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 NO<sub>x</sub> 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 and 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 consist 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<sub>2</sub> and H<sub>4</sub>C 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<sub>2</sub> 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:

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

This is equivalent to:

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

Where:

- LHV = Lower Heating Value of the Gas Fuel (Btu/scf)
- SG<sub>gas</sub> = Specific Gravity of the Gas Fuel relative to Air
- MW<sub>gas</sub> = 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  $\pm 10\%$  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 <sup>(a)</sup> in gas fuels used with engines having marinized (corrosion-resistant) coatings on the high pressure turbine blading shall not exceed 0.2 ppm <sup>(b)</sup>.

- (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:

$$\begin{array}{rcl}
 \text{ppm sodium inlet air} \times \text{Air/Fuel Ratio} & = & \\
 \text{ppm sodium in water or steam} \times & & \\
 \quad \frac{\text{Water or Steam}}{\text{Fuel}} \text{ ratio} & = & \\
 \text{ppm sodium in fuel} & = & \\
 \text{Total fuel equivalence for sodium from all} & \text{_____} & \\
 \text{sources not to exceed} & 0.2 \text{ ppm} & 
 \end{array}$$

#### **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 HRSG supplier for additional information.

#### **4.3.3 Selective Catalytic Reduction (SCR) Deposition**

Units utilizing ammonia injection downstream of the gas turbine for NO<sub>x</sub> 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.

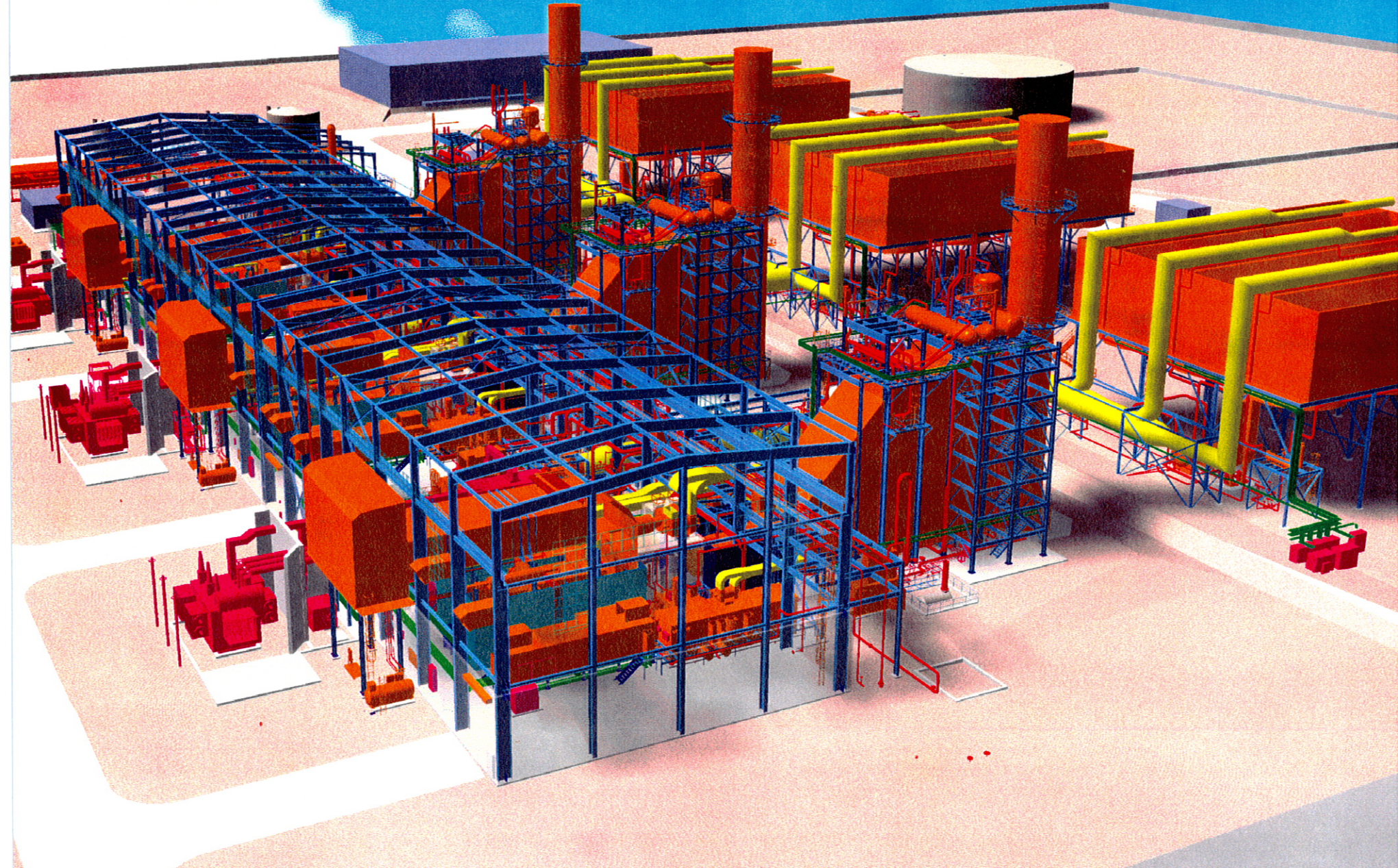
***Saturation Line***

This is the same as the dew point line.

***Wet Saturated Conditions***

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







Derwick Corp. ("DC") is pleased to provide this proposal to Corporacion Venezolana de Guyana ("CVG") for One (1) Brand New GE Frame 7F Gas Turbines.

## **SCOPE OF SUPPLY**

### **Gas Turbine**

Base-mounted gas turbine including:

- Modulating IGV (inlet guide vanes)

### **Combustion System**

- Dry Low NOx combustion system
- Combustion system features
  - Thermal barrier coated liners
  - Nimonic transition pieces
  - Reuter Stokes SiC flame detectors
  - Compressor inlet heating
    - Stainless steel water injection piping (GT unit)
- Water injection for NOx control
  - Liquid fuel
  - Off base water injection skid with:
    - Enclosure
    - Space heater
    - Water injection pump with variable frequency drive
    - Water filter

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## **Fuel Systems**

### **Gas Fuel System**

- Natural gas only
- Stainless steel gas piping
- Natural Gas Flow measurement System Orifice Plate
- Calibration of Natural Gas Flow Measurement System - Orifice
- Single gas strainer
- Gas fuel valves on accessory base
- Gas fuel temperature < 365°F (185°C)
- Gas fuel conditioning equipment
  - Fuel gas scrubber, cyclone type
  - Duplex absolute separator filter
    - Fuel gas chromatograph system
    - One (1) system provides signals for up to four (4) gas turbines

### **Liquid Fuel System**

- 
- Stainless steel fuel oil piping
- Duplex, low pressure fuel filters, on-base
- Main liquid fuel filter differential pressure transducer, 96LF
- Liquid fuel/atomizing air module
- Single, motor driven, atomizing air compressor
- Motor driven, 1x100% capacity, main liquid fuel pump
- Main liquid fuel pump inlet pressure transducer, 96LP
- Liquid fuel recirculation system during gas fuel operation
  - On-base piping in turbine compartment and LF/AA module
  - Requires fuel forwarding pump in operation if not supplied with gas turbine scope
- Distillate fuel forwarding system configured to supply one (1) gas turbine
  - Inlet/discharge valves for skid isolation
- Duplex fuel oil strainer with differential pressure switch and gauge
  - AC motor driven distillate fuel pump with pressure switch

- One (1) back-up ac motor driven distillate fuel pump per forwarding skid
  - Motor starters not provided in the gas turbine scope of supply
  - Pressure regulating valve
  - Separate distillate fuel heater skid (up to 20°F rise) with thermal relief valve (one (1) heater skid per turbine)
    - Inlet/discharge valves for skid isolation
    - SCR control panel mounted on skid unless area is rated Class 1, Group D, Div 2 or IEC Zone 2. When skid is rated as a hazardous area, the control panel must be installed in a climate controlled, non-hazardous area. This installation is not included in the gas turbine scope of supply.
  - Carbon steel fuel oil piping
  - Electrical conduit & junction boxes
  - Instrumentation and gauges (dual metric/English)
  - Weatherproof acoustic enclosure(s)
    - With fire detectors
    - With vent fan and lighting
  - No enclosure for the fuel forwarding skid
  - Hazardous area rating (Class 1, Group D, Div 2 or IEC Zone 2)
- Distillate fuel management spool piece
    - Inlet/discharge valves for skid isolation
    - Combined pressure regulating/stop valve
    - Flow meter
      - With local and remote flow and totalizer readout
      - With  $\pm 0.5\%$  system accuracy for the design fuel
    - Carbon steel fuel oil piping

## **Lubricating and Hydraulic Systems**

### **Pumps**

- AC motor driven dual lube oil pumps
- AC motor driven dual hydraulic pumps
  - Used for jacking oil also
- DC motor driven, emergency lube oil pump
- AC/DC motor driven auxiliary generator seal oil pump

**Filters and Coolers**

- Dual lube oil system filters
- Dual hydraulic oil filters
- Dual lube oil coolers
  - Plate/frame type with stainless steel plates
- ASME code stamp
  - Lube oil coolers
  - Lube oil filters

**Lube Oil Piping**

- 304L stainless steel lube oil feed pipe
- Carbon steel lube oil drain pipe
- Lube system valve stainless steel trim
- Automatic GMAW or GTAW root pass weld, lube oil feed and drain piping

**Mist Elimination**

- Lube vent demister

**Oil Reservoir**

- With heater for -20°F (-29°C) ambient temperature
- With provisions for lube oil conditioner

**Instrumentation**

- Delta pressure switches for alarm for lubrication and hydraulic oil filters
- Lubrication oil tank level transmitter

**Inlet System**

- Refer to GEK 111330a “Operation and Maintenance Recommendations for Gas Turbine Inlet Air Filter Compartments” provided in chapter 22 of this Appendix, for operation and maintenance information for the GT inlet system.
- Inlet system arrangement
  - Up and forward inlet system arrangement
- Inlet compartment
  - Self-cleaning inlet filter

- 
- Compressor bleed air supply for filter cleaning
  - Severe duty filter media (high humidity/corrosive environments)
  - 50 micron moisture separator
  - Coalescing filters
  - Inlet compartment local differential pressure indicator (gage) across each stage of filtration and overall filter compartment system
  - Inlet compartment differential pressure alarm
  - Three thermocouples for inlet air temperature measurement
  - Inlet filter compartment support steel (Seismic Zone 4,  $\leq$  120 mph wind speed loads per UBC 1997)
  - Evaporative cooler, 85% effective
    - Stainless steel piping
    - Redundant pumps (lead/lag)
    - Stainless steel pump casing material
  - Caged ladder access to inlet filter compartment
  - Left hand access to inlet filter compartment
  - Electric hoist with 500 lb lift capacity
  - Inlet filter compartment interior lighting
  - Air processing unit (APU) for filter cleaning
    - With 304 stainless steel piping and dual filters
    - APU heat tracing kit if required due to site minimum ambient temperature rating
  - Inlet compressor bleed heating
    - DLN premix turndown inlet bleed heat control
    - Compressor pressure ratio operating limit bleed heat control
    - Bleed heat manifold located in inlet duct
    - Inlet bleed heat control valve(s)
  - Inlet ducting
    - Inlet duct section arrangement per proposal mechanical outline
    - Inlet silencing
    - Inlet 90 degree elbow
    - Inlet transition piece
    - Inlet expansion joint
    - Inlet ducting support steel (Seismic Zone 4,  $\leq$  120 mph wind speed loads per UBC 1997) (Refer to proposal drawing for scope)

- Outdoor unit
  - Compressor inlet humidity sensor
    - Triple redundant sensors
  - Compressor inlet temperature thermocouple
- Inlet viewing window in plenum area
- Inlet system atmospheric protection
  - Zinc rich paint inside and outside of inlet filter compartment
- Two-part epoxy overcoat inside and outside inlet filter compartment
  - Zinc rich paint with two-part epoxy overcoat on evaporative cooler unwetted section
  - Zinc rich paint inside and outside of inlet ducting with two-part epoxy overcoat on all inside surfaces exposed to airflow as well as all outside surfaces
  - Galvanized, galvanized or carbon steel with zinc-rich primer for all interior surfaces not exposed to airflow
  - Corrosion-resistant inlet silencing perforated sheet
  - Galvanized inlet support steel

## **Exhaust System**

### **Arrangement**

- Exhaust diffuser with an axial exit
- Exhaust expansion joint
- Exhaust system materials and atmospheric protection
  - Carbon steel exhaust system shell and stiffeners
  - 409 stainless steel internal lagging
  - Inorganic zinc primer

### **Couplings**

- Rigid load coupling
- Load coupling guard

## **Gas Turbine Packaging**

- Lagging and enclosures
  - On-base accessory compartment lagging
  - Off-base acoustic enclosure for turbine only
  - Off-base load coupling compartment enclosure
  - Acoustic barrier wall around exhaust diffuser
- External junction boxes
  - Epoxy-coated carbon steel junction boxes, rated NEMA 4 or glanded IP56, dependent on whether wiring is compliant with NEC or IEC standards
  - Cast aluminum may be substituted as needed for flame-proof enclosure requirements, as determined by the hazardous area map for the project
- Compartment ventilation, pressurization and heating
  - Dual turbine compartment vent fans
  - Dual accessory compartment vent fans
  - Dual load compartment vent fans
  - Dual vent fans for liquid fuel and atomizing air skid
  - Compartment freeze protection heating
- Heated turbine and accessory compartments for humidity control
- Plant arrangement
  - Turbine designed for installation outdoors
  - Right hand accessory module
  - Multi shaft STAG
  - Mounting pads only; exterior unit walkways are not part of the power train scope of supply
  - Interior turbine compartment grating
- Base painting
  - Standard primer only
- Interconnecting Lube Oil Feed and Drain piping between accessory compartment and liquid fuel/atomizing air skid
- UBC 1997 Seismic Zone 4 loads (except for inlet and exhaust)

- UBC 1997 Seismic Zone 4 loads for inlet and exhaust
- Hazardous area classification
  - NEC Class1, Group D, Division 2
    - Turbine compartment
    - Natural gas fuel compartment
    - Liquid fuel/atomizing air module
- Special features
  - Blank set of nameplates for on-site engraving by others
  - Dual (metric-English) indicators and gauges

### **Fire Protection System**

- Fire detection system - heat detectors
  - Turbine compartment
  - Accessory compartment
  - Number 2 bearing tunnel
  - Generator collector compartment
  - Liquid fuel and atomizing air skid
- Smoke detection system
  - Control cab/PEECC
- Compartment warning signs
- Compartment exterior alarms
- CO2 supply system
  - One low pressure CO2 tank per unit
  - Tank suitable for 0-120°F (-18 to 49°C)
  - Tank also suitable for temperatures below 0°F (-18°C)
  - Tank to be located in a shelter (not part of the power train scope of supply), for ambient temperature above 120°F (49°C)
- Fire protection piping
  - Purchaser's connections on right side of unit only
  - Turbine compartment
  - Accessory compartment
  - Number 2 bearing tunnel
  - Liquid fuel and atomizing air skid



- FM-200 fire protection piping for the PEECC
- Hazardous atmosphere sensors in compartments
  - CHx sensors - natural gas compartment
  - Triple modular redundant sensors in the gas compartment
  - CHx sensors- turbine compartment
  - Triple modular redundant sensors in the turbine vent duct
  - H2 sensors - generator collector compartment
    - Triple modular redundant sensors in the collector compartment
  - H2 sensors - generator terminal enclosure
- Hazardous atmosphere detector readout
  - CHx
  - H2

### **Cleaning Systems**

- On base piping for on and offline compressor water wash system
- Water wash skid
  - Water storage tank and freeze protection
  - Stainless steel tank
  - Capability to heat water to 180°F (82°C)
  - Single skid for the site
    - One (1) skid can be connected to up to four (4) units, washing one (1) unit at a time (on-base storage tank sized for one [1] off-line wash)

### **Cooling Water System**

- Cooling system temperature regulating valve
- System suitable for:
  - Water/propylene glycol coolant mix

### **Starting Systems**

- Generator start with load commutated inverter
- Static start isolation transformer
  - Oil filled
  - Outdoor installation
  - Bottom entry cable connection, HV and LV

- Isolation transformer fed from auxiliary bus
- Redundant Ethernet link to turbine control panel
- Shared static start across power blocks using cross ties
  - Two (2) static starts for three (3) gas turbines
- Change-over function in LCI controls
- LCI output isolation switch (89MD)
- LCI cross-connect tie switch (89TS)
- AC line reactor
- Single dc link reactor
- Water-to-water heat exchanger, shipped loose
- Rotor turning systems
  - Turning gear and motor for rotor cooldown
  - Rotor indexing (borescope inspection)

## **Miscellaneous Systems**

### **Special Systems**

- Exhaust frame blowers on turbine compartment roof
  - Bearing area blowers also included

## **Generator**

### **General Information**

- Hydrogen cooled generator with conventionally cooled armature
- Outdoor installation
- 60 Hz generator frequency
- Generator voltage 18.0 kV
- 0.85 power factor (lagging)
- Capability to 0.95 power factor (leading)
- Class “F” armature and rotor insulation
- Class “B” temperature rise, armature and rotor winding
- Generator bearings
  - End shield bearing support
  - Elliptical journal bearings
  - Roll out bearing capability without removing rotor

- Insulated collector end bearing
- Online bearing insulation check
- Offline bearing insulation check with isolated rotor
- Monitoring Devices
  - Two (2) velocity vibration probes at turbine end, one (1) at collector end
  - Provisions for key phasor-generator
  - Permanently mounted flux probe mounted in stator wedge (Monitoring system not included)
  - Proximity vibration probes
    - Two (2) probes per bearing at 45° angle
- Generator Field
  - Direct cooled field
  - Two-pole field
  - Finger type amortisseurs

### **Generator Gas Coolers**

- Coolers shipped installed
- Generator gas cooler configuration
  - Five (5) horizontally mounted simplex coolers
  - Coolers located in generator base
- Cooler piping connections on left side as viewed from collector end
  - ASME code stamp
  - Single wall cooler tubes
  - Victaulic cooler couplings
  - Plate fins
  - Cooling water manifold and isolation valves
  - Companion flanges for cooler connection
- Generator gas cooling system characteristics
  - Coolant temperature - 20°F approach
  - Generator capacity with one section out of service 80% with Class “F” rise
  - TEMA class C coolers
  - Maximum cooler pressure capability - 125 psi

- Coolant 55% water and 45% propylene glycol by volume
- Fouling factor 0.0010
- Generator gas cooler construction materials
  - 90-10 copper-nickel or copper tubes as appropriate
  - Carbon steel tube sheets
  - Carbon steel waterbox and coupling flanges with epoxy coating
  - Aluminum cooler tube fins

### **Generator Lube Oil Systems and Equipment**

- Bearing lube oil system
  - Generator lube oil system integral with turbine
  - Sight flow indicator
- Bearing lift oil system
  - Stainless steel lift oil piping and tubing
  - Lift oil supplied from turbine oil system
- Lube oil system piping materials
  - Stainless steel lube oil feed pipe
  - Carbon steel lube oil drain pipe
  - Welded oil piping

### **Generator Grounding Equipment**

- Neutral grounding equipment
  - Neutral ground transformer and secondary resistor
  - Mounted in terminal enclosure
  - Motor operated neutral disconnect switch

### **Generator Temperature Devices**

- Stator winding temperature devices
  - 100 ohm platinum RTDs (resistance temperature detector)
  - Dual element RTDs
  - Grounded RTDs
  - Nine (9) stator slot RTDs
- Gas path temperature devices
  - 100 ohm platinum gas path RTDs
  - Dual element temperature sensors

- Four (4) cold gas
- Two (2) hot gas
- GTG-2 (common cold gas)
- Bearing temperature devices
  - Chromel alumel (type K) thermocouples
  - Dual element temperature sensors
  - Two (2) bearing metal temperature sensors per bearing
- Collector temperature devices
  - 100 ohm platinum RTDs
  - Single element temperature sensors
  - Collector air inlet temperature sensor
  - Collector air outlet temperature sensor
- Lube oil system temperature devices
  - Chromel alumel (type K) thermocouples
  - Dual element temperature sensors
  - One (1) bearing drain temperature sensor per drain

## **Packaging, Enclosures, and Compartments**

- Paint and preservation
  - Epoxy based primer
- High voltage bushings
  - High voltage bushings shipped installed
  - Six (6) ambient air cooled, high voltage bushings
- Generator Terminal Enclosure
  - Terminal enclosure shipped separate
  - Top mounted
  - Neutral terminals integral with line-side terminal enclosure
- Line-side terminal enclosure
  - Terminal enclosure shipped separate
- Generator Terminal Configuration
  - Phase sequence R-C-L when looking at enclosure terminals
  - Outgoing power connection on right side when viewed from collector end
- Collector compartment/enclosure
  - Collector compartment/enclosure shipped separate

- Collector/brush holding rigging
- Generator Terminal Accessories
  - Line CTs
  - Lightning arresters
  - Voltage transformers
  - Neutral CTs
- Compartment lighting
  - AC lighting
    - Collector compartment
- Foundation hardware
  - Generator alignment fixators
  - Generator alignment key(s) - collector end
  - Generator alignment key(s) - turbine end

### **Hydrogen Systems and Accessories**

- Hydrogen gas manifolds
  - Auto purge gas purge control manifold
  - Hydrogen/CO2 control valve assembly
  - H2/CO2 bulk feed connections
  - H2 Bottle manifold not provided
  - CO2 bottle manifold not provided
- Hydrogen detection system
  - H2 detection sensor(s)
    - Collector compartment
    - Terminal enclosure
- Seal oil system
  - Control unit mounted in collector compartment
  - Stainless steel seal oil feed pipe
  - Carbon steel seal oil drain pipe

## **Electrical Equipment**

- Motors
  - TEFC motors
  - Coated with antifungal material for protection in tropical areas
  - Energy saver motors
  - Extra severe duty motors
  - Cast iron motor housings
- Heaters
  - Generator stator heaters
  - Generator collector heaters
  -

## **Generator Excitation Systems, Static Components**

- Bus fed static excitation with warm backup bridge

### **Excitation Module Features**

- Control/monitor/display through turbine control panel
  - Voltage matching in turbine control system
  - Power factor controller in turbine control system
  - Var controller in turbine control system
  - Selection of automatic or manual regulator
  - Raise-lower of the active regulator setpoint
  - Enter setpoint command
  - Display field amps
  - Display field volts
  - Display transfer volts
- Redundant Ethernet link to turbine control panel
- Built-in diagnostic display panel
  - Automatic voltage regulator (AVR)
  - Manual voltage regulator (FVR)
  - Automatic and manual bi-directional tracking
  - Reactive current compensation (RCC)
  - Temperature compensation for UEL and OEL
  - Volts per hertz limiter (V/Hz LIM)
  - Volts per hertz protection (24EX) (Backup to 24G)
  - Over excitation limiter (OEL)

- Offline/online over excitation protection (76EX)
- Loss of excitation protection (40EX)
- Bridge ac phase unbalance protection (47EX)
- Under excitation limiter (UEL)
- Generator overvoltage protection (59EX)
- Generator field ground detector trip (64FT)
- Field over-temperature alarm
- Field ground detector alarm (64FA)
- Exciter phase voltage imbalance (47EX)
- Bridge over-temperature (26EX)
- Local operator interface, panel mounted
- Dual source internal bulk power supply
- Millivolt shunt for field
- Surge protection
  - VT disconnect and CT shorting switches
  - Two phase current sensing
  - Three phase voltage sensing
  - Single pole dc field contactor/bridge
- Thyristor bridge circuit filtering
- Shaft voltage suppressor circuit (mounted in panel)
- Power system stabilizer

### **Performance**

- 2.0 response ratio and 160% VFFL (100°C) ceiling @  $V_t = 1.0\text{pu}$

### **Excitation Location**

- Installed in LCI/EX compartment

### **PPT Features**

- Freestanding oil-filled PPT for outdoor installation
- PPT fed from auxiliary bus

### **LCI Features**

- LCI located in LCI/EX compartment
- LCI output isolation switch (89MD)



- Located in LCI compartment
- LCI cross-connect tie switch (89TS)
  - Located in LCI compartment
- LCI disconnect switch (89SS)
  - Located in generator terminal enclosure
- LCI fuse
  - Located in compartment with LCI

### **Generator Current Transformers and Voltage Transformers**

- Current transformers (CTs)
  - Line-side CTs with relaying class C800 and metering class 0.3B-1.8 (ANSI C57.13)
  - Neutral-side CTs with relaying class C800 and metering class 0.3B-1.8 (ANSI C57.13)
  - Line side CTs
    - CT 13, 14, 15 (miscellaneous functions)
    - CT 19A, C (excitation)
    - CT 21, 22, 23 (generator differential relay)
  - Neutral CTs
    - CT1, CT2, CT3
    - CT4, CT5, CT6
    - CT7, CT8, CT9
    - CT10, CT11, CT12
- CT calibration curves, provided after equipment ships
  - For line-side CTs
  - For neutral-side CTs
- Voltage transformers (VTs)
  - Fixed
  - VT2, generator line side
  - VT4, generator line side

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## **Gas Turbine-Generator Controls and Electric Auxiliaries**

### **Control Cab/Packaged Electric and Electronic Control Compartment (PEECC)**

- Weatherproof, climate controlled, base mounted enclosure
- Redundant HVAC system
- Mounted on pedestals

### **Gas Turbine Control System Panel Features**

- Triple Module Redundant (TMR) SPEEDTRONIC™ Mark VIe with non-remote I/O
  - Redundant unit data highway (UDH)
- Auto/manual synchronizing module with synchronizing check function
- Generator stator overtemperature alarm (49)
- Load limiter
- Purge cycle
- Island mode operation for DLN units
- Automatic transfer from gas to liquid fuel
- Customer alarm/trip contact for CRT display
- Additional customer input contacts (digital), as available
- Additional customer output contacts (digital), as available
- Provision for analog inputs from customer, as available
- Provision for analog outputs to customer, as available
- Maximum of 12 RTDs inputs for customer use
- Power source selector
- Totalizing fuel flows
- Vibration alarm readout and trip
- Electrical overspeed protection
- Constant settable droop
- Power factor calculation and display
- Power factor control
- VAR control
- VARS shedding
- Tie-line VAR control

- Manual set point preselected load
- External load setpoint, 4-20 mA control
- Airflow calculation and readout
- Inhibit/initiate auto synchronization from remote location
- Time synch
  - Time input signal, for devices on the power train network, is not part of the power train scope of supply

### **Local Operator Station**

- Commercial grade personal computer
- Operator interface 19" rack
- PC table
- Color monitor
  - Rack mounted
  - 17 in. LCD monitor or equivalent
- Keyboard with built-in cursor positioning device
- Printer
  - Color ink jet printer
- Display in English language
- Unit Ethernet equipment

### **Generator Protection Panel**

#### **Generator Protection Panel Hardware**

- Mounted in PEECC
- GE Multilin G60 Generator Management Relay
- GE Multilin T60 Transformer Management Relay
- GE Multilin C60 Breaker Management Relay
- Generator Digital Multimeter
- Lockout relays
- Test switches (per one-line)
- Generator breaker trip switch (52G/CS) and lamps
- Gas auxiliary monitoring panel (GAMP)

- Humidity sensor readout
- Hazardous atmosphere detector readout
- Bently Nevada 3500 vibration monitor

### **Generator Management Relay (G60)**

- Generator overexcitation (24)
- Phase undervoltage (27P)
- Reverse power/anti-motoring (32)
- Loss of excitation (40)
- Current unbalance/negative phase sequence (46)
- Phase time overcurrent (51PV)
- Neutral ground overvoltage (stator ground) (59N)
- Phase overvoltage (59P)
- Stator ground protection, (third harmonic) (27TN)
  - Site data required for setting
- Generator over frequency (81O)
- Generator under frequency (81U)
- Phase Distance (21)
- Out of Step (78)
- Stator differential (87S)
- Voltage transformer fuse failure (VTFF)

### **Breaker Management Relay (C60)**

- Inadvertent energization (50/27)
- Breaker failure with timer (50/62BF)
- Breaker failure (50BF)
- Bus ground detection (59BN)
- Voltage transformer fuse failure (VTFF)

### **Transformer Management Relay (T60)**

- With three (3) restraints
- Unit differential (87U)
- Transformer neutral overcurrent (51TN)
- Latch output contact for transformer fault pressure (63PTX)

### **Digital Generator Protection System (DGP)**

Note: Refer to proposal one-line diagram for complete discrete relay scope

- Generator protection lock-out relay (86G1A)
- Generator protection lock-out relay (86G2A)
- Inadvertent energization lock-out relay (86IE)
- Breaker failure lock-out relay (86BF)
- Unit differential lock-out relay (86U)
- Transformer differential lock-out Relay (86T)
- Breaker Cross tripping dual breaker trip coils (94GB-1,2)
- Breaker status auxiliary relay (52GX-1)

### **Features Integrated Into Gas Turbine Control System**

- Gas turbine control system with speed matching, synchronization and check
- Manual synchronization displayed on gas turbine control system operator interface
- Auto/manual synchronizing module with generator voltage matching displayed on gas turbine control system operator interface
- Load control in gas turbine control system
- Temperature indication for generator RTDs

### **Generator Protection Panel Metering**

- Generator digital multimeter (Nexus)
  - Generator volts
  - Generator Amps: Phase 1,2,3 and Neutral
  - Generator Watts
  - Generator VARs
  - Generator frequency
  - Generator VA
  - Generator power factor
  - MWH - Generator Watt-Hours
  - MVAH - Generator VA-Hours
  - Generator VAR-Hours

### **Generator Protection Panel Outputs**

- Nexus meter with KYZ pulse output module (field configurable)
- Generator watt/VAR transducer 4-20 mA output for input to TCP (96GG-1)
- Generator TCP/droop control transducer 4-20 mA output (96GW-1)

### **Generator Protection**

- Generator electrical protection equipment
  - Shaft voltage monitor in turbine controls

### **Batteries and Accessories**

- Lead acid battery
- Two (2) single-phase battery chargers, each sized 100% capacity

### **Motor Control Center**

- MCC mounted in control compartment
- Tin-plated copper bus-work

### **Remote Control and Monitoring Systems**

- HMI Ethernet communications link using GSM protocol
- Site Ethernet equipment in central control room
- Ethernet cables internal to components and compartments, as well as Ethernet switches
- Remote HMI, multi-unit control
  - Two (2) per site
- Commercial grade personal computer
- Color monitor
  - Table top
  - 20 in. LCD monitor
- Trackball cursor control
- Mouse cursor control
- Table top keyboard
- Printer
  - Black and white laser network printer
  - Color laser jet network printer - One (1) per site

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## **Rotor, Bearing and Performance Monitoring Systems**

- Performance monitoring systems
  - Air flow measurement sensors wired to gas turbine control system
    - Gas turbine performance monitoring calculations in operator interface
- Vibration sensors
  - Velocity vibration sensors
  - Proximity vibration sensors
  - Transducer for atomizing air compressor
- GE proximity vibration sensor monitoring
  - In the SPEEDTRONIC™ Mark VIe panel
  - HMI display
- Bently Nevada 3500 proximity vibration sensor monitor
  - Signals provided from turbine control panel
  - Mounted with auxiliary panel

### Bearing thermocouples

- Bearing drain thermocouples
- Bearing metal thermocouples
- Borescope access holes

### Bently Nevada System 1

#### TGVAS

- Software for gas turbine/generator(s) Universal On Site

#### Monitoring System (uOSM)

- Rack Mounted
- Shares HMI monitor, keyboard and positioning device
- ADH equipment for turbine control system
- Requires two dedicated analog phone lines, which are not part of the power train scope of supply

## **Motor Features**

- TEFC motors less than or equal to 200 hp
- Coated with antifungal material for protection in tropical areas
- High ambient motor insulation
- Energy saver motors
- Extra severe duty motors
- Cast iron motor housings
- All redundant motors to be lead/lag
- Motor heaters connected to AC power, for all motors greater than 1 hp
- WP motors >200 hp
- NEMA Class F insulation, Class B temperature rise

## **Services**

- Transportation
  - Generator shipped with rotor installed
- Documentation
  - English language
    - Motor data sheets (sent after equipment ships)
  - Copy of material certifications for gas turbine rotor forgings
  - Gas Turbine
    - Reference Drawing Manual
      - Online
      - Hardcopy: Quantity 2
      - CD ROM format: Quantity 5
    - Service Manuals
      - Online
      - Hardcopy: Quantity 2
      - CD ROM format: Quantity 5
  - Generator
    - Station Designer Handbook
      - Online
    - Reference Drawing Manual
      - Online
    - Service Manuals



- Online
- Turbine maintenance tools
  - Guide pins (for removal or replacement of bearing caps, compressor casing and exhaust frame)
  - Fuel nozzle wrenches
  - Fuel nozzle test fixture
  - Spark plug electrode tool
  - Clearance tools
  - Fuel nozzle staking tool
  - Combustion liner tool
  - Bearing and coupling disassembly fixture
  - Turbine rotor lifting beam (one [1] for every four [4] units)
  - Turbine rotor lifting guides (one [1] for every four [4] units)
  - Basic maintenance tools and cart (one [1] set per site)
  - Hydraulic tools for removal of casing bolts (one [1] set per site)
  - Hydraulic bolt tensioning tool (one [1] set per site)
- Generator maintenance tools (one [1] set per site)
  - Rotor lifting slings
  - Rotor removal equipment including shoes, pans, pulling devices
  - Rotor jacking bolts
- Installation equipment
  - Trunions for generator
    - On permanent basis
  - Jacking bolts for generator
  - Turbine base fixators and shim packs
  - Turbine flush piping and consumables
    - One (1) set of piping for up to four units
    - One (1) set of consumables per unit
  - Power system stabilizer tuning study
  - Power system stabilizer (PSS) site testing

## **Customer Observation Points**

- Observe unit rotor final balance
- Observe gas turbine unit ready for shipment
- Observe final electrical test (stator)
  - Winding resistance measurement
  - Insulation resistance measurement
  - High potential test
- Observe generator field overspeed and balance
- Observe final electrical test (generator field)
  - Winding resistance measurement
  - Insulation resistance measurement
  - High potential test
- Control panel inspection observations
  - Turbine control panel visual inspection
  - Turbine control panel software test

## **EXCLUSION**

Listed below are the limits/exclusions to the Seller standard Scope of Supply. All piping, wiring, cables, ducts, etc. connecting to these points is furnished by Purchaser (others) unless modified by specification agreement.

<b>Equipment System</b>	<b>Limits of Seller Scope</b>
All piping, including Fuel Gas, Fuel Oil, Steam, Cooling Water, Heating Water, Demineralized Water, Lube Oil, Compressed Air, Instrument Air, Hydraulic Start Oil	Flanged or threaded connection on Seller baseplate.
Inlet Air-to-Filter	Atmosphere (non-standard duct by others)
Turbine Package Ventilation/Cooling Air	Atmosphere (non-standard duct by others)
Turbine Exhaust	Exhaust flange on main baseplate

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Instruments on Seller's Baseplate	Terminal box on baseplate
Instrument wiring in Turbine Control Panel	Wiring Terminal block in Turbine Control Panel
High Voltage Connections	Bus bar in Seller Lineside cubicle
Generator Ground Connections	Seller Neutral cubicle
Electric Motors	Terminal box on individual motor
Ladders and Platforms for Air Filter	Ladders and Platforms for Inlet Air Filter maintenance only
24 V DC Batteries and Chargers for Control System and Fire and Gas Systems	Battery terminals to baseplate (if supplied loose)

**Exclusions**

- Civil engineering design of any kind
- Building and civil works
- Site facilities
- Drains and/or vent piping from the gas turbine package to a remote point
- Fuel storage, treatment and forwarding system
- Site grounding
- Lightning protection
- Power system studies
- Sensing and metering voltage transformers
- Machine power transformers, and associated protection
- Grid failure detection equipment
- Off-loading, transportation and storage
- Off-skid cabling, and design of off-skid cable routing
- Balance of plant and energy optimization controls
- Anchor bolts, embedments, and grouting (quoted separately)
- Distributed plant control
- Purchaser's remote control
- Field supervision (quoted separately)
- High voltage transformer(s), cables, and associated equipment
- Interconnecting piping, conduit, and wiring between equipment modules

- Plant utilities, including compressed air supply and off-skid piping
- Battery containment
- Lube oil measurement other than that defined in the scope of supply
- Additional lube oil breather ducting other than that defined in the scope of supply
- Fuel transfer pump
- Off-skid fuel block and vent valves
- Fuel supply pipework beyond the scope of supply
- Generator controls other than that defined in the scope of supply
- Load sharing control
- Balance of plant controls
- Field Performance Testing
- Site Labor
- Ladders, Stairs, and Platforms for equipment beyond the gas turbine

**Attachment    Scheduled Date(s)**

Reference	Equipment Description	Scheduled Date
Unit 1	GE Frame 7F Generating Set (Never Used)	December 31,2009

## 1 GENERAL

GE 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 USABILITY						
Fuel Type	LHV Btu/SCF (kJ/NM <sup>3</sup> )	Wobbe Number	Major Components	Operation al Comments	Applicability SAC	DLE
Pipeline Natural Gas	850- 1200 (33383-	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 <sup>3</sup> ) for starting. May require modified fuel nozzles.	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 - Oxygen Blown	150-200 (5891- 7855) 200- 400 (7855- 15709)	6-8  8-20	Carbon monoxide, Hydrogen, HC, Nitrogen, Water Vapor 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 <sup>3</sup> ) for starting. Restricted	Yes	See Note 8
Refinery Gases	1000- 1300 (39274- 51056)	45-60	Methane, Hydrogen, Carbon monoxide,	No restrictions. Hydrogen content should be reviewed by	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.

### ***Design Criteria***

The following table outlines the criteria conditions at the proposed jobsite for the design of the equipment:

Location	TBD
Elevation	TBD
Design Point Ambient Temperature / Relative Humidity	TBD
Primary Fuel Source	TBD
Secondary Fuel Source	TBD
Seismic Design Criteria (BOP Equipment)	TBD
Maximum Wind Speed (Wind Load), MPH	TBD
Near Field Noise at 3 ft horizontal and 5 ft vertical, dBA NOTE 1	TBD
Far Field Noise, dBA NOTE 1	TBD at 400 ft / TBD at 700 ft

NOTE 1: Far field noise is based on single-unit only operation. Multiple units operating at the same time will have an impact on both near and far field noise levels.





DERWICK ASSOCIATES S.A.

# GE Frame 7EA



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## **Introduction**

Derwick Associates S.A. proposes to supply a group of gas turbine-based simple cycle power plant equipment nominally rated at 170 MW that contains two (2) GE Frame 7EA ("7EA") gas turbines with test hours only. Industrial gas turbines are not normally tested prior to installation; the completed testing of these turbines will significantly reduce the installation time. These are completely operational units and ready to be disassembled and transported to your job site.

## **Scope of Supply**

The following is a complete description of the Frame 7EA gas turbine units which Derwick Associates S.A. is quoting:

### **Two GE Frame 7EA Gas Turbines**

2X Gas fueled General Electric (PG7121) 7EA Dry Low NO<sub>x</sub> (DLNI) gas turbine rated at 84.4 MW ISO / 60 Hz (59 °F/15 °C, sea level, 60% RH).

### **Brush-Generator**

Air cooled Brush BDAX 8.365 ER generator with an EX2000 brushless excitation system that is rated at 101.8 MVA@0.85 PF, 13.8 kV, 3600 rpm, 60 Hz, 3 phases. The generator is a synchronous two-pole cylindrical rotor machine.

- **Generator Air Filter**  
Donaldson self cleaning, single stage, pulse clean filter system.
- **Generator-Control-System**  
The Generator Control System includes a Beckwith, Automatic Voltage Regulator (AVR), Digital Generator Protection (DGP) and Nexus 1250 metering module. The system is located in the PEECC and interfaces directly with the turbine control system. Other components included in the generator control system include the GE Multilin transformer protection relay, the EX2000 Excitation System and the lock out relays
- **Generator Auxiliary Compartment**  
Contains the GE 15 kV vacuum circuit breaker. The 15 kV class, vacuum, metal clad switchgear is installed in a NEMA 3R enclosure. Circuit breaker charging and trip/close mechanisms operate from a 125 VDC battery supplied system.

- **Generator Lineside and Neutral Grounding Equipment**

The generator lineside equipment for the gas turbine generators is contained within the 15 kV switchgear that connects the generators to the generation bus. The neutral grounding equipment for the gas turbine generators, consisting of a typical transformer/resistor combination, is contained on the GTG skid within the generator package. The lineside and neutral grounding equipment is comprised of connections, surge arresters, surge capacitors, CTs, PTs and grounding transformers and resistors.

**Accessory Module**

Skid containing the 800 hp electric starting motor, auxiliary gearbox, torque converter and the following equipment for the lube oil system: integrated tank, filter, tube and shell heat exchanger, AC and DC pumps.

**Exhaust Frame Blowers**

Two air blowers provide cooling air to the rear frame of the gas turbine.

**Turbine Inlet Filter**

Donaldson air inlet filter system for the turbine provides clean filtered air for combustion use. The unit includes the louvered inlet, inlet heating, synthetic canister filter elements, pulse cleaning system, turbine inlet silencer, ductwork, ladders/platforms and support steel.

- **Fogging System**

A MEE Industries fogging system consisting of one pump skid, one sub-micron water filter and six high pressure pumps provides a cooling effect to the turbine inlet air by injecting demineralized water under high pressure directly into the inlet air stream. By lowering the temperature of the inlet air, the power output and the efficiency of the turbine is increased.

The skid with a design flow rate of 37.6 gpm contains six high pressure Cat Pump pumps. Five 10 hp pumps are rated for 7 gpm each and one 5 hp pump is rated for 3.5 gpm each for a total water pumping capacity of 38.5 gpm.

- **Air Processing Unit**

Air processing unit provides pressurized air for pulse cleaning of the turbine and generator inlet air filters and instrument actuation. The system dries and cools compressor bleed air.

## Fuel Gas Module

Fuel gas is controlled with the fuel gas stop/ratio valve, gas control valve (GCV), gas splitter valve (GSV) and the gas transfer valve (GTV) assemblies. The stop/ratio valve and the GCV work in conjunction to regulate the total flow to the gas turbine and the GSV and GTV are used to control the distribution of the fuel flow delivered to the GE DLNI combustion chambers. Servo valves, controlled from the TCS control panel, actuate the gas system valves. The system is designed to deliver natural gas fuel at the correct pressure and flow rates to meet all starting, acceleration and loading requirements of gas turbine operation. The following major components comprise the off-base fuel gas system:

- Gas Strainer
- Gas flow meter (corrected)
- Block valves
- Electronic flow control valves
- Electronic and local instrumentation

Fuel gas from the off-base supply system passes through the strainer. The fuel gas flow is controlled by the block valves and electronic control valves before passing to the distribution manifolds and combustion systems. The position of these valves is servo-controlled by electrical signals from the TCS position feedback signals

A flow meter measures fuel gas consumed by the gas turbine. The control valves are activated by the turbine control system to provide the amount and distribution of fuel required by the turbine for a given load or speed. The block valves shut off fuel flow to the turbine when necessary.

## Packaged Electrical and Electronic Control Center (PEECC)

A control module for each gas turbine is provided to minimize field installation. The control module is designed to accommodate the turbine control system, motor control center (MCC), lighting/distribution transformer, misc. electrical panels, battery system, and the Generator Control System. The module is supplied with an HVAC system and ceiling mounted fluorescent lighting fixtures.

- **480V MCC**  
A 480V motor control center, located in the PEECC, serves the gas turbine generator. This includes the 480 VAC and 120 VAC and 120 VDC distribution panels.

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- **Batteries System and UPS**  
125 VDC batteries with two chargers, for reliability. The battery charger maintains the station batteries in a fully charged condition. The uninterruptable Power Supply (UPS) provides power for plant control system backup and protection.
  - **Turbine Control System**  
GE Mark VI Speedtronic Turbine Control System (TCS) that provides operating and controls sequencing for the safe operation and control of the package. The TCS is located inside the Packaged Electrical and Electronic Control Center (PEECC) and is rated for an indoor, non-hazardous environment.

Starting of the gas turbine is accomplished using a closed loop process of temperature and/or speed control for an electrically driven torque converter system for consistent and reliable starts. Bumpless transitions between start, temperature, and speed PID's minimizes wear and reduces maintenance requirements of the package. Temperature and speed rate control during startup allow the turbine to warm up to the manufacturer's specifications.

Generator output controls offer multiple modes of operation. User selectable modes allow for operation of gas turbine on isolated grids. Manual, Megawatt, and Frequency modes are easily selected through the appropriate screens of the Human Machine Interface (HMI).

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## **Balance of Plant Equipment**

### **Mechanical Systems**

- **Lube Oil Demister**  
R.K. Chase mist eliminator system.
- **Fuel Gas Heater**  
500 kW Watlow heater capable of increasing the temperature of the gas 50°F to meet the superheat requirement.
- **Fuel Gas Scrubber**  
National Filtration System vertical dry scrubber knocks out drum that utilizes centrifugal action to achieve last stage removal of solids and entrained liquids. The capacity of the scrubber is 22,100 scfm.
- **Cooling Water Module**  
The cooling water system provides the cooling requirements for the lubricating oil, turbine support legs and flame detectors. The major equipment includes an expansion tank, an air cooled heat exchanger and two circulating pumps. The system utilizes a coolant consisting of a solution of 50% ethylene glycol in demineralized water.

Bailiff Enterprise's 178 gallon expansion tank is open to the atmosphere to allow for coolant expansion due to increases in ambient temperature.

Ecodyne forced draft air heat exchanger designed to supply coolant at a temperature not to exceed 125°F.

Two 75 hp Goulds Pumps, 100% capacity, rated at 967 gpm.

- **Carbon Dioxide Fire Extinguishing System**  
The carbon dioxide (CO<sub>2</sub>) fire protection system supplied by Chemtron for GT fire protection is designed to reduce to an acceptable level the risk of a fire developing within the gas turbine that could result in damage to the plant and/or possible loss of life.

The system consists of the following major components that are located both on base and off base:

- 1) CO<sub>2</sub> tank system
- 2) Discharge pipes and nozzles
- 3) Pilot cylinder and solenoid valve
- 4) Isolating valves and limit switches
- 5) Fire (heat) detectors
- 6) Pressure switches

CO<sub>2</sub> is supplied to a distribution system that conducts the extinguishant through pipes to discharge nozzles located in the various compartments of the gas turbine.

The solenoid valve that opens the CO<sub>2</sub> tank and initiates the discharge is located on the skid. This solenoid valve is automatically actuated by the fire panel when it receives an electrical signal from the heat-sensitive fire detectors that are strategically located in the various compartments of the unit. The system may also be actuated manually in the event of an electrical power failure by means of a lever at the top of each CO<sub>2</sub> tank. Actuation of the system, either electrically or manually, will trip the gas turbine.

Within a few seconds after actuation, a sufficient CO<sub>2</sub> flow from the initial charge system into the compartment of the machine to rapidly build up to an extinguishing concentration. This concentration is maintained for a prolonged period of time by the gradual addition of more CO<sub>2</sub>.

### **Exhaust Stack**

92' Braden simple cycle exhaust stack with silencer panels and emissions monitoring

### **Electrical Systems**

The electrical system is comprised of the generator and associated equipment necessary to supply power to its auxiliary electrical equipment and systems as well as deliver power to the switchyard.

Each of the generators generates electrical power at 13.8 kV, 3-phase, 60 Hz. The output of each will be connected to a generation bus via its own 15 kV class, vacuum type, metal clad, and circuit breaker

Station service power will be supplied from the utility system by backfeed during plant start-up, shutdown, and maintenance periods. The station service power will be supplied at 480V, 3-phase from one of the two station service busses which are fed by the two station service transformers.

Each generator will be synchronized to the utility system by closing its respective 15 kV circuit breaker.

- **Power Distribution Center (PDC)**

The PDC contains various breakers and control equipment including: motor starters, motor management relay, and switchgear breakers for the MCCs located in the PEECC. Other equipment such as the heat trace panel, BOP MCC, UPS, and 125VDC power distribution are also in the PDC.

- **Auxiliary Transformers**

Two low voltage distribution transformers manufactured by Virginia Transformer, suitable for outdoor service, one rated at 13.8 kV/480V, 2341 KVA and one rated at 13.8 kV/4160V, 3000 KVA.

- **Generator Step-Up Transformer**

230 kV Ferranti Packard generator step-up (GSU) transformer, including appropriate protection. The GSU is rated at approximately 200 MVA. Its purpose is to step the 13.8 kV outputs of the generators up to 230 kV as required for interconnection to the utility transmission system.

- **Switchyard Equipment**

- Includes an SF-6 breaker and air switch, CTs, PTs and appropriate relaying, protection and control equipment.



## **Commercial**

There were a number of plants which were available several years ago similar to this one but they have all since been sold and relocated. The Derwick Associates S.A. team has relocated (8) of these Frame 7EA machines and constructed new power plants in the US utilizing the relocated units. Based on our experience, we propose to provide the same services for your company.

These are complete operational units and ready to be disassembled and transported to your job site. The serial numbers of the units are as follows:

**Serial Numbers: 297635, 297636**

## **Price**

**ALL EQUIPMENT IS SUBJECT TO PREVIOUS SALE**

## **Payment**

<b>Transfer Instructions:</b>	
Intermediary Bank: Citibank, N.A. ABA: 021000089  Address: 111 Wall Street, New York, NY 10043	Beneficiary: International Union Bank, S.A. Account: 36246731 Address: Ave. Samuel Lewis, Edif. Omega Piso 5, Apartado 0391 Wtc Panamá, Republica de Panamá  FFC: Davos International Bank/000767- 224-001  Ref: Derwick Associates/ 13102362

## **Availability**

These units are currently available for immediate purchase. Disassembly and transport to the nearest port can be completed in less than 30 days (Optional) from date of contract and receipt of payment.

## **Validity**

This proposal is valid for a period on 30 days.



## Typical Performance Characteristic Curves

## General Electric Model PG7121EA Gas Turbine

### Estimated Performance - Configuration: DLN Combustor

Compressor Inlet Conditions 59 F (15 C), 60% Relative Humidity

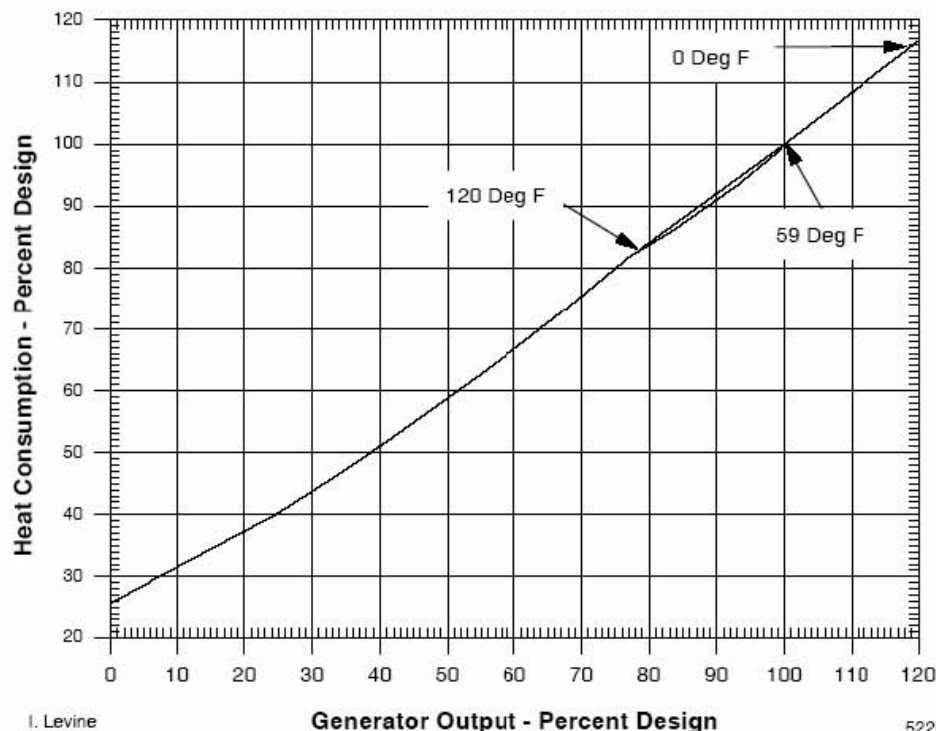
Atmospheric Pressure 14.7 psia (1.013 bar)

Fuel:			Natural Gas	Distillate
Design Output	kW		84360	82890
Design Heat Rate (LHV)	Btu/kWh (kJ/kWh)		10480 (11050)	10570 (11150)
Design Heat Cons (LHV)	Btu/h (kJ/h)x10 <sup>6</sup>		884.1 (932.5)	876.1 (924.2)
Design Exhaust Flow	lb/h (kg/h)x10 <sup>3</sup>		2361 (1071)	2368 (1074)
Exhaust Temperature	deg. F (deg. C)		998 (536.7)	999 (537.2)
Load			Base	Base

#### Notes:

- Altitude correction on curve 416HA662 Rev A.
- Ambient temperature correction on curve 522HA283 Rev 2.
- Effect of modulating IGV's on exhaust temperature and flow on curve 522HA284 Rev 2.
- Humidity effects on curve 498HA697 Rev. B - all performance calculated with a constant specific humidity of .0064 or less as not to exceed 100% relative humidity.
- Plant Performance is measured at the generator terminals and includes allowances for the effects of inlet bleed heating, excitation power, shaft driven auxiliaries, and 3.5 in H<sub>2</sub>O (7.29 mbar) inlet and 5.5 in H<sub>2</sub>O (13.70 mbar) exhaust pressure drops and a DLN Combustor.
- Additional inlet and exhaust pressure loss effects:

	% Effect on		Effect on	
	Output	Heat Rate	Exhaust Temp.	
4 in Water (10.0 mbar) inlet	-1.40	0.42	1.9F (1.0C)	
4 in Water (10.0 mbar) exhaust	-0.42	0.40	1.8F (1.0C)	



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8/17/98

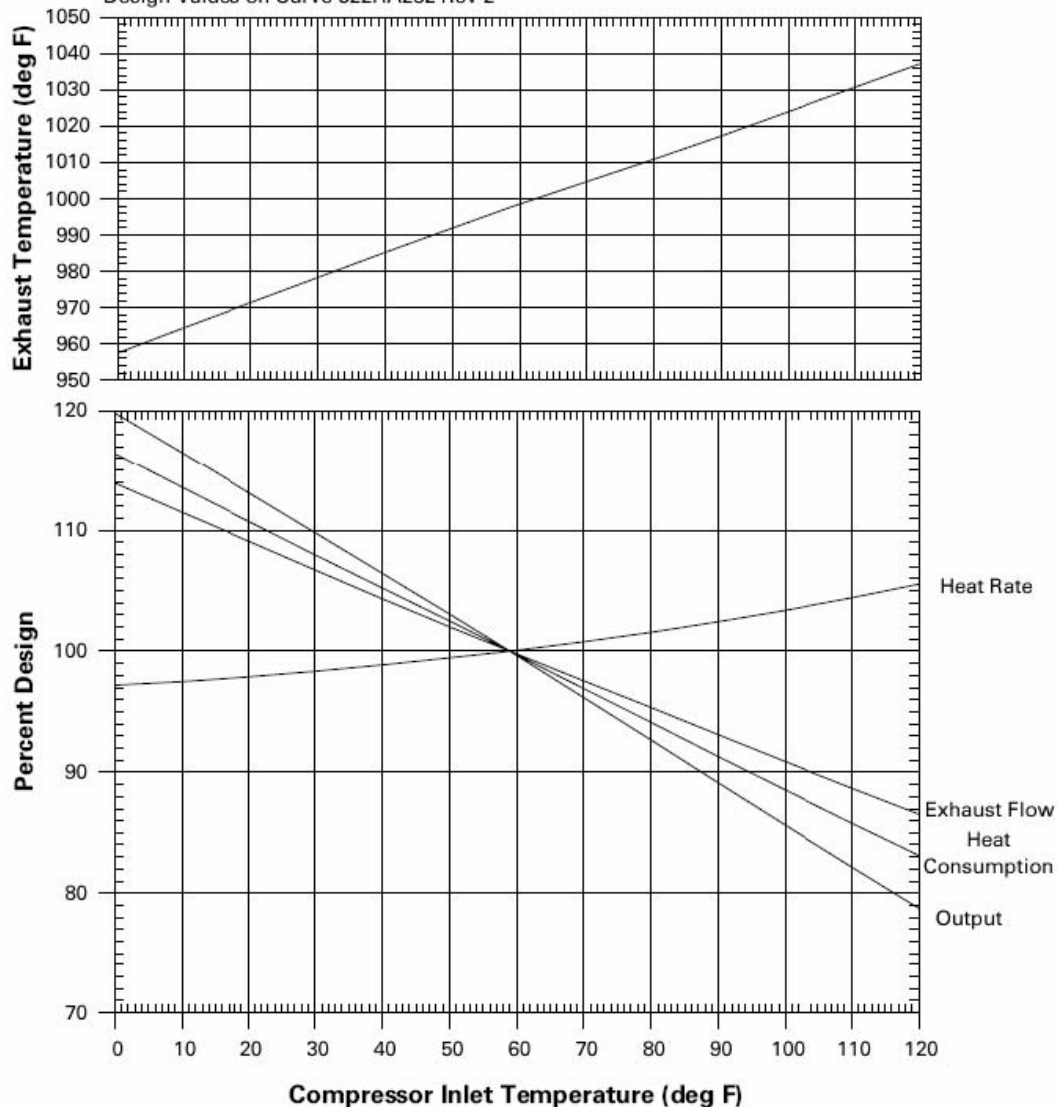
Generator Output - Percent Design

522HA282  
Rev - 2

## GENERAL ELECTRIC MODEL PG7121EA GAS TURBINE

**Effect of Compressor Inlet Temperature on  
Output, Heat Rate, Heat Consumption, Exhaust Flow  
And Exhaust Temperature at Base Load and 100% speed.**

Configuration: DLN Combustor  
Fuel: Natural Gas  
Design Values on Curve 522HA282 Rev 2



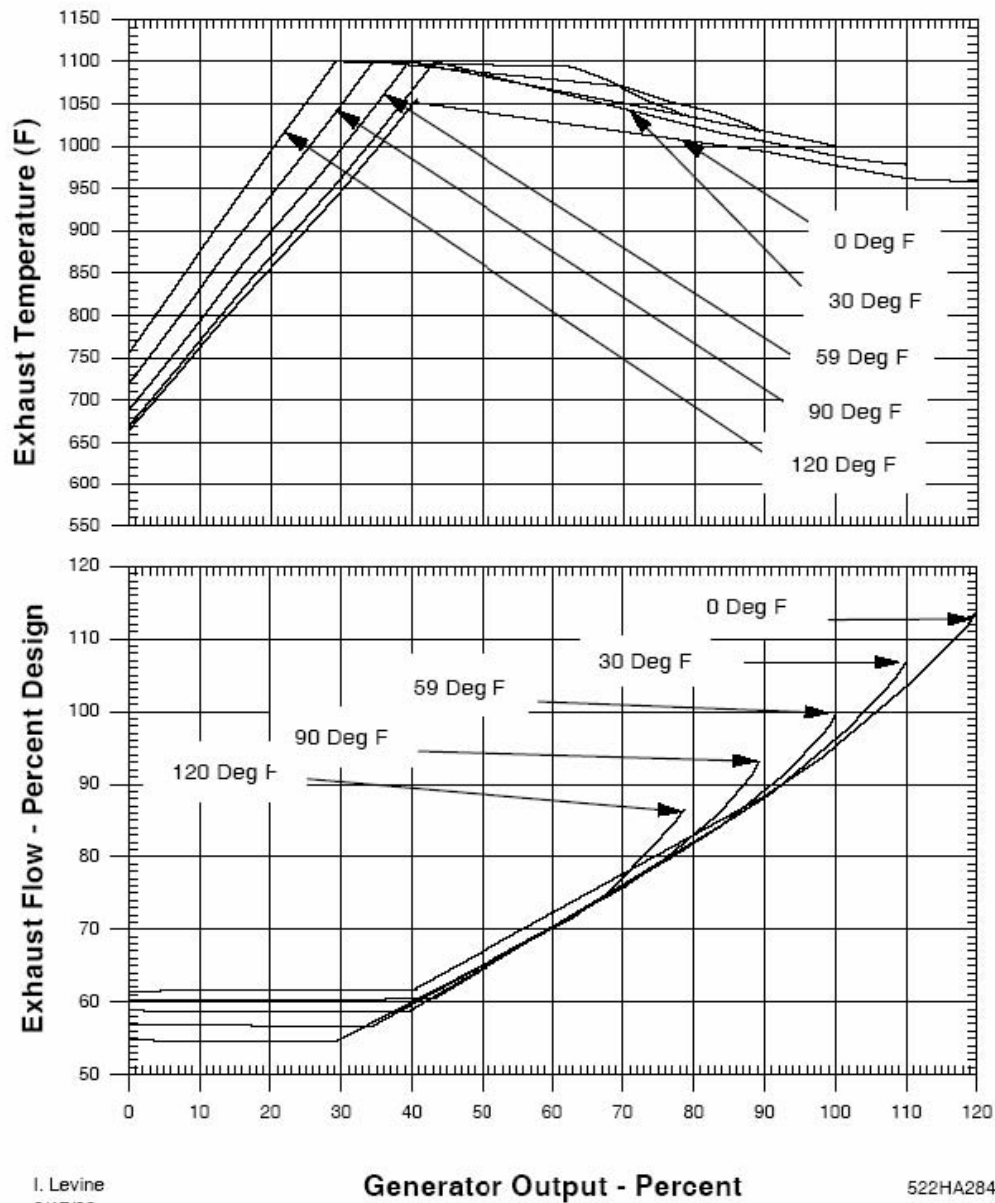
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522HA283  
Rev - 2

## GENERAL ELECTRIC MODEL PG7121EA GAS TURBINE

### Effect of Inlet Guide Vane on Exhaust Flow and Temperature As a Function of Output and Compressor Inlet Temperature

Fuel: Natural Gas  
Design Values on Curve 522HA282 Rev 2



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Generator Output - Percent

522HA284  
Rev - 2





