

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply



1. Introduction

1.1 General

The GE MS9001E was introduced in 1970 to meet the growing need for 50 Hz gas turbine industrial and utility units with capability to burn a broad spectrum of fuels. It was the world's first gas turbine larger than 100MW.

The MS9001E has been updated and improved using information accumulated from thousands of operating hours across the product line.

The MS9001E is renowned for its extensive experience, reliability record and state-of-the-art fuel handling capabilities, making it well suited to:

- Power generation (simple cycle or combined cycle)
- Cogeneration (process steam or district heating)
- Base load, peak load, standby power

The MS9001E gas turbine is GE's 50 Hz workhorse, proven in more than 3 million hours of utility and industrial service, many in arduous climates ranging from desert heat to tropical humidity to arctic cold.

1.2 Prepackaged for Rapid Installation

The packaged power plant concept is derived from cumulative experience with thousands of successful GE gas turbine installations. This experience has led the way to installation and startup that is both rapid and cost-effective.

The MS9001E features a unique accessory packaging concept with an improved "split base" design. The gas turbine and accessory compartments contain the turbo machinery as well as the mechanical and electrical support equipment for starting, operation and shutdown.

With the packaging concept, the majority of the supporting equipment is skid-mounted and the locations standardized. This design maximizes factory piping and wiring, requiring less assembly work in the field. Incorporating field experience in the design provides easier access to accessory components during operation and maintenance.

1.3 Availability / Reliability

GE heavy-duty gas turbines lead the industry in reliability and availability statistics. One key factor in the unmatched reliability of GE's gas turbines is the redundancy built into GE's state-of-the-art gas turbine control system. Because this microprocessor-based turbine control system employs a distributed processor and a redundant architecture, its overall performance is unmatched in the industry. The control system uses independent digital controllers to achieve the reliability of triple redundancy for the turbine control and protective functions.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply



1.4 Reduced Maintenance Costs

When assessing improvements to gas turbine equipment, GE maintains a strict adherence to key design parameters affecting maintenance. The advantage of analysis and feedback from the largest fleet of gas turbines enables GE to develop design improvements and better maintenance procedures.

To keep customers informed of such new technology, GE conducts Gas Turbine User and Maintenance Seminars and issues technical publications to GE customers. The operating data from the vast fleet of gas turbines in service, coupled with an evolutionary design philosophy, enables GE to keep customers abreast of the latest advances and know-how in servicing and supporting their units.

1.5 Service and Plant Support

GE provides full-time support of the largest localized service network in the world. GE service is full scope, extending from unit order through unit retirement. GE field engineers are available to assist with installation and start-up and also with planned and emergency maintenance, with capabilities to perform diagnostics, performance assessment, craft labor coordination, repairs, overhauls, and upgrades.

Backing up these field service engineers is a network of GE service centers located around the globe. Whether for routine maintenance or emergency repairs, spare parts are available from warehouses and manufacturing centers all over the world.

2. General Plant Description

Characteristic	Specification
Atmospheric pressure	1,012 mbar
Design ambient temperature	50 °C
Minimum ambient temperature	-6 °C
Maximum ambient temperature	55 °C
Design relative humidity	30 %
Minimum relative humidity	5 %
Maximum relative humidity	95 %
Basic Wind speed	114km/h
Wind applicable Code	UBC97
Wind exposure	C
Wind importance factor	1.15
Salt classification	none
Other contaminants	none
Dust level	none
Snow load	none

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Seismic Code	U8C97
Seismic importance factor	1.5
Customer specified horizontal acceleration	0.2 g
Grid code	No specific requirement for the generator

Note: Refer to the Design Criteria/Assumptions Tab for additional plant design information



2.1 Equipment Overview

2.1.1 Gas Turbine

Feature	Specification
Frame Size	PG9171
Fuel System	Dual Fuel (Natural Gas + Light Diesel Oil, Standard Burner)
Starting Means	Electrical Motor
Air Filtration	Self Cleaning
Compressor / Turbine Cleaning	ON- and OFF-line compressor water wash and off-line turbine washing
Exhaust System	Side right
Fire Protection	High Pressure CO ₂

2.1.2 Generator

Feature	Specification
Model	Models GE 9A5 or Brush BDAX9. Please refer to chapter
Frequency	50 Hz
Power factor (pf)	0.85 Lagging
Power factor (pf)	Capability to 0.95 Leading
Terminal Voltage	15.0 kV
Acoustical Treatment	Standard On-Base package

2.1.3 Control System

Feature	Specification
Gas Turbine	Speedtronic Mark VIe (TMR)
Generator	Control, excitation, regulation and protection panel
Operator interface	Local <HMI>, Remote <HMI>

3. Performance Data

3.1 Guaranteed Performance

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- Liquidated damages, if any, would only be paid on the worst of the two guaranteed conditions. If at the time of the test, water is not available according to the need the only guaranteed condition is evaporative cooler off.

Operating Point	Evaporative cooler status	Fuel	Net output at generator terminals (kW)	Net Heat Rate at generator terminals kJ/kWh)	Gas Turbine Model
Base load	Present & ON	Distillate with water injection			PG9171E
Base load	Present & OFF	Distillate with water injection			PG9171E

Net Heat Rate = Fuel Consumption (LHV) / Net Output (kW)

3.1.1 Basis for Unit Performance

The performance guarantees listed above are given at the generator terminals and based on the scope of equipment supply as defined in the proposal and as stated for the following operating conditions and parameters:

<u>Measurement</u>	<u>Value</u>
Atmospheric pressure mbar	
Ambient temperature °C	
Relative humidity %	
Inlet system pressure drop H ₂ O mm	75
Outlet static pressure @ ISO condition H ₂ O mm	90
Fuel heating value (LHV) kJ/kg	41,800
Fuel Temperature °C	40
Fuel Pressure at inlet flange of GT bar(g)	Refer to tab09
Combustion system type	Conventional
Grid frequency	50 Hz
Power factor	0.85
Water injection (kg/h) for NO _x reduction with evaporative cooler ON	
Water injection (kg/h) for NO _x reduction with evaporative cooler OFF	

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- A. The natural gas fuel is in compliance with Seller's Gas Fuel Specification GEI-41040 last revision and with the design basis of this proposal.
- B. The liquid fuel is in compliance with Seller's Liquid Fuel Specification GEI-41047 last revision and with the design basis of this proposal.
- C. Gas turbine is operating at steady state base load.
- D. Tests to demonstrate guaranteed performance shall be conducted in accordance with the ASME Modified Performance Test Procedure as defined in Seller's GEK-107551.
- E. Performance is measured at the generator terminals and includes allowances for excitation power and the shaft-driven equipment and the normally operating equipment supplied herein by GE.
- F. The equipment is in a new and clean condition (less than 200 fired hours of operation).
- G. Final performance curves such as ambient effects curves and generator loss curves will be provided after contract award. These curves along with correction factors such as fuel property corrections are to be used during the site performance test to correct performance readings back to the site conditions at which the performance guarantees were provided.
- H. Compressor air extraction from gas turbine = 0.

3.1.1.1 Aux. Power Consumer List

Electrical Auxiliary's Consumption is calculated at guarantee point ambient temperature.

In the list of installed Electrical Auxiliaries present below, only equipment with a Y on the column "Present at guarantee point Yes=Y No=N" are considered as operating at guarantee condition.

Guarantee Point	Base Load Evaporative cooler ON	Base Load Evaporative cooler OFF
<u>Water Cooler</u>		
Auxiliary cooling water pump motor (GT + Gen)	Y	Y
Off base fin fan coolers (GT + Gen)	Y	Y
<u>APU</u>		
APU bleed extractor	N	N
APU compressor motor	N	N
Clim / Heater	Y	Y
<u>Sump Tank</u>		
Waste transfer pump motor	N	N
Heater	N	N
<u>Distillate Fuel</u>		

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5 of 144



Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Distillate fuel forwarding pump motor	Y	Y
<u>Fire fighting C02 high pressure</u>		
Container heater	N	N
Container climatisation	Y	Y
<u>Washing Skid</u>		
Washing Skid	N	N
<u>Turbine Control Equipment</u>		
MCC subdistribution	Y	Y
Battery charger	Y	Y
TCC air conditioning	Y	Y
Excitation transformer	Y	Y
<u>Generator</u>		
Bearing lift oil pump motor	N	N
Space heater generator compartment	N	N
AC ventilation motor fans redundant set	Y	Y
<u>Electrical Starting Means</u>		
Electrical starting motor	N	N
<u>Gas Turbine Auxiliaries</u>		
Emergency lube oil pump	N	N
Turning gear motor	N	N
Torque adjuster drive motor	N	N
Auxiliary lube oil motor	N	N
Immersion heater lube oil tank	N	N
Turbine exhaust frame cooling fan motor	Y	Y
Auxiliary hydraulic supply pump motor	N	N
Lube oil mist separator fan motor 2x100%	Y	Y
Atomizing air booster motor	N	N
Liquid fuel flow divider starting motor	N	N
<u>GT-G Enclosures</u>		
Accessory compartment space heater	N	N
Turbine compartment space heater	N	N
Turbine compartment cooling air fan motor	Y	Y
Load coupling compart. ventilation fan motor	Y	Y
Exhaust lagging cooling air fan motor	Y	Y
<u>Gas Enclosures</u>		
Gas valve compart. ventilation fan motor	Y	Y
Gas compartment space heater	N	N
Gas compartment air inlet heater	N	N
<u>Liquid Fuel Oil</u>		
Dosing pump motor	Y	Y
Dosing pump motor	Y	Y
Unloading inhibitor pump motor	N	N
<u>Self Cleaning Filter</u>		
400V AC	Y	Y
230V AC	Y	Y
230V UPS	Y	Y
Evaporate cooler water pump motor	Y	N



Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

<u>Injection for DeNOx</u>		
NOx reduction water injection pump – 1x100% normal flow	Y	Y
Air atomization (AA) & water injection (WI) compartment cooling air fan motor / water inject pump motor / 2x50%	Y	Y
Water injection compartment inlet heater	N	N
Water injection compartment space heater	N	N

3.2 Emissions Guarantees

Emissions levels below are subject to sufficient water availability.

NOx exhaust gas emissions shall not exceed the following concentrations during steady-state operation from base load down to 30% load over the ambient temperature range from – 6 °C to 55 °C.

Pollutant	Gas Fuel with water injection	Liquid Fuel with water injection
NOx, ppmvd @ 15% O ₂		

3.2.1 Basis for Emissions Guarantees

- A. The customer gas fuel is in compliance with Seller's Gas Fuel Specification GEI-410401 and with the design basis of this proposal.
- B. The customer liquid fuel is in compliance with Seller's liquid Fuel Specification GEI.41047H and with the design basis of this proposal.
- C. Testing and system adjustments are conducted in accordance with Sellers GEK-28172F, Standard Field Testing Procedure for Emissions Compliance.
- D. Atmospheric pressure = 1,012 mbar.
- E. Emissions are per gas turbine on a one hour average basis.
- F. Fuel bound nitrogen =0.015%.
- G. Fuel ash content =0%.
- H. Sulfur emissions are a function of the sulfur present in the incoming air and fuel flows. Since the gas turbine(s) have no influence on the sulfur emissions, Sulfur emissions are not guaranteed.
- I. GE reserves the right to determine the emission rates on a net basis wherein emissions at the gas turbine inlet are subtracted from the measured exhaust emission rate if required to demonstrate guarantee rate.
- J. Gas turbine is operating with a steady state frequency.

3.3 Noise Guarantees **CONFIDENTIAL!!!**

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

3.3.1 Near Field Noise Guarantees

Fuel	Gas Turbine Load	SPL, dB(A)
Natural gas	Base	85
Distillate Oil	Base	85

The sound pressure levels (SPL) (re: 20 micropascals) from the outdoor supplier equipment defined in this proposal, shown in the Drawing / Diagrams Section of this proposal, shall not exceed the value stated above, when measured 1m (3 ft) in the horizontal plane and at an elevation of 1.5 m (5 ft) above the gas turbine operating level, steam turbine operating level (if different), and generator operating level (if different) identified on the General Arrangement drawings with the equipment operating at base load in accordance with contract specifications. Walkways and / or platforms that are not easily accessible by stairs are excluded from the above guarantee.

Near field guarantees apply to areas along a Site specific Source Envelope(s), determined by a line established 1 meter (3 ft.) from the outermost surface of the equipment defined in the proposal scope of supply (including noise abatement equipment). Depending on the site arrangement and relationship of equipment locations, multiple source envelopes may be designated. (See sample 3.4.1 attached)

3.3.1.1 Basis for Near Field Noise Guarantee

- A. The GE supplied equipment will be deemed compliant with the acoustic guarantee if results from measurements taken at agreed upon locations along the source envelope(s), after background and other corrections for environmental influences and test factors have been applied do not exceed the noise limit(s) specified above. For cases where noise abatement equipment is included to meet the guaranteed sound pressure level, all measurements for compliance verification will be taken outside of the noise abatement equipment
- B. Testing will be conducted in accordance with a project specific test plan agreed to by both the Owner and GE. The test plan must adhere to the requirements listed in the standard ISO 3746 "Acoustics - Determination of sound power levels of noise sources using pressure - Comparison method *in situ*".
- C. Equipment is operated in a new and clean condition when measurements are taken. All access compartments, doors, panels and other temporary openings are fully closed, all silencing hardware is fully installed and all systems designed to be airtight are sealed. Inspection of Installation Quality will be conducted prior to compliance testing. Identified defects must be corrected prior to Compliance Testing.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- D. Corrections for background noise will be made to the measured SPL, as referenced in the standard ISO 3746 "Acoustics - Determination of sound power levels of noise sources using pressure - Comparison method *in situ*". Background noise is defined as the noise measured with all equipment identified in the proposal scope of supply not operating and all other plant equipment in operation. If the above guaranteed SPL is greater than 10 dBA above the measured background noise, no correction to the measured SPL is necessary.
- E. Free field conditions must exist at measurement locations. Testing for and corrections to a free field are per the applicable standard ISO 3746 "Acoustics - Determination of sound power levels of noise sources using pressure - Comparison method *in situ*".
- F. Noises of an interim nature such as steam blow down valves, filter pulse noise, and startup / shutdown / steam turbine bypass activities are not included in the above guarantee.
- G. Measurements shall be taken 1 m (3 ft) away from the outermost exterior surfaces of equipment including piping, conduit, framework, barriers, noise abatement equipment and personnel protection devices if provided.
- H. Measurements shall not be taken in any location where there is an airflow velocity greater than 1.5 m/s (5 ft/s) including nearby air intakes or exhausts. Outdoor measurements shall not be taken when wind speeds exceed 1.5 m/s (3 mi/hr).
- I. Responsibility for measurement and development of the project specific test plan will be stated in the Contract. Testing shall be conducted in accordance with the standard ISO 3746 Acoustics - Determination of sound power levels of noise sources using pressure - Comparison method *in situ*". The test plan must be submitted minimum of 30 days prior to the noise test for review and approval of all parties. If the Owner performs the compliance measurements, GE reserves the right to audit or parallel these measurements.

3.4 Gas Turbine Estimated Performances

3.4.1 Estimated Performance in Base Load Operation, Liquid Fuel

PG9171

Load Condition		BASE	BASE	BASE
Exhaust Static Pressure	mm H2010	6.7	75.6	72.4
Ambient Temperature	deg C	-5.	50.	55.
Evap. Cooler Status		Off	On	On
Evap. Cooler Effectiveness		CONFIDENTIAL!!!	85	85
Fuel Type		Liquid	Liquid	Liquid

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Fuel LHV	kJ/kg	41800	41800	41800
Fuel Temperature	deg C	40	40	40
Liquid Fuel H/C Ratio		1.64	1.64	1.64
Gross Output	kW	137 500.	105 100.	101 500.
Gross Heat Rate (LHV)	kJ/kWh	10 770.	11 380.	11 470.
Heat Cons. (LHV)	GJ/hr	1 480.9	1196.0	1164.2
Exhaust Flow	x10 ³ kg/hr	1658.3	1381.2	1350.8
Exhaust Temperature	deg C	500.6	533.3	537.2
Exhaust Mol Wt	kg/kgmol	28.79	28.40	28.31
Exhaust Energy	GJ/hr	884.7	724.8	710.6
Water Flow	kg/hr	22 639.	12 388.	10 088.

EMISSIONS

NOx	ppmvd @15% O ₂	80.	80.	80.
CO	ppmvd	10.	10.	10.
UHC	ppmvw	7.	7.	7.
Particulates	kg/hr	5.	5.	5.

(PM 10 Front-half filterable only)

EXHAUST ANALYSIS (% VOL)

Argon				
Nitrogen		74.86	72.16	71.54
Oxygen		13.74	13.29	13.17
Carbon Dioxide		4.53	4.34	4.30
Water		5.98	9.36	10.14

SITE CONDITIONS

Site Pressure	bar	1.012
Inlet Loss	mmH ₂ O	75.00
Exhaust Static Pressure	mmH ₂ O	<u>90.00@ISO</u> Conditions
Relative Humidity	%	30
Application		TEWAC Generator
Power Factor (lag)		0.85
Combustion System		Non-DLN Combustor

Emission information based on GE recommended measurement methods. NOx emissions are corrected to 15% O₂ without heat rate correction and are not corrected to ISO reference condition per 40CFR 60.335(a)(1)(i). NOx levels shown will be controlled by algorithms within the SPEEDTRONIC control system.

Output contingent upon generator water at adequate temperature, pressure, and flow.

Liquid Fuel is assumed to have 0.015% Fuel-bound Nitrogen, or less.

FBN amounts greater than 0.015% will add to the reported NOx value.

(General Electric Proprietary Information)

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3.4.2 Estimated Performance in Base Load Operation, Gas Fuel

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

PG9171

Load Condition		BASE	BASE	BASE
Exhaust static pressure	m H2O	06.2	75.4	72.3
Ambient Temperature	deg C	-5.	50.	55.
Evap. Cooler Status		Off	On	On
Evap. Cooler Effectiveness	%		85	85
Fuel Type		Cust Gas	Cust Gas	Cust Gas
Fuel LHV	k.J/kg	46 670	46 670	46 670
Fuel Temperature	deg C	42	42	42
GrossOutput	kW	140 500.	108 200.	104 600.
Gross Heat Rate (LHV)	k.J/kWh		10 680.	11 290.
		380.		11
Heat Cons. (LHV)	GJ/hr	1 500.5	1 221.6	1190.3
Exhaust Flow x10 ³	kg/hr	1654.7	1380.3	1349.9
Exhaust Temperature	deg C	499.4	532.4	536.1
Exhaust Energy	GJ/hr	893.8	733,2	718.9
Water Flow	kg/hr	22453.	13 989.	11816.

FUEL COMPOSITION

CH4 - Methane	%vol	85.00	85.00	85.00
H2 - Hydrogen	%vol	0.10	0.10	0.10
C2H6 - Ethane	%vol	11.00	11.00	11.00
C3H8 - Propane	%vol	1.00	1.00	1.00
C4H10 -n-Butane	%vol	0.30	0.30	0.30
N2 - Nitrogen	%vol	0.50	0.50	0.50
CO2. Carbon Dioxide	%vol	2.00	2.00	2.00
H2S - Hydrogen Sulfide	%vol	0.10	0.10	0.10

EMISSIONS

NOx	ppmvd @ 15% O ₂	50.	50.	50.
CO	ppmvd	10.	10.	10.
UHC	ppmvw	7.	7.	7.
Particulates	kg/hr	2.	2.	2.
	(PM 10 Front-half Filterable Only)			

EXHAUST ANALYSIS (% VOL)

Argon		0.89	0.86	0.85
Nitrogen		73.88	71.10	70.48
Oxygen		13.43	12.92	12.80
Carbon Dioxide		3.38	3.25	3.23
Water		8.43	11.88	12.64

SITE CONDITIONS

Site Pressure	bar	1.012		
Inlet Loss	mm H ₂ O		75.00	
Exhaust static pressure	mm H ₂ O		90.00 @ ISO Conditions	

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Relative Humidity	%	30
Application		TEWAC Generator
Power Factor (lag)		0.85
Combustion System		Non-DLN Combustor

Emission information based on GE recommended measurement methods. NO_x emissions are corrected to 15% O₂ without heat rate correction and are not corrected to ISO reference condition per 40CFR 60.335(a)(1)(i). NO_x levels shown will be controlled by algorithms within the SPEEDTRONIC control system.

Output contingent upon generator water at adequate temperature, pressure, and flow.

(General Electric Proprietary information)

3.5 Generator Estimated Performance Specifications

For GE 9A5 generator, please refer to chapter 07a_9A5 Generator description.

For Brush BDAX9 generator, please refer to chapter 07d_BDAX Generator Data Sheet.

4. Performance Curves and Estimated Generator Data

4.1 Gas Turbine Performance Curves

Following correction curves are preliminary typical curves submitted in the proposal phase for information only.

Final curves applicable to the project that will apply for performance tests, will be submitted during the Contract implementation phase.

Curve	Number	Date
Estimated Single Unit Performance, Base with Natural Gas	533H1005-1 Rev.1	03/06/04
Compressor Inlet Temperature Corrections, Base with Natural Gas	533H1005-2 Rev.1	03/06/04
Modulated Inlet Guide Vanes Effect, Base with Natural Gas	533H1005-3 Rev.1	03/06/04
Estimated Single Unit Performance, Base with Distillate	533H1005-1 Rev.1	03/06/04
Compressor Inlet Temperature Corrections, Base with Distillate	533H1005-2 Rev.1	03/06/04
Modulated Inlet Guide Vanes Effect, Base with Distillate	533H1005-3 Rev.1	03/06/04
Frequency affects curves, standard comp	9171-A-1615 to 9171-A-1619	04/11/06

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12 of 144

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Degradation Curves for Heavy Duty Product Line Gas Turbines	519HA772 & 744 Rev. A	09/02/95
Altitude Correction for Turbine	416HA662 Rev. B	06/30/99
Humidity Effects Curve	416HA697 Rev. B	10/10/99

4.2 TEWAC Generator Performance Curves

For 9A5 GE generators, please refer to chapter 07b_9AS Generator curves 700139g.

For Brush BDAX9 generators, please refer to chapter 07e_BDAX9_Gen_curves.

4.3 Degradation Curves for Heavy Duty Product Line Gas Turbines

Gas turbine performance loss during extended operational periods is largely due to compressor fouling. The rates of both compressor fouling and performance loss are a result of the variation in environmental conditions, fuel used, machine operating scenario and maintenance practices.

Performance loss during normal operation is minimized by periodic on-line and off-line compressor water washes. Performance loss during extended operation is expected to be greater for plants that are located in humid and/or contaminated industrial environments. Also, plants operated under non-ideal running scenarios, along with neglected or poorly performed maintenance practices can be expected to exhibit increased performance losses. Plants that are sited in relatively clean less humid environments, operated within equipment design recommendations and cleaned with regular on and off-line compressor washes will experience less performance degradation.

Performance recovery, beyond that which occurs with normal maintenance, including on and off-line washes, can be achieved following other off-line procedures. One procedure in particular involves removing both the compressor and turbine casing to accommodate hand scouring of the compressor rotor and stator airfoils. Compressor inlet air filter cleaning/replacement, along with other required maintenance, may also be performed during these inspections. Such an outage would most likely coincide with hot gas path or major inspection intervals, since significant machine disassembly is required.

A typical gas turbine operation profile, reflecting on- and off-line maintenance procedures, is presented in the attached figures. Plant performance degradation during normal operation is cyclic as impacted by on- and off-line compressor water washes. Drawing 519HA772 represents expected performance loss, in accordance with the stated basis for operation, maintenance and testing procedures. Note that this curve represents the locus of points following specific on-line maintenance activities, not actual continuous on-line operating capability. Drawing 519HA744 represents a

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

comparable locus of data following the more extreme machine disassembly and hand scouring procedure.

EXPECTED GAS TURBINE PLANT PERFORMANCE LOSS FOLLOWING NORMAL

MAINTENANCE AND OFF-LINE COMPRESSOR WATER WASH

The aging performance effects represented by these curves are based on the following:

- Performance is relative to the guarantee level.
- All GT plant equipment shall be operated and maintained in accordance with GE's recommended procedures for operation, preventive maintenance, inspection and both on-line and off-line cleaning.
- All operations shall be within the design conditions specified in the relevant technical specifications.
- A detailed operational log shall be maintained for all relevant operational data to be agreed to amongst the parties prior to commencement of Contract.
- GE technical personnel shall have access to plant operational data, logs, and Site visits prior to conducting a performance test. The Owner will clean and maintain the equipment. The degree of cleaning and maintenance will be determined based on the operating history of each unit, atmospheric conditions experienced during the period of operation, the preventive and scheduled maintenance programs executed and the results of the GE inspection.
- The GT will be shut down for inspection and off-line compressor water wash as a minimum, immediately prior to performance testing to determine performance loss. The GT performance test shall occur within 100 fired hours of these actions.
- Demonstration of GT plant performance shall be in accordance with test procedures which are mutually agreed upon..

(Drawing 519HA744)

**EXPECTED GAS TURBINE PLANT NON-RECOVERABLE
PERFORMANCE LOSS DURING EXTENDED PERIOD OPERATION**

The aging performance effects represented by these curves are based on the following:

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- Performance is relative to the guarantee level.
- All GT plant equipment shall be operated and maintained in accordance with GE's recommended procedures for operation, preventive maintenance, inspection and both on-line and off-line cleaning.
- All operations shall be within the design conditions specified in the relevant technical specifications.
- A detailed operational log shall be maintained for all relevant operational data to be agreed to amongst the parties prior to commencement of Contract.
- GE technical personnel shall have access to plant operational data, logs, and Site visits prior to conducting a performance test. The Owner will clean and maintain the equipment. The degree of cleaning and maintenance will be determined based on the operating history of each unit, atmospheric conditions experienced during the period of operation, the preventive and scheduled maintenance programs executed and the results of the GE inspection.
- The GT will be shut down for inspection and off-line compressor water wash as a minimum, immediately prior to performance testing to determine performance loss. The GT performance test shall occur within 100 fired hours of these actions.

Demonstration of GT plant performance shall be in accordance with test procedures which are mutually agreed upon.

(Drawing 519HA772)

5. Plant Operating Philosophy

5.1 Introduction

This section describes the startup, on-line operation and shutdown of a gas turbine unit.

The following paragraphs briefly describe the general operating philosophy and operator's responsibilities for gas turbine unit operation. The description is of a general nature. Specifics may vary pending detail design definition.

5.1.1 Gas Turbine Unit Mode of Operation

The gas turbine unit can be started from the control panel of the gas turbine control system. Plant permissive circuits must be satisfied that the unit is capable of coming to full speed and synchronizing to the system. Systems must be placed in the ready to start mode:

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- MCC breakers set in automatic mode.
- Cooling water module local disconnect switches closed.
- Fuel systems mode ready.
- Gas turbine/generator permissive to start systems ready.

5.1.2 Starting and Loading

All starting is done automatically, with the operator given the opportunity to hold the startup sequence at either the crank (pre-ignition) or fire (post-ignition, pre-accelerate) points of the startup. An Auto mode selection results in a start without any holds.

Either before issuing a start command, or during the start, the operator may make the following selections:

- Select or disable the automatic synchronization capability of the gas turbine control system. Auto synch utilizes the proven micro-synchronizer first introduced in the SPEEDTRONIC™ controller. The micro-synchronizer provides extremely accurate and repeatable breaker closures based on phase angle, slip, slip rate of change and the response time of the breaker which is stored in the system memory.
- Selection of Pre-selected (Intermediate) Load or Base Load. If a selection is made, the unit will automatically load to the selected point and control there. If no selection is made, the unit will load to a low load referred to as Spinning Reserve after synchronization. The turbine governor is automatically regulated to maintain the megawatt setting assigned to Spinning Reserve.

5.1.3 Operating

Once the unit is on line, it may be controlled either manually or automatically from the Gas turbine control system operator interface.

Manual control is provided by the governor raise / lower control displayed on the operator interface screen. Automatic operation is switched on when the operator selects load points (pre-select or base) from the turbine control interface.

For a fully automatic start with automatic loading to Base load, the operator selects the "Auto" operating mode, enables auto synchronization and selects "Base" load. Given a "Start" signal, the unit will then start, synchronize and load to Base load with no further input on the part of the operator.

5.1.4 Shutdown

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On shutdown, the system will automatically unload, coast down and initiate slow speed rotation until proper wheel space cool down temperatures are reached.

6. Scope, Limits and Exclusion of Supply

6.1 Gas Turbine Generator Unit, each including:

6.1.1 The Gas Turbine Package, consisting of:

6.1.1.1 The Gas Turbine Compartment:

- Multi-stages, axial flow compressor.
- Modulated inlet guide vanes.
- Three-stages turbine.
- Multi-chambers combustion system.
- Dual gas / liquid combustion system with conventional combustors.
- Ignition system with spark plugs and U.V. flame detectors.
- Boroscope openings for maintenance inspection.
- Seismic type vibration sensors on bearing caps for protection.
- Proximity type sensors for shaft line displacement monitoring.
- Thermocouples for measuring exhaust temperature.
- Thermocouples on bearing drains.
- Thermocouples on bearing metal.
- Exhaust plenums.
- Exhaust frame blowers.
- On/off line compressor and off line turbine wet washing system.
- Water injection system for NOx control.

6.1.1.2 The Auxiliary Systems and Separate Skids:

- Starting and cool down system with:
 - MV starting AC motor (11 kV).
 - Hydraulic torque converter.
 - Rotor turning device by AC Pony motor.
- Auxiliary coupling and gear
 - Flexible auxiliary coupling.
 - Auxiliary gear box.
- Lubricating oil system with **CONFIDENTIAL!!!**
 - Duplex lube oil filters.

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- Duplex lube oil to water heat exchangers.
- ASME code without stamp U for lube oil cooler and lube oil filter.
- Shaft driven main lube oil pump.
- Full flow AC motor-driven auxiliary lube oil pump.
- One (1) partial flow 125V DC motor driven emergency lube oil pump.
- Lube oil tank.
- Lube oil mist eliminator with dual extraction fans.
- Lube oil heater.
- Hydraulic oil system with:
 - Shaft driven hydraulic oil pump.
 - Full flow AC motor driven auxiliary hydraulic oil pump.
 - Duplex hydraulic oil filters.
- Gas fuel system with (separate module):
 - Hitch hat.
 - Gas fuel stop and control valves.
- Liquid fuel system with:
 - One (1 x 100%) high pressure fuel pump.
 - Duplex high pressure fuel filters.
 - Flow divider.
- Atomizing air system with:
 - One (1 x 100%) atomizing air cooler.
 - One (1 x 100%) atomizing air compressor.
- Water Injection for NOx level reduction with:
 - One (1 x 100%) AC motor driven pump.
 - Single filter.
 - Flow metering system.
 - Flow control valve.

6.1.1.3 Couplings:

- Gas turbine load coupling for generator.

6.1.1.4 Gas Turbine Packaging:

- Lagging and enclosures.

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- Enlarged acoustical enclosure around gas turbine and accessory compartments.
- Off-base enclosure for gas fuel module with dual vent fans.
- Compartment ventilation and heating.
- Dual vent fans (2 x 100%).
- Simple heating system (1 x 100%).
- Gas detection system:
 - Turbine compartment.
 - Accessory compartment.
 - Gas fuel compartment
- Fire detection and protection system with:
 - Thermal detectors.
 - UV detectors.

6.1.1.5 Hazardous Area Classification

- GE'S equipment (e.g. air intake, gas turbine enclosures, etc.) must be installed outside any Site Hazardous Area Classification (HAC). For equipment part of GE's scope of supply, a Hazardous Area drawing will be provided.
- Based on latest revision of GEI4104b and GEI41047.
- Classification of Hazardous area is based on IEC 60079-10 & API 505 standards:
 - Gas Turbine Compartment classified zone 2 group IIA T3.
 - Gas Module classified zone 2 group II A T1.

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6.1.2 Elin Generator Type 9A5

Characteristics:

Generator type	9A5
Electrical Design Number	700 139G
Apparent Power	155,000 kVA
Power Factor Leading	0.95
Power Factor Lagging	0.85
Active Power	131,750 kW
Nominal Speed	3,000 rpm
Rated Voltage	15,000 Volts
Line Current	5966 Amps
Cooling System	TEWAC Air/Water
Short Circuit Ratio	0.50
Site Altitude	55 ft
Rated Cold Gas Temperature	40 °C
Exciter Design (Amps / kW / Voltage)	1013 A / 380 kW / 375 V
Exciter (IGNL / IFNL / IFFL)	302 /331 / 898
Rating (i.e., ANSI / IEC)	IEC
Temperature Rise Class	B
Coolant (Type / Fouling Factor/ Flow)	Water / 0.0010 / 700 GPM
Guaranteed 12 SQ.T (s)	8
TIF (L-L /L-N/ Residual)	0.10/00.1/0.001
Field Resistance @ 25 °C	0.2506
Armature Resistance @ 25 °C	0.00 1392
No-Load Saturation Factor (S1.0 /I S1.2)	0.0978 / 0.7516
Efficiency	98.50%
Direct Axis Reactances (PU, rounded)	
Synchronous (XD)	1.94
Transient Sat (X'DV)	.0195
Transient Unsat (X'DI)	0.215
Subtransient Sat (X"DV)	0.125
Subtransient Unsat (X"DI)	0.160
Negative Sequence Sat (X2V)	0.123
Negative Sequence Unsat (X2I)	0.159
Zero Sequence Sat (X0V)	0.088
Zero Sequence Unsat (X0I)	0.088
Armature Leakage Sat (XLV)	0.109
Armature Leakage Unsat (XLI)	0.117
Quatrature Axis Reactance (PU, rounded)	
Synchronous (XQ)	1.84
Transient (X'Q)	0.39
Subtransient Sat (X"QV)	0.12
Subtransient Unsat (X"QI)	0.16
Hipots	
Armature / Field (Volts)	31000 / 3118
Resistance (Per Units)	
Armature (DC) (RA)	0.001236
Positive Sequence (R1)	0.0031
Negative Sequence (R2)	0.0113
Zero Sequence (R0)	0.0058
Time Constant (Seconds) CONFIDENTIAL!!!	
Direct:	

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Transient, Open circuit (T'DO)	10.501
Transient, 3 Phase (T'D3)	0.945
Transient, Line – Line (T'D2)	1.614
Transient, Line – Neutral (T'D1)	0.976
Subtransient (T''DO)	0.049
Subtransient (T''D)	0.031
Armature (TA2 = TA3)	0.370
Armature (TA1)	0.286
Quadrature:	
Transient (T'Q)	0.133
Transient, Open Circuit (T'Q0)	0.632
Subtransient (T''Q)	0.031
Subtransient (T''Q0)	0.097

For GE 9A5 generator scope and description please refer to chapter XX, Generator Type 9A5 description.

6.1.3 Brush BDAX Generator

Characteristics:

1. Rating Details

1.1	Frame size	BDAX 9-450ERH
1.2	Terminal voltage	15.00 kV
1.3	Frequency	50 Hz
1.4	Speed	3,000 rpm
1.5	Power factor	0.800
1.6	Applicable national standard	IEC 60034-3
1.7	Rated coolant inlet temperature	47.0 °C
1.8	Rated output	113.000 MW, 141.250 MVA

2. Performance Curves

2.1	Output vs coolant inlet temperature	H.E.P. 20947
2.2	Reactive capability diagram	H.E.P. 20948
2.3	Efficient vs output	H.E.P. 11765
2.4	Open and Short circuit curves	H.E.P. 11766
2.5	Permitted duration of negative sequence current	H.E.P. 2959

3. Reactances

3.1	Synchronous reactance, X d(i)	182 %
3.2	Saturated transient reactance, X' d (v)	19.0 %
3.3	Saturated sub transient reactance X'' d(v)	13.2 %
3.4	Unsaturated negative sequence reactance, X 2(i)	16.0 %
3.5	Unsaturated zero sequence reactance, X 0(i)	8.0 %
3.6	Synchronous reactance, X q(v)	135 %

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3.7	Saturated transient reactance $X' q(i)$	23.0 %
3.8	Saturated sub transient reactance, $X q(v)$	16.0 %
3.9	Short circuit ratio	0.59
4.	Resistance at 20°C	
4.1	Rotor resistance	0.092 ohms
4.2	Stator resistance per phase	0.0012 ohms
5.	Time Constants at 20°C	
5.1	Transient O.C. time constant, $T' do$	15.5 seconds
5.2	Transient S.C. time constant, $T' d$	1.29 seconds
5.3	Sub transient O.C. time constant $T'' do$	0.05 seconds
5.4	Sub transient S.C. time constant $T'' d$	0.04 seconds
6.	Inertia	
6.1	Moment of inertia, WR ² (see note 2)	3,915 kg.m ²
6.2	Inertia constant, H	1.37 kW. Secs/KVA
7.	Capacitance	
7.1	Capacitance per phase of stator winding to earth	051 Microfarad
8.	Excitation	
8.1	Excitation current at no load, rated voltage	544 amps
8.2	Excitation voltage at no load, rated voltage	50 volts
8.3	Excitation current at rated load and P.F.	1,392 amps
8.4	Excitation voltage at rated load and P.F.	184 volts
8.5	Inherent voltage regulation, F.L. to N.L.	33 %

Notes:

The electrical details provided are calculated values. Unless otherwise stated, all values are subject to tolerances as given in the relevant national standards.

The rotor inertia value may vary slightly with generator/turbine interface. In the even of conflict, the figure quoted on the rotor geometry drawings takes precedence.

For Brush BDAX generator scope and description, please refer to chapter YY, Generator Type BDAX9 description

6.1.2.1 Generator Protection against Sand and Noise

- Acoustical ventilated package.

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- OFF-BASE acoustical enclosure for generator.

6.1.4 The Gas Turbine Generator Control Equipment

The Gas Turbine Generator Control Equipment is located into an air conditioned Turbine Control compartment (TCC) designed for outdoor installation and consisting of:

- SPEEDTRONIC Mark VIe turbine control panel
 - Including proximitor monitoring.
- Local operator interface <HMI> server including desktop computer with 20 LCD color display, Keyboard & mouse.
- Color printer for local <HMI>.
- ETHERNET interface to the plant DCS via <HMI>, TCP/IP-OPC protocol (local).
- Generator control, excitation, regulation and protection panel with:
 - One (1) digital automatic channel and one (1) digital manual channel.
 - One (1) power circuit to feed the exciter field.
- One (1) digital generator protection relay
 - Power system stabilizer (PSS) system software.
 - Modbus interface.
 - Protection settings calculation.
 - Generator gross output meter active and reactive power class 0.2 (could be located in the auxiliary cubicle if lack of space in the generator control panel).
- Unit AC/DC Motor Control Center, withdrawable type.
- Unit AC/DC sub-distribution panel, non- withdrawable.
- 125 VDC lead acid unit battery with two (2x100%) battery chargers.
- One (1) gas detection rack.

6.2 Off-Base Unit Mechanical Auxiliaries

6.2.1 The Inlet Air System, for each Unit, with:

- Up & forward orientation.
- Self cleaning type air filter:
 - With pressure drop transmitter.
 - With evaporative cooler.
- Ducting and inlet silencer.

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- Supporting steel structure.
- Extra painting for corrosive and/or salt environment.

6.2.2 Side Exhaust System, for each Unit, with:

- Expansion joint between the exhaust plenum and the transition piece including low frequency silencer.
- Insulation under exhaust plenum.

6.2.2.1 Vertical Elbow

- Exhaust duct personnel protection around low frequency silencer only.
- 40m exhaust stack of the double sheath type with:
 - Supporting steel structure transition piece liner shell top access.
 - Additional intermediate circular platform.
 - Aluminum cladding.
 - Lighting protection.
- One Continuous Emission Monitoring System (CEMS) per unit

including:

- Analyzers included: NO_x, CO, O₂; SO₂.
- In situ monitoring included: Opacity.
- One common DAHS.
- On site certification by third party not included.
- Sampling line per stack included.
- Sample line support not included.

6.2.3 The Gas Fuel Off-Base System, including for each Unit:

- Duplex coalescing filter, manual drain.
- Automatic drain for duplex coalescing filter.
- Shut off and vent valve skid, gas piloting system stainless steel.
- Gas flow meter.
- One gas chromatograph.

6.2.4 Air Processing Unit

Each gas turbine is supplied by an outdoor air processing unit, located close to the GT and is designed to supply compressed air to the GT's self-cleaning air filter. It includes:

- Air processing unit for extract air from GT compressor & auxil. compressor and adsorption

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- Extra painting for corrosive ambient conditions.
- Air processing unit in container 10 feet.

6.2.5 Liquid Fuel Forwarding System, including for each Unit:

Skids are suitable for installation in hazardous area classified zone.

One (1) liquid fuel forwarding skid with:

- Two (2) full flow AC motor driven forwarding pumps.
- Insulation and electrical heat tracing for pumps forwarding skid if fuel pour point is higher than minimum ambient temperature.
- Extra painting for corrosive ambient conditions.

6.2.6 The Light Liquid Fuel Filtering System, including for each Unit:

Skids are suitable for installation in hazardous area classified zone 1.

One (1) liquid fuel filtering skid with:

- Two (2) filters with synthetic cartridge Beta 17=200.
- One (1) fuel accumulator.
- One (1) volumetric flow meter with by-pass.
- One (1) stop valve.
- Insulation and heat tracing if fuel viscosity is lower than 10 cSt at minimum ambient temperature.
- Temperature regulating system when there is an electrical fuel heater close to filtering skid without its own SCR control panel.
- Extra painting for corrosive ambient conditions.
- Pulse transmitter added on the oval wheels fuel totalizer for remote indication of totalized flow or actual flow.
- Interconnecting fuel piping between fuel filtering and GT.
- Interconnecting fuel piping between fuel forwarding and fuel filtering excluded.

6.2.7 Liquid Fuel Vanadium Inhibitor Skid

- One (1) vanadium inhibitor injection skid with:
 - Two (2) AC motor driven metering pumps.
 - One (1) tank.
 - One (1) unloading pump.
- Interconnecting piping.

6.2.8 Sump Tank

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The sump tank is preassembled and includes:

- One (1) steel tank (2 m³ capacity) with electrical pump and heater.

6.2.9 Off-Base Cooling Loop for Gas Turbine and Generator Cooling Systems, including for each Unit:

- One (1) battery of water to air fin fan coolers with AC motor driven fans (with 100% capacity).
 - With one (1) extra motor fan for the complete battery.
- Two (2 x 100%) AC motor driven water pumps (on closed circuit loop) and valves.
- Atmospheric expansion tank with level, filling plug with steel structure.
- Closed loop interconnecting piping.

6.2.10 Fire Protection for Gas Turbine Unit Including For Each Unit

- One (1) HP CO₂ bottles rack:
 - Inside a storage container with air conditioning system.
 - Remote weighing device.
- Unit fire protection panel installed in TCC.
- Equipment designed with specific treatment for aggressive site conditions.
- Interconnecting piping up to protected compartments:
 - Gas turbine 9E auxiliaries.
- CO₂ bottle charge
 - Double HP CO₂ bottles only for one CO₂ concentration test with cylinder valves not connected (range storage condition -18°C to 45°C).
 - Additional charge for full flooding test provided by GE.

Execution of test to be done by others.

- Interconnecting piping.

6.2.11 One Washing Skid, including:

- Compressor (On & Off-Line) and Turbine (Off-Line) Washing skid with:
 - Water tank 20m³ stainless steel.
 - First charge of detergent supplied by GE.
 - Under container.

- Interconnecting piping. **CONFIDENTIAL!!!**

6.3 Off-Base Unit Electrical Auxiliaries, including:

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6.3.1 Connection between Generator Package and GNAC, GLAC By:

- Metal enclosed air insulated non segregated phase bus bars.

6.3.2 One (1) Generator Line Accessory Compartment

Designed for outdoor installation, consisting of:

- PTs and CT's.
- Capacitors and lightning arrestors.

6.3.3 One (1) Generator Neutral Accessory Compartment

Designed for outdoor installation, consisting of:

- CTs.
- Generator grounding.

6.3.4 One (1) Starting Motor MV Cell

6.3.5 Off Base LV Cabling

- Maximum distance of 100 meters.
- Low voltage power, control and instrumentation cables between equipments.
- Coaxial cables for remote.
- Optical fiber for remote.
- MV cables for starting motor supply excluded.

6.4 Remote Control & Monitoring

- Five (5) Remote <HMI> with 20" LCD and with laser color printer.
- ETHERNET interface to the plant DCS via <HMI>. TCP/IP OPC protocol (remote).

6.5 Miscellaneous

- The following consumables are included:
 - First charge of lubricating oil plus 10%.
- Anchoring and base plates for turbo generator.
- Embedded pieces for turbo generator.
- Touch up products for primary coat on external surfaces of equipment (supplied by GE, to be applied on site by others).
- Painting products for final coat on external surfaces of equipment (supplied by GE, to be applied on site by others).
- Major inspection specific tools for GT rotor dismantling (lateral exhaust).

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- Rotor turning device with hand pump.
- Major inspection tool kit for GT for casing dismantling.
- Generator test according to manufacturer's standard.

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6.6 Services

- End of Manufacturing Report (EOMR) containing inspection & test records as per Contract Manufacturing Quality Plan (Tab.19) in English language on the following support:
 - CD-ROM (two (2) sets).
- Operation and maintenance manuals, according GE Energy Products — Europe on the standard form in English language on the following support:
 - CD-ROM.
 - Hard copies (3 (Three) sets).
- Transportation as per commercial section.
- Installation commissioning site testing in respect of the fire protection system are excluded from GE's scope of supply.

6.7 Terminal Points

7.1.1 Mechanical

- Air
 - Inlet face of the gas turbine air filter.
- Gas fuel
 - Inlet flange of the coalescing filter.
- Liquid fuel
 - Inlet and outlet flanges of the LDO forwarding skid.
 - Outlet flange on the LDO filtering skid for the recirculation to storage.
 - Inlet flange on the LDO filtering.
- Cooling Water (Open Circuit)
 - Inlet flange on expansion tank.
- Demineralized Water (NOx Control)
 - Inlet flange of water injection skid.
 - Outlet flange on the skid for water recirculation to storage.
- Washing Water (ON/OFF Line)
 - Filling connection on washing water tank.
- Detergent (OFF Line Compressor Washing)
 - Filling connection on washing detergent tank.
- Water for Evaporative Cooler

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- Inlet flange on evaporative cooler water reservoir.
- Water drain connection for blow down.
- Lube Oil
 - Inlet and outlet connection on lube oil tank for filling and emptying.
- Drains.
- Sump
 - Outlet flanges of the sump pump.

7.1.2 Electrical

- Low Voltage (400 VAC)
 - Incoming circuit breaker terminals on GT MCC.
 - Terminals on GTG unit(s) package(s) and various skids.
 - Terminals of the washing skid cubicle.
 - Terminals of the liquid fuel forwarding skid.
- Medium Voltage 15kV
 - Outgoing terminals of the GLAC.
- Medium Voltage (11 kV)
 - Incoming terminals on the starting motor.
 - Incoming terminals on the starting motor MV cell.
 - Outgoing terminals on the starting motor MV cell.
- Control and instrumentation
 - Terminals at control panels.
- Earthing
 - Terminal points on GTG base frame and various auxiliaries.

7.2 Supplied by Others (Off-Base Equipment)

7.2.1 Mechanical

- Gas fuel system
 - Gas heater (if necessary).
 - Gas fuel treatment station including: primary filter and / or separator, pressure boosters, pressure reducing valve, heater, tariff metering, condensate tank, vent stack, flare (if any).
 - Gas fuel density or calorific value measurements.
- Liquid fuel system and associated temperature regulating system

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- Fuel oil heater (if any).
- Liquid fuel unloading, metering, storage tanks, low pressure forwarding pump and treatment station (if any).
- Fire fighting system
 - Site fire protection and detection system.
- Piping
 - Piping beyond terminal points defined before.
- Compressed air system (service and control) (if any).
- Washing water (if any) and oily water drain system including water recovery pit, piping from connecting flange near the GT base, water treatment before discharge in sewage system (if any).
- Any crane and / or lifting facilities.
- Machine shop equipment (if any).
- Laboratory equipment (if any).
- Turbine hall ventilation (if any).
- Various vents to be piped outside the turbine hall (if any).

6.8.2 Electrical

- Unit generator circuit breaker.
- Site auxiliary transformer.
- Unit step-up/step down transformer.
- All MV and HV cables.
- Any MV and / or LV site switchboards.
- Emergency diesel generating set and black start equipment.
- Grounding grid and connections to the grounding system.
- Site lighting, fencing.
- Cathodic protection.
- Aircraft warning.

6.8.3 Miscellaneous & Services

- Any generator type test.
- Any on site painting product application.
- All consumables, chemicals during erection, commissioning, testing and running of the unit(s)

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- Including first charge of anti corrosion and / or anti freeze product for the closed cooling system.
- Soil investigation, analysis and factual report.
- Any civil work, concrete structure, road, including design studies (except guide drawings for the supplied equipment).
- Grouting compound for GT unit(s).
- Transportation up to site.
- Factory and / or on site training.
- Any tax, import duty or import license in the final Country.
- All environmental permits and / or approvals such as (but not limited to) air, waste, fluids, coastal zone, noise, hydrology study.
- All governmental permits and / or approvals such as (but not limited to) construction permit, environmental impact statements, licenses, exemptions.
- Any other equipment or service not clearly indicated in our Scope of supply.

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7. Description of Equipment

This section provides detailed description of the equipment defined in Section 6: Scope, Limits, and Exclusions of Supply.

7.1 Description of Gas Turbine and Mechanical Auxiliary Equipment

7.2.4 Description of Gas Turbine

The gas turbine compressor consists of 17 stages, the design of which is based upon earlier successful General Electric gas turbine compressors. The compressor rotor consists of individual discs for each stage, which are connected by through bolts.

The turbine rotor consists of three stages, with one wheel for each stage. The turbine rotor wheels are assembled by through bolts similarly to the compressor with two spacer pieces: one between the first and second stage wheels, the other between the second and third stage wheels.

The entire rotor assembly is supported by three bearings.

All turbine stages utilize precision cast, segmented nozzles, the 2nd and 3rd stage segments are supported from the stationary shrouds. This arrangement removes the hot gas flow from direct contact with the turbine shell.

The turbine stages also have precision cast, long shank buckets and this feature effectively shields the wheel rims and bucket dovetails from the high temperatures of the hot gas stream.

The gas turbine unit casings and shells are split and flanged horizontally for convenience of disassembly. Compressor discharge air is contained by the discharge casing and turbine shell. The 14 combustion casings are mounted from the discharge casing.

7.2.5 Turbine Base and Supports

7.1.2.1 Turbine Base

The base that supports the gas turbine and inlet plenum is a structural-steel frame about 9 meters long and fabricated of steel beams and plate. The base frame, consisting of two longitudinal 90 cm wide flange beams with three cross members, forms a bed upon which the vertical supports for the turbine are mounted. A steel sealing plate is welded to the bottom of the frame.

On the longitudinal left beam and the rear cross-member, steel seating plates are also welded to provide lubricating oil drain from the bearing No. 2 and 3 and the generator bearing.

Lifting trunnions and supports are provided, two on each side of the base in line with the two main structural cross members of the base frame. Machined pads, four on each side on the bottom of the base, facilitate its mounting to the site foundation. Two machined pads on the base frame are provided for mounting the oft turbine supports.

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7.1.2.2 Turbine Supports

The gas turbine is mounted to its base by vertical supports at three locations: the forward support at the lower half vertical flange of the forward compressor casing, and the other two on either side of the turbine shell.

The forward support is a flexible plate that is bolted and doweled to the forward flange of the forward compressor casing and fastened to the forward base cross frame beam. This type of support permits axial expansion of the turbine.

The other supports are fixed and are mounted upon the machined pads on each side of the frame base, extending up to and attaching to each side of the turbine exhaust frame. These leg-type supports permit radial expansion, but control the axial and vertical position of the unit horizontal centerline to assure proper casing alignment.

On the inner and outer surface of each support leg a water jacket is provided through which cooling water is circulated to minimize thermal expansion and to assist in maintaining alignment between the turbine and the generator. The leg-type supports maintain the axial and vertical position of the turbine, while a gib key coupled with the turbine support legs maintain its lateral position.

7.1.2.3 Gib Key and Guide Block

A gib key is machined on the lower half of the turbine shell. The key fits into a guide block which is welded to the turbine base aft cross beam. The key is held securely in place in the guide block with bolts that bear against the key on each side. The key and block arrangement prevents lateral or rotational movement of the turbine casings while permitting axial and radial movement resulting from thermal expansion.

7.2.6 Axial Compressor

The axial flow compressor section consists of the compressor rotor and the enclosing stator casing. Mounted from the casing are the 17 stages of compressor blading, including the inlet and the exit guide vanes.

In the compressor air is compressed in stages by a series of alternate rotating (rotor) and stationary (stator) airfoil shaped blades. Compressed air is extracted from the compressor for turbine cooling, for bearing sealing, and for compressor pulsation control during startup and shutdown. Off-base motor driven blowers are used for turbine shell and exhaust frame cooling.

One row of stator blades (inlet guide vanes) is variable to aid in limiting the air flow during start-up and to improve the part load efficiency of combined cycle plants.

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The compressor rotor assembly consists of:

- A forward stub shaft, on which are mounted the 1st stage rotor blades.
- Fifteen blades and wheel assemblies (rotor stages 2 to 16 inclusive).
- An aft stub shaft on which are mounted the 17th stage rotor blades.

Each stage of the compressor is on individual bladed disk. The disks are held together axially by a 16 through-bolts arranged around the bolting circle. The wheels are positioned radially by a robbeted fit near the center of the disks and do not contact at the rim. Transmission of torque is accomplished by the face friction at the bolting flange.

Each wheel and the wheel portion of each stub shaft have broached slots around its periphery. The rotor blades are inserted into these slots and they are held in axial position by staking each end of the slot. Selective positioning of the wheel is made during assembly to optimize the rotor balance.

The forward stub shaft is machined to provide the forward and aft thrust bearing faces and the journal for the No. 1 bearings, as well as the sealing surfaces for No. 1 bearing oil seals and the compressor inlet low-pressure air seal.

7.1.3.2 Compressor Stator

The stator (casing) area of the compressor section is composed of four major sub-assemblies:

- Inlet casing.
- Forward compressor casing.
- Aft compressor casing.
- Compressor discharge casing.

These sections, in conjunction with the turbine shell, constitute the outer wall and the structural backbone of the unit. The casing bore is maintained with respect to the rotor blade tips for maximum aerodynamic efficiency.

7.1.3.3 Inlet Casing

The inlet casing is located at the forward end of the gas turbine. Its prime function is to direct the air uniformly into the compressor. The inlet casing also supports the No. 1 bearing assembly, thrust bearing, and variable inlet guide vane assembly. The variable inlet guide vanes are located at the aft end of the inlet casing.

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The forward compressor casing contains the 1st through 4th compressor stages. One end for the forward support plate is bolted and doweled to this casing's forward flange, and the other end is bolted and doweled to the turbine base. It is equipped with two large integral casing trunnions which are used to lift the gas turbine when it is separated from its base.

7.1.3.5 Aft Compressor Casing

The aft compressor casing contains the 5th through 10th compressor stages. Extraction ports in the casing permit removal of 5th stage and 11th stage compressor air. The 5th stage air is used for cooling and sealing functions, and the 11th stage extraction is used for bleeding air to the exhaust plenum during start-up and shut-down for pulsation control.

7.1.3.6 Compressor Discharge Casing

This casing contains the 11th through 17th compressor stages, two rows of exit guide vanes, and the discharge diffuser.

The functions of the compressor discharge casing are to support the stator blading, and the combustion cans to provide the inner and outer side walls of the diffuser, and to join the compressor and turbine stators. This casing also provides an inner support for the No. 2 bearing assembly and seal with the first stage turbine nozzle assembly via the support ring.

The compressor discharge casing consists of two cylinders, one being a continuation of the compressor casings and the other being an inner cylinder that surrounds the rotor distance piece. The two cylinders are connected by radial struts.

The supporting structure for the No. 2 bearing assembly is contained within the inner cylinder. A diffuser is formed by the tapered annulus between the outer and inner cylinders of the discharge casing.

7.1.3.7 Compressor Blading

The compressor rotor blades are airfoil shaped and are designed to compress air efficiently at high blade tip velocities. The forged blades are attached to their wheels by axial dovetail connections. The dovetail is accurately machined to maintain each blade in the desired location on the wheel.

The compressor stator blades are also forged and airfoil shaped. Stages 1 through 8 are mounted by axial dovetails into blade ring segments. The blade ring segments are inserted into circumferential grooves in the casing and are held in place with locking keys. Stage 9 through the exit guide vanes is mounted on individual rectangular bases that are inserted directly into circumferential grooves in the casings.

7.1.3.8 Compressor Air Extraction

During operation of the gas turbine, air is extracted from various stages of the axial flow compressor to:

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1. Cool the turbine parts subject to high operating temperatures.
2. Seal the turbine bearings.
3. Provide an operating air supply for air-operated valves.
4. Fuel nozzle atomizing air (if applicable).

5th Stage Air

Air is extracted from the compressor 5th stage and is externally piped from connections in the upper and lower half of the casing for cooling and sealing of all rotor bearings. An off base motor driven blower is used to cool the shell and exhaust frame.

11th Stage Air

Air from the compressor 11th stage is bled only during unit start up and shutdown for pulsation control. The compressor bleed valves are closed during unit operation, so that maximum energy is available to the output shaft

17th Stage Air

Air extracted from the compressor 17th stage flows radially inward between the stage 16 and 17 wheels, to the rotor bare, and thence off to the turbine where it is used for cooling the turbine 1st and 2nd stage buckets and rotor wheel spaces.

7.1.3.9 Compressor Air Discharge

Air extracted from compressor discharge is used for:

- Stage 1 nozzle vane and retaining ring cooling.
- Self-cleaning air filter.
- L liquid fuel atomizing air.

7.1.3.10 Compressor Washing System

Compressor blades are subject to deposits from surrounding atmospheres during gas turbine operation. These deposits arise from dirt, oil mist, industrial or other atmospheric contaminants, or a salty atmosphere. Deposits will gradually reduce the thermal efficiency and output of the gas turbine. These deposits can be largely removed by intermittent washing.

If compressor inlet, bell mouth, inlet guide vanes and early stage blading deposits are oil or water soluble, the compressor should be washed with either a detergent solution for oil deposit or plain water for water soluble deposits such as salts.

Wash liquid is sprayed into the compressor inlet. The entire compressor inlet circumference is covered with:

- 8 plugged nozzles located on the forward wall of the compressor inlet bell mouth for off-line washing.

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- 16 plugged nozzles for on-line washing located as follows:
 - On the forward wall of the compressor inlet mouth.
 - On the back wall of the compressor inlet mouth.

Wash liquid is supplied from an off-base water wash skid.

7.2.7 Combustion System

The combustion system is of the reverse-flow type and consists of canted combustion chambers arranged around the periphery of the compressor discharge casing.

This system also includes the fuel nozzles, spark plug ignition system, flame detectors, and crossfire tubes. Hot gases generated from burning fuel in the combustion chambers, are used to drive the turbine.

High-pressure air from the compressor discharge is directed around the transition pieces and into the annular spaces that surround each of the 14 combustion chamber lines. This air enters the combustion liners through small holes and slots that cool the liner, and through other holes that control the combustion process. Fuel is supplied to each combustion chamber through a nozzle designed to disperse and mix the fuel with the proper amount of combustion air within the liner.

7.1.4.1 Combustion Chambers and Transition Pieces

Discharge air from the axial-flow compressor flows forward along the outside of the combustion liner towards the fuel nozzle end of the liner. A portion of the air flows all the way forward and enters the combustion chamber reaction zone through the liner cap holes and swirl plate.

The hot combustion gases from the reaction zone pass through a thermal and then into a dilution zone where additional air is mixed with the combustion gases. Metering holes in the dilution zone allow the correct amount of air to enter and cool the gases to the desired temperature. Distributed along the length of the combustion liner are annular slots whose function is to provide a film of air for cooling the walls of the liner. The cap is cooled by louvers.

Transition pieces direct the hot gases from the liners to the first stage turbine nozzle. The 14 combustion chamber liners and casings are identical with the exception of those fitted with spark plugs or flame detectors.

7.1.4.2 Spark Plugs

Combustion is initiated by means of the discharge from two high voltage electrode spark plugs. At the time of firing, one or both sparks of these plugs ignite a chamber. The remaining chambers are ignited by crossfire through the tubes that interconnect the remaining chambers.

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As rotor speeds up and the air flow increase, chamber pressure rises, causing the spark plugs to retract, and the electrodes are removed from the combustion zone.

7.1.4.3 Ultraviolet Flame Detectors

During the startup sequence, it is essential that an indication of the presence or absence of flame be transmitted to the control system.

Four flame detectors are installed in four different combustors.

The control system continuously monitors the presence or absence of flame. The “failure to fire” or “loss of flame” is indicated on the control panel.

7.1.4.4 Crossfire Tubes

The 14 combustion chambers are interconnected by means of crossfire tubes. These tubes enable flame from the fired chambers containing spark plugs to propagate to the non-ignited chambers.

7.1.4.5 Fuel Nozzles

Each combustion chamber is equipped with a fuel nozzle that sprays a metered amount of fuel into the liner. Liquid fuel is atomized in the fuel nozzle swirl chamber by means of pressurized air and then passes into the combustion zone. Gaseous fuel is admitted directly into each combustion chamber through metering holes located at the inner edge of the swirl plate. Action of the swirl plate imparts a spin to the combustion air that enhances combustion, and results in essentially smoke-free operation of the unit. Both gas and oil fuel may be burned simultaneously in a dual-fuel turbine configuration, the percentage of each fuel being determined by the operator within the control system limits.

7.2.8 Turbine Washing System

Turbine washing is used for oil fired machines using low grade liquid fuels such as contaminated light oils, blended distillates, crude oils and heavy fuel oils when significant amounts of contaminants are in the fuel.

Washing should be scheduled during normal shutdown and the preparation is approximately the same as for compressor off-line washing.

The water is injected through the atomizing air manifold in of each fuel nozzle assembly.

However, there should be no large accumulation of water in the turbine at any time. After passing through the turbine water will be exhausted in the form of a spray and also in the form of run-off water through an exhaust plenum drain and a false start drain have to be employed.

Wash water is supplied from an off-base water wash skid.

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The three stage turbine section is the area in which the energy contained in the hot pressurized gas produced by the compressor and combustion section is converted to mechanical energy.

The MS 9001 E major turbine section components include:

- Turbine rotor.
- Turbine shell.
- Exhaust frame.
- Exhaust diffuser.
- Nozzles and diaphragms.
- Stationary shrouds.

7.1.6.1 Turbine Rotor

The turbine rotor assembly consists of a forward shaft, the first, second and third stage turbine wheels and buckets, two turbine wheel spacers, and the aft stub shaft. Concentricity control is achieved with mating rabbets on the distance piece, turbine wheels, spacers and stub shaft. The turbine rotor is held together by through bolts.

Selective positioning of rotor members is performed during assembly to minimize balance corrections during dynamic balance of the assembled rotor. The distance piece extends from the first stage turbine wheel to the aft flange of the compressor rotor assembly. The aft stub shaft connects the third stage turbine wheel to the load coupling. The stub shaft includes the No.2 bearing journal.

The aft shaft connects the third stage wheel to the load coupling. The shaft includes the No.3 bearing journal.

Spacers between the first and second-stage turbine wheels and between the second and third Stage turbine wheels provide axial separation of the individual wheels. The spacer faces include radial slots for cooling air passages, and labyrinth packings are located between each spacer and the second and third diaphragms for interstage sealing.

7.1.6.2 Buckets

The turbine buckets increase in length from the first to the third stage. The first and second- stage buckets are cooled by internal air flow. Air is introduced into each bucket through a plenum at the base of the bucket dovetail. The air flows outward through a series of radial cooling holes. For the first stage, cooling air exits from these holes into gas path at the tip and at the trailing edge. For the second stage cooling air exits only through the tip.

The third-stage buckets are not air cooled. The second and third stage buckets have tip shrouds which interlock from bucket to bucket to provide

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vibration damping, and which mount seal teeth that reduce the tip leakage flow.

The three stages of turbine buckets are attached to their wheels by straight, axial-entry; multiple tang dovetails that fit into machined cutouts in the rims of the turbine wheels. The bucket vanes are connected to their dovetails by means of shanks. These shanks locate the bucket-to-wheel attachment at a significant distance from the hot gases, which reduces the temperature at the dovetail. The turbine rotor assembly is arranged so that the buckets can be replaced without unstacking the wheels, spacers, and stub shaft assemblies. Buckets are selectively positioned such that they can be replaced without having to rebalance the wheel assembly.

7.1.6.3 Turbine Rotor Cooling

The turbine rotor is cooled to maintain satisfactory metal temperatures and to assure a long turbine service life.

The turbine rotor is cooled by means of a positive flow of relatively cool (relative to hot gas path air) air extracted from compressor. Air extracted through the rotor, ahead of the compressor 17th stage, is used for cooling the 1st and 2nd stage buckets and rotor wheel spacers. This air also maintains the turbine wheels, turbine spacers and wheel shaft at approximately compressor discharge temperature to assure low steady state thermal gradients thus ensuring long wheel life. The 1st stage forward wheel space is cooled by air that passes through the high pressure packing seal at the aft end of the compressor rotor.

The 1st stage aft and 2nd stage forward wheel spaces are cooled by compressor discharge air that passes through the stage 1 shrouds and then radially inward through the Stage 2 nozzle vanes.

The 3rd aft wheel space is cooled by cooling air that exits from the exhaust frame cooling circuit.

7.1.6.4 Turbine Stator

The turbine shell and the exhaust frame complete the major portion of the MS 9001 E gas turbine structure. The turbine nozzles, shrouds and turbine exhaust diffuser are internally supported from these components.

7.1.6.5 Turbine Shell

The turbine shell controls the axial and radial positions of the shrouds and nozzles and thus controls turbine clearances and the location of the nozzles relative to the turbine buckets. This positioning is critical to gas turbine performance.

In addition, eddy current probes, reflection holes and boroscope holes are provided for inspection of buckets and nozzles.

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The turbine shell is cooled by air from two motor driven blowers which are piped into the exhaust frame plenum. Part of this cooling air passes through a series of axial holes and exits into the turbine compartment before venting.

7.1.6.6 Nozzles

In the turbine section, there are three stages of stationary nozzles. Because of the high pressure drop across these nozzles, there are seals at both the inside and outside diameters to prevent loss of system energy by leakage.

The first-stage nozzle is made up of 18 cast nozzle segments, each with two vanes, and is cooled with compressor discharge air. A care plug is inserted in each vane to improve cooling effectiveness. The segments are contained by a horizontally split retaining ring which remains centered in the shell and allows for radial growth resulting from changes in temperature.

The second-stage nozzle is cooled with 13th stage compressor air. A care plug is inserted in each vane to improve cooling effectiveness. This nozzle is made up of 16 cast segments, each with three vanes. The nozzle segments are held in the circumferential position by radial pins from the shell into axial slots in the nozzles outer sidewall.

The third-stage nozzle consists of 16 cast segments, each with four vanes. It is held in the turbine shrouds in a manner identical to that used on second-stage nozzle.

7.1.6.7 Diaphragms

Attached to the inside diameters of both the second and third-stage nozzle segments are the nozzle diaphragms. These diaphragms prevent air leakage between the inner sidewall of the nozzles and the turbine rotor. The high/low labyrinth-type seal teeth are machined into the inside diameter of the diaphragm. They mate with opposing sealing lands on the turbine rotor. Minimal radial clearance between stationary ports (diaphragm and nozzles) and the moving rotor are essential for maintaining low interstage leakage. This results in higher turbine efficiency.

7.1.6.8 Shrouds

The turbine bucket tips run directly under stationary annular curved segments called turbine shrouds. The shroud's primary function is to provide a cylindrical surface for minimizing bucket tip clearance leakage. The turbine shroud's secondary function is to provide a high thermal resistance between the hot gases and the comparatively cool shell.

By accomplishing this function, the shell cooling load is drastically reduced, the shell diameter is controlled, the shell roundness is maintained, and the important turbine clearances are assured. The shroud segments are

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maintained in the circumferential position by radial pins from the shell. Joints between shroud segments are sealed by an interlocking labyrinth.

7.1.6.9 Exhaust Frame

The exhaust frame is bolted to the aft flange of the turbine shell. Structurally, the frame consists of an outer cylinder and an inner cylinder interconnected by the radial struts. The No. 3 bearing is supported from the inner cylinder.

The exhaust diffuser is located between the outer and inner cylinders. Gases exhausted from the third turbine stage enter the diffuser where the velocity is reduced by diffusion and pressure is recovered. At the diffuser exit turning vanes assist in directing the gases radially outward into the exhaust plenum.

The exhaust frame is cooled by a portion of cooling air supplied by off-base motor driven blowers then enters the turbine shell after cooling the outer frame and the radial support struts. This cooling air then flows into the 3rd aft wheel space cavity and port is vented through the inner barrel to atmosphere via a load compartment.

7.2.10 Bearings

The MS 9001 E gas turbine unit contains three main journal bearings used to support the gas turbine rotor. The unit also includes thrust bearings to maintain the rotor-to-stator axial position. These bearing assemblies are incorporated in three housings: one at the inlet casing, one in the compressor discharge, and one in the exhaust frame. These main bearings are pressure-lubricated by oil supplied from the main lubricating oil system. The oil flows through branch lines to an inlet in each bearing housing.

	<u>Bearings</u>	
Housing	Class	Type
1	Journal	Elliptical
1	Loaded Thrust	Self-Aligned (equalized)
1	Unloaded Thrust	Tilting Pod
2	Journal	Elliptical
3	Journal	Elliptical

7.1.7.1 Bearing Housing No. 1

The No. 1 bearing subassembly is located in the center of the inlet casing and contains three bearings: (1) active (loaded) thrust bearing, (2) inactive (unloaded) thrust bearing, and (3) No. 1 journal bearing. Additionally, it contains a floating or ring shaft seal, labyrinth seals, and a housing in which the components are installed. **CONFIDENTIALS** are keyed to the housing to prevent rotation. The housing is a separate casting.

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The No. 1 bearing assembly is centerline supported from the inner cylinder of the inlet casing. This support includes ledges on the horizontal and an axial key at the bottom centerline. The upper half of the bearing housing can be removed for bearing liner inspection without the removal of the upper half inlet casing. The lower half of the bearing assembly supports the forward stub shaft of the compressor rotor.

The labyrinth seals at each end of the housing are pressurized with air extracted from the compressor 5th stage. The floating ring seal and a double labyrinth seal at the forward end of the thrust bearing cavity are to obtain the oil and to limit entrance of air into the cavity.

7.1.7.2 Bearing Housing No. 2

The No. 2 bearing assembly is centerline supported from the inner cylinder of the compressor discharge casing. This support includes ledges on the horizontal and on axial key at the bottom centerline permitting relative growth resulting from temperature differences while the bearing remains centered in the discharge casing. The lower half of the bearing assembly supports the forward wheel shaft of the turbine rotor assembly. This assembly includes three labyrinth seals at both ends of the housing. The No. 2 bearing is located in a pressurized space between the compressor and the turbine, and air leaks through the outer labyrinth at each end of the housing. The space between the two other seals is cooled by air extracted from the 5th compressor stage. Air flows through this seal into the drain space of the housing and is vented outside the machine via the inner pipe connecting to the bottom of the housing.

This drain space vent piping continues to the lubricating oil tank. The middle labyrinth prevents the hot air leakage from mixing the oil. The mixture of hot air and cooler air is vented outside the unit via the outer pipe connected at the top of the bearing housing.

7.1.7.3 Bearing Housing No. 3

The No. 3 bearing assembly is located at the aft end of the turbine shaft in the center of the exhaust frame assembly. It consists of a tilting pad bearing five labyrinth seals, and a bearing housing. The individual pads are assembled so that converging passages are created between each pad and the bearing surface. These converging passages generate a high-pressure oil film beneath each pad that produces a symmetrical loading or "clamping" effect on the bearing surface. The clamping action helps to maintain shaft stability. Because the pads are point-pivoted, they are free to move in two directions, which make them capable of tolerating both offset and angular shaft misalignment

The tilting pad journal bearing comprises two major components: pads and a retainer ring. The retainer ring **CONFIDENTIAL** and support the pads. It is **44 of 144** horizontally split member that contains the pad support pins, adjusting shims,

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oil feed orifices, and oil discharge seals. The support pins and shims transmit the loads generated at the pad surfaces and are used to set the bearing clearance. An anti-rotation pin locates the bearing within its housing and serves to prevent the bearing from rotating with the shaft.

7.2.11 Lubrication

The three main turbine bearings are pressure-lubricated with oil supplied from the lubricating oil reservoir. Oil feed piping, where practical, is run within the lube oil reservoir drain line, or drain channels, as a protective measure. This procedure is referred to as a double piping and its rationale is that in the event of a pipeline leak, oil will not be lost or sprayed on nearby equipment, thus eliminating a potential safety hazard.

When the oil enters the bearing housing inlet, it flows into an annulus around the bearing liner. From the annulus the oil flows through machined slots in the liner to the bearing face. The oil flow is prevented from escaping along the turbine shaft by labyrinth seals.

7.2.12 Oil Seals

Oil on the surface of the turbine shaft is prevented from being spun along the shaft by oil seals in each of the three bearing housings. These labyrinth packings and oil deflectors (teeth type) are assembled on both sides of the bearing assemblies where oil control is required. A smooth surface is machined on the shaft and the seals are assembled so that only a small clearance exists between the oil and seal deflector and the shaft. The oil seals are designed with two rows of packing and an annular space between them. Pressurized sealing air is admitted into this space and prevents lubricating oil from spreading along the shaft. Some of this air returns with the oil to the main lubricating oil reservoir and is vented through a lube oil vent.

7.3 Instrumentation

7.3.1 Non Contacting Vibration Probes

This description covers the shaft vibration and axial position monitoring using non-contacting eddy current proximity devices.

7.3.1.1 Gas Turbine Bearing No. 1

- One (1) radial probe X.
- One (1) radial probe V (90 degrees apart).
- Two (2) thrust position axial probes Z.
- One (1) key phasor.

7.3.1.2 Gas Turbine Bearing No. 2

- Two (2) radial probe X, one active and the second as a spare.

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- Two (2) radial probe V (90 degrees apart), one active and the second as a spare.

7.3.1.3 Gas Turbine Bearing No. 3

- One (1) radial probe X.
- One (1) radial probe V (90 degrees apart).

7.3.1.4 System Components

Proximity transducer system includes the following:

- Extension cable.
- Proximitator.

7.3.1.5 Tests

Standard factory testing procedure including a functional checkout of the probes will apply.

7.3.2 Bearing Metal Temperature

This description covers the bearing metal temperature monitoring.

7.3.2.1 Gas Turbine Bearing No. 1

- Two (2) thermocouples, journal bearing.
- Three (3) thermocouples, inactive thrust.
- Three (3) thermocouples, active thrust.

7.3.2.2 Gas Turbine Bearing No. 2

- Two (2) thermocouples, journal bearing.

7.3.2.3 Gas Turbine Bearing No. 3

- Two (2) thermocouples, journal bearing.

7.3.2.4 System Components

- Chromel alumel, type K, twin elements (one connected / one unconnected) thermocouples for turbine bearings.
- Temperature read out is available on the gas turbine control panel.

7.3.3 Gas Turbine Special Tools

7.3.3.1 Gas Turbine Commissioning Tools

One set of commissioning tools per site (*to be discussed with GE*).

Commissioning tools are provided in order to support teams during commissioning operations. They include:

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- Pressure and temperature instrumentation.
- Flushing equipment.
- Alignment fixture.
- Jib crane for coupling shaft.

<u>DESIGNATION</u>	<u>QTY</u>
COMMISSIONING TOOLS	1
ACCUM. CHARGING EQUIPMENT PARKER	1
ACCUM. CHARGING EQUIPMENT OLAER	1
PRESSURE GAUGE 0-6 BAR	1
PRESSURE GAUGE 0-16 BAR	1
PRESSURE GAUGE 0-160 BAR	1
DIFF. PRESS. GAUGE 0 -1,75 BAR	1
DIFF. PRESS. GAUGE 0 -7 BAR	1
TEST GAUGE CONNECT. Lenth 2 m	3
BENDER THERMOCOUPLE	1
FLUSHING EQUIPMENT	4
FIXTURE, ALIGNEMENT	1
GREASE GUN	1
COUPLING TOOLS	1
THERMOMETER 4", 0-300°C	1
EF THERMOCOUPLE PLUG GAUGE	1

7.3.3.2 Major Inspection Specific Tools for GT Rotor Dismantling

One set of tools per site *(to be discussed with GE)*.

Kit for major inspection, including lifting beam (30T capacity) for rotor disassembly, rotor compressor & rotor turbine supports.

DESIGNATION	QTY
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7.3.3.3 Rotor Turning Device with Motor Pump

One set of tools per site.

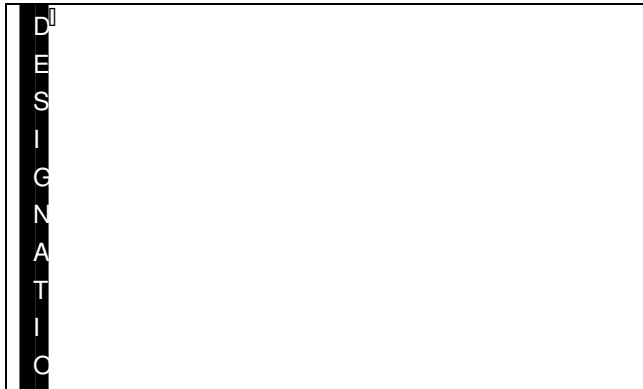
GT rotor barring tool is used for both commissioning and maintenance operations (fits GT rotor flange holes in front of generator for coupling shafts during installation & rotate GT rotor for video scope inspection).

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7.3.3.4 Major Inspection Tool Kit for GT Casing Dismantling

One set of tools per site.

Kit for major inspection, including casing, nozzle, injection nozzle and bearing dismantling tools.



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7.3.4 Description of Accessory Compartment

7.3.4.1 General

The accessory compartment, mounted on a separate base from the turbine compartment, contains the mechanical and control elements necessary to allow the PG9171E gas turbine to be a self-contained operational station. The major components located in the accessory compartment are the lubricating oil system and reservoir, starting system, accessory gear, fuel system and hydraulic system.

7.3.4.2 Lubrication System

The lubricating provisions for the turbine, generator, torque converter and accessory gear are incorporated in a common lubrication system that includes the following equipment:

- Oil reservoir mounted within the accessory compartment base, having a nominal capacity of 12,500 liters, with the following devices mounted on it:
 - Pressure relief valve in the main pump discharge.
 - Duplex full-flow lube oil coolers (oil-to-water exchanger).
 - Dual full flow oil filters with associated transfer valve are mounted in the module. The replaceable filter cartridges Beta 40 = 75 are part of the lubricating system module. A differential pressure switch is used to detect the filter clogging.
 - Immersion heats maintain suitable operating temperature during shutdown and standby periods.
 - Bearing header pressure regulator to maintain 1.7 bar header pressure at rated speed.
- Main lubrication oil pump - shaft-driven from the accessory gear.
- Full capacity AC motor driven auxiliary lube oil pump.
- Emergency lube oil pump driven by a DC motor.
- Temperature and pressure switches, thermocouples for control, indication and protection of the lube oil system. Pressure gauge plugs are available on the lube oil circuit for checking during the maintenance operation.
- Level switches for lube oil tank low and high level alarm.
- Flow sights are provided in the bearing drains for visually checking the oil flow from each of the bearings of the gas turbine.

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The objects of this equipment are:

- To exhaust the oil mist flow from the gas turbine oil vent.
- To create an adjustable depression in the gas turbine oil tank.
- To eliminate oil droplets from the extracted air.

The oil mist eliminator consists in the following components fitted together on a steel section frame:

- One (1x 100%) set of coalescing cartridges.
- Two (2x100%) electric motor blowers.
- The necessary instrumentation and valving..
- One differential pressure switches for remote alarm in case of the cartridges clogging.
- One silencer connected at the blower outlet.

The control is directly depending on the gas turbine control system.

7.3.4.4 Starting and Cool Down Systems

The starting system includes the drive equipment to bring the unit to self-sustaining speed during the starting cycle. The cool-down system provides uniform cooling of the rotor after shutdown. The unit is ready to start on signal during coast down. The starting system consists of the following equipment:

- Medium Voltage starting electric motor.
Rated power: 1,000 kW. Maximum power during starting cycle (to be used for starting motor power supply design): 1,450 kW, Voltage: 11 kV.
- Barring motor, rating 30 kW, 750 rpm, 400 V AC.
- Hydraulic torque converter.

The torque converter will have a variable stator to control firing speed and rotor turning speed (120 rpm).

The torque converter is also drainable and will allow restart on coast down: therefore, no starting clutch is required.

7.3.4.5 Accessory Drive System

During start-up the accessory gear transmits torque from the starting device and torque converter assembly to the gas turbine shaft. After start-up torque is transmitted from the gas turbine shaft via suitable gear drives to the following:

- Fuel oil pump.
- Main lube oil pump. **CONFIDENTIAL!!!**

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- HP hydraulic supply pump.
- Main atomizing air compressor.

The accessory gear trains are lubricated from the bearing header supply and drains back to the lube oil reservoir by gravity.

7.3.4.6 Hydraulic Oil System

The hydraulic pumps are included as part of the hydraulic supply system and supply high-pressure oil for the control system. The main hydraulic pump is driven by the accessory gear while the auxiliary hydraulic pump is motor driven. The auxiliary hydraulic pump provides oil to the system when the accessory gear is operating at low speeds, as in turbine starting and shutdown

A standby hydraulic pump driven by an AC motor is also provided.

Duplex filters (efficiency Beta 40=75) are provided to maintain high purity oil for the control devices.

7.3.5 Fuel Systems

On dual fuel machines with automatic control, the fuel changeover is initiated manually through the fuel selector switch or automatically by the fuel gas pressure switch that is operated when the fuel gas pressure drops below a preset value.

The automatically initiated changeover occurs only when the transfer is from gas to liquid fuel operation and only when the turbine has reached operating speed.

The transfer back to fuel gas has to be manually initiated after fuel gas pressure has been reestablished.

7.3.5.1 Gas Fuel System

The fuel gas compartment is provided in the accessory compartment and contains the stop/ratio valve and the gas control valve combined into one assembly.

A gas strainer is provided upstream of the above assembly.

7.3.5.1.1 Gas control Valve

The gas control valve provides the final precise metering of fuel gas flow to the combustors. The inlet pressure to the gas control valve is regulated by the ratio function of the stop/ratio valve described hereafter.

7.3.5.1.2 Stop / Ratio Valve

The ratio function of the stop/ratio valve provides a regulated inlet pressure for the control valve.

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The stop function of the valve serves to provide a tight shut-off of the fuel gas flow when required.

Positioning of both stop/ratio valve and control valve is hydraulically operated and based on signals from the control system.

7.3.5.2 Liquid Fuel System

The GT unit is designed with a liquid fuel system for burning liquid fuel. It consists of the following equipment

- Fuel oil stop valve.

- Fuel Pump

The main fuel pump is a screw-type pump, driven by the accessory gear.

- By-pass valve

The by-pass valve is hydraulically actuated and is used to regulate fuel flow to the combustors based on signals from the control system.

- Flow divider

The flow divider is a metering device consisting of 14 elements that distribute the fuel equally to each fuel nozzle. It is fitted with magnetic speed pickups to provide feedback signals to the control systems.

- High pressure filter

A duplex (2x100%) cartridge type high-pressure fuel oil filters (efficiency Beta 40 = 75) downstream of the fuel pump and by-pass valve arrangement.

- Atomizing air system

The atomizing air is extracted from the gas turbine compressor discharge, passes through the air pre-cooler before entering the atomizing air compressor. The main atomizing air compressor is a centrifugal type, driven by the accessory gear.

A booster compressor, driven by the starting means, provides air during unit start-up and acceleration.

7.3.6 GT Cooling Water System

The GT cooling water system is designed to accommodate the heat dissipation requirements of:

- The lubricating oil system.
- The turbine supports.
- The flame detector mounts.

- The liquid fuel atomizing air system.

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The gas turbine cooling water piping connects the lubricating oil heat exchanger system, turbine supports and flame detector mounts into one piping system.

7.3.6.1 Duplex Lube Oil Coolers

The lubricating oil cooling system consist of 2 oil to water heat exchangers (2x100%).The temperature regulating valve will be on water side.

7.3.6.2 Atomizing Air Heat Exchanger

This system contains a heat exchanger and a temperature-regulating valve. Coolant is circulated through the atomizing air pre-cooler to lower the temperature of the air entering the atomizing air compressor.

A temperature-regulating valve is provided to control the atomizing air temperature.

The two-way valve adjusts to allow the correct coolant flow to the heat exchanger to maintain the air within the temperature control range.

7.3.6.3 Flame Detectors and Turbine Supports Cooling

The turbine supports are cooled so that thermal expansion is minimized thereby keeping rotor shaft misalignment to a minimum.

The flame detector mounts are cooled to extend the life of the flame detectors.

No temperature regulation is necessary for the turbine supports or flame detector mounts.

7.3.7 Description of the GT Acoustical Enclosure

7.3.7.1 General Description

The main purpose of the acoustical enclosure is the reduction of the noise generated by the gas turbine to a compatible level with the project requirements.

The gas turbine acoustic enclosure contains different adjacent sections forming an outdoor or indoor protective housing.

The gas turbine acoustic enclosure is divided into two compartments:

- Accessory compartment.
- Turbine compartment.

In addition, the acoustic enclosure includes the following functions:

- Protection of the personnel from heat radiation.
- Fire protection with fire extinguishing media containment.
- Ventilation to remove the heat and achieve enough air changes.

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- Heating to maintain the internal temperature at the required level and/or avoid condensation phenomena when the gas turbine is stopped.
- Weather protection during turbine operation and small maintenance work (in case of outdoor installation).

7.3.7.2 GT Enclosure Characteristics

The gas turbine off base acoustic enclosure is installed on a foundation block separated from the gas turbine pedestal.

The acoustic enclosure consists of:

- A steel structure made of vertical columns, horizontal members and wind bracing.
- Acoustical roof and wall panels with turbine section removable roof to facilitate maintenance operations.
- Pipe penetration sealing system.
- Maintenance access hatches installed on lower concrete wall.
- Internal partition wall to separate the accessory compartment from the turbine compartment.
- Internal platform inside the accessory and turbine compartments.
- Fan installed on roof with access facilities.
- The acoustic panels are composed of:
 - An outer painted steel sheet.
 - A perforated inner steel sheet.
 - A compound with the required acoustic property sandwiched between outer sheets.

One door is provided on each side of the accessory and turbine compartments.

7.3.7.3 GT Enclosure Equipment

7.3.7.3.1 Lighting and sockets

- AC Lighting. Accessory compartment is equipped with AC lighting system giving a minimum illumination value of 200 Lux at access locations.
- DC Lighting.

Accessory compartment is equipped with DC security lighting system giving a minimum illumination value of 50 Lux at access locations.

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Turbine compartment is equipped with DC security lighting system giving a minimum illumination value of 50 Lux at access locations.

- Turbine compartment lights are mounted externally with a window that will provide illumination inside the compartment.
- Sockets.
- 16A convenience sockets are located dose to some doors for small hand tool portable lamp use.

7.3.7.3.2 Lifting Device

A manual traveling crane is installed in the accessory compartment for routine maintenance operations of accessory modules. In addition, a fixed 0.5 ton runway beam is installed above the combustion cans in the turbine compartment.

7.3.7.3.3 Painting

Painting system of all external surfaces of enclosure exposed to an aggressive environment (maritime, industrial, corrosive) is re-enforced. Please refer to GE specification ST001 enclosed.

7.3.7.3.4 Fire Detection and Protection

Duplicate thermal fire detectors are installed inside the accessory and gas turbine compartments and are wired on two loops such that CO₂ is discharged only when one detector of one loop and one detector of the other loop are both activated.

When the fire detection operates an alarm is activated, the unit is tripped and the ventilation fans are stopped, the dampers on air inlet openings close by gravity, CO₂ is discharged by piping and nozzles in the accessory and turbine compartments.

7.3.7.3.5 Heating and Ventilation System

Electric space heaters are provided in the accessory and the turbine compartments, to maintain suitable temperature and anti-condensation preservation during stand by periods at low ambient temperature.

Duplicate fans ensure the ventilation of the compartments to remove the heat radiated by the equipment and achieve the minimum required air changes.

The turbine compartment is induce draft ventilated in series with the accessory compartment, air is drawn into the accessory compartment from atmosphere through openings in the end wall of the enclosure, then cooling air passes from the accessory compartment to the turbine compartment through openings in the partition wall.

7.3.7.3.6 Filtered Air

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Filtration of the ventilation air may be necessary for some sites where severe atmospheric pollution is present. This requirement will be met by filtering the air as it enters the respective compartment ventilation systems. Simple washable metallic filter elements are used. The filtration system includes a solenoid actuated by-pass system that allows un-filtered air to enter the system in the event of filter blockage. The by-pass system will be controlled by a differential pressure switch installed across the filters. This switch will be used to signal an alarm and to initiate the operation of the by-pass damper solenoid actuator. When energized the solenoid actuator will hold the filter by-pass damper in the closed position. When de-energized the solenoid actuator will allow the by pass damper to open and allow the ventilation air to by-pass the filters. This system is to be designed for easy access and maintenance.

7.3.7.3.7 Gas Detection

A gas leakage detection system with triplicate gas sensors suitable for the detection of natural gas is provided for the gas turbine compartment.

Two levels of gas detection are provided by the turbine control system, one high level (5% of LEL) to signal an alarm and one high-high level (8% of LEL) to initiate a turbine trip. 2/3 voting shall avoid spurious trip.

7.3.7.4 Auxiliary Module Enclosure(s)

The gas module enclosure forms an off-base weather protective housing mounted on a foundation block.

The gas module enclosure provides thermal insulation and acoustic attenuation, and achieves enough air changes.

The auxiliary module enclosure(s) contain the following equipments:

- Doors for access to equipments during routine inspections and maintenance.
- Electric heaters are provided to maintain suitable operating temperature, and anti-condensation preservation during stand by periods.
- The gas compartment is equipped with DC security lighting system giving a minimum illumination value of 50 Lux at access locations, light is mounted externally with a window that will provide illumination inside the compartment.
- Duplicate ventilation fans for gas compartment.

A gas leakage detection system with triplicate gas sensors suitable for the detection of natural gas is provided for gas module compartment.

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Two levels of gas detection are provided by the gas turbine control system, one high level (5% of LEL) to signal on alarm and one high-high level (8% of LEL) to initiate a turbine trip. 2/3 voting shall avoid spurious trip.

- 16 A convenience sockets are located close to some doors for small hand tool and portable lamp use.

Painting system of all external surfaces of enclosure exposed to a very aggressive environment (maritime, industrial, corrosive), is re-enforced. Please refer to GE specification ST001 enclosed.

Filtration of the ventilation air may be necessary for some sites where severe atmospheric pollution is present. This requirement will be met by filtering the air as it enters the respective compartment ventilation systems. Simple washable metallic filter elements are used. The filtration system includes a solenoid actuated by-pass system that will allow un-filtered air to enter the system in the event of filter blockage. The bypass system will be controlled by a differential pressure switch installed across the filters. This switch will be used to signal an alarm and to initiate the operation of the by-pass damper solenoid actuator. When energized the solenoid actuator will hold the filter by-pass damper in the closed position. When de-energized the solenoid actuator will allow the by pass damper to open and allow the ventilation air to by-pass the filters. This system is to be designed for easy access and maintenance.

7.4 Air Inlet and Exhaust Gas Systems

7.4.1 Inlet System

The turbine air inlet system is the means of receiving, filtering, and directing the ambient air flow into the inlet of the compressor. The system consists of an inlet filter house, ducting, silencing, elbows and inlet plenum. The ducting and silencing that come out from the filter house pass over the acoustical enclosure and down into the inlet plenum. This arrangement requires minimum plot area and provides easy access to the various compartments.

Maintenance requirements are minimal and consist of annual inspection of the inlet equipment. Any entrapped foreign material should be removed. Rust and oxidation spots should be scraped and repainted.

7.4.1.1 Description

The inlet air filter house consists basically of the filter equipment, a transition duct for connection with the inlet silencer.

The inlet filter house includes:

7.4.1.2 Self Cleaning Air Filter

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The self-cleaning inlet filter utilizes high efficiency media filters which are automatically cleaned of accumulated dust by a reverse pulse of compressed air, thereby maintaining the inlet pressure drop below a preset upper limit. This design provides single-stage high efficiency filtration for prolonged periods without frequent replacements.

Dust-laden ambient air flows at low velocity into filter modules which are grouped before a clean-air plenum. The filter elements are made of pleated media to provide an extended filtration surface, and of galvanized steel plates. The air, after being filtered, enters the clean air module through holes in the vertical wall supporting the filter elements.

As the outside of the filter elements become laden with dust, increasing differential pressure is sensed by a pressure switch in the plenum. When the set point is reached, a cleaning cycle is initiated. The elements are cleaned in a specific order, controlled by an automatic sequencer.

The sequencer operates a series of solenoid-operated valves, each of which controls the cleaning of a small number of filters. Each valve releases a brief pulse of compressed air into a blowpipe which has orifices located just above the filter cartridge. This pulse shocks the filters and causes a momentary reverse flow, disturbing the filter coke. Accumulated dust breaks loose, falls, and disperses. The cleaning cycle continues, until enough dust is removed for the compartment pressure drop to reach the lower set point. The design of the sequencer is such that only a few of the many filter elements are cleaned at the same time. As a consequence, the airflow to the gas turbine is not significantly disturbed by the cleaning process.

Included with the filter compartment are a pulse air source, necessary support structures, walkways and ladders. Access to the clean-air plenum is by means of a bolt-on hatch. A lighting system of the filter's internal maintenance areas and convenience outlet are provided. A differential pressure gauge is supplied to read plenum pressure. An alarm is provided for excessive differential pressure in the plenum or for low pressure in the pulse cleaning air supply. Gas turbine stop is also controlled in case of very high pressure drop due to the filtration system.

For particular humid ambience, droplet catcher made of PVC is installed in the weather hoods. Due to change in direction of the air flow, liquid droplets gather on the covers' air.

7.4.1.3 Evaporative Cooler

The evaporative cooling process involves the adiabatic exchange of heat.

The sensible heat of the air is reduced proportionally to the amount of evaporation that takes place.

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The evaporative cooler media is a direct contact, irrigated media utilizing cross fluted cellulose blocs.

Water enters the sump tank through a water supply automatic valve located on the tank and the water level is controlled by a float switch.

Water is supplied to the distribution manifolds by a pump. The distribution manifolds are located directly above the evaporative cooler media.

The distribution manifold evenly wets the media by spraying water through small holes, spaced along its length, into a deflector shield. Only a small percentage of the water pumped to the media is evaporated, the remainder is filtering through the media and back to the water tank. The pump continually re-circulates water to the media. Water quantity to the evaporative cooler media is regulated through an arrangement of orifice plates, valves and flow meters. To prevent scale formation, a percentage of water must be discharged to the drain. This water is referred to as "Blow down" or "Bleed-off".

Blow down system is fully automatic and based on the water conductivity measurement in the sump.

When high conductivity in the sump is detected, water discharge into the drain is initiated through a solenoid valve. When conductivity in the sump reaches pre-determined low level the solenoid valve redirects water back into the sump.

The designed system ensures a uniform airflow to prevent water carry-over with air velocity leaving the media not exceeding 2.5 to 4.5 m/s. However, a water droplet eliminator is included downstream to ensure no water re-entrainment into the air stream. The media compartment allows for media pods adjustment to eliminate possible gaps between the individual media pods.

Water Level Control

The water level in the sump tank is controlled by a float level switch which energizes a solenoid valve to allow water to fill the tank. When the sump tank is full (high water level reached), the float switch will start the pump automatically. Sump tank level may fluctuate between high and low levels during unit operation. If low level is reached, the float switch will then activate the solenoid valve to refill the sump tank.

In case of very low water level, an alarm signal is available on terminals of the control box; pump stops automatically, start of pump is not possible.

In case of very high water level, an alarm signal is available on terminals of the control box; water overflow is evacuated by the tank overflow connection. An emergency make up shut off valve is closed to stop sump water feeding.

No Water Flow

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The pump has a water flow switch installed on its outlet line to detect the water flow. When the flow is abnormal or in case of no water flow, an alarm signal is available on terminals of the control box.

Blow Down

For blow down requirement and control, refer to the Design Basis chapter

7.4.1.4 Inlet Ducting and Silencing

The silencers are of baffle-type construction to attenuate the high-frequency tones from the compressor. Elbows and transition sections are partially acoustical lined to aid in noise reduction.

The inlet plenum is a lined sheet metal “box” type structure that is mounted on the turbine base and encloses the compressor inlet casing. Its top side is connected to the inlet ducting. It is mounted and welded to the I-beam turbine base.

7.4.2 Exhaust Gas System

The exhaust system is that portion of the turbine in which the gases are redirected before being released to the atmosphere or to an exhaust heat recovery equipment.

The exhaust system includes:

7.4.2.1 Exhaust Plenum

The exhaust plenum is the beginning of the exhaust system, receiving the gas flow from the GT exhaust diffuser. The exhaust plenum is bolted to the turbine base and is connected to the exhaust frame with flex-plate expansion joints. The exhaust temperature thermocouples are mounted in the oft wall of the exhaust plenum to sense exhaust temperatures and provide electrical signals to the gas turbine control system.

7.4.2.2 Exhaust Transition Duct Including Exhaust Silencer

The exhaust transition duct is bolted to the exhaust plenum by mean of on expansion joint to accommodate thermal expansion and provides a flow path by which the gases travel from the exhaust plenum section to the silencer. The silencer design is a parallel baffles type: it consists of a low frequency silencing. Acoustic treatment is provided by mineral wool sandwiched between steel linings.

7.4.2.3 Insulation under Exhaust Plenum

7.4.2.4 Vertical Exhaust Elbow

The vertical exhaust elbow is bolted to the lateral exhaust system and redirect gas flow upward to the atmosphere.

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7.4.2.5 Exhaust Stack

The exhaust stack, of the double shield type, is the part downstream the exhaust system which conveys the hot exhaust gas upward to the atmosphere. Its main components are the structural frame, the shell, the suspended internal stainless steel liner, and transition piece with an inlet square cross section and an outlet circular cross section. The height and the distance of the plant equipment located in the by-pass stack area shall be defined considering the temperature of exhaust gas. In case of high wind velocity the exhaust gas could move in the stack outlet horizontal plan. The accessible areas during GT running shall be located at a lower level than stack outlet. A top circular platform is supplied at 2.5m from the stack outlet. Stack circular gangway is designed for 250 N/m², with a maximum of 2,500 N.

The exhaust stack is equipped with an additional circular platform. At this level, emission test ports are foreseen to allow taking exhaust gas samples.

The exhaust stack is also fitted with cladding. It consists of aluminium sheets which cover the external shell.

7.4.2.6 Exhaust Duct Acoustic Enclosure

The main purpose of the exhaust duct acoustical barrier wall is the reduction of the noise. It ensures also personal protection from heat radiation.

7.4.2.7 Exhaust Overpressure Monitoring System

Gas turbine exhaust duct overpressure protection is necessary to prevent duct mechanical damage and personnel hazards resulting from restrictions in the gas turbine exhaust path. This protective function involves pressure sensing in the gas turbine exhaust duct prior to any potential flow restrictions. The pressure sensing equipment purpose is to trip the gas turbine in the event of excessive backpressure in the exhaust duct. Excessive backpressure can be caused by exhaust duct failure or malfunction of an isolation damper/stack closure.

- Protective degree: IP 66.
- integrated heater, 230 VAC dependent on ambient conditions.

This system consists of an instrumentation panel, containing the pressure sensing devices, which are:

- Three pressure switches, used for high pressure alarm, and overpressure trip.
- One pressure transmitter, used for performance monitoring.

The instruments are connected to the exhaust gas path via adequate tubing and pressure topping.

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7.5 Off-Base Mechanical Auxiliaries

7.5.1 Fuel Gas Filtering Equipment

Vertical carbon steel pressure vessel, ASME VIII div.1 without U stamp, (located close to GT unit), fitted with condensate level monitoring system, including:

- 1st Stage: baffle plate.
- 2nd Stage: filtration and coalescing cartridges.

This system removes the solids over 0.3 microns with 99.99% efficiency and liquids over 0.3 microns with 99.50% efficiency. Instrumentation is in accordance with IEC or CENELEC.

- Automatic draining system.
- Heat insulation for personal protection and/or to maintain the gas temperature during GT stop.
- Electrical tracing.
- Extra painting system.
- CE marking.
- Shut off valve and vent valve skid.

The shut off valve cuts the gas turbine feeding line in case of GT stop, GT fire detection or GT gas detection and the vent valve depressurizes the GT inlet gas pipe.

One shut off valve (piloted by fuel gas) with spring return pneumatic actuator and open/closed limit switches for valve monitoring system, one vent valve (piloted by fuel gas) with spring return pneumatic actuator and open/closed limit switches for valve monitoring system. The valves are in accordance with API 6D, API 607, body in carbon steel, boll in stainless steel. Instrumentation in accordance with IEC or CENELEC.

7.5.2 Fuel Oil Equipment

7.5.2.1 Fuel Oil Forwarding Skid

The fuel oil forwarding skid feeds fuel oil to the gas turbine at a pressure consistent with the gas turbine fuel supply requirements.

The fuel oil forwarding skid is preassembled and includes:

- Two (2) 100 % fuel forwarding centrifugal pumps (one duty/one standby) each designed for the maximum fuel flow necessary to the gas turbine and driven by an AC motor.
- Skid suitable for installation in hazardous area classified zone 2.

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- One (1) suction strainer upstream each pump, nominal filtration size: 1.5 mm.
- One (1) relief valve.
- One (1) complete set of piping including valves, gauges and fittings of all lines terminating at the skid boundary.

Insulation and electrical heat tracing for 2 pumps forwarding skid if fuel pour point is higher than minimum ambient temperature.

Extra painting system for corrosive ambient conditions.

7.5.2.2 Fuel Oil Filtering Skid

The fuel oil filtering skid provides fuel oil filtration and pressure regulation upstream the gas turbine unit. Skid is suitable for installation in hazardous area classified zone 1.

The fuel oil filtering skid is preassembled and includes:

- One (1) fuel pressure regulating valve.
- Two (2) fuel filters (one duty/one standby). Synthetic filter cartridges rating: Beta 17=200.
- One (1) pressure metering panel board including:
 - One (1) pressure switch.
 - One (1) pressure gauge (fuel pressure control).
 - One (1) differential pressure switch.
 - One (1) differential pressure gauge for filter clogging monitoring.
- One (1) fuel accumulator.
- One (1) volumetric flow meter with:
 - Two (2) isolating and one (1) bypass valves.
 - Local indication of totalized fuel flow.
 - One (1) pulse transmitter for remote indication.
- One (1) automatic skid outlet stop valve.
- One (1) complete set of piping including valves and fittings of all lines terminating at the skid boundary.
- The electrical equipment is suitable for hazardous area classified Zone 1.
- Insulation and heat tracing if fuel viscosity is lower than 10 cSt at minimum ambient temperature.
- Temperature regulating electrical fuel heater is located close to the filtering skid without its own SCR control panel.

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- Extra painting system for corrosive ambient conditions.
- Pulse transmitter added on the oval wheels fuel totalizer for remote indication of totalized flow or actual flow.

7.5.2.3 Sump Tank

The sump tank allows to drain liquid fuel from the combustion system and from the exhaust plenum in case of false start.

The sump tank is preassembled and includes:

- One (1) steel tank (2 m3 capacity) electrical pump.

7.5.3 Off-Base Closed Cooling Water System

A closed cooling water loop is used to evacuate the heat losses from:

- The lubricating oil circuit common to the Gas Turbine and the Generator.
- The gas turbine atomizing air.
- The generator inner cooling air.

The closed cooling water loop configuration is as follows:

- Generator and gas turbine in parallel.

The Off-Base cooling water system consists of:

- The fin fan coolers which assume heat transfer from closed cooling water to ambient air.
- The expansion tank which ensures minimal pressure at water pump suction and compensates water volume variations due to dilatations and eventual leakage.
- Water pumps to circulate water-cooling.
- The connecting pipes, instrumentation and isolating valves.

7.5.3.1 Fin Fan Coolers

The fin fan coolers consist of one or several modules. The number and length of modules and number of motor-fans are determined according to the site conditions and the Gas Turbine unit working duty.

This thermal design includes an additional capacity of one motor fan in extra for the whole fin fan cooler battery.

The fin fan module is in accordance with the standard noise level.

Each module consists of:

- One heat exchanger battery in horizontal position with fin tubes bundle made of seamless cooper tubes and (in most cases) aluminum fins.

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- Motor fan units normally installed above the heat exchanger and each of them equipped with its own plenum chamber; this configuration is called induced draft. Each fan wheel is directly mounted onto the end shaft motor, the fan blades are made of aluminum.
- Steel support structure.
- Pipes between water headers and heat exchanger equipped with isolating butterfly valves.

The whole set of modules is supplied with:

- Ladders and walkways for access to the motor fan units.
- Cold and hot water headers pipes for interconnection of the required modules and connection with the cooling water circuit.
- Vent piping.
- Instrumentation with:
 - One pressure gouge and one thermometer on the hot water inlet header.
 - One thermometer and one thermocouple on the cold water outlet header.

7.5.3.2 Water Pumps Skid

This skid includes two water pumps (2x100%), i.e. one in service, the other in stand-by.

Each centrifugal type pump is driven by an AC electrical motor through a flexible spacer coupling. Each pump unit is installed on its own steel frame. The suction and discharge flanges of each pump are connected to piping by means of anti-vibrate coupling.

The suction line of each pump includes one isolating butterfly valve and one strainer. The discharge line of each pump includes one isolating butterfly valve and one non-return valve.

Installed in parallel with the pumps, a small pot allows chemicals make up to the cooling water during pump operation.

The common discharge pipe of the water pump skid is equipped with one pressure gauge, one low pressure switch and one orifice plate between flanges (each of them equipped with pressure test point with ball valves).

The pumping module is in accordance with the standard noise level.

7.5.3.3 Atmospheric Expansion Tank

The atmospheric type expansion tank is installed at 6 meters height on its own steel structure support.

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This 0.9 m³ capacity tank is fitted with one local level indicator combined with a low level switch for remote indication and a connection pipe for make up.

7.5.3.4 Pressurized Expansion Tank

The expansion tank is installed at ground level. It is pressurized at 0.6 bar(g) with nitrogen or air.

This 0.75 m³ capacity tank is fitted with:

- One pressure relief valve on N₂ (or air) side.
- One low pressure switch and one pressure gauge on water side.
- One making up connection pipe installed on the linking pipe of the expansion tank.
- Design according to ASME VIII without U Stamp.

7.5.4 Fire Protection

7.5.4.1 General

A high pressure CO₂ bottles system assures the fire protection.

Materials for corrosive site conditions: Nickel for the CO₂ cylinder valves. AISI 316 for the check valves and flexible hoses and aluminum for cylinder supports and weighing system.

Remote weighting device provided.

The equipment will be installed in a container.

The role of the fire protection system is to inject automatically the required quantity of CO₂ into the protected zones to extinguish a fire and to maintain the concentration of CO₂ in these zones at a level high enough to prevent re-ignition of the fire during the cool-down period.

Initiation of the system will automatically trip the unit; provide on alarm, trip ventilation fans and close ventilation openings.

Following zones of the gas turbine are protected.

Zone 1: The internal volume of gas turbine and auxiliaries' compartment.

Zone 2: The internal volume of load compartment.

7.5.4.2 Design Assumptions

The fire protection system is designed in accordance with NFPA 12/2005.

Full compliance with NFPA 12 will be possible provided that:

- Installation and commissioning of the fire protection system, and of other related equipment and systems (including, for example,

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equipment enclosures, ventilation systems, etc.). is carried out in accordance with the corresponding installation and commissioning manuals, and

- Testing of the completed system is carried out in accordance with the relevant specifications, including GE's installation and commissioning manuals which are in accordance with the installation and commissioning requirements of the NFPA 12.

The CO₂ emission is made in 2 steps:

7.5.4.3 Initial Discharge

The system reaches the concentration of CO₂ required by the current standard within the minute after detection of the fire.

7.5.4.4 Extended Discharge

The extended discharge maintains a non-combustible atmosphere during the period of possible fire re-ignition:

7.5.4.5 Scope of Equipment

The main equipment of the gas turbine fire protection system is:

- The CO₂ storage including:
 - High pressure CO₂ bottles.
 - A manifold for each type of discharge.
 - A release system.
- A fire detection system consisting of several thermo switch detectors as follows:

4 detectors 163°C (+8 if ATEX)	Auxiliaries Compartment
6 detectors 316°C	GT Compartment
2 detectors 316°C + 2 detectors 385°C	Load Compartment

The fire protection is automatically released on a two of two voting basis. The fire detectors are arranged in two loops:

- One loop energized: fire pre-alarm.
- Two loops energized: fire alarm, with GT trip and CO₂ release.

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In case of fire being detected by an operator before automatic actuation of the fire fighting, the system can be actuated manually from the CO₂ storage.

The fire protection system can be de-energized during stand-by of the gas turbine for maintenance, etc.

7.5.4.7 Local Fire Protection Panel

The local fire protection panel will be installed in PEECC (operating temperature range = -5 °C/+40 °C).

7.5.4.8 CO₂ Bottle Charge

Double HP CO₂ bottles only for one CO₂ concentration test with cylinder valves not connected.

7.5.5 Water Injection Skid

A pre-assembled water injection skid located near the gas turbine takes water from the customer storage facility and deliver it at the proper pressure and flow rate to the gas turbine for NO_x suppression.

To prevent hot corrosion of the gas turbine blading or turbine fouling, demineralized water must be used.

The water injection skid consists of:

- One (1) AC motor-driven water injection centrifugal pump.
- One (1) control valve.
- One (1) one pump inlet strainer.
- One flow measurement device (flow meter).
- One (1) HP filter (Beta 40 = 75) downstream the pump with diff. pressure switch.
- One solenoid stop valve.
- One (1) on-base return line to the water storage tank.
- The necessary instrumentation: pressure and water flow measurement.

The control of the system is directly depending from the gas turbine control system (SPEEDTRONIC).

7.5.6 Compressor and Turbine Washing

7.5.6.1 Washing Skid

The washing skid is used:

- During normal operation of the unit for washing the compressor and the turbine in case of fouling to restore clean condition performance.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- After a shutdown of the unit when a long period of stand-by is foreseen. The detergent contains elements that prevent corrosion of blades during stand-by periods.

The skid feeds water to the compressor and turbine spray nozzles at a pressure and a flow suitable for the gas turbine supply requirements.

All hot surfaces (tank, on base piping) are insulated for safety reason, except when an enclosure is supplied by GE.

The compressor and turbine washing skid is preassembled and includes:

- One (1) water pump (centrifugal type).
- One (1) strainer upstream the pump.
- One (1) venturi ejector to regulate the detergent flow into the water.
- One (1) detergent tank (content 400 liters) with filling flange and drainage valve and one tube level indicator.
- One (1) detergent flow meter (orifice type).
- One (1) pressure gauge (downstream the pump).
- Two (2) pressure switches (downstream and upstream the pump).
- One (1) water flow switch.
- One (1) solenoid valve on the detergent line.
- One (1) terminal board and electrical panel (for feeding of the pump).

7.5.6.2 Wash Water Tank

One (1) wash water tank (20 m³ capacity), made of stainless steel (AISI 304L) Including:

- Three (3) heaters (3 x 54 kW) for water heating.
- A thermo-switch.
- One (1) low level switch.
- One (1) tubular level indicator.
- One (1) vent.
- One (1) filling flange.
- One (1) drainage valve.
- One (1) temperature gauge.
- Complete set of piping including valves, gauges, end fittings of all lines terminating at the skid flanges.

7.5.7 Air Processing Unit

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Each Gas Turbine is supplied with an air processing unit, located close the GT, which is designed to supply compressed air to the GT's self-cleaning air filter.

It includes:

- Air processing unit with adsorption air dryer.
- The air cooler cools the compressed air coming from the GT when the GT is in operation or from an auxiliary air compressor when the GT is shutdown. The adsorption air dryer dries the compressed air and the compressed air tank stores the compressed air.
- Extra painting for corrosive ambient conditions.
- Air Processing Unit in container 10 feet.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8. GE Generator Type 9A5 (Elin)

8.1 General Information

- Totally enclosed water-to-air-cooled (TEWAC) generator
- Outdoor installation
- 50 Hz generator frequency
- Generator voltage 15.0 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.
 - Titling pad bearings.
 - Roll our bearing capability without removing rotor.
 - Insulated collector end bearing.
 - Offline bearing insulation check with isolated rotor.
- Monitoring Devices:
 - Provision for key phasor-generator.
 - Permanently mounted flux probe (stator wedge).
 - Proximity vibration probes: Two probes per bearing at 45 angle.
- Generator Field.
 - Direct cooled field.
 - Two-pole field.
 - Finger type amortisseurs.

8.2 Generator Gas Cooler

- Cooler assembly shipped separate
- Generator gas cooler configuration
 - Two (2) horizontally mounted duplex coolers.
 - Coolers located on generator roof.
 - Cooler piping connections on left side as viewed from collection.
End.
 - ASME code stamp.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Single wall cooler tubes.
- Raised cooler face flanges.
- Plate fins.
- Generator gas cooling system characteristic
 - Coolant temperature: 20°F approach
 - Generator capacity with one section out of service 100% with Class "F" rise
 - TEMA class C coolers
 - Maximum cooler pressure capability – 125 psi
 - Coolant 100% fresh water
 - Fouling factor 0.001
- Generator gas cooler construction materials
 - 90-10 copper-nickel tubes
 - Carbon steel tube sheets
 - Carbon steel water box and coupling flanges with epoxy coating
 - Aluminum cooler tube fins

8.3 Generator Lube Oil Systems and Equipment

- Bearing lube oil system:
 - Generator lube oil system integral with turbine.
 - Pre-fabricated factory fitted lube oil pipe.
 - Sight flow indicator.
- Lube oil System piping materials:
 - Stainless steel lube oil feed pipe.
 - Stainless steel lube oil drain pipe.
 - Welded oil piping.

8.4 Generator Temperature Devices

- Stator winding temperature devices:
 - 100 ohm platinum RTD's (resistance temperature detector).
 - Dual element RTDs.
 - Ungrounded RTDs.
 - Six (6) stator slot RTDs.
 - Six (6) extra stator RTDs in separate slots.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Stator core thermocouples.
- Gas path temperature devices:
 - 100 ohm platinum RTDs.
 - Dual element temperature sensors.
 - Two (2) cold gas.
 - Two (2) hot gas.
- Bearing temperature devices:
 - 100 ohm platinum RTDs.
 - Dual element temperature sensors.
 - Two (2) bearing metal temperature sensors per bearing.
- Collector temperature devices:
 - 100 ohm platinum RTDs.
 - Dual element temperature sensors.
 - Collector air outlet temperature sensors.
- Lube oil system temperature devices:
 - 100 ohm platinum RTDs.
 - Dual element temperature sensors.
 - One (1) bearing drain temperature sensor per drain.

8.5 Generator Packaging, Enclosures, and Compartments

- Paint and preservation:
 - Epoxy based primer.
 - Terminal enclosure shipped separate.
- Collector compartment / enclosures:
 - Collector compartment / enclosure shipped installed.
- Foundation hardware:
 - Generator shims and plates.
 - Generator centerline alignment guide.
 - Generator alignment key(s) – collector end.
 - Generator alignment key(s) – turbine end.

8.6 Electrical Equipment

- Motors:
 - TEFC motors.

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- Coated with antifungal materials for protection in tropical areas.
- Energy saver motors.
- Extra severe duty motors.
- Cast iron motor housings.
- Heaters
 - Generator stator heaters.
 - Terminal enclosure heaters.

8.7 Generator Protection against Sand and Noise

- Acoustical ventilated package.

8.8 Description of the Type 9A5 Generator

This description is generic and could be adapted depending of the project particularities.

8.8.1 Electrical Rating

The generator is designed for continuous operation. The generator is constructed to withstand per ANSI or IEC standards, without harm, all normal conditions of operation, as well as transient conditions such as system faults, load rejection and mal-synchronization.

The armature and field windings of the generator are designed with insulation systems that are proven Class "F" materials.

Temperature detectors installed in the generator permit the measurement of the stator winding and gas temperatures. The temperature rise limits, per ANSI or IEC standards (as applicable), will be limited to the following, throughout the allowable operating range:

- Class "B" temperature rise limits.

The generator is designed to exceed the turbine capability as stated in the performance section of this proposal.

8.8.2 Packaging

The generator is a three phase, synchronous machine designed for compactness and ease of service and maintenance. The machine is designed for continuous operation at rated conditions as well as providing maximum protection against damage due to abnormal operating conditions, per ANSI or EIC standards.

Location permitting, the generator will be shipped with the major components factory assembled:

- Generator rotor.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- End shields.
- Collector compartment.

The following items will ship separate for assembly to the generator at the Customer's site:

- Monitor brush rigging.

All generator wiring, including winding and gas Resistance Temperature Detectors (RTDs), bearing metal and drain temperature detectors (as applicable), and vibration detection systems are terminated on the main unit with level separation provided.

- Feed piping between the bearings is stainless steel and mounted on the units to a common header.

8.8.3 Terminal Arrangement

All lead connections terminate at the excitation end of the generator, Customer line connections and the generator neutral tie make-up is made external to the main generator stator frame.

The main armature leads are brought out of the upper side portion of the stator and are suitable for connection to bus bars. The leads exit the frame through insulated terminal plates, which clamp and support the leads. Line leads exit either the left or right side with the neutral leads exiting the opposite side

8.8.4 Generator Stator

8.8.4.1 Stator Frame Fabrication

The stator frame is a simple structure, designed to support the stator core and winding, while providing guidance to the airflow in the machine. The combined core and frame are designed to have a 4-nodal natural frequency well removed from 100 Hz or 120 Hz.

A series of floating support rings and core rings are welded to key bars which in turn support the core, allowing the entire core to be spring mounted. This arrangement isolates the core vibration, resulting from the radial and tangential magnetic forces of the rotor, by damping the amplitude and reducing the transmissibility by 20.1. Excessive movement of the core, as may result from out of phase synchronization, is limited by the use of stop collars at certain circumferential locations around the frame. The clearance is designed to allow the spring action of the bar to be unrestricted during normal operation but to transmit the load of excessive movement through the structure prior to yielding of any of the components. This entire arrangement is in keeping with long standing practices and experience with similar frame designs that have proven to be very effective and reliable.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8.8.4.2 Stator Core

The core is constructed from laminated, silicon steel. The laminations are coated on both sides to ensure electrical insulation and reduce the possibility of localized heating resulting from circulation currents.

The overall core is designed to have a natural frequency in excess of 170 Hz, well above the critical two-per-rev electromagnetic stimulus from the rotor. The axial length of the core is made up of many individual segments separated by radial ventilation ducts. The ducts at the core ends are made of stainless steel to reduce heating from end fringing flux. The flanges are made of cast iron to minimize losses. To ensure compactness, the unit receives periodic pressing during stacking and a final press in excess of 700 tons after stacking.

8.8.4.3 Armature Winding

The armature winding is a three phases, two circuit design consisting of "Class F" insulated bars. The stator bar stator ground insulation is protected with a semi-conducting armor in the slot and well proven voltage grading system on the ends arms.

The ends of the bars are pre-cut and solidified prior to insulation to allow strap brazing connections on each end after the bars are assembled.

The bars are secured in the slot with side ripple springs (SRS) to provide circumferential force and with a top ripple spring (TRS) for additional mechanical restraint in the radial direction. The end winding support structure consists of glass binding bands, radial rings, and the conformable resin-impregnated felt pads and glass roving to provide the rigid structure required for systems electrical transients.

8.8.4.4 Ventilation

The generator is cooled by an internally re-circulating gas stream that dissipates generator heat through gas-to-water heat exchangers. The ventilation system is completely self contained, including the gas coolers within the structure.

Ventilation fans are mounted at each end of the rotor. The fans provide cooling gas for the stator winding and core. Cooling of the stator core is accomplished by forcing gas through the radial ducts formed by the space blocks in the punching. The axial length of the core is made up of many individual segments separated by the radial ventilation ducts. This arrangement results in substantially uniform cooling of the windings and core.

The rotor winding, which is a directly cooled radial flow design, is self-pumping and does not rely on the fan for airflow. The rotor is cooled externally by the gas flowing along the gap over the rotor surface, and internally by gas that flow through sub slots under the field coils within the

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

rotor body and passes directly through cooling ducts in the copper coils and wedges.

After the gas has passed through the generator, it is then directed to two duplex horizontally mounted gas-to-water heat exchangers. After the heat is removed, cold gas is returned and re-circulated.

Water inlet, outlet and vent pipe connections for the generator cooler are made externally to the machine. The method of sealing is such that the water boxes and covers can be removed to clean a cooler without opening the generator ventilation circuit.

8.8.5 Rotor

The rotor is machined from the single-piece, high-strength alloy steel forging. The retaining ring is nonmagnetic 18 Cr 18 Mn stainless steel for low losses and high stress-corrosion resistance. The ring is shrunk onto the rotor body, thus eliminating any risk of top turn breakage. A snap ring is used to secure the retaining ring to the rotor body, which minimizes the stresses in the tip of the retaining ring. An illustration of the rotor is provided below.

Axial slots are machined radially in the main body of the shaft to locate and retain the coils. The axial vent slots machined under the main coils slots are narrower than the main slots and provide the direct radial cooling of the field copper.

Depending on the design, wedges may be stainless steel, or a combination of aluminum, stainless steel, and magnetic steel.

8.8.5.1 Field Assembly

The field consists of several coils per pole with turns made from high conductivity copper. Each turn has slots punched in the slot portion of the winding to provide direct cooling of the field.

The slot armor used in the slots is a Class "F" rigid epoxy glass design, and insulated covers is positioned at the bottom of each slots armor and on top of the sub slot. The cover will provide the required creep age between the lower turns and the shaft. Epoxy glass insulation strips are used between each coil turn. A pre-molded glass retaining ring insulation is utilized over the end windings and a partial amortisseur is assembled under the rings to form a low resistance circuit for eddy current to flow.

The entire rotor assembly is balanced up to 20% over operating speed.

The rotor slot armor, and all the insulation materials in contact with the winding, are full class "F" materials and are proven reliable materials through use on other generator designs.

8.8.6 End Shield Bearings

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

The lower halves of the bearings are equipped with dual elements temperature detectors. Provisions for both velocity type vibration sensors and proximity probes are included.

The bearings at the exciter end of the generator are electrically insulated from the generator frame to prevent the flow of shaft current.

8.8.7 Lubrication System

Lubrication for the generator bearings is supplied from the turbine lubrication system. Generator bearings oil feed and drain interconnecting lines are provided, and have a flanged connection at the turbine end of the generator package for connection to the turbine package.

8.8.1 Jacking Oil System

On a generator of this size, the breakaway torque required to set the rotor in motion is high, and excessive wear can take place on regular starting on low speed barring. To minimize this, a very high-pressure oil supply is provided at the bottom of each bearing to jack up the rotor and establish an oil film before the normal hydrodynamic effect takes over. This jacking oil supply, taken from the main oil feed pipe to the bearings, is provided by two positive displacement pumps, mounted in tandem and driven by a single electric motor.

8.8.2 Brushless Exciter

The generator is fitted with a brushless excitation system. The brushless exciter consists of a three phase, rotating armature, alternating current generator, with a shaft mounted fused rotating rectifier. The field winding is stationary. The brushless concept enables the exciter output to be connected to the generator field without the use of commutators, brush gear or slip rings.

The armature core is build up from insulated circular laminations of electrical steel. These are clamped between end rings that are securely keyed and shrunk on the exciter shaft. The armature windings comprise pre-formed copper bar type coils retained by fully cure glass fiber bands. The armature outputs is three phase, the three terminals being connected to a full wave rectifier bridge (the rotating rectifier).

The rotating rectifier assembly is made up of insulated high-grade aluminum heat sinks. On these are mounted six anode based diodes and six cathode based diodes, two in parallel in each arm of the three phase bridge. A fuse is connected in series with each diode to ensure that any arm of the bridge containing a short circuited diode becomes open circuit, thus averting a short circuit on the exciter winding. The positive and negative dc outputs from the bridge are connected to the generator main field winding by copper connectors from the fuses. The rating of the rotating rectifier and armature is such that a full load rotor current supplied with one are of the three phase bridge inoperative. A failure would be identified by a brush continuous

**Draft Technical Specifications for GE Frame PG9171E Gas
Turbine Generator and direct Auxiliaries and Limits of Supply**

monitoring system, so that the circuit could be shut down and the fault corrected at the first convenient opportunity.

The exciter magnet frame is formed from heavy rolled steel plate. Copper strip would field coils are resin bonded to laminated pole bricks which are bolted to the magnet frame.

8.8.3 Generator Field Ground Fault Detector

This device mounted on the brushless exciter which detects possible faults between generator field winding or exciter rotor and ground. It consists of transmitter mounted on the exciter diode bridge assembly and receiver (stationary) mounted on the exciter frame. The transmitter monitors the leakage current from the generator field/exciter rotor to ground. If the leakage current exceeds alarm level indicating a ground fault. The transmitter and sends alarms signal to the receiver. The receiver then sends a ground fault alarm to a remote monitoring device for annunciation and protective action.

Attached: 9A5 Generator Curves.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8. Generator Type BDAX9 (Brush)

8.1 General Information

- Reference norm: IEC 60034.
- Generator construction IM1005.
- IP 55 according IEC 60034.5.
- Totally enclosed water-to-air cooled (TEWAC IC 8A1 W7) generator.
- Outdoor installation.
- 50 Hz generator frequency.
- Generator voltage 15.0 kV.
- 0.85 power factor (lagging).
- Class “F” armature and rotor insulation.
- Class “B” temperature rise, armature and rotor winding.
- Seismic zone:
 - Horizontal acceleration: 0.4 g.
 - Vertical acceleration: 0.2 g.
 - UBC 1997 zone 4.
- Generator bearings:
 - End frame bearing support.
 - Tiltling pad bearings.
 - Roll our bearing capability without removing rotor.
 - Insulated bearings at drive end and non drive end.
- Monitoring Devices:
 - Seismic vibration detectors.
 - Two detectors at drive end, one at non drive end.
- Generator Field:
 - Indirectly cooled field.
 - Two-pole field.
 - Fully interconnected amortisseur winding.
- Bearing Protection:
 - Rotor shaft earthing brush in DE bearing housing.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8.2 Generator Gas Coolers

- Cooler assembly shipped separate.
- Generator gas cooled configuration:
 - Four (4) vertically mounted coolers.
 - Coolers located on generator roof.
 - Single wall cooler tubes.
 - Raised cooler face flanges.
 - Plate fins.
- Cooling water lead detectors:
 - 2 floats switches mounted at stator side.
- Generator gas cooling system characteristics:
 - Generator capacity with one section out of service 100% with Class "F" rise.
 - Working cooler pressure – 6 bar.
 - Design cooler pressure – 6.9 bar.
 - Test cooler pressure – 9 bar.
 - Coolant – water, containing up to 100% fresh water.
 - Fouling factor 0.00009 m²*K/W (0.0005 hr*°F*ft² / BTU).
- Generator gas cooler construction materials:
 - 90/10 copper – nickel tubes.
 - Carbon steel tube plates with epoxy or polyamide coating.
 - Carbon steel water box and coupling flanges with epoxy or polyamide coating.
 - Aluminum cooler tube fins.

8.3 Generator Lube Oil Systems and Equipment

- Bearing lube oil system:
 - Generator lube oil system integral with turbine.
 - Pre-fabricated factory fitted lube oil pipe.
 - Sight flow indicator.
- Lube oil system piping materials:
 - Stainless steel lube oil feed pipe.
 - Carbon steel lube oil return pipe.
- Lube oil system pressure monitoring:

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Two (2) low oil pressure switches.
- Jacking oil system pressure monitoring:
 - Two (2) pressure switches.
 - Two (2) oil pressure relief valves.
- Lube oil connection:
 - Left side of the generator view from DE.

8.4 Generator Temperature Devices

- Stator winding temperature devices:
 - 100 ohm platinum RTDs (resistance temperature detector).
 - Single element RTDs.
 - RTDs fitted with over voltage protection.
 - Nine (9) stator slot RTDs (+three(3) in spare).
- Gas path temperature devices:
 - 100 ohm platinum gas path RTDs.
 - Dual element temperature sensors.
 - Two (2) cold gas.
 - One (1) hot gas.
- Exciter temperature devices:
 - 100 ohm platinum RTDs.
 - Dual element temperature sensors.
 - One (1) exciter air outlet temperature sensor.
- Bearing temperature devices:
 - 100 ohm platinum gas path RTDs.
 - Dual element temperature sensors.
 - Two(2) bearing metal temperature sensors per bearings.
- Lube oil system temperature devices:
 - 100 ohm platinum gas path RTDs.
 - Dual element temperature sensors.
 - One (1) bearings drain temperature sensors per drain.

8.5 Generator Packaging, Enclosure, and Compartments

- Paint and preservation:
 - Finish painted for use in non corrosive environment.

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- Exciter enclosure:
 - Exciter enclosure for brushless exciter.
- Foundation hardware:
 - Generator shims.
 - Generator anchor pin – drive end.
 - Generator guide block – non drive end.

8.6 Electrical Equipment

- Lighting:
 - AC and DC (emergency)lights mounted on generator.
- Sockets outlets:
 - Mounted on generator.
- Heaters:
 - Generator stator heaters.
- Field earth fault monitor:
 - Generator mounted, Brush PRISMIC R10 rotor earth fault monitor.
- Jacking oil system pump motor:
 - 18.5 kW, 1,450 rev/min, 400 Volt, 3 phase, 50 Hz induction motor.
(one AC motor for two pumps).
 - Manifold assembly.
- Generator power outgoing:
 - GNAC left side view from NDE.
 - GLAC right side view from NDE.
- Rotor withdrawal / insertion equipment (one per site).

8.7 Generator Protection against Sand and noise

- Acoustical ventilated package.

8.8 Description of the Type BDAX9 Generator

This description is generic and could be adapted depending of the project particularities.

8.8.4 Electrical Rating

The generator is designed for continuous operation. The generator is constructed to withstand per IEC standards, without harm, all normal

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conditions of operation, as well as transient conditions such as system faults, load rejection and mal-synchronization.

The stator winding and field windings of the generator are designed with insulation systems that are proven Class "F" materials.

Temperature detectors installed in the generator permit the measurement of the stator winding and gas temperature. The temperature rise limits, per IEC standards, will be limited to the following, throughout the allowable operating range

- Class "B" temperature rise limits.

The generator is designed to exceed the turbine capability as stated in the performance section of this proposal.

8.8.5 Packaging

The generator is a three phase, synchronous machine designed for compactness and ease of service and maintenance. The machine is designed for continuous operation at rated conditions as well as providing maximum protection against damage due to abnormal operating conditions, per IEC standards.

The generator has the following features:

- Simple foundation design for economic and speedy civil work.
- Minimum number of individual power station components, offering substantial saving on expensive site time.
- All units are fully factory tested, reducing commissioning to proving interconnections and combined turbine / generator testing.
- Modular construction giving a fine balance between flexibility and standardization of components for fast economic construction.

Location permitting, the generator will be shipped with the major components factor assembled:

- Generator rotor.
- End frames.
- Brushless exciter.

All generator wiring, including winding and gas resistance temperature detectors (RTDs), bearings metal and drain temperature detectors (as applicable), and vibration detection systems are terminated on the main units with level separation provided.

- Feed piping between the bearings is mounted on the units to a common header.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8.8.6 Terminal Arrangement

All lead connection terminates at the excitation end of the generator. Customer line connections and the generator neutral tie make-up are made external to the main generator stator frame.

The main stator winding leads are brought out of the upper side portion of the stator and are suitable for connection to bus bars. The leads exit the frame through insulated bushings. Line leads exit either the left or right side with the neutral leads exiting the opposite side.

8.8.7 Generator Stator

8.8.7.1 Stator Frame Fabrication

The stator frame is a rigid, box frame structure, designed to support the stator core and winding, while providing guidance to the airflow in the machine. The combined core and frame are designed to have a 4 nodal natural frequency well removed from 100 Hz or 120 Hz.

The stator frame is fabricated from mild steel plate, with mounting pads at appropriate points on the underside. Holes are provided in each pad for foundation bolts. There is a single location pin at drive end and a guild block at the exciter end.

8.8.7.2 Stator Core

The core is build up from segmented lamination of low-loss, high permeability, high silicon content electrical steel. The lamination of the core are located by means of "dovetail" profile key bars, bolted to suitably placed members of the stator frame. The insulated steel laminations are debarred to minimize interlaminar contact and restrict eddy current losses.

Radial ventilation ducts are formed at intervals along the core by "H" section steel spacers. The spacers extend to the end of the slot teeth to increase tooth rigidity.

The core is hydraulically pressed at predetermined stages during the building operation to ensure uniform compaction, the pressure being carefully monitored.

The finished core is clamped between heavy endplates which are located by keys inserted in slots in the stator frame members whilst the core is under pressure. Substantial non-magnetic tooth supports transmit the pressure from the endplates to the stator teeth. The end plate and tooth supports are formed in a single cast unit, using a non-magnetic alloy.

8.8.7.3 Stator Winding

The stator winding is of the three phase, two-layer diamond type, half coils being used for ease of handling during manufacture and winding.

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To satisfy the electrical design requirements, the winding may be of the single or multiple conductor type, with parallel connections where necessary.

In order to minimize eddy current losses, each conductor is subdivided into appropriate size strands which are insulated from each other by lapped layers of resin impregnated glass tape and fully transposed to minimize circulating currents. Transpositions of the Roebel type, within the lots, are used.

The insulation system is based on a resin rich mica glass tape which, when processed, results in a high performance insulation capable of continuous operation at temperature up to 155 °C (Class F).

The insulation possesses high dielectric strength and low internal loss. The resin system is thermo setting so that the resulting insulated coil sides are dimensionally stable. Additionally, it is highly resistant to most of the common electrical machine contaminants such as hydrocarbons, acids, alkalis and tropical moulds.

The insulated copper strands are cut to lengths, stacked together and the coil ends formed into the required end winding shape on a jig. They are then clamped tightly together, taped with an initial layer of tape and hot pressed to consolidate the conductor stack. Following this, the main insulation is applied and pressed to size. The amount of the compression is carefully controlled to ensure correct resin flow and produce a consistent high standard of void free insulation.

Each finished half coil is subjected to dimensional checks to ensure that a correct fit in the stator slot is achieved. To prevent the possibility of insulation damage due to corona discharge in the slots, the surface of the coil in contact with the core is made conductive by the application of a graphite impregnated polyester tape. A silicon carbide impregnated polyester tape is applied to the coil surface immediately outside the slot to control the voltage gradient in this region.

The half coils are placed in the stator slots in two layers and wedged securely in position by polyester glass wedges prior to connection of the end winding. The end winding is securely braced to insulated support boards bolted to the core endplate. Spacer blocks are fitted between adjacent coil sides to produce a strong arch bound, yet resilient, composite structure, capable of withstanding the forces that could arise in the event of an accidental short circuit.

Finally, the completed stator is heated in an oven to fully cure the insulation. Resistance temperature detectors are embedded in the windings at selected points, and anti-condensation heaters are fitted in the stator frame.

Graded high voltage tests are carried out at stages during manufacture of the coils and assembly of the winding. This ensures a high standard of insulation and also that any faults are detected at the earliest possible stage.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

8.8.7.4 Ventilation

The generator is cooled by air in a closed air circuit configuration, where the hot exhaust air is cooled by a secondary coolant before being returned to the inlet. The secondary coolant is water, containing ethylene glycol according to site conditions.

Cooling air is forced around the generator by means of two axial flow fans mounted on the rotor shaft. The stator core has radial ventilating ducts at intervals along the core. The generator is too long for the stator cooling air requirements to be supplied by simple air gap flow, and this is overcome by arranging radial inward flow of air over sections of the stator to provide adequate airflow over the entire core length. To achieve this, the space behind the stator core is divided into five compartments. The first, third and fifth compartments are open at the top, forming the air exhaust flanges. The second and fourth compartments are sealed at the outside, but are connected to the stator end winding compartments by ducts through which they are fed with cool air in parallel with the air gap.

The rotor is cooled by air flowing under the rotor end caps, past the end winding and through axial cooling slots (interslots) between the winding slots. Exhaust ducts in the closing wedges of the interslots allow the air to escape at the centre of the rotor. In addition to the interslots, the rotor also incorporates cooling slots (sub slots) beneath the winding slots. The cooling air escapes from the sub slots through the radial exhaust ducts along the length of the winding. Rotors with sub slot cooling have independent cooling air paths over the end winding to minimize the temperature gradient across the winding.

On a closed air circuit water cooled generator, cooling is accomplished by means of water cooled heat exchangers containing tube nests which are arranged to permit cleaning in situ. But which can be easily removed for maintenance if required. The tube nests are complete with flanges for connection to the customer's water supply and are arranged to permit full load operation with one or more tube nests inoperative. The tube nests are mounted in sheet steel housing on top of the generator.

8.8.8 Rotor

The rotor is manufactured from a one-piece forging of nickel chromium molybdenum alloy steel which is de-gassed and vacuum poured to obtain a uniform material which has excellent tensile properties. The manufacture of the forging is closely supervised by the forge master to an agreed quality control procedure, including checks for freedom from porosity and for mechanical and thermal stability.

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The standard forging materials is suitable for use in ambient temperature down to minus 20°C. In situations where the rotor may be subjected to lower temperature, special materials are available.

Axial slots, to carry the windings and for ventilation, are milled on the periphery of the body of the rotor. Axial grooves are milled along the top of both winding and ventilation slots to hold the slot closing wedges. At the exciter end, a hole is bored along the axis of the shaft to take the leads from the main exciter to the rotor field winding. The connection to the rotor winding is brought from the bore by radial copper studs.

Bearing journal are machined to exacting tolerance, and tracks for non-contacting vibration probes are accurately machined and “de-glitches” to minimize magnetic run-out.

The drive coupling is shrink and doweled fitted to an accurate surface machined to accept it.

The rotor winding conductor materials is high conductivity copper/silver alloy strip. The pre-formed coils are inserted into the slots, each turn being insulated from the next. The class “F” insulation system is moisture resistant, shockproof and capable of withstanding the high mechanical forces to which it will be subjected. After completion of the winding, the conductors are heated electrically and pressed to the correct depth using pressing rings. The conductors are held in place by aluminum alloy retaining wedges, which are connected together at each end by copper quarter-rings to form a fully interconnected damper winding.

The rotor end winding is braced with packing blocked between the conductors and is wrapped with insulation, after which the rotor end caps are fitted. The end caps, which retain the rotor end winding, are manufactured from austenitic non-magnetic 18/18 manganese chromium steel which is cold expanded during manufacture to produce the high mechanical strength required. The end caps are shrink fitted to spigots at each end of the rotor body.

All completed rotor are tested in the Company’s rotor overspeed test facility, which is equipped with comprehensive monitoring equipment. The rotor is first given a low speed balance and is then overspeed to 20% above its normal operating speed for two minutes. The rotor is then heated to its maximum operating temperature, check balance and the overspeed test repeated. Finally, the balance at normal running speed is checked.

Balance adjustment planes are provided in the rotor body itself, in the ventilating fan rings and in the main exciter diode carrier fan hub.

Following overspeed testing, the rotor is subjected to high voltage tests to prove the integrity of the insulation systems.

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The lower halves of the bearings are equipped with dual elements temperature detectors. Provision for both velocity type vibration sensors and proximity probes are included.

Both bearings are electrically insulated from the generator frame to prevent the flow of shaft currents.

8.8.10 Lubrication System

Lubrication for the generator bearings is supplied from the turbine lubrication system. Generator bearing oil feed and drain interconnecting lines are provided, and have a flanged connection at the turbine end of the generator package for connection to the turbine package.

8.8.11 Jacking Oil System

On a generator of this size, the breakaway torque required to set the rotor in motion is high, and excessive wear can take place on regular starting on low speed barring. To minimize this, a very high-pressure oil supply is provided at the bottom of each bearing to jack up the rotor and establish an oil film before the normal hydrodynamic effect takes over. This jacking oil supply, taken from the main oil feed pipe to the bearings, is provided by two positive displacement pumps, mounted in tandem and driven by a single electric motor.

8.8.12 Brushless Exciter

The generator is fitted with a brushless excitation system. The brushless exciter consists of a three phase, rotating armature, alternating current generator, with a shaft mounted fused rotating rectifier. The field winding is stationary. The brushless concept enables the exciter output to be connected to the generator field without the use of commutators, brush gear or slip rings.

The armature core is build up from insulated circular laminations of electrical steel. These are clamped between end rings that are securely keyed and shrunk on the exciter shaft. The armature windings comprise pre-formed copper bar type coils retained by fully cure glass fiber bands. The armature outputs is three phase, the three terminals being connected to a full wave rectifier bridge (the rotating rectifier).

The rotating rectifier assembly is made up of insulated high-grade aluminum heat sinks. On these are mounted six anode based diodes and six cathode based diodes, two in parallel in each arm of the three phase bridge. A fuse is connected in series with each diode to ensure that any arm of the bridge containing a short circuited diode becomes open circuit, thus averting a short circuit on the exciter winding. The positive and negative dc outputs from the bridge are connected to the generator main field winding by copper connectors from the fuses. The rating of the rotating rectifier and armature is such that a full load rotor current supplied with one are of the three phase bridge inoperative. A failure would be identified by a brush continuous

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monitoring system, so that the circuit could be shut down and the fault corrected at the first convenient opportunity.

The exciter magnet frame is formed from heavy rolled steel plate. Copper strip would field coils are resin bonded to laminated pole bricks which are bolted to the magnet frame.

8.8.13 Generator Field Ground Fault Detector

This device mounted on the brushless exciter which detects possible faults between generator field winding or exciter rotor and ground. It consists of transmitter mounted on the exciter diode bridge assembly and receiver (stationary) mounted on the exciter frame. The transmitter monitors the leakage current from the generator field/exciter rotor to ground. If the leakage current exceeds alarm level indicating a ground fault. The transmitter and sends alarms signal to the receiver. The receiver then sends a ground fault alarm to a remote monitoring device for annunciation and protective action.

Attached: BDAX9 Generator Curves

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

9. Description of Off-Base Electrical Auxiliary

9.1 Generator Accessory Compartment

9.1.1 GNAC (Generator Neutral Accessory Compartment)

The GNAC is designed for outdoor operation (IP 54).

Low voltage wiring for power and instrumentation are terminated on terminal boards located in a separated junction box accessible by means of doors.

Anti-condensation heaters are provided.

9.1.2 Generator Star Point Grounding

The generator star point is grounded through a resistor limiting the current to 10 Amp for 30 seconds.

One current transformer associated with generator ground fault relay is supplied:

- Primary 5 Amp.
- Secondary 1 Amp class 1.

9.1.3 Measurement of the Stator Currents

Each bar is equipped with current transformer(s), encapsulated primary traversing bar type rated, 17.5 kV insulating class, having the following characteristics:

- 8000/ 1/1 Amp, PX Class for protections, differential generator protection and if applicable generator block protection.

9.1.4 GLAC (Generator Line Accessory Compartment)

The GLAC is designed for outdoor operation (IP 54).

It includes the necessary components for the following functions:

- CT's and VT's for generator monitoring and protection.
- Surge capacitors and lightning arrestors.

Low voltage wiring for power and instrumentation are terminated on terminal boards located in a separated box (including the MCB's for voltage measuring protection) accessible by means of doors.

Anti-condensation heaters are provided.

9.1.5 Measurement of the Stator Currents

Each bar is equipped with current transformer(s), encapsulated primary traversing bar type rated, 17.5 kV insulating class, having the following characteristics:

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- 000/1/1 Amp class 0.2 for metering and voltage regulation and PX class for generator differential protection.

9.1.6 Generator Voltage Measurement

This function is performed by means of one set of three single voltage transformers encapsulated with two secondary windings fix type having an insulating class of 17.5 kV. These voltage transformers are protected by MCB's at their secondary side.

They have the following characteristics:

- Primary (generator rated voltage/ $\sqrt{3}$) Volt.
- Secondary ($100/\sqrt{3}$) Volt.
- Class 3P for the generator protective relays.
- Class 0.2 for metering, synchronization and AVR.

9.1.7 Generator Surge Protection

One set of three lightning arrestors (metal oxide) and three surge capacitors are provided, having the following characteristics:

- Lightning arrestors:
Standard: JEC 60099.4.
Type: Continuous operating voltage.
Rated voltage: adopted to the voltage on duty.
Nominal discharge current 10 kA.
- Surge capacitors:
Type: single phase. Stationary, indoor use.
Rated voltage: 17.5 kV.
Capacity. 0.25 μ F.

9.1.8 GLAC Outgoing

The GLAC is designed for a connection to the circuit breaker or to the transformer terminals by means of metal enclosed bus.

9.1.9 Others

The 3 phases are segregated by means of metal sheets.

9.1.10 Non Segregated Medium Voltage Bus Ducts between Generator and GLAC/GNAC

The connection from generator to the GNAC and GLAC is made by means of bus ducts.

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The bus ducts are of rectangle type, enclosed current conductor with air insulation and with supporting elements which have high mechanical and electro insulating resistance.

Each conductor is simple-supported (it is enable to perform longitudinal movements) by cost resin insulators. The enclosure is made of aluminum and the electrical conductor's are mode of aluminum or copper.

The enclosure could be supported by adequate support or self-supported. If there is on acoustical enclosure, its structure could also be used as support.

- The bus duct basis rated as follows:
 - Nominal voltage: 15 kV.
 - Rated insulation level: 17.5 kV.
- Power frequency withstand for one minute: 38 kV rms.
- Basic impulse level BIL (wove 1,2/50) 95 kV peak Rated current (In) 8000A at 30 °C.
- Short circuit current (thermal withstand) main connection: 80 kA rms 1 sec.
- Short circuit current (mechanical withstand) main connection: 200 kA peak.

9.1.11 Starting Motor MV Cell

The starting motor cell is an electrical cubicle for GT electrical MV starting motor (88CR). It includes:

- A standout metal enclosure.
- A withdrawable device managed by the SPEEDTRONIC.
- An earthing switch.
- Anti-condensation heater.
- Motor protection relay with associated CTs.

Mechanical characteristic:

- IP 30 (for indoor installation).
- Approximate dimensions:
 - Width: 800 mm.
 - Depth: 1,880 mm.
 - Height 2,30 mm.
- Approximate Weight: 1,200 kg
- MV Incoming connection by bus bars by others.

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- MV Outgoing connection by cables by others.

Electrical characteristics:

- Rated voltage: +1- 5% adapted to the starting motor (refer to single line diagram).
- Rated frequency 50Hz +/-2%.
- Rated current: adopted to the starting motor (refer to single line diagram).
- Maximum short circuit current: 25kA, 3 sec.
- 125 V DC for the auxiliary voltage.
- 230 V AC for heaters.

9.2 Description of the Cabling Systems

9.2.1 Cabling System between GTG, Modules, GT MCC and Supplied Cubicles

The cabling system consists of:

- Power cables with connection fittings (glands, terminals, ...)
- Control and measure / instrumentation and data processing cables with connection fittings (glands, terminals,..)

All cables will be in accordance with IEC standard suitable for outdoor use (protective sheath UV stabilized). All cables will be hydrocarbon resistant, flame retardant (according to IEC 6033 2-1) and low smoke (IEC 61034) and water resistant AD7 (temporary submerged IEC 60529).

Cable installation and segregation principles:

All the cables will be suitable to be laid in embedded PVC ducts and on some additional cable trays at the junction of the cable pits and the equipment, as well as on some structures such as air filter or stack

9.2.2 LV Power Cables

LV power cables will have a minimum cross section of 2.5 mm².

- Standard: IEC 60502-1, IEC 60228.
- Cable type: XLPE/PVC power cable rated voltage 0,6/1kV
- Insulation: Cross link polyethylene (XLPE).
- Conductors: Plain copper stranded according to IEC 60228 class 2.
- Identification: Manufacturers standard.

9.2.3 Control Cables

Control cables will have a minimum cross section of 1.5 mm².

- Standard: IEC 60502/1, IEC 60228.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Cable type: XLPE/PVC control cable rated voltage 500 V.
- Insulation: Cross link polyethylene (XLPE).
- Conductors: Plain copper stranded according to IEC 60228 class 2.
- Identification: 1 to 5 cores: supplier standard, 6 and more cores: black cores numbered from 1 to n-1 (the last core being green/yellow).

9.2.4 Measuring, Instrumentation Cables (except Thermocouple Extension Cables)

Measuring/instrumentation cables will have a minimum cross section between 0.75 and 1 mm².

- Standard: IEC 60228.
- Insulation: Polyethylene (PE) or cross-linked polyethylene (XLPE).
- Conductors: Stranded Plain copper.
- Identification: Manufacturers standard.

9.2.5 Thermocouple Extension Cables

The thermocouple extension cables will have a cross section of 1 mm² (single pair cable) and 0.5 mm² (multi pair cable).

- Standard: IEC 60584. Class 1, IEC 60228 class 2.
- Insulation: Polyethylene (PE) or cross-linked polyethylene (XLPE).
- Conductors: Copper-Constantan (T type) or Chromel (nickel chromium) - Alumel (nickel alloy HK type).
- Identification: T type (brown (+) copper / white(-) constantan) K type (green(+) chromel / white (-) constantan).

9.2.6 Data processing Cables

The data processing cables will be of the coaxial 50 Ohm for ETHERNET links, and 93 Ohm for ARCNET links.

- Standard: RG 58 C/U (MIL-C-17D) / 50-3-1 (IEC 60096, IEC 60332-1) ETHERNET or RG62 A/U (MIL C 17D) ARCNET.
- Insulation: Polyethylene.
- Identification: Manufacturer's standard.

9.2.7 Optical Cables

The optical cables will have a core diameter of 62.5 / 125 micron.

- Fiber type: Multi-mode.

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- Coating diameter 500 microns cladding diameter 125 microns.
- Tight buffer material: Hard elastomeric 900 microns diameter.
- Identification: Color code standard supplier.

9.2.8 High Temperature Cables

High temperature cables are used when the permanent working ambient temperature is high. They are halogen free non corrosives non toxicity (see IEC 60754 part 1 and 2), fire resistant (IEC 60331), low smoke (IEC 60034), AD7 water resistant (temporary submerged IEC 60529), flame retardant (IEC 60332-1 and IEC 60332-3) and hydrocarbon resistant.

9.3 Description of Control and Auxiliary Equipment

9.3.1 Description of Gas Turbine Control Equipment

The SPEEDTRONIC (Mark VIe turbine control is the latest state-of-the-art control for GE turbines with a heritage of more than 30 years of successful operation of electronic turbine control systems. It is designed as a complete integrated control, protection, and monitoring system for generator and mechanical drive applications of gas and steam turbines. It is also an ideal platform for integrating all power island and balance of plant controls. Hardware and software are designed with close coordination between GE's turbine design engineering and controls engineering to insure that your control system provides the optimum turbine performance and you receive a true "system" solution.

With Mark VIe, you receive the benefits of GE's unmatched experience with an advanced turbine control platform.

9.3.1.1 Mark VIe Architecture

A Compact PCIR based Controller communicates with networked I/O over one or multiple Ethernet networks. The Controller rack consists of a main processor and one or two power supplies. A QNX real time, multitasking operating system is used for the main processor and I/O. Application software is provided in a configurable control block language and is stored in non-volatile memory. It conforms to IEEE-854 32-bit floating point format.

IONet is a dedicated, full-duplex, point-to-point protocol that provides a deterministic, high-speed 100MB communications network. It is used to communicate between the main processor(s) and networked I/O blocks, called I/O Packs.

Each I/O Pack is mounted on a termination board with barrier or box type terminal blocks. The I/O Pack contains two Ethernet ports, a power supply, a local processor, and a data acquisition card. Computation power grows as I/O packs are added to the control system enabling an overall control system

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

frame rate of 10ms. The local processors in each I/O Pack execute algorithms at higher rates as required for the application. Each I/O Pack contains on AMD Au 1000 266 MHz processor. GE manufactures the I/O Pack boards with surface mounted technology and conformal coats them per IPC-CC-830.

9.3.1.2 Triple Redundancy

Triple redundant systems are available to protect against soft or partial failures of devices that continue to run but with incorrect signals/data. These systems “out vote” a failed component with a 2-out-of-3 selection of the signal. Application software in all three controllers runs on the voted value of the signal while diagnostics identify the failed device.

Controllers are continuously online and read input data directly from IONet. Redundant systems transmit inputs from redundant I/O packs on IONets to redundant controllers. Outputs are transmitted to an output I/O pack that selects either the first healthy signal or the signal of choice. Three output packs can be provided to vote output signals for mission-critical field devices.

Diagnostics monitor all system components and provide on alarm identifying faults. This enables maintenance personnel to perform on-line repair and extend the mean-time-between-forced- outages (MTBFO). Note that every I/O Pack communicates directly on the IONet. Which enables each I/O Pack to be replaced without affecting any other I/O in the system. Also, the I/O Pack can be replaced without disconnecting any field wiring.

9.3.1.3 Mark VIe Control Configuration

The control system provides complete monitoring control and protection for Gas Turbine-Generator and Auxiliary systems. The scope of control is broken down into three (3) sections:

- Control.
- Sequencing.
- Protection.

9.3.1.4 Control Functions

- Start-up control

The control panel will provide the necessary sequences and protections to insure the cranking of the shaft, ventilation before firing, firing, and acceleration of the Gas Turbine up to Full Speed No Load.

- Speed/load set-point and governor

This function allows controlling the gas turbine speed and the load once the breaker is closed. The speed/load loop controls speed after the turbine has been brought to governed speed. The speed control circuit compares turbine

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

shaft speed to the digital set-point, and regulates FSR to maintain the speed driven by the digital set-point

- Temperature Control

A temperature control system is required, to control fuel flow to the gas turbine to maintain operating temperatures within design thermal stress limitations of turbine parts. The highest temperature attained in the gas turbine occurs in the combustion chambers and that same gas temperature occurs at the turbine inlet. This temperature must be limited by the control system. The temperature control system is designed to measure and control turbine exhaust temperature because it is impractical to measure temperatures in the combustion chambers or at the turbine inlet directly.

According to whether the machine is in simple cycle or combined cycle, the privileged way followed in loading will be different. Thus, in simple cycle the optimal efficiency on gas turbine is required whereas in combined cycle, optimal efficiency on all the power station is required. Therefore the sequence of opening or closing of IGV is not the same one.

In simple cycle, the sequence known as "IGV-off" is used whereas in combined cycle, sequence "IGV one" is used:

IGV-Off sequence: One goes up in load with mini IGV until the temperature exhaust reaches 700F (371°C). Then, the IGV are gradually open with consign to keep the temperature exhaust equal to 700°F. When the angle of maximum IGV is reached, this isotherm is left to gradually join the base curve.

IGV-On sequence: Loading with mini IGV until the partial load control curve is reached. This curve can be the same curve that the base one (standard chamber or MNQC), or a particular curve (DLN chamber - the particular curves are built in order to avoid unstable zones of combustion). The IGV are then gradually opened with exhaust temperature consign corresponding to the control curve in partial load. When the maximum angle of IGV is reached, the base load curve is finally joined.

In a general way, the partial load control curves are built to keep the firing temperature quasi-constant at the time of the opening of the IGV. This is why, even in simple cycle, the machines equipped with DLN chamber go up in load while following preferably the IGV ON sequence. Combustion in premix is done thus on a greater range of load.

9.3.1.5 Fuel Control

- Dual fuel

This gas turbine has dual fuel capability; it is supplied with both a natural gas fuel system and a liquid fuel (distillate oil) system with automatic and/or manual changeover under load. Both mechanical handling and electrical control components are incorporated in the design of both fuel systems as

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

well as a fuel nozzle, capable of burning either of the two type fuels, natural gas and distillate oil.

- Mixed running at constant threshold

Units with standard combustors (non DLN) may be operated on a mixture of liquid and gas fuel as permitted. Operation on a selected mixture is obtained by initiating a normal transfer and select "MIXV" operation when the desired mixture is obtained. Limits on the fuel mixture, are required to insure proper fuel combustion, gas fuel distribution, gas nozzle flow velocities.

- Gas manifold purge

The gas turbine burns natural gas or fuel oil. The fuel purge system supplies air to the inactive fuel nozzles to prevent fuel accumulation and combustion back-flow in the associated gas turbine fuel piping. When burning natural gas, the fuels purge system supplies purging air to the fuel oil passages of the dual-fuel nozzles. When burning oil the fuel purge system supplies purging air to the gas turbine natural gas manifold.

- Inhibitor injection

Gas turbine may burn heavy fuel oil contaminated with vanadium, in this case a vanadium inhibitor injection skid is required. Vanadium Inhibition function sets the dose rate inhibitor based on vanadium content of the crude fuel and crude flow-rate. One 100% pump is provided for inhibitor injection. The pump is started after transfer to crude has been selected and limit switch on the transfer valve indicating the transfer valve, is transitioning. During crude operation, proper operation of the injection skid is monitored. If a fault is detected an alarm will be generated at the turbine control panel and the turbine control commands an auto transfer to distillate. Auto or manual transfer to distillate fuel operation stops the injection.

- Power factor control

The PF set point and the calculated feedback based on MVAR and MW operating set point develop an error signal, which is then input to comparators with some dead-band, to allow for a steady state error. The comparator logical outputs are then passed to the appropriate raise or lower contacts, after some time delay, to allow settling in the closed loop voltage control. The PF control is enabled only if the turbine load is above a minimum value.

- Var control

The Var control is accomplished by sending excitation raise and lower commands to the Exciter from the turbine control panel through hardwired contacts. The raise and lower commands are pulses. The VAR set point and the measured feedback develop an error signal, which is then input to comparators with some dead-band, to allow for a steady state error. The

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

comparator logical outputs are then passed to the appropriate raise or lower contacts, after some time delay, to allow settling in the closed loop voltage control. These raise and lower commands are the same functions that are normal operator interfaces to the excitation system. The action of the VAR control is to in fact emulate the some action that on operator would take to adjust Var output, only in an automated fashion.

- Compressor water washing

Gas turbines can experience a loss of performance during operation as result of contaminants on internal components. The dry contaminants that pass through the filters as well as wet contaminants, such as hydrocarbon fumes, have to be removed from the compressor by washing with a water detergent solution followed by a water rinse.

- Compressor pressure & exhaust temperature control

Gas turbine combustion reference temperature is determined by the measured parameters of exhaust temperature and CPD. In case of CPD failure, a backup function is included which uses fuel consumption (proportional to FSR) or output (in Megawatts).

- Wet water injection for NOx reduction

The water injection system provides water to the combustion system of the gas turbine to limit the levels of nitrogen oxides (NOX) in the turbine exhaust. The water injection system schedules water flow to the turbine as a function of total fuel flow, relative humidity, and ambient temperature. The required water/fuel ratio is established through field compliance testing of the individual turbine. A final control schedule based on these tests is programmed in the SPEEDTRONIC control, which then regulates the system.

9.3.1.6 Sequencing

- Start-up, purge, ignition, running and shutdown.

General

Starting the gas turbine involves proper sequencing of command signals to the accessories, starting device and fuel control system. Since a safe and successful startup depends on proper functioning of almost all of the gas turbine equipment, it is important to verify the state of selected devices in sequence. Much of the control logic circuitry is associated not only with actuating control devices, but enabling protective circuits, and obtaining permissive conditions before proceeding. Startup and shutdown cycle improvements have been included to reduce low cycle fatigue of hot gas path parts.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

An important part of the startup/shutdown sequence control of the turbine is proper speed sensing. This is necessary for the logic sequences in startup and shutdown of the gas turbine.

Start-up control

The startup control operates as an open loop control in the use of preset levels of the fuel command signal, FSR. The levels set are "FIRE", "WARM-UP", and "ACCELERATE LIMIT". Startup control FSR signals operate through a minimum value gate to insure that speed control and temperature control can limit FSR if required. During the starting sequence, rates of increase in speed and exhaust temperature are restricted to protect the turbine parts from excessive mechanical and thermal stresses.

- Control mode display

Display Condition:

STARTUP = Start-up Program

ACCEL = Acceleration Control

DROOP SPEED = Speed Control

TEMP = Temperature Control

- Fired shutdown

A normal shut-down is initiated by selecting STOP from the control panel followed by execute.

- Purge and ignition

During startup sequence, the starting means will hold the turbine speed at a constant value before firing; this is done to force four changes of exhaust duct air to insure no combustible mixture is in the exhaust. The duration of this purge time will depend on the volume of the exhaust duct and may vary between on open cycle and a combined cycle configuration. When the purge timer is completed, the firing timer is initiated and the fuel flow set to the firing value. When flame detectors indicate flame is established in the combustors, the fuel flow is set to the warm-up value. The warm up time is provided to minimize the thermal stresses during startup.

- Droop-Isochrone mode

Droop speed control is based on the fact that the power grid to which the generator is connected, will hold a synchronous generator speed at grid frequency. The turbine load will be proportional to the difference between the grid frequency and speed/load set point.

Isochronous control mode is used when the turbine is operating on an isolating grid. The turbine load will be proportional to the difference between the frequency set point and the actual frequency of the grid.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Constant settable droop

Constant Settable Droop Speed/Load control represents a method of formulating the gas turbine droop response as a function of the unit power output. This method of speed/load control is applied to units where the fuel stroke reference (FSR) is not predictable as a function of the gas turbine output power. Standard droop control utilizes the approximate linear relationship between FSR and the gas turbine power output as the basis for reacting to variations in electrical grid frequency. Constant Settable Droop Speed/Load Control is a method where gas turbine megawatt output is used as a control parameter to formulate the turbine droop response to electrical grid perturbations.

Dual redundant megawatt transducers are required at a minimum to provide megawatt feedback to the Constant Settable Droop sequencing.

- Fuel changeover

During a fuel transfer, the equivalent heat consumption as a function of fuel command is matched between the two fuels, so that equivalent gas and liquid commands will result in a constant heat consumption release in the gas turbine combustors. The fuel signal divider then splits the signal to each fuel system in a manner that maintains the sum of the two signals equal to the total required fuel demand.

The transfer sequence is divided into two parts, a line filling period and the actual transfer. During the first period, the incoming fuel command is raised to a level that will allow filling of the system in about 10 or 30 seconds, while the outgoing fuel command is maintained at its current amount. After fuel has reached the fuel nozzles, the Incoming fuel is ramped up to equal the total fuel demand, and the outgoing fuel is romped down to zero. Water injection (when provided) must be stopped during the pre-fill and transfer sequence.

Since total heat consumption to the gas turbine is held reasonably constant, load variations for a properly matched and tuned system are minimal, and, generally are less than + or - 5 to 10% of nameplate rating initial power. The reliability and the load variation amplitude during transient depend on the respect of the TIL 1107-3 recommendations for the liquid fuel line ; the liquid fuel system should be activated on a regular basis (1 transfer gas to liquid and then to gas once a week or 2).

- Automatic Fuel Transfer on gas fuel fault

In the event of fuel gas fault (typically low pressure or low temperature), turbine operation will automatically transfer to liquid fuel. The transfer will occur with no delay for line filling to return to gas fuel operation after on automatic transfer, manually reselect gas fuel.

9.3.1.7 Protection Functions **CONFIDENTIAL!!!**

- General (refer to the scheme below)

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

The protection of the turbine against potential damaging conditions is provided by redundant controllers: critical protection sensors are triple redundant and voted out the processors. An independent over speed protective module provides triple redundant hardwired detection and shutdown on over speed along with flames detection.

- Over-speed, redundant electronic

Over-speed protection consists of three magnetic pick-ups which provide electrical pulses to the Controllers which compare the pulse rate to a pre-set level.

- Over-temperature protection

The over temperature system protects the gas turbine against possible damage caused by over firing. It is a back-up system which operates only after failure of the speed and temperature override loops.

Under normal operating conditions, the exhaust temperature control system reacts to regulate fuel flow when the firing temperature limit is reached. In certain failure modes however, exhaust temperature and fuel flow can exceed control limits. With such circumstances the over temperature protection system provides an over-temperature alarm annunciation prior to tripping the gas turbine. This allows the operator to unload the gas turbine to avoid the trip.

- Vibration protection

The vibration protection system employed for gas turbine units is designed to adequately protect the unit while maintaining a high level of unit running reliability and starting availability.

Multiple vibration sensors are mounted on the rotor bearing housings of the gas turbine and generator, and if applicable, on the load gear bearings. The Speedtronic vibration protection has the standard capability for 12 vibration sensor inputs that are classified and processed in the following four groups:

- Gas Turbine Vibration Sensors.
- Load Gear Vibration Sensors.
- Generator or Driven Load Vibration Sensors.
- Miscellaneous Vibration Sensors (Spare Group).

- Flame detection and protection

The SPEEDTRONIC flame detectors perform two functions, one during the starting sequence and the other in the protective system. During a normal startup the flame detectors indicate when a flame has been established in the combustion chamber, and allow the startup sequence continue. Should the flame detectors indicate a loss of flame condition while the gas turbine is

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

running, fuel is immediately shut off. This avoids the possible accumulation of an explosive mixture in the turbine and any exhaust heat recovery equipment which may be installed. The flame detector system, used with the SPEEDTRONIC system, detects flame by sensing ultraviolet radiation (UV).

- Dew point Protection

GE currently requires the Gas Fuel supplied to the FG1 connection to be superheated. The requirements and basis of this superheat are defined in Specification GE141040. If sufficient superheat is not supplied, liquid hydrocarbons may condense out of the gas fuel stream and result in damage to hardware. Therefore, a three-tiered protection strategy will be implemented to Alarm, Shutdown and Trip the Gas turbine, if there is insufficient superheat.

As stated in GE141040, GE will require a temperature input signal from the customer into the Speedtronic™ Controller. This should be a 4-20mA analog signal from the Plant Level control system. The temperature should represent the gas fuel temperature downstream of any Gas Pressure Regulating Stations or Gas Compressors, but upstream of any heating equipment recommended in GER3942. This temperature will be referred to as the “unconditioned gas temperature.” GE recommends that the temperature measuring device contain redundancy.

GE will use the unconditioned gas temperature signal, along with the Hydrocarbon Dew point breakpoint described in GE141040 to determine if sufficient superheat is being supplied. An alternate method to the hydrocarbon dew point breakpoint is for the customer to supply a signal to the Speedtronic™ Controller for the Hydrocarbon dew point once again; this signal should be a 4-20mA analog signal from the Plant Level control system. In this case, GE will use the unconditioned gas temperature signal and the hydrocarbon dew point signal, to determine if sufficient superheat is being supplied.

The Speedtronic™ Controller will provide an alarm, when the risk of liquid hydrocarbon condensation is approximately 3 defects per million opportunities. (6 Sigma) This level is equal to the superheat values contained in GE141040. The operator should check to insure that all of the necessary heaters are operational when this alarm becomes active. This alarm will be active above 50% turbine speed.

The Speedtronic™ Controller will provide a load runback and normal shutdown command, when the risk of liquid hydrocarbon condensation is approximately 1350 defects per million opportunities. (3 Sigma) This level is approximately equal to 75% of the Alarm Level. The operator should check to insure that all of the necessary heaters are operational when the unit begins the load runback. If sufficient superheat can be re-established during the load runback then the unit will continue to operate. The load runback and

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

shutdown command will become active at Full Speed No Load during turbine startup.

The Speedtronic™ Controller will provide trip command, when the risk of liquid hydrocarbon condensation is approximately 500,000 defects per million opportunities. (0 Sigma) This level is approximately equal to 20% of the Alarm Level. This condition presents a high risk of liquid hydrocarbon condensation and potential damage to hardware. The trip command will become active at Full Speed No Load during turbine startup.

This protection strategy does not contain any field adjustable values. If a one time change in Gas Fuel Supply condition occurs, that may result in crossing the hydrocarbon dew point break point described in GEI41040; GE Engineering will need to be contacted. If the hydrocarbon dew point is expected to have significant variation, especially at or near the hydrocarbon dew point break point described in GE141040, then the use of a continuous Hydrocarbon dew point analyzer is recommended.

A 4-20 mA analog signal from the Plant Level control system that represents the gas fuel temperature downstream of any Gas Pressure Regulating Stations or Gas Compressors, but upstream of any heating equipment recommended in GER3942,

or

a 4-20 mA analog signal from the Plant Level control system that represents the real time measurement of the Hydrocarbon dew point in the fuel line.

- Liquids in the Fuel

GE will require a Digital input signal from the Plant Level control system that represents a High-High liquid level indication from the closest gas processing equipment, upstream of the FG1. This signal should come from the conditioning device that is closest to the FG1 connection and has the ability to sense liquid levels. This signal should indicate the condition when the level in the equipment has reached a fault level, typically a High-High Level. It is highly recommended that this signal come from a redundant device. This signal will be used to Trip the Gas Turbine when it is activated. It is also highly recommended that a lower level device, indicating a High Level condition, be utilized in the overall plant control (not the Speedtronic™ Controller) to signal an Alarm condition.

Digital input signal from the Plant Level control system that represents a High-High liquid level indication from the closest gas processing equipment, upstream of the FG1.

- Combustion monitoring function

Monitoring of the exhaust thermocouples to detect combustion problems is performed by the SPEEDTRONIC™ software coupled with solid state analog devices for interfacing with the primary controls and protective devices. The

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

primary function of the combustion monitor is to reduce the likelihood of extended damage to the gas turbine if the combustion system deteriorates. The monitor does this by examining the temperature control system exhaust temperature thermocouples and compressor discharge temperature thermocouples. From changes that may occur in the pattern of the thermocouple readings, warning and protective signals are generated by the combustion monitor and sent to the gas turbine control panel.

- Air flow calculation

The airflow calculation uses the inlet bell mouth as the flow measuring device, measuring total pressure at the bell mouth throat, compressor inlet temperature, and barometric pressure, Flow is calculated using a flow coefficient determined in factory test against a calibrated flow metering tube. Inlet Air temperature may be sensed by the available inlet thermocouples. Airflow is calculated using the ambient pressure and the pressure drops across the compressor bell mouth and the inlet duct. All come in as or are converted to inches of mercury. Also used in the equation is the compressor inlet temperature (converted to Rankine) and the compressor inlet absolute humidity. Dry air flow (AFQD) is equal to AFQ multiplied by (1-CMHUM).

9.3.1.8 I/O Interface

One or multiple I/O packs are mounted on each board to digitize the sensor signal, perform algorithms, and communicate with a separate controller that contains the main processor.

I/O packs have a local processor board that runs a QNX operating system and a data acquisition board that is unique to the type of input device. Local processors execute algorithms at faster speeds than the overall control system. An infrared transceiver is useful for low-level diagnostics. I/O values can be monitored, I/O pack host / function names can be programmed, and error statuses can be checked. This requires a Windows-based diagnostic tool on a laptop or a handheld pc.

The I/O Processor contains a temperature sensor that is accurate to within $\pm 2^{\circ}\text{C}$. Detection of an excessive temperature generates a diagnostic alarm and the logic is available in the database (signal space) to facilitate additional control action or unique process alarm messages. In addition, the temperature is continuously available in the database.

A power supply provides a regulated 28Vdc power feed to each I/O pack. The negative side of the 28Vdc is grounded through the I/O pack metal enclosure and its mounting base. The positive side has solid-state circuit protection built into the I/O pack, with a nominal 2A trip point. On-line repair is possible by removing the 28Vdc connector, replacing the I/O pack, reinserting the power connector, and downloading software from the software maintenance tools.

9.3.1.8.1 Terminal Blocks

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Signal flow begins with a sensor connected to a terminal block on a board. Boards contain two 24 point, barrier type, and removable terminal blocks. Each point can accept two 3.0 mm² (#12AWG) wires with 300 V insulation per point with spade or ring type lugs. In addition, captive clamps are provided for terminating bare wires. Screw spacing is 9.53mm (0.375") minimum, center-to-center.

9.3.1.8.2 I/O Types

Two types of I/O are available. General purpose I/O is used for both turbine applications and process control and turbine-specific I/O is used for direct interface to the unique sensors and actuators on turbines. This reduces or eliminates a substantial amount of interposing instrumentation. As a result, many potential single point failures are eliminated in the most critical area for improved running reliability and reduced long-term maintenance. Direct interface to the sensors and actuators also enables the diagnostics to directly interrogate the devices on the equipment for maximum effectiveness. This data is used to analyze device and system performance. Also, fewer spare parts are needed.

9.3.1.8.3 General Purpose I/O

I/O packs for discrete inputs and outputs have LEDs for each point. Contact output ratings vary between magnetic relays, solid-state relays, solenoid application, and class 1, division 2 rating. Please refer to Mark VI e System Guide GEH-6721 for these details. The following table lists only general-purpose relay selections. Relay arrangements and ratings for specific hydraulic trip solenoid arrangements are described in the System Guide.

- Discrete Input

A PDIA I/O pack provides the electrical interface between one or two I/O Ethernet networks and a discrete input terminal board. The pack contains a processor board common to oil Mark VIe distributed I/O packs and an acquisition board specific to the discrete input function. The pack accepts up to 24 contact inputs and terminal board specific feedback signals. System input to the pack is through dual PJ45 Ethernet connectors and a three-pin power input. Discrete signal input is through a DC-37 pin connector that connects directly with the associated terminal board connector. In the Mark VIe system, the PDIA I/O packs plug into the TBCI. The contact input terminal board (TBCI) accepts 24 dry contact inputs wired to two barrier type terminal blocks. DC power is wired into TBCI for contact excitation. The contact inputs have noise suppression circuitry to protect against surge and high frequency noise.

- Discrete Outputs

A PDOA provides the electrical interface between one or two I/O Ethernet networks and a discrete output terminal board. The pack contains a processor

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

board common to all Mark VIe distributed I/O packs and on acquisition board specific to the discrete output function. The pack is capable of controlling up to 12 relays and accepts terminal board specific feedback. Input to the pack is through dual RJ45 Ethernet connectors and a three-pin power input. Output is through a DC-37 pin connector that connects directly with the associated terminal board connector. In the Mark VIe system, the PDOA I/O packs work with the TRLY board.

- Analog I/O

The PAIC I/O pack provides the electrical interface between one or two I/O Ethernet[®] networks and on analog input terminal board. The pack contains a processor board common to all Mark VIe distributed I/O packs and on acquisition board specific to the analog input function. The pack is capable of handling up to 10 analog inputs, the first eight of which can be configured as ± 5 V or ± 10 V inputs, or 0-20 mA current loop inputs. The last two inputs may be configured as ± 1 mA or 0-20 mA current inputs. The load terminal resistors for current loop inputs are located on the terminal board and voltage is sensed across these resistors by the PAIC. Input to the pack is through dual RJ45 Ethernet connectors and a three-pin power input. Output is through a DC-37pin connector that connects directly with the associated terminal board connector.

- Temperature Inputs

The PTCC provides the electrical interface between one or two i/O Ethernet networks and a thermocouple input terminal board. The pack contains a processor board common to all Mark VIe distributed I/O packs and an acquisition board specific to the thermocouple input function. The pack is capable of handling up to 12 thermocouple inputs. In the TMR configuration with the TBTCH1B terminal board, three packs are used with three cold junctions, but only 12 thermocouples are available. Input to the pack is through dual RJ45 Ethernet connectors and a three-pin power input. Output is through a DC-37 pin connector that mates directly with the associated terminal board connector. In the Mark VIe system, the PTCC I/O pack works with the TBTC board. The thermocouple terminal board TBTC accepts 24 type E, J, K, S, or T thermocouple inputs. These inputs are wired to two barrier-type blocks on the terminal board. Communication with the I/O processor is through DC-type connectors.

9.3.1.8.4 Turbine Specific I/O

A variety of I/O types are used for the unique sensors and actuators used on turbines. This I/O varies with the turbine class and application.

- Speed Sensors

Redundant, passive, magnetic speed sensors are normally used for reliability. Input circuits have sufficient sensitivity to detect a 2 rpm rotation

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

while the turbine is on turning gear. This enables the diagnostics to begin monitoring the health of the sensors prior to starting the turbine.

- Over speed Protection

Backup electronic over speed protection is a common feature in modern control systems. GE's system is fast and reliable, and also features Ethernet links to pass detailed diagnostic data back to maintenance stations on the network

- Vibration Protection

GE has provided built-in vibration trip protection as part of the basic turbine control since the 1960's. Today, a wide variety of sensors can be monitored including seismic probes, proximity probes, velometers, and accelerometers. Vibration data is part of the turbine database, which provides a cohesive picture of vibration in relation to the current and post operating conditions of the equipment. Standard diagnostics monitor the composite vibration. 1x and 2X components, and the phase angle. Radial and axial monitoring of generator, compressor, and pump bearings is normally integrated into the system.

- Synchronizing

A typical Mark VIe provides automatic synchronizing, a manual synch scope display on the operator station, and backup synch check protection in the "turbine" control. Voltage matching and subsequent Var/power factor control are communicated to the GE exciter over the redundant 100MB Ethernet highway.

- Servo Control

Servo valves can be controlled with traditional current drivers for coils on the valve actuators or with communication links. A valve stroke reference is calculated in the Controller(s), which drive the control valves. To preserve the fault tolerance of these critical outputs, individual I/O Packs drive separate / redundant coils on the valve actuators, monitor the position feedback with LVDTs, and regulate the fast inner valve loop directly inside each I/O Pack

9.3.1.8.5 IONet

Communication between the controller and the I/O packs is performed with the internal IONet. This is a 100 MB Ethernet network. Ethernet Global Data (EGD) and other protocols are used for communication. EGD is based on the UDP/IP standard (RFC 768). EGD packets are broadcast at the system frame rate from the controller to the I/O packs, which respond with input data.

IONet conforms to the IEEE 802.3 standard. A star topology is used with the controller on one end, a network switch in the middle, and I/O packs at the other end.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Maximum IONet distances including field devices

Industrial grade switches are used for the IONet that meet the codes, standards, performance, and environmental criteria for industrial applications including an operating temperature of -40 to 85°C and class 1. div. 2. Switches have provision for redundant 10 to 30 V dc power sources (200/400 mA) and are mounted on a DIN rail. LEDs indicate the status of the IONet link speed, activity, and duplex.

9.3.2 Operator Interface

9.3.2.1 General

The operator interface is commonly referred to as the Human-Machine Interface (HMI). It is a PC with a Microsoft Windows-based operating system with client/server capability, a CIMPLICITY graphics displays system and software maintenance tools (Toolbox ST). It can be applied as:

- Primary operator interface for one unit or the entire plant.
- Gateway for communications to other systems.
- Maintenance station gateway.
- Engineers' station.

The HMI can be re-initialized or replaced with the process running with no impact on the control system. It communicates with the main processor board in the Mark VIe Controller(s) through the Unit Data Highway (UDH) and to third party control and monitoring systems via the Plant Data Highway (PDH). Data management between redundant Controllers is transparent to the HMI, which communicates exclusively with the designated Controller. All analog and digital data in the Mark VIe is accessible for screens, including high-resolution time togs for alarms and events.

System (process) alarms and diagnostic alarms for fault conditions are time tagged at frame rate in the Controller(s) and transmitted to the HMI alarm management system. System events are time tagged at frame rate, and Sequence of Events (SOE) for contact inputs are time tagged at 1ms in the I/O Packs. Alarms can be sorted according to ID, Resource, Device, Time, and Priority. Operators can add comments to alarm messages or link specific alarm messages to supporting graphics.

A standard alarm / event log is provided that stores all alarms and events for 30 days and can be sorted either in chronological order or according to the frequency of occurrence. In addition, a trip history is provided that stores the key control parameters and alarms / events for the last 30 trips. This includes 128 points (typical) and 200 alarms, events, and SQE points.

Data is displayed in (either English or) Metric engineering units with a one second refresh and one second typical display graphic. Operator commands can be issued by incrementing/decrementing a set point or

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

entering a numerical value for the new set point. Responses to these commands can be observed on the screen one second from the time the command was issued. Security for HMI users is important to restrict access to certain maintenance functions, such as editors and tuning capability, and to limit certain operations. A system called User Accounts is provided to limit access or use of particular HMI features. This is done through the Windows User Manager Administration program that supports five (5) user account levels.

9.3.2.2 HMI Product Features

GE Fonuc's CIMPLICITY HMI system serves as the basic core system, which is then enhanced by the addition of power plant control hardware and software from GE Industrial systems. The HMI system includes the system Toolbox for maintenance, software interface for the mark VIe and a number of products features which are unmatched by other monitoring and control systems. These features bring value to the user of power plant control, and include the following:

9.3.2.3 Graphics - CimEdit and CimView

The key functions of the HMI system are performed by its graphic system which provides the operator with process visualization and control in a real-time environment. In the HMI system, this important interface is accomplished through CimEdit, a graphics editing package, and CimView, a high performance runtime viewing package.

CimEdit is an object-oriented program that creates and maintains the graphic screen displays that represent the plant systems to the operators. Powerful editing and animation tools, with the familiar Windows environment, provide an intuitive interface that is easy to use.

CimView is the run-time portion of the HMI system, where the operator sees the process information displayed in graphic and textual formats. With CimView, the operators can view the system screens and screens from other applications via OLE automation, run scripts, get descriptions of object actions, and display system and object help.

9.3.2.4 Functions Facility

The operator interface, <HMI> consists of a commercial grade PC, color monitor, cursor positioning device, keyboard, and printer, all installed in a panel. It can be used as the sole operator interface or as a local maintenance work station with oil operator control and monitoring coming from communication links with a plant Distributed Control System (DCS) if any.

The Interface Operator is used for monitoring the operation of the turbine and the driven device, issuing commands to the control panel, (e.g. to view / acknowledge / reset alarm **CONFIDENTIAL!!!** advertise operator displays **191 of 144** maintenance and diagnostic displays, control parameters, etc ...).

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Following facilities are available on operators' interfaces:

- The main display shows the machine with important parameters such as shaft speed, exhaust temperature, fuel command, flame on-off, operating mode selected, control mode for fuel (speed, temperature. start-up) and a field showing three alarms that have not been acknowledged.
 - Various commands and operators screen control list.
 - An alarm management and log prints display, with alarm's time tags.
 - Administrative display's (menu for various functions access).
 - Diagnostics displays providing information on the machine condition and control system healthy.
 - The monitoring and diagnostics can be performed in the following fields:

Power sources check in.

- Power distribution check in.
- Battery earth fault.

Display of following values:

- Thermocouple circuits.
- Vibration transducers.
- LVDT signals.
- Servo valve current feedback.
- Loop back testing (4-20 mA inputs).
- Tests on relay drivers.
- Home detectors UV light level.
- Synchronization tests.
- Trip contact status monitor.
- Voting mismatch.

The logging printer 150 cps, type provides on alarm log, event log, historical trip log and the ability to print hardcopies.

Commands may be given to the turbine and driven device, for example:

Master control function:

Start - Stop – Fast Load Start - Cooldown.

Load control function:

Base - Peak (if applicable) - Preset - Droop - Isochrone.

Speed / Load set point function:

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Raise - Lower.

Fuel types (if applicable):

Gas / Mix / Distillate.

9.3.2.5 Display Facilities

Many displays may be accessed for different view, such as:

- Data display - The operator's normal display:

A menu of data can be selected by the keyboard to create a display which shows oil key gas turbine parameters that are relevant to a particular mode (e.g. start up - shut down - running – etc.). Once a useful display is made, it can be saved and named for easy recall.

- Alarm display:

System (process) alarms and diagnostics alarms for fault conditions are time tagged at frame rate in the Mark VIE control and transmitted to the HMI alarm management system. System events are time tagged at frame rate, and Sequence of Events (SCE) for contact inputs are time tagged at 1ms on the contact input cord in the Control Module. Alarms can be sorted according to ID, Resource, Device, Time, and Priority. Operators can add comments to alarm messages or link specific alarm messages to supporting graphics.

- Load display:

This view shows the load status (e.g. circuit breaker. kVA, MW, MVARs, temperatures, GT general diagram, etc.). It presents a concise summary of plant information and is intended for general monitoring.

9.3.2.6 Colour Graphic Monitor Interface

The following displays are provided on the screen:

- Counters:
 - Total fired hours.
 - Starts counter.
 - Emergency stops counter.
- Normal:

All normal operating data, automatically sequenced between shutdown status, startup status and run status. First 3 unacknowledged alarms also appear on normal display.
- Alarm system (diagnostic):

Separate alarm list assessing status of the control panel hardware for use in troubleshooting, repair, etc., same features as alarms (operating).

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

9.3.2.7 Mark VIe Applicable Software

The Mark VIe is a fully programmable control system. Application software is created from in-house software automation tools which select proven GE control and protection algorithms and integrate them with the I/O, sequencing, and displays for each application. A library of software is provided with general-purpose blocks, math blocks, macros, and application specific blocks. It uses 32-bit floating point data (IEEE-854) in a QNX operating system with real-time applications, multitasking, priority-driven preemptive scheduling, and fast context switching.

9.3.2.8 Real Time Plot

Any Gas Control Panel data base points shall be easily selected for creation of a real time plot. The plot shall appear like a strip chart recorder with the oldest points disappearing at the left side of the screen and new points being added on the right side.

The HMI shall be capable of providing small windows with real time up by clicking on point name when in any display.

9.3.2.9 Software Maintenance Tools (ToolboxST)

The Mark VIe is a fully programmable control system. Application software is maintained by in-house software automation tools that select proven GE control and protection algorithms and integrate them with the I/O, sequencing, and displays for each application. A library of software is provided with general-purpose blocks, math blocks, macros (user blocks), and application specific blocks.

Changes to the application software can be made with multi-level password protection and downloaded to the controller(s) while the system is running without rebooting the main processors. In redundant control systems, the application software in each controller is identical and is represented as a single program to maintenance personnel. Downloads of changes are automatically distributed to the redundant controllers by the control system, and any discrepancies between the controllers are monitored by diagnostics. All application software is stored in the controller(s) in non-volatile memory.

Application software is executed sequentially and represented in its dynamic state in function block and ladder diagram format. Maintenance personnel can add, delete, or change analog loops, sequencing, I/O assignments, and tuning constants. To simplify editing, data points can be selected, dragged, and dropped on the screen from one block to another. Other features include logic forcing, analog forcing, and trending at frame rate.

Application software documentation is created directly from source code and can be compiled and printed at the site. This includes the application software diagram, I/O assignments, the **CONFIDENTIAL** constants, etc. The software **14** of **144** maintenance tools (Control Systems Toolbox) are available for use in the HMI

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

or as a separate software package on a Windows-based PC. The same tools are used for GE Generator Excitation Systems and Static Starters.

9.3.2.10 Diagnostics

I/O Packs contain system (software) limit checking, high/low (hardware) limit checking, and comprehensive diagnostics for abnormal hardware conditions. System limit checking consists of two (2) limits for every analog input signal, which can be set in engineering units for high/high, high/low, or low/low with the I/O configuration editor. In addition, each input limit can be set for latching/non-latching and enable/disable. Logic outputs from system limit checking are generated per frame and are available in the database (signal space) for use in control sequencing and alarm messages.

High/low (hardware) limit checking is provided for each analog input. These limits are not configurable and are selected to be outside the normal control requirements range but inside the linear hardware operational range (before the hardware reaches saturation). Diagnostic messages for hardware limit checks and oil other hardware diagnostics for the cord can be accessed with the software maintenance tools. A composite logic output is provided in the database for each I/O Pack, and another logic output is provided to indicate a high/low (hardware) limit fault of any analog input or the associated communications for that signal.

The alarm management system collects and time stamps diagnostic alarm messages at frame rate in the Controller(s) and displays the alarms on the HMI. Communication links to a plant DCS Can contain both the software (system) diagnostics and composite hardware diagnostics.

Diagnostic LEDs are provided on I/O packs as previously shown for the Analog I/O pack Standard LEDs indicate: power status, attention (abnormality detected), Ethernet link connected, and Ethernet link communicating. LEDs on discrete I/O packs also indicate the status of each point All boards feature an electronic ID that contains the board name, revision, and a unique serial number. When power is applied to the I/O processor, it reads the ID of the terminal board, application card, and itself. It then uses this information for a start permissive, diagnostics, and system asset management Since the terminal boards can be mounted remote at the equipment, local temperature sensors monitor the temperature at each I/O pack Excessive temperature causes on alarm message. The alarm state and current temperature value are available for display and for use in the application software.

9.3.3 Communication

9.3.3.1 General

There are three levels of communications:

- Internal Mark Via Communication between its Controller(s) and I/O Packs.

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Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Unit Level Communications between GE controls.
- External Communications between Mark VIe and third party interfaces.

Communications within a Mark VIe using IONet were discussed earlier. Communications between GE control systems is performed on the Unit Data Highway (UDH). This is an Ethernet based LAN with peer-to-peer communications. It uses Ethernet Global Data (EGD), which is a message based protocol with support for sharing information with multiple nodes based on the UDP/IP standard (RFC 768). Data can be broadcast to peer control systems with 4K of data shared with up to 10 nodes at 10ms. A variety of other protocols are used with EGD to optimize communication performance.

Control loops are normally closed within each unit control. Variations of this exist such as transmitting set points between turbine and generator controls for voltage matching and var/power factor control. Trips between units are normally hardwired even if the trip signals are passed between units on a redundant UDH.

The UDH interface is located on the main processor board in the Mark VIe Controller. It is the same board that executes the application software and controls the IONet. This oil-in-one design reduces failure points and maximizes data throughput. Network topologies conform to Ethernet IEEE 802.3 standards. External communications between Mark VIe and third party I/O and control / monitoring systems can be provided either from I/O Packs on the IONet or from a HMI.

9.3.3.2 Ethernet to DCS via <HMI>, OPC TCP/IP Protocol

- The turbine control panel is capable of interfacing with a DCS computer via the OPC protocol with Ethernet physical support. Analogue and digital signals can be transmitted using OPC.
- Periodic transmission of data from the Mark VIe using definable data lists is possible.
- OPC server does provide time tagged alarms and events.

Ethernet provides high speed 100 MB transmission rates combined with TCP-IP which is widely used throughout the world.

9.3.3.3 Time Synchronization

Time synchronization is available to synchronize all controls and HMI's to a Global Time Source (GTS). Typical GTS's are Global Positioning Satellite (GPS) receivers such as the Star Time GPS Clock or other time processing hardware. Preferred time sources are Universal Time Coordinated (UTC) or GPS; however, the time synchronization option also supports a GTS using local time. The GTS supplies **CONFIDENTIAL** to one or more HMI's with **116 of 144** time/frequency processor board. When the HMI receives the time signal, it is

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

sent to the Mark Vle(s) using Network Time Protocol (NTP), which synchronizes the units to within +/-1ms time coherence. Time sources that are supported include IRIG-A, IRIG-B, 2137, NASA-36, and local signals.

9.3.3.4 Typical Alarms List

The list below is a typical one which may be finalized according final design.

Alarms are logged as they occur with 62 ms resolution. These information are available for the operator on the display and on the printer.

The list below is a typical one which may be finalized according final design.

- System Failure - Check Diagnostic Alarms.
- Fuel Hydraulic Trip Pressure Low.
- Hydraulic Protective Trouble.
- Aux. Lube Oil Pump Motor Running.
- Aux. Lube oil Pump Motor Running.
- Aux. Hydraulic Oil Pump motor Running.
- Hydraulic Supply Pressure Low.
- Lube Oil Level High.
- Lube Oil Level Low.
- Lube Oil Pressure Low.
- Emergency Lube Oil Pump Motor Running.
- Lube Oil Tank Temp Low.
- Lube Oil Header Temp High.
- Loss of Flame Trip.
- Exhaust Thermocouple Trouble.
- Cooling water Level Low.
- Failure to Ignite.
- Chamber Flamed Out during Shutdown.
- Exhaust Temperature High.
- Flame Detector Trouble.
- Air Inlet Filter Differential Pressure.
- Turbine Incomplete Sequence.
- Failure to Start.
- Fire Protection System Trouble.
- Fire in Turbine or Accessory Area.

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- Starting Device Protective Lockout.
- Cool-down System Trouble.
- Starting Motor Overload.
- FSR Gag Not at Max. Limit.
- Customer Trip.
- Turbine Compartment Temp High.
- Vibration Transducer Fault.
- Master Protective Start-up Lockout.
- 20 % Speed and No Flame.
- Compressor Bleed Valve Position Trouble.
- MCC Under Voltage.
- Battery Charger AC Under Voltage.
- Battery DC Under Voltage.
- Battery 125 DC Ground.
- DC Motor Under Voltage (lube oil).
- Auxiliary Motor Overload.
- Manual Trip.
- Low Lube Oil Pressure Trip.
- Under Speed Trip.
- High Vibration Trip Level.
- Start-up Fuel Flow Excessive Trip.
- High Exhaust Temp Spread Trip.
- Exhaust Over-temperature Trip.
- Electrical Over Speed Trip.
- Starting Device Trip.
- Lube Oil Header Temp High Trip.
- Off-line Diagnostic Running.
- Wheel space Temp Differential High.
- Wheel Space Temperature High.
- Fuel Pressure Low (if applicable).
- Fuel Pressure High (if applicable).
- Vibration Detectors Trouble.

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- Vibration Sensors Inoperative or Disabled.
- High Vibration Alarm Level.
- Lube oil Temperature Switch Trouble.
- Lube Oil Pressure Switch Trouble.
- Fuel Hydraulic Pressure Switch Trouble.
- Fire Detector System Trouble.
- Main Lube Oil Filter Differential Pressure high.
- Hydraulic filter Differential Pressure high.

Turbine trip log:

If a trip occurs, the trip log captures all key control parameters and alarm messages at the time of the trip and at several time intervals preceding the trip. (Typically 38 pre-trip samples for 63 parameters. 3 post-trip samples for 63 parameters and up to 63 alarms captured at the time of the trip).

9.3.3.5 Codes and Standards

ISO 9001 in accordance with Tick IT by Lloyd's Register Quality Assurance Limited. ISO 9000-3 Quality Management and Quality Assurance Standards, Part 3: Guidelines for the Application of ISO 9001 to Development Supply and Maintenance of Software.

- Safety Standards:
 - UL 508A Safety Standard Industrial Control Equipment.
 - CSA 22.2 No, 14 Industrial Control Equipment.
- Printed Wire Board Assemblies:
 - UL 796 Printed Circuit Boards.
 - UL recognized PWB manufacturer, UL file number E110691.
 - ANSI IPC guidelines.
 - ANSI IPC/EIA guidelines.
- Electromagnetic Compatibility (EMC) Directive:
 - EN 50081-2 Generic Emissions Standards.
 - EN 50082-2:1994 Generic Immunity Industrial Environment.
 - EN 55011 Radiated and Conducted Emissions.
 - IEC 61000-4-2:1995 Electrostatic Discharge Susceptibility.
 - IEC 6100-4-3: 1997 Radiated RF Immunity.
 - IEC 6100-4-4: 1995 Electrical Fast Transient Susceptibility.
 - IEC 6100-4-5: 1995 Surge Immunity.

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IEC 61000-4-6: 1995 Conducted RF Immunity.

IEC 61000-4-11: 1994 Voltage Variation, Dips, and Interruptions.

ANSI/IEEE C37.90.1 Surge.

- Low Voltage Directive 72/23/EEC:

EN 61010-1 Safety of Electrical Equipment, Industrial Machines.

IEC 529 Intrusion Protection Codes / NEMA 1/ IP 20.

Reference the Mark VI Systems Manual GEH-6421, chapter 5 for additional codes and standards.

- ATEX Directive 94/9/EC:

ISO 9001: In accordance with Tick IT by Quality Management Institute (QMI).

ISO 9000-3: Software certified to Quality Management and Quality Assurance Standards, Part 3: Guidelines for the Application of ISO 9001 to Development, Supply, and Maintenance of Software.

9.3.3.6 Environment

The control system is designed for operation in an air-conditioned equipment room with convection cooling.

Special cabinets can be provided for operation in other types of environments.

Temperature:

Operating: 0 to +45 °C (+32 to +113 °F)

Storage: -40 to +70 °C (-40 to +158 °F)

The control system can be operated at 50 °C during maintenance periods to repair air-conditioning systems. It is recommended that the electronics be operated in a controlled environment to maximize the mean-time-between-failure (MTBF) on the components.

Purchased commercial control room equipment such as PCs, monitors, and printers are typically capable of operating in a control room ambient of 0 to +40 °C with convection cooling.

- Humidity
 - 5 to 95%, non-condensing

Exceeds EN50178: 1994

- Elevation

Exceeds EN50178: 1994

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120 of 144

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- Gas Contaminants
EN50178: 1994 Section A.6.1.4 Table A.2 (m)
- Dust Contaminants
Exceeds IEC 529: 1989-11 (IP-20)
- Seismic Universal Building Code (UBC)
Section 2312 Zone 4

9.4 Description of Generator Control Equipment

9.4.1 General

This cubicle includes the following functions:

- Excitation power circuits.
- Voltage regulation.
- Generator protection.
- Generator control.

.This equipment is used for the control of the generator.

9.4.2 Structure

Freestanding cubicle, protection degree IP 21, equipped with the necessary lifting facilities. Doors are foreseen for the easy access to the different devices implemented inside the cubicle. The openings of the doors are of 90° maximum with a mechanical stop at 90°. The doors are key-locked.

All devices have easy removal for replacement.

9.4.3 Description

Generator excitation voltage is supplied via a dry type transformer, from the MCC.

The generated voltage is rectified through one rectifier bridge.

The excitation system supplies the inductor of the rotating diode exciter.

9.4.4 Excitation Functions

Starting conditions are:

- Closing order received.
- No tripping signal present.
- Speed>90%.

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If the regulator is available, the closing order causes the closing of the field breaker and the increase of the stator voltage up to the automatic channel set point (automatic sequence).

- Forcing system (supply change-over)

The excitation supply is normally fed by the MCC 400 V AC circuit. If for any reason, this voltage is no more available, an under voltage relay connected to this bus will automatically switch over from the normal supply to a 400 V AC customer supply independent from our system.

During this switch-over, a single-phase thyristor rectifier connected to the 125 V DC battery allows the excitation generator at an intermediate field current, this to avoid any loss of excitation.

The forcing is validated only when the excitation breaker is closed and generator breaker is closed.

- Boosting

The excitation power circuit is fed by excitation transformer. If stand by circuit is not secured during transient conditions (i.e. short circuits), the excitation supply voltage is no more sufficient to maintain the excitation value, this circuit is therefore triggered to permit the activation at 70% of stator voltage of the excitation ceiling.

The supply of the boosting circuit is taken from the 125 V DC battery.

The boosting is stopped as soon as the stator voltage reaches 80% of rated stator voltage. The duration of the boosting sequence is limited by the excitation ceiling time. If the stator voltage stays under the high threshold after the ceiling time delay (about 5 second), the excitation system is tripped.

- Field breaker opening

The field breaker opening will be allowed only if the unit breaker open position acknowledgement is given to the excitation system. This is to avoid the generator from running under asynchronous mode.

- Rotating diode fault (74DR)

The rotating diode fault detection is able to detect exciter diode fault. This detection is carried out by rotating earth fault detection. The fault is sent to the GCP. If the threshold is reached, the excitation system is tripped.

- Over-excitation

The excitation current level is controlled by the automatic voltage regulator (permanent limitation: 1.1 I_{fn} and ceiling limitation 14 I_{fn} for typical values). In case of generator non-eliminated fault or regulation failure, the excitation current level may exceed the permanent limitation.

A protection relay connected to a shunt measures the current and ensures the following actions:

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- Gives a change over order to the regulation to go to manual regulation if the threshold is reached for more than 5 seconds typical time.
- Gives a trip order to the excitation breaker if the threshold is reached for more than 6 seconds typical time.

9.4.5 Regulation Functions

This system function is to regulate the generator stator voltage by adjusting its field current.

The excitation field current value is permanently controlled by the generator regulation.

- The regulation system functions are to:
 - Adjust the generator stator voltage.
 - Be active for the stability of energy evacuation to the grid.
 - Have a good response time on troubles (short circuits...).
 - Keep the generator in its stability area.
- The regulation is divided in two channels:
 - Automatic channel including the stator voltage regulation (Digital Voltage Regulator) with the four following realized functions:
 - Excitation current limitation.
 - Under excitation limitation.
 - Volt /Hertz limitation.
 - Line droop compensation.

Manual channel including the manual excitation current loop (Digital Current Regulator).

- Regulator performances
 - Automatic regulation set point range: 90 % to 110 % typical of rated voltage.
 - Accuracy: +1- 0.5%
 - Manual regulation set point range: 30 % of no load to 110 % of rated excitation.
 - Current: Accuracy: +1 - 0.5%.
 - Line droop compensation setting value: 0 to +1 - 10 %.
 - Excitation current permanent limitation setting to 1.1 Ifn.
 - Over-excitation ceiling setting to 1.4 Ifn for 10 s (typical setting).
 - Frequency range limit: 50 Hz to 60 Hz.

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- Display & keyboard

A regulation display device is required to permit easy access for normal operation, tests and maintenance. This display will indicate status, measurements, alarms and faults dedicated to the regulation purpose.

- Optional Functions

Stator current limitation.

Stator voltage limitation.

Power System Stabilizer (PSS) software enable.

9.4.6 Protection Functions

The protection system function is to protect the generator.

The protection system includes the necessary treatment, interface display and control for the trips and alarms initiation.

- Measurement

All currents, voltages measured and calculated values can be displayed. The measurement card includes necessary filtering and calibrating circuits.

- Display & keyboard

A protection display device is required to permit easy access for normal operation, tests and maintenance. This display will indicate status; measurements, alarms and faults dedicated to the protection purpose.

- Watch-dog and cold tests Cold tests are carried out by the relay when it is energized

Continuous self-monitoring, in the form of a watchdog, memory checks and analog input module tests, is performed. In case of a failure, the relay will either lockout or attempts a recovery, depending on the type of failure detected.

- Functions

The protection includes the following functions:

Generator protective relays:

- Rotor Earth Fault (64F)
- Field Over current (50/76)
- Rotating Diode Fault (74DR)
- Generator differential (87G)
- Negative phase sequence (46)
- Reverse power (32R)
- Generator over voltage (159)

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

- 95% stator earth fault (SIGN or 64G)
- Loss of excitation 140)
- Voltage restrained over current (51V)
- Leads earth fault (648)
- Over fluxing (59/81)
- Over & under frequency (810-81U)
- Under voltage (27)
- Balance voltage (6OVTS)
- Out of step or loss of synchronism (78)
- 100% stator earth fault (27TN) 3rd harmonic
- 50/27 accidental energization
- 5OBF breaker failure
- Low Power (32L)

9.4.7 Control Functions

The control system includes the necessary treatment and HMI interface for the included functions. The control equipment is directly connected to the excitation, regulation and protection.

The control includes the following functions:

Display for electrical data, alarms and status

- Manual synchro on the HMI.
- Excitation Ammeter.
- Tripping relay monitoring.
- Modbus AVR.
- Modbus Protection.
- Active and reactive energy meter class 0.2.

9.4.8 Wiring

- Wiring entries

All the external wiring coming to the cubicle is realized from the bottom. A gland plate (removable from indoor), sufficiently sized for the complete wiring is installed.

- Wiring

PVC insulation	Yellow-green for the ground wire, CONFIDENTIAL!!!
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9.5 Description of M [Redacted] Auxiliary Equipment

9.5.1 Description of Control Compartment

The Turbine Control Compartment (ISO container, refer to internal arrangement) is designed to house the following equipment:

- Generator control panel.
- Motor Control Center (MCC).
- Battery (if applicable).
- Battery charger (if applicable).
- Human machine interface.

9.5.2 Characteristics

9.5.2.1 Structure

The TCC is designed P154 for outdoor use, except HVAC 1P44. A single fabricated structural base is provided for the support of the equipment contained in the TCC.

The base is sufficiently rigid to permit, handling, and skidding during shipment and installation as a fully assembled unit except for the batteries.

Two (2) doors are provided in the electrical/control compartment. Each door is provided with an emergency release panic bar on the inside and keyed lockable (for the main entrance only) handle on the outside.

The removable floor of non-slipping type allows an easy wiring between the internal equipments.

9.5.2.2 Enclosure Lighting and Receptacles

Industrial type fluorescent lighting system is provided in the cubicles inside the TCC. It's controlled by two switches located near each door.

125 VDC stand-by lighting is provided. It shall automatically be energized whenever the normal AC lighting power source is unavailable.

General purpose convenience outlet is provided.

9.5.2.3 Enclosure Heating, Ventilating and Cooling System

Two redundant (2x100%) space heaters and air conditioners are provided to maintain an ambient temperature inside the TCC under all combinations of site conditions. Temperature switch is furnished to provide over and under temperature alarms.

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The TCC air conditioners are equipped with a shelter in order to have a better protection against solar radiation or to avoid snow overload on the air conditioner.

9.5.2.4 Wiring

All the external wiring is connected to the terminal board compartment except power cables connected directly to the MCC. The terminal type is dedicated to the different circuit control, measures, safety and power.

9.5.3 Description of the Motor Control Center (MCC)

9.5.3.1 General

The MCC is used to feed power to all the gas turbine auxiliaries. It is equipped with incoming column(s), outgoing drawers, and sub distribution panels (AC and DC).

9.5.3.2 Technical Data

- Protective degree: IP 32.
- Form: 3b (IEC) for withdrawable section and incoming breakers.
- Incoming supply by cable.
- Cable entry and outgoing on the bottom of the cubicle.
- Seism: 0.4 g.
- Standard: IEC 60439-1, EEC 60 947, EEC 60-695, EEC 61-641, IEC 60-073, EEC 60-364.
- Vertical 1000A bare Copper bus bars.
- Horizontal 1600A bore Copper bus bars.
- Short circuit current main AC bus bar: 50 kA, 1 sec.
- Short circuit current main DC bus bar: 10 kA, 1sec.
- Rated insulation voltage: 1,000 V.
- Number of phases: 3.
- Neutral grounding mode: solidly grounded, not distributed.

9.5.3.3 Description

9.5.3.3.1 Incoming Panel

The incoming panel is equipped with 2 open air circuit breakers mechanically and electrically interlocked. In case of under voltage fault on main Bus bar, the supply is automatically switched to the Standby breaker.

When the fault disappeared the supply switches back automatically on Normal circuit breaker.

9.5.3.3.2 Panel with Outgoing Withdrawable Feeders

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All critical energy consumers are powered from the drawers. These drawers are equipped with:

All the drawers are controlled by input contacts coming from the associated skid or Speedtronic.

Each drawer can be locally controlled from MCC front panel with a 3 positions switch (Stop/Auto/Manu) and with 3 signal lights (ON/OFF/Fault).

9.5.3.3.3 AC Sub-Distribution Panel

This AC sub-distribution is equipped with fixed circuit breakers or miniaturized circuit breakers and circuit breaker-contactors. This sub-distribution is fed by a transformer included in the MCC. The neutral for the sub-distribution is realized by this transformer.

Those feeders are used for lighting, panels and other small auxiliaries, when necessary.

9.5.3.3.4 DC Sub-Distribution Panel

This sub distribution is supplied by unit battery and battery charger.

This part of sub distribution is used for Emergency lube oil pump, over excitation, turbine regulator and all Direct Current feeders.

9.5.3.3.5 AC UPS Sub-Distribution

This sub distribution is used mainly to energize Generator Control Panel and Speedtronic Human Machine Interface.

9.5.3.3.6 Excitation System Supply

This equipment includes the following:

The excitation transformer, three phases natural air cooled type with primary voltage fed by the MCC and rated power adapted to the type of generator.

The transformer is provided with temperature sensors.

9.5.3.3.7 MCC Miscellaneous

Additional Withdrawable Drawer up to 55 kW:

One or several withdrawable drawer in the outgoing column, controlled by input contacts coming from GT controller and equipped with fuses and contactor with thermal protection. Each drawer can be locally controlled from MCC front panel using a three positions switch (Stop/Auto/Manu) and equipped with three signal lights (ON/OFF/Fault).

Additional Withdrawable Drawer up to 160 kW:

One or several withdrawable drawer in the outgoing column, controlled by input contacts coming from GT controller and equipped with fuses and contactor with thermal protection. Each drawer can be locally controlled from

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MCC front panel using a three positions switch (Stop/Auto/Manu) and equipped with three signal lights (ON/OFF/Fault).

9.5.3.4 Description of Battery and Charger

Sequencing circuits and emergency functions are fed from the unit battery, which is supplied from the battery charger.

9.5.3.4.1 The Battery Charger

It is fed from the a.c. auxiliary sub-distribution, and provides a regulated direct voltage, with current limitation by on electronic regulator and thyristor/diode units.

Two battery chargers are supplied in order to ensure a 2 x 100% redundancy.

There are two operating modes which are selectable either from a keypad or programmable in automatic for floating / equalizing.

Output values of the charger:

- Automatic mode:
 - Floating-Equalizing: 2.27 V/cell 136.2 V Nominal current (In): 100 A.
- Manual mode:
 - Commissioning: 2.40 V/cell: 144 V (with consumers disconnected).

An AC UPS system, installed inside the battery charger panel, is supplied in order to mainly energize the Generator Control Panel and Speedtronic Human Machine Interface (HMI). Its rated power is 3,000 VA.

9.5.3.4.2 The Unit Battery

It is constituted with batteries of 12 V stationary sealed gas recombination lead acid cells (Valve Regulated Lead Acid), the battery has the following characteristics:

- Floating voltage: 2.27 V/cell
- End voltage: 105 V
- Capacity: 244 Ah

10. Design Basis

10.1 Fuel System Design Conditions

10.1.1 Gas Fuel

The gas fuel shall have the physical and chemical characteristics required in specification GEI 41040.

10.1.2 Liquid Fuel

Light distillate fuel shall be in accordance with specification GEI 41047.

10.2 Lube Oil

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The lube oil shall be in accordance with attached specification GEK 32568.

10.3 Washing Water

10.1.3 Compressor Washing Water (On-Off Line) and Turbine Washing Off line

Compressor washing water shall be in accordance with GEI 41042 (Demineralized water).

Note that for turbine washing, level of water quality required is the same as for off-line compressor washing.

Chemical content of washing detergent: Refer to table AI of GEI 41042.

10.1.4 Water Requirements

For details, please refer to GEI 41042.

Off-line water washing shall be done at a compressor inlet temperature not less than 4°C.

10.4 Cooling Water

The cooling water quality for closed loop shall be in accordance with the specification GE141004.

10.5 Water for NOx Control

Water quality specifications furnished in the liquid fuel specifications GEI 41047 paragraph 5.2 and Requirement for water/steam purity in GT; GEK-101944 GE associated with document GE 334A773 1.

Quality: see document GE-334A7731 (Demineralized water).

Conditions:

10.6 Water for Evaporative P r Cooler

The Water quality for evaporative cooler use shall be in accordance with the specification GEK 107158 (Demineralized water).

10.7 Electrical Auxiliary Consumption

GE supplied equipment Electrical Auxiliary Consumptions are estimated values only for design and information purposes, and are not guaranteed. In these here below tables GE has considered maximum estimated values.

10.7.1 MCC Supply



Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

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10.8 Noise Level Data

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The sound pressure level measured at a distance of 1 meter from the gas turbine turbine-generator set and at 1.5 m height above ground shall not exceed 85dB(A).

Temporary noise sources are not taken into account in our data or calculation.

10.9 Exhaust Data

Please refer to exhaust interface specifications:

- N 91-466261 Exhaust Interface Specification (lateral exhaust, LF silencer)
- Interface specification ref 379A9707 (lateral exhaust, GT exhaust plenum outlet flange)
- Note: Flow data in the document above are given only at base load operation.

10.10 Voltage and Current Levels

- 15kV Medium Voltage – Generator Outgoing:

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Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

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- 11 kV Medium Voltage - Starting Motor



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- Gas Turbine Motor Control Center (MCC)

400 VAC Switchboard

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230 VAC Sub-distribution

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Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

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230 VAC UPS

-125 VDC Switchboard

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10.11 Codes and Standards

The used codes and standards for the Gas Turbine Generator

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and its auxiliaries are listed in the Codes and Standards chapter.

For others codes and standards not mentioned in this Specification, Manufacturer standards shall apply.

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

CODES AND STANDARDS - SUMMARY

- 1 - SUBJECT
- 2 - FIELD OF APPLICATION
- 3 - DEFINITIONS
- 4 - INSTRUCTION
- 5 - ANNEX

1. SUBJECT

The purpose of this instruction is to provide a list of the main codes and standards that are generally applicable to GE Energy Products - Europe products and activities. This list is in Annex.

2. FIELD OF APPLICATION

The following equipment is covered by this Instruction:

- The gas turbine and its direct auxiliaries called on-base equipment,
- The generator (and load gear if applicable),
- Other auxiliaries generally used for a gas turbine In simple cycle called off-base equipment,

3. DEFINITIONS

Code of practice (code): document that recommends practices or procedures for the design, manufacture, installation, maintenance or utilization of equipment, structures or products.

Standards: document, established by consensus and approved by recognized, body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

4. INSTRUCTION

4.1- GE Energy Products-Europe considers the codes and standards listed in Annex to be the most relevant for the gas turbine industry.

4.2 - The gas turbine and its direct auxiliaries (on-base) are manufactured by GE Energy Products-Europe are consequently designed and constructed using General Electric Internal specifications. In a same way, the generator and the off-base equipment are designed and constructed as per the Manufacturers Internal specifications.

In general, these specifications comply with the applicable sections of the codes and standards (listed in annex) which have nevertheless been used for guidance only.

4.3 - The list of codes and standards produced herewith is based on GE Energy Products-Europe experience and standardization of equipment. Any modification of this list will be subject to negotiation between the Purchaser and GE Energy Products-Europe.

4.4 - The applicable revision of the codes and standards is the one published and effective at the date of submittal of the tender. The date of this revision is mentioned for Information after the reference of each code and standard.

Any modification In the codes and standards posterior to the date of tender submittal, and required by the Purchaser, Will be taken into account, by GE

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

Energy Products-Europe only upon mutual agreement between the Purchaser and GE Energy Products-Europe.

On the contrary, and In order to enable the necessary changes to be made in the designs and procedures, it is acceptable that some codes and standards become really applicable in our company only 6 to 12 months after their date of effectiveness.

4.5 - Copy of codes and standards are not authorised by the Standards Organizations. As an option GE Energy Products-Europe can supply original documents at cost.

4.6 - The listed codes and standards do not necessarily exist in the national language of the Purchaser or in English. GE Energy Products-Europe will supply no translation, neither with the tender nor with the contract.

4.7. In case of installation In an EC country, the European Community directives in force at the date of the signature of the contract will apply.

In case of a contractual requirement for the application of the European regulations for an Installation outside the EC, European Community directives in force at the date of the signature of the contract will apply after mutual agreement between the parties.

According to the European regulations, regarding the pressure equipments (as pressure vessels, piping & theirs associated accessories, Safety accessories, steam generators. pressure assemblies), the Pressure Equipment Directive 971231EC (PED) will apply.

For pressure equipments which need to be compliant with the annex I - essential safety requirements - of the Pressure Equipment Directive, CE marking will be made where applicable, according to the PED directive classification.

These pressure equipments according to the PED, for the gas turbine and its on-base auxiliaries supplied by GE Energy Products-Europe are consequently designed and constructed using General Electric specifications. In a same way, the pressure equipments according to the PED, for the off-base equipments are designed and constructed as per the Manufacturer internal specifications.

5. ANNEX

Annex: list of applicable codes and standards.

**Draft Technical Specifications for GE Frame PG9171E Gas Turbine
Generator and direct Auxiliaries and Limits of Supply**

ANNEX: MAIN APPLICABLE CODES AND STANDARDS

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AISC M016	ASD MANUAL OF STEEL CONSTRUCTION	9ED 89 ERRATA	United States
API 505	RECOMMENDED PRACTICE FOR CLASSIFICATION OF LOCATIONS FOR ELECTRICAL INSTALLATIONS AT PETROLEUM FACILITIES CLASSIFIED AS CLASS 1, ZONE 0, ZONE 1 AND ZONE 2	IED 97 ERRATA 98	United States
API 520PTI	SIZING, SELECTION AND INSTALLATION OF PRESSURE-RELIEVING DEVICES IN REFINERIES SIZING AND SELECTION	7ED 2000	United States
API 521	GUIDE FOR PRESSURE-RELIEVING AND DEPRESSURING SYSTEMS	4ED 97 ERRATA 1	United States
API 526	FLANGED STEEL PRESSURE RELIEF VALVES	4ED 95	United States
API 5L	SPECIFICATION FOR LINE PIPE	42ED 2000	United States
API 607	FIRE TEST FOR SOFT-SEATED QUARTER-TURN VALVES	4ED 93	United States
API 610	FORCES AT NOZZLE POINT (PUMP)	8ED 95	United States
API 617	FORCES AT NOZZLE POINT (COMPRESSOR)	6ED 95	United States
API 650	WELDED STEEL TANKS. FOR OIL STORAGE	10ED 98	United States
API 6D	SPECIFICATION FOR PIPELINE VALVES (GATE, PLUG, BALL AND CHECK VALVES)	21ED 94 SUPR 2 E1	United States
ASCE 7.98	MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES	95	United States
ASHRAE HDBK – FUNDAMENTALS	ASHRAE HANDBOOK. FUNDAMENTALS	97	United States
ASME B133.8	INSTALLATION SOUND EMISSION. GAS TURBINE,	77(R189)	United States
ASME B16.1	CAST IRON PIPE FLANGES AND FLANGED FITTINGS. CLASS 25, 125,250,800,	98	United States
ASME B16.10	FACE-TO-FACE AND END-TO-END DIMENSIONS OF VALVES	92	United States
ASME B16.11	FORGED STEEL FITTINGS, SOCKET-WELDING AND THREADED.	96	United States
ASME B16.25	BUTT WELDING ENDS	97	United States
ASME B16.28	WROUGHT STEEL BUTT WELDING SHORT RADIUS ELBOWS AND RETURNS	94	United States
ASME B16.34	VALVES-FLANGED, THREADED AND WELDING END	96 ADDENDA A 98	United States
ASME B16.5	PIPE FLANGES AND FLANGED FITTINGS	96 RS AD A 98	United States
ASME B16.9	FACTORY-MADE WROUGHT STEEL BUTT WELDING FITTINGS	93	United States
ASME B31.1	POWER PIPING	98 ADDENDA A 99	United States

CONFIDENTIAL!!!

136 of 144

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

ASME B31.3	PROCESS PIPING	99 RS	United States
ASME B36.10M	WELDED AND SEAMLESS WROUGHT STEEL PIPE	96	United States
ASME B36.19M	STAINLESS STEEL PIPE	85(R69)	United States
ASME PTC19.3	PERFORMANCE TEST CODE TEMPERATURE MEASUREMENT	74(R1998)	United States
ASME PTC19.5	APPLICATION-PART II OF FLUID METERS	72	United States
ASME PTC19.5.1	INSTRUMENTS AND APPARATUS- WEIGHING SCALES	64	United States
ASME PTC8.2	CENTRIFUGAL PUMPS	90	United States
ASME PV CODE 8 DIV 1	PRESSURE VESSELS- DIVISION 1	98 INTERP 45 99	United States
ASME PV CODE 9	WELDING & BRAZING QUALIFICATIONS	98 INTERP 45 99	United States
ASTM A 105/A105M	SPECIFICATION FOR CARBON STEEL FORGINGS FOR PIPING APPLICATIONS	98	United States
ASTM A 106	SPECIFICATION FOR SEAMLESS CARBON STEEL PIPE FOR HIGH-TEMPERATURE SERVICE	99 E1	United States
ASTM A 182/A182M	SPECIFICATION FOR FORGED OR ROLLED ALLOY-STEEL PIPE FLANGES, FORGED FITTINGS, AND V VALVES AND PARTS FOR HIGH TEMPERATURE SERVICE	99	United States
ASTM A 193/A193M	SPECIFICATION FOR ALLOY-STEEL AND STAINLESS V STEEL BOLTING MATERIALS FOR HIGH-TEMPERATURE SERVICE	99	United States
ASTM A 194/A194M	SPECIFICATION FOR CARBON AND ALLOY STEEL NUTS FOR BOLTS FOR HIGH PRESSURE OR HIGH TEMPERATURE SERVICE, OR BOTH	99	United States
ASTM A 216/A216M	SPECIFICATION FOR STEEL CASTINGS CARBON SUITABLE FOR FUSION WELDING FOR HIGH-TEMPERATURE SERVICE	93(R1998)	United States
ASTM A 234/A234M	SPECIFICATION FOR PIPING FITTINGS OF WROUGHT CARBON STEEL AND ALLOY STEEL FOR MODERATE AND HIGH TEMPERATURE SERVICE	99	United States
ASTM A 312/A312M	SPECIFICATION FOR SEAMLESS AND WELDED AUSTENITIC STAINLESS STEEL PIPE	99	United States
ASTM A 333/A333M	SPECIFICATION FOR SEAMLESS AND WELDED STEEL PIPE FOR LOW-TEMPERATURE SERVICE	99	United States
ASTM A 403/A403M	STANDARD SPECIFICATION FOR WROUGHT AUSTENITIC STAINLESS STEEL PIPING FITTINGS	99	United States
AWS D1.1	STRUCTURAL WELDING CODE - STEEL	2000	United States
BS 4076 (1989)	SPECIFICATION FOR STEEL CHIMNEYS		United Kingdom
	SPECIFICATION FOR STEEL BALL VALVES FOR THE PETROLEUM PETROCHEMICAL AND ALLIED INDUSTRIES	AMD 6271	United Kingdom
BS 6374:PT5(1985)	LINING OF EQUIPMENT WITH POLYMERIC MATERIALS FOR THE PROCESS INDUSTRIES – SPECIFICATION FOR LINING WITH RUBBERS		

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BS 8110:PT1(1997)	STRUCTURAL USE OF CONCRETE - CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION	AMD 9682	United Kingdom
BS 8110:PT2(1985)	STRUCTURAL USE OF CONCRETE - CODE OF PRACTICE FOR SPECIAL CIRCUMSTANCES	AMD 5914	United Kingdom
DIN 4024(PTI)	MACHINE FOUNDATIONS THAT SUPPORT MACHINES WITH ROTATING ELEMENTS	88	Germany

CONFIDENTIAL!!!

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

DIN 4024(PT2)	MACHINE FOUNDATIONS ; RIGID FOUNDATIONS FOR. MACHINERY WITH PERIODIC EXCITATION	91	Germany
DTU P 06-002	RULES DEFINING THE EFFECTS ON BUILDINGS OF SNOW AND WINDS (CALLED RULES NV 65) AND APPENDICES	98 AMD 2 99	France
DTU P 06-008	REGLES PS MI 89-CONSTRUCTIONS PARASISMQUES DES MAISONS INDIVIDUELLES	90	France
DTUP 22.701	RULES FOR THE DESIGN OF STEEL STRUCTURES (CALLED RILES CM 68)	66	France
EJMA	STANDARDS OF THE EXPANSION JOINT MANUFACTURERS ASSOCIATION		United States
EN 287 P11	APPROVAL TESTING OF WELDERS -FUSION WELDING - STEELE	92 AMD 1 97	Europe
EN 288 P13	SPECIFICATION AND APPROVAL OF WELDING PROCEDURES FOR METALLIC MATERIALS - WELDING PROCEDURE TESTS FOR THE ARC WELDING OF STEELS	92 AMD 1 97	Europe
EN 60584 P71	INDUSTRIAL-PROCESS CONTROL VALVES - THERMOCOUPLES - REFERENCE TABLES	95	Europe
EN 60584 P12	THERMOCOUPLES. TOLERANCES	93	Europe
FCI 70.2	CONTROL VALVE SEAT LEAKAGE	91	United States
IEC 60034.3	ROTATING ELECTRICAL MACHINES -SPECIFIC REQUIREMENTS FOR TURBINE TYPE SYNCHRONOUS MACHINES	88 CORR 97	International
IEC 60034 P71	ROTATING ELECTRICAL MACHINES -RATING AND PERFORMANCE	99 (COND ED)10.2	International
IEC 60034 P716.1	ROTATING ELECTRICAL MACHINES - EXCITATION SYSTEMS FOR SYNCHRONOUS MACHINES- DEFINITIONS	IED 91	International
IEC 60034 P72	ROTATING ELECTRICAL MACHINES - METHODS FOR DETERMINING LOSSES AND EFFICIENCY OF ROTATING ELECTRICAL MACHINERY FROM TESTS (EXCLUDING MACHINES FOR TRACTION VEHICLES)	72 AMD 29672	International
IEC 60034 PT2A	ROTATING ELECTRICAL MACHINES- MEASUREMENT OF LOSSES BY THE CALORIMETRIC METHOD	84	International
IEC 60034 P74	ROTATING ELECTRICAL MACHINES - METHODS FOR DETERMINING SYNCHRONOUS MACHINE QUANTITIES FROM TESTS	85 AMD 1 95	International
IEC 60034 P15	ROTATING ELECTRICAL MACHINES - CLASSIFICATION OF DEGREES OF PROTECTION PROVIDED BY ENCLOSURES FOR ROTATING MACHINES.	3ED94	International
IEC 60034 P17	ROTATING ELECTRICAL MACHINES - SYMBOLS FOR TYPES OF CONSTRUCTION AND MOUNTING ARRANGEMENTS OF ROTATING ELECTRICAL MACHINERY (IM CODE)	2ED 92	International
IEC 60044 P11	INSTRUMENT TRANSFORMERS - CURRENT TRANSFORMERS	1ED 92	International
IEC 60060 P11	HIGH VOL.TAGE TEST TECHNIQUES - GENERAL DEFINITIONS AND TEST REQUIREMENTS	89 CORRIGENDUM 1	International
IEC 60072 P11	DIMENSIONS AND OUTPUT SERIES FOR ROTATING ELECTRICAL MACHINES. FRAME NUMBERS 5610 400 AND FLANGE NUMBERS 55T0 1080	6ED 91	International
IEC 60079 P10	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES - GENERAL REQUIREMENTS	98 AMD 1 2000	International
IEC 60079 P11	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES - CONSTRUCTION AND VERIFICATION TEST OF FLAMEPROOF ENCLOSURES FOR ELECTRICAL APPARATUS	90 AMD 298	International

CONFIDENTIAL!!!

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

IEC 60079 PT10	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES - CLASSIFICATION OF HAZARDOUS AREAS	3ED 95	International
IEC 60079 PT11	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES. INSTRINSIC SAFETY F	4ED 99	International
IEC 60079 PT1A	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES. CONSTRUCTION AND TEST OF FLAMEPROOF ENCLOSURES OF ELECTRICAL APPARATUS- APPENDIX 0: METHOD OF TEST FOR ASCERTAINMENT OF MAXIMUM EXPERIMENTAL SAFE GAP	75	International
IEC 60079 PT4	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES -METHOD OF TEST FOR IGNITION TEMPERATURE	76 AMD 195	International
IEC 60079 PT4A	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES- METHOD OF TEST FOR IGNITION TEMPERATURES -FIRST SUPPLEMENT	70	International
IEC 50079 PT7	ELECTRICAL APPARATUS FOR EXPLOSIVE GAS ATMOSPHERES. INCREASED SAFETY I	90 AMD 293	International
IEC 60085	THERMAL EVALUATION AND CLASSIFICATION OF ELECTRICAL INSULATION	2ED 84	International
IEC 60227 PT1	POLYVINYL CHLORIDE INSULATED CABLES OF RATED VOLTAGES UP TO AND INCLUDING 450750 V – GENERAL REQUIREMENTS	98 (CON ED) 2.2	International
IEC 60255 P73	ELECTRICAL RELAYS.. SINGLE INPUT ENERGIZING QUANTITY MEASURING RELAYS WITH DEPENDENT OR INDEPENDENT TIME	2ED 89	International
IEC 60364 P75-51	ELECTRICAL INSTALLATIONS OF BUILDINGS. SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT-COMMON RULES	3ED 97	International
IEC 60502 P71	POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 1KV (UMs1 .21(V) UP TO 30KV (UM38 1(V) — CABLES FOR RATED VOLTAGES OF 1 KV (UM.1.2 1(V) UP TO 3KV (UM.3.6 1('f)	97 AMD 1 98	International
IEC 60502 P72	POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIES FOR RATED VOLTAGES FROM 1KV (UM-1 .2KV) UP TO 30KV (UMs36 1(V) - CABLES FOR RATEDVOLTAGESOF5KV(UMs1.2KV)UPTO3KV (UMs6 1(V)	97 AMD 1 98	International
IEC 60502 PT4	POWER CABLES WITH EXTRUDED INSULATION AND THEIR ACCESSORIESFOR RATED VOLTAGES FROM 1KV (UM1.2 1(V) UP TO 30 KV(UMs36 KV)—TEST REQUIREMENTS ON ACCESSORIES FOR CABLES WITH RATED VOLTAGES FROM 6 KV (IJM.7.2 1(V) UP TO 30 Ky (UM36 1(V)	1BD 97	International
IEC 60529	3EGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP CODE)	89 AMD 1 99	International
IEC 61131 PT1	PROGRAMMABLE CONTROLLERS GENERAL INFORMATION	IED 92	International
IEC 61131 P12	PROGRAMMABLE CONTROLLERS EQUIPMENT REQUIRMENTS AND TESTS	IED 92	International
IEC 61131 PT3	PROGRAMMABLE CONTROLLERS - PROGRAMMING LANGUAGES	IED 93	International
IEEE 421..2	GUIDE FOR IDENTIFICATION, TESTING AND EVALUATION OF DYNAMIC PERFORMANCE OF EXCITATION CONTROL SYSTEMS	90	United States

Draft Technical Specifications for GE Frame PG9171E Gas Turbine Generator and direct Auxiliaries and Limits of Supply

IEEE 803	UNIQUE IDENTIFICATION IN POWER PLANTS AND RELATED FACILITIES- PRINCIPLES AND DEFINITIONS. RECOMMENDED PRACTICE FOR	83(R1 999)	Untied States
IEEE 803.1	UNIQUE IDENTIFICATION IN POWER PLANTS AND RELATED FACILITIES -COMPONENT FUNCTION IDENTIFIERS	92	Untied States
IEEE C37.1	IEEE STANDARD DEFINITION, SPECIFICATION. AND ANALYSIS OF SYSTEMS USED FOR SUPERVISORY CONTROL. DATA ACQUISITION. AND AUTOMATIC CONTROL	94	Untied States
IPC-A600	ACCEPTABILITY OF PRINTED BOARDS	F	Untied States
IPC.A610	ACCEPTABILITY OF ELECTRONIC ASSEMBLIES	C2000	Untied States
ISO 10494-	GAS TURBINES AND GAS TURBINE S5TS- MEASUREMENT OF EMITTED AIRBORNE NOISE - ENGINEERING SURVEY METHOD	1993	International
ISO 10816/1-	MECHNICAL VIBRATION -EVALUATION OF MACHINE VIBRATION BY MEASUREMENTS ON NON-ROTATING PARTS. GENERAL GUIDELINES	1995	International
ISO 1217.	DISPLACEMENT COMPRESSORS -ACCEPTANCE TESTS	1996	International
ISO 1460-	METALLIC COATINGS. HOT DIP GALVANIZED COATINGS ON FERROUS MATERIALS - GRAVIMETRIC DETERMINATION OF THE MASS PER UNIT AREA	1992	International
ISO 1461.	METALLIC COATINGS- HOT DIP GALVANIZED COATINGS ON FABRICATED FERROUS PRODUCTS- REQUIREMENTS	1999	International
ISO 1680.	ACOUSTICS - TEST CODE FOR THE MEASUREMENT OF AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINERY - ENGINEERING METHOD FOR FREE FIELD CONDITIONS OVER A REFLECTING PLANE	1999	International
ISO 1680/2.	ACOUSTICS -TEST CODE FOR THE MEASUREMENT OF AIRBORNE NOISE EMITTED BY ROTATING ELECTRICAL MACHINERY-SURVEY METHOD	1986	International
ISO 2314-	GAS TURBINES -ACCEPTANCE TESTS	89 CORRIGENDUM 1	International
ISO 2409-	PAINTS AND VARNISHES -CROSS CUT TEST	1992	International
ISO 9906	ROTODYNAMIC PUMPS - HYDRAULIC PERFORMANCE ACCEPTANCE TESTS - GRADES 1 AND 2	1996	International
ISO 3746-	ACOUSTICS - DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND PRESSURE - SURVEY METHOD USING AN ENVELOPING V MEASUREMENT SURFACE OVER A REFLECTING PLANE	95 CORRIGENDUM 1	International
ISO 3977/1-	GAS TURBINES - PROCUREMENT- GENERAL INTRODUCTION AND DEFINITIONS	1997	International
ISO 3977/2-	GAS TURBINES - PROCUREMENT - STANDARD REFERENCE CONDITIONS AND RATINGS	1997	International
ISO 4624.	PAINTS AND VARNISHES. PULL OFF TEST FOR ADHESION V	1978	International
ISO 4628/3	PAINTS AND VARNISHES - EVALUATION OF DEGRADATION OF PAINT COATINGS - DESIGNATION OF INTENSITY. QUANTITY AND SIZE OF COMMON TYPES OF DEFECT - DESIGNATION OF DEGREE OF RUSTING	1982	International

**Draft Technical Specifications for GE Frame PG9171E Gas Turbine
Generator and direct Auxiliaries and Limits of Supply**

ISO 5167/1	MEASUREMENT OF FLUID FLOW BY MEANS OF PRESSURE DIFFERENTIAL DEVICES - ORIFICE PLATES, NOZZLES AND VENTURI TUBES INSERTED IN CIRCULAR CROSS SECTION CONDUITS RUNNING FULL	91 AMD 198	International
ISO 5199	TECHNICAL SPECIFICATIONS FOR CENTRIFUGAL PUMPS - CLASS II	1986	International
ISO 6180.	ACOUSTICS - MEASUREMENT OF SOUND PRESSURE LEVELS OF GAS TURBINE INSTALLATIONS FOR EVALUATING ENVIRONMENTAL NOISE- SURVEY METHOD	1988	International
ISO 850111.	PREPARATION OF STEEL SUBSTRATES BEFORE APPLICATION OF PAINTS AND RELATED PRODUCTS-. VISUAL ASSESSMENT OF SURFACE CLEANLINESS - RUST GRADES AND PREPARATION GRADES OF UNCOATED STEEL SUBSTRATES AND OF STEEL SUBSTRATES AFTER OVERALL REMOVAL OF PREVIOUS COATING	88 INF SUPP	International
ISO 850411.	PREPARATION OF STEEL SUBSTRATES BEFORE APPLICATION OF PAINTS AND RELATED PRODUCTS. SURFACE PREPARATION METHODS - GENERAL PRINCIPLES	2000	International
ISO 850412	PREPARATION OF STEEL SUBSTRATES BEFORE APPLICATION OF PAINTS AND RELATED PRODUCTS - SURFACE PREPARATION METHODS - ABRASIVE BLAST CLEANING	2000	International
ISO 961411 - .	ACOUSTICS - DETERMINATION OF SOUND POWER LEVELS OF NOISE SOURCES USING SOUND INTENSITY- MEASUREMENT AT DISCRETE POINTS	1993	International
USS SP 44	STEEL PIPELINE FLANGES	96 ERRATA	United States
NACE MR 01 75	SULFID STRESS CRACKING RESISTANT MATERIALS FOR OILFIELD EQUIPMENT	2000	United States
NFA 91-122	METALLIC COATINGS - FINISHED PRODUCTS OF HOT DIP GALVANIZED STEEL- SPECIFICATIONS FOR THE ZINC COATING AND RECOMMENDED METHOD OF FABRICATION FOR THE PRODUCTS TO BE GALVANIZED	87	FRANCE
NFP 06.013	REGLES DE CONSTRUCTION PARASISMIQUES- REGLES PS92	95	FRANCE
NFP 06414	REGLES DE CONSTRUCTION PARASISMIQUES – REGLES PS-MI 89 REVISEES 92	95	FRANCE
NFPA 11	LOW EXPANSION FOAM	98	United States
NFPA 12	CARBON DIOXIDE EXTINGUISHING SYSTEMS	2000	United States
NFPA 15	WATER SPRAY FIXED SYSTEMS FOR FIRE PROTECTION	96	United States
NFPA 20	INSTALLATION OF CENTRIFUGAL FIRE PUMPS	99	United States
NFPA 70	NATIONAL ELECTRICAL CODE	99 ERRATA 99	United States
NFPA 72	NATIONAL FIRE ALARM CODE	99	United States

**Draft Technical Specifications for GE Frame PG9171E Gas Turbine
Generator and direct Auxiliaries and Limits of Supply**

NFPA 850	FIRE PROTECTION FOR ELECTRIC GENERATING PLANTS AND HIGH VOLTAGE DIRECT CURRENT CONVERTER STATIONS	2000	United States
TEMA STANDARDS	STANDARDS OF THE TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION	8 ED 99	United States
UNIFORM BUILDING CODE	UNIFORM BUILDING CODE	97	United States

**Draft Technical Specifications for GE Frame PG9171E Gas Turbine
Generator and direct Auxiliaries and Limits of Supply**

20. Scope of GE Supply

		Volume (estimated)	Weight (estimated)
Item	Description	m ³	kg
1009E	GAS TURBINE Thermal Bloc	293	204,800
0639A	FUEL GAS FLOW MEASUREMENT SYSTEM	1	340
0706B	EXHAUST DIFFUSER	107	10,030
0969B	PIPING INSULATION AND TRACING	38	4,590
0991A	GAS FUEL MODULE	38	5,250
1113A	GT ACOUSTIC ENCLOSURE ELECTR. EQUIPMENT	18	3,215
1195A	ACOUSTIC ENCLOSURE ELECTR. EQUIPMENT	3	880
1196A	WATER INJECTION SKID ENCLOSURE EQUIP.	6	900
1233A	BLOWER-EXHAUST FRAME COOLING	8	1,560
1309A	HARDWARE-LOAD COUPLING	1	440
1313A	COUPLING-ACCESSORY GEAR	1	280
1319A	COUPLING-RIGID OUTPUT	5	2,460
1605A	GT UNIT OFF BASE ACOUSTIC ENCLOSURE	538	98,563
1617A	PACKAGE LOAD INDOOR SITE	31	3,400
1658A	MODULE OFF BASE ACOUSTIC ENCLOSURE	69	15,400
1659A	WATER INJECTION SKID ENCLOSURE	25	8,000
190A1	BASE GROUP ACCESSORY MODULE	127	53,000
A033A	HANDLING SPREADER	7	1,815
A035A	WATER FORWARDING UNIT-NOX REDUCTION	13	3,401
A040A	INLET COMPARTMENT ARRANGEMENT-AIR FILTER	898	70,230
A041A	DUCT ARRANGEMENT-AIR INLET	326	37,500
A042B	EXHAUST EXTENSION	112	15,300
A098A	VENT SYSTEM COMPONENT-LUBE OIL	11	1,700
A980A	AIR INLET & FILTER SUPPORTING STRUCTURES	80	29,594
A990A	LUBE OIL FIRST FILL	31	14,915
E021A	INHIBITION SKID VANADIUM	10	1,100
MS99A	EXHAUST PLENUM	90	15,000
220A1	TEMPLATE	46	17,720
220E1	ANCHORING	12	8,300
220F1	EMBEDDED PIECES	0	69
240A1	GT UNIT FIRE FIGHTING SYSTEM	120	34,000
260B1	EXHAUST DUCT OFF BASE ACOUSTIC PROTECTION	93	25,500
260K1	GENERATOR OFF BASE ACOUSTIC PROTECTION	151	36,650
260M1	GENERATOR OFF BASE ACOUSTIC PROTECTION ELECTR. EQUIPMENT	10	1,400
270A1	SUMP TANK	12	1,562
280C1	TURBINE WASHING LINE, Compressor washing skid	72	10,356
2C0A1	LIGHT DISTILLATE OIL FORWARDING SKID	6	1,315
2D0A1	LIGHT DISTILLATE OIL FILTERING SKID	14	2,240
2F0G1	GT UNIT WALKWAYS	33	7,280
2G0A1	GT GAS FUEL SUPPLY	60	7,650
2GZZ3	CHROMATOGRAPH	118	13,720
2J0A1	GT AIR PROCESSING UNIT	21	3,000
420B1	SIDE EXHAUST	486	76,402
420D1	EXHAUST EXPANSION JOINT	5	496

CONFIDENTIAL!!!

143 of 144

**Draft Technical Specifications for GE Frame PG9171E Gas Turbine
Generator and direct Auxiliaries and Limits of Supply**

420E1	INSULATION UNDER EXHAUST	2	450
420G1	SMOKE ANALYSER	7	880
420J1	ELBOW AND DOWNSTREAM DUCTING	561	61,457
420M1	EXHAUST ELBOW EXPANSION JOINT	5	476
430B1	STACK ON SIDE EXHAUST	551	115,419
460A1	EXHAUST PROTECTION ENCLOSURE	39	4,600
510A2	GENERATOR (N°) - MANUFACTURING COMPLETE	253	184,476
540F1	GENERATOR ACCESSORY COMPARTMENT	74	14,700
810A1	SIMPLE CYCLE FIN FAN COOLERS	237	35,232
910A1	PIPING (INITIAL MATERIAL TAKE OFF)	402	201,400
910R1	PIPING INSULATION	563	73,285
A30A1	SPEC. CONTROL SYST & ASSOCIATED INSTRUMENTATION	1	110
B10B1	PACKAGED ELECTRONIC & ELECTRICAL CONTROL CABINET (PEECC)	147	22,450
B50C1	125 VDC BATTERY	3	1,613
CF0A1	PAINTING	45	22,360
DC0E1	LV CABLES < 1000 V	121	84,965
DC0M1	GENERAL CABLING - CABLE TRAYS	97	12,625
DC0K1	GENERAL CABLING - CONNECTING ACCESSORIES	30	17,130
DF0A1	SITE LIGHTNING PROTECTION	3	1,100