BEFORE
THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Application of Ormet Primary Aluminum Corporation for Approval of a Unique Arrangement with Ohio Power Company	))))	**Case No. 09-119-EL-AEC**

TESTIMONY OF MARK D. THOMPSON

Q1. PLEASE STATE YOUR NAME, EMPLOYER, AND BUSINESS ADDRESS.

A1. My name is Mark D. Thompson. I am an operating partner with Wayzata Investment Partners (Wayzata). My business address is 701 E. Lake Street, Suite 300, Wayzata, Minnesota 55391.

Q2. ON WHOSE BEHALF ARE YOUR TESTIFYING?

A2. I am testifying on behalf of Ormet Primary Aluminum Corporation ("Ormet").

Q3. PLEASE STATE YOUR EDUCATIONAL BACKGROUND AND WORK EXPERIENCE.

A3. I have over 18 years experience in energy commodity risk management, resource procurement and asset optimization specifically related to the electric and natural gas markets. In my role at Wayzata, I am responsible for the daily commercial dispatch and optimization of 2,200 MW of merchant GE combined-cycle natural-gas fired generation located in the NYISO, ERCOT and Southwestern markets, owned and operated by the funds managed by Wayzata. My experience at Wayzata includes acquisition, development, hedging and optimization, risk management and divestiture of merchant, natural gas-fired generation. Responsibilities also include negotiation and review of interconnection agreements, operating agreements and environmental permits, including ongoing compliance with all such agreements. Previous to my role at Wayzata, I was responsible for logistics and marketing of natural gas from the Lake Charles LNG facility as well as an extensive gulf coast natural gas storage and pipeline transportation portfolio for BG Group. Previous to joining BG Group, I was the executive director of energy supply for Northwestern Energy with electric and natural gas service territories in Montana, South Dakota and Nebraska. Direct responsibilities included management, procurement, optimization, resource planning and regulatory compliance for the default supply portfolio (similar to a standard offer service) for the deregulated and unbundled electric service territory in Montana as well as management of the natural gas core supply requirements for each service territory through optimization of transportation and storage agreements. While at Northwestern I directed the procurement and regulatory approval efforts for natural gas fired and wind generation resources to compliment to default supply portfolio requirements. I was also responsible for the restructuring of a 225 MW long-term base-load coal resource agreement. Previous to Northwestern I held various positions in commodity optimization and risk management at Avista Corp and other energy companies. I began my career in commodity trading and risk management at ConAgra, a world leader in agricultural commodity and packaged foods. I maintain degrees in Economics and Finance from Creighton University.

Q4. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A4. I was asked by Ormet to provide a sustainable, environmentally responsible energy supply strategy that would that would provide long-term price stability for ongoing operations. To that end, I conducted a feasibility study for the development, operations and maintenance of an on-site 540 MW natural gas-fired electric generation facility with optimal dispatch flexibility to adjust to various levels of operations as well as dynamic market conditions. I supplemented the feasibility study with specific cost structure and timeline for the facility equipment and related infrastructure. As such, the long-term energy supply price stability analysis incorporated existing market products with the economic dispatch parameters and operational and capital expenses of the proposed facility.

Q5. WHAT WERE THE GENERAL CONSIDERATIONS EMPLOYED IN THE PREPARATION OF THE COST AND TIME ESTIMATES FOR THE ORMET POWER PLANT?

A5. First, I utilized my expertise in the electric power and natural gas markets in general to assess the most optimal resource to efficiently meet the base-load requirements of the Ormet operations, with specific consideration of the market dynamics and supply and demand of capacity, energy and fuels in the region. I utilized our relationships with major energy producers, wholesale and retail energy providers, independent power generators, equipment providers, consultants and engineers to evaluate the commodity markets, PJM capacity and market dynamics, logistical natural gas supply, interconnection requirements, permitting and environmental compliance. I also utilized our internal operating experience with four identical 550 MW combined cycle electric generation facilities owned and operated by Wayzata, as well as construction experience in permitting and developing combined cycle and simple cycle generation facilities to develop the construction and operating budget estimates for an efficient, low emission and highly reliable 2x1 combined cycle facility that could be dispatched for capacity, energy and ancillary services in various configurations and compliment a comprehensive long-term competitive "all-in" energy supply portfolio. A general description of the power plant design is identified in Exhibit MDT-1.

I was also tasked with surveying the retail power market for energy supply products to compliment the intermediate and long-term energy supply requirements for Ormet prior to the commercial operation of the on-site generation facility as well as post operations, as part of the total energy supply portfolio. Ormet is a highly efficient load with low reliance on costly capacity and ancillary service (for load following and integration). The on-site generation compliments the market-based products and resources available to optimize the load requirements. Wayzata's presence in the energy markets has established stable energy supply relationships with wholesale and retail providers that will assist with bridge energy contracts and exchanges. The information I developed and assembled, including pricing from three major energy suppliers for bridge energy was incorporated into an appropriate portion of the Ormet Power Plant Report. The Ormet Power Plant Report is part of the confidential Ormet Business Plan. I am sponsoring the Ormet Power Plant Report as it was submitted under seal in this proceeding as evidence in this proceeding.

Q6. WOULD YOU PLEASE SUMMARIZE THE IMPORTANT FINDINGS FROM THE ORMET POWER PLANT REPORT.

A6. With the assistance of qualified consultants and Wayzata operational staff, we have identified, inspected and negotiated the procurement of a complete generation equipment set with all necessary equipment included except for the heat recovery steam generator, SCR and transformers. This ability to take immediate delivery of equipment reduces the project schedule substantially and also assists with clearly defining the construction budget. Given Wayzata's operational familiarity with the GE equipment and our relationships with equipment vendors, we were able to review numerous equipment alternatives and assess the lead times of each. A detailed equipment list of the identified equipment in storage available for procurement is provided in Exhibit MDT-2. In the development of the timeline and budget, we also met with the environmental consultants and nationally recognized vendors for various systems of the facility related to lead time and build out costing. I added contingency costs for construction as well as for supplemental market purchases to bridge any delay in the construction schedule and amortized such cost into the project. With this information, I supplemented the feasibility study with specific cost structure for the equipment and related infrastructure. Such information was incorporated as part of the Ormet Power Plant Report, a section of the confidential Ormet Business Plan.

Q7. PLEASE DESCRIBE THE SUSTAINABILITY OF FUEL SUPPLY IN THE REGION AND THE ABILITY TO SUPPORT THE LONG-TERM STABLE PRICE FORECAST OF POWER PRICES.

A7. I researched the availability and sustainability of natural gas fuel and related deliverability infrastructure. The Hannibal Ormet smelter is located within the prolific Marcellus and Utica shale regions. In fact, the Ormet property includes 3 working natural gas wells and agreements to drill additional wells. This production, which is not currently consumed by the Ormet facility is delivered to Dominion pipeline. The Marcellus and Utica shale formations maintain proven natural gas reserves with a significant amount of acreage in production. The major trading index location of Clarington, Oh is just miles from the Ormet site and thus provides ideal price transparency and liquidity. Please see Exhibit MDT-3, which identifies the Marcellus and Utica shale region and project production levels. The regions proven deliverability is just beginning to be tapped with a significant ramp up in production already committed for 2014 and 2015. The forward markets recognize the new, sustainable supply, as Clarington and related areas are valued at a discount to the national natural gas hub in Louisiana (Henry Hub). The development of infrastructure has been ongoing for several years, as the vast reserves have been proven. Dominion pipeline and several other pipelines have already built gathering and processing facilities to access the wellhead supply. In fact a Dominion processing station is less than four miles from the site and a delivery pipeline crosses the Ormet property. In addition to the infrastructure built to support the shale production and the existing long haul transportation infrastructure from the Gulf Coast, a new major interstate pipeline, named Rockies Express, delivers natural gas from the Rockies to the Ohio region, providing for "gas on gas" competition at Clarington. Due to the fact that shippers have committed demand cost for transportation on Rockies Express, the pipeline continues to flow based on variable economics and provides blending of natural gas with the local shale production.

Wayzata has communicated with Dominion pipeline and another major pipeline company to scope deliverability capacity. Both pipelines have confirmed that sufficient capacity exists for cost effective and reliable interconnection and further expressed their interest in accommodating such request for interconnection. Producers are clearly keenly focused on seeking new local demand to reduce interstate transportation charges. Coordinating with these producers, I received numerous, highly competitive long-term quotes for the physical, fixed price supply of natural gas contracts. Thus hedging fuel risk is not only feasible, but a concentrated element of the plan that will be implemented in a disciplined hedging strategy. Wayzata and Ormet are in the business of managing volatile commodities and cyclical markets, thus we are very comfortable that the procedures and controls will be implemented prudently.

This stated, the Ormet supply portfolio will not solely rely upon the price of natural gas. The generation facility will provide Ormet with the right, but not obligation to dispatch for the highly reliably, low emissions resource. However, Ormet will also have the ability to access low cost market power from other sources, including coal and renewables and utilize the generation facility to capture ancillary service revenue.

Q8. BASED ON YOUR ANALYSIS, DO YOU BELIEVE THAT A LONG-TERM COMPETITIVE SUPPLY IS AVAILABLE TO SUSTAIN OPERATIONS AT ORMET UPON TERMINATION OF THE EXISTING UNIQUE ARRANGEMENT?

A8. Yes, utilizing industry accepted third party market price projections and incorporating the electric and natural gas supply and demand influences, including known additions and retirements in the region, I evaluated the most efficient combination of energy supply products to compliment the high load factor of the Ormet operations. I also considered the cost effectiveness of the on-site generation in a pure merchant scenario, much in the same manner we would implement in a due diligence investment acquisition review of an existing resource. Utilizing the specific combined cycle design, available hedge instruments for mitigating power and fuel supply risk, equipment costing, construction and considering transmission, ancillary service and capacity values, I project the all-in cost to be sustainable at approximately $41.00 - $43.00 per MWh for the 2016 -2022 time period.

We are encourage that through this proceeding, Ormet will demonstrate the economic benefits of sustained operations and will be able to reach a collaborative agreement for a transition period that provides economic incentives as well as market access and in accordance with existing Commission policy.

Wayzata has the capability and desire to proceed with a comprehensive energy supply plan, which includes an on-site generation resource to ensure the long-term viability of the Ormet operations and jobs in Monroe County. Wayzata has demonstrated its continued support of Ormet through the liquidity provisions in the asset purchase agreement ("APA"), which will be closed upon the emergence of restructuring period. The final condition precedent to the execution of the APA remains the restructuring of power supply for the transition period. Furthermore, it is important to note that embedded in our economic assumptions for the construction of a generation resource are contingency funds for any short term bridge contracts that may be necessary commencing 2016 if the project is delayed for a few months, without any further assistance from a regulatory process.

We realize the dedication of our team members at the site and the concessions that have been implemented to adapt to the industry evolution and position. Each step was necessary to achieve a sustainable and competitive position. As communicated since last fall, the transitional energy supply plan requested in this petition is last vital component in successfully completing the re-organization and ensuring the necessary liquidity for sustainable operations.

Q9. DOES ORMET MAINTAIN AN ENERGY SUPPLY PLAN FOR 2014 – 2015 DURING THE TRANSITION PERIOD SUCH THAT THE COMMISSION CAN BE ASSURED THAT NO FURTHER REQUEST WOULD BE REQUESTED PRIOR TO THE IMPLEMENTATION OF THE LONG-TERM POWER SUPPLY?

A9. Yes. We have also diligently completed a transition plan for Ormet's energy supply requirements, which includes hedging of energy supply to ensure price stability. Upon transition, Ormet will not return to the regulated or standard offer service for any reason and AEP would have no responsibility to supply standard service energy and capacity. Specifically, Ormet has coordinated energy supply proposals from three independent power suppliers, which when combined with the existing provisions of the Unique Arrangement, as amended pursuant to the petition to the Commission, will provide a competitive, stable and economic power supply agreement. Wayzata has reviewed the construct to ensure that no further relief would be required to support ongoing operations. The transition period is line with previous Commission orders to allow for an orderly transition to choice. Furthermore, as stated above, embedded in the long-term energy cost projections is the cost for procuring short-term contracts if the on site generation unit is delayed by a few months into 2016, such that no detrimental cost impact to operations will result.

Q10. WHAT ARE THE PERMITING REQUIREMENTS AND EMISSIONS BENEFITS OF THE PROPOSED PROJECT?

A10. Ormet has engaged two highly qualified environmental consulting firms to assist in the development of the site and air permits. The comprehensive scope includes the on-site civil review as well as the technical air emission calculations and much of the background technical data review necessary for the permit applications has been completed. Due to the use of best available control technology (BACT), the project emissions will be below federal Title V thresholds. However due to GHG reporting standards, the project will be included in the EPA Title V umbrella. The environmental engineers are also coordinating permit compliance for specific site-related and support resource. In the first instance, Ohio requires a use permit to be approved by the Ohio Power Siting Board, which will detail all aspects of the facility and its proposed operations. The initial application could be ready to be filed with the Ohio Power Siting Board within the next 4 weeks if the amendments are approved. A list of the general permits necessary for operation of the power plant is provided in Exhibit MDT-4.

Q11. HOW LONG WILL IT TAKE TO CONSTRUCT THE POWER PLANT ON SITE AT ORMET THAT YOU STUDIED?

A11. The actual construction period is 18 months with two months of commissioning. The GE equipment and combined cycle configuration is the preferred technology in the industry with over 750 units in service with 28.5 million fired hours and over 723,000 fired starts. All civil, mechanical and electrical engineering drawings have been completed and the equipment is available for immediate delivery. Ormet will utilize nationally recognized vendors as well as local skilled labor for the construction and engineering oversight. The construction period will include over 300 jobs. As stated, the generation equipment maintains best available control technology for emissions and will utilize locally produced natural gas as the fuel source. There are no known environmental or ground conditions that would delay the normal permitting process. A detailed timeline for the construction and commissioning is provided in Exhibit MDT-5, under confidentiality. While Wayzata has identified and inspected the equipment, the procurement of such equipment will not occur until the closing of the APA and clearance of normal permitting requirements.

Q12. DOES THIS CONCLUDE YOUR TESTIMONY?

A12. Yes, it does.

CERTIFICATE OF SERVICE

The undersigned certifies that a copy of the foregoing document has been served upon the persons below via electronic mail this 6th day of August, 2013.

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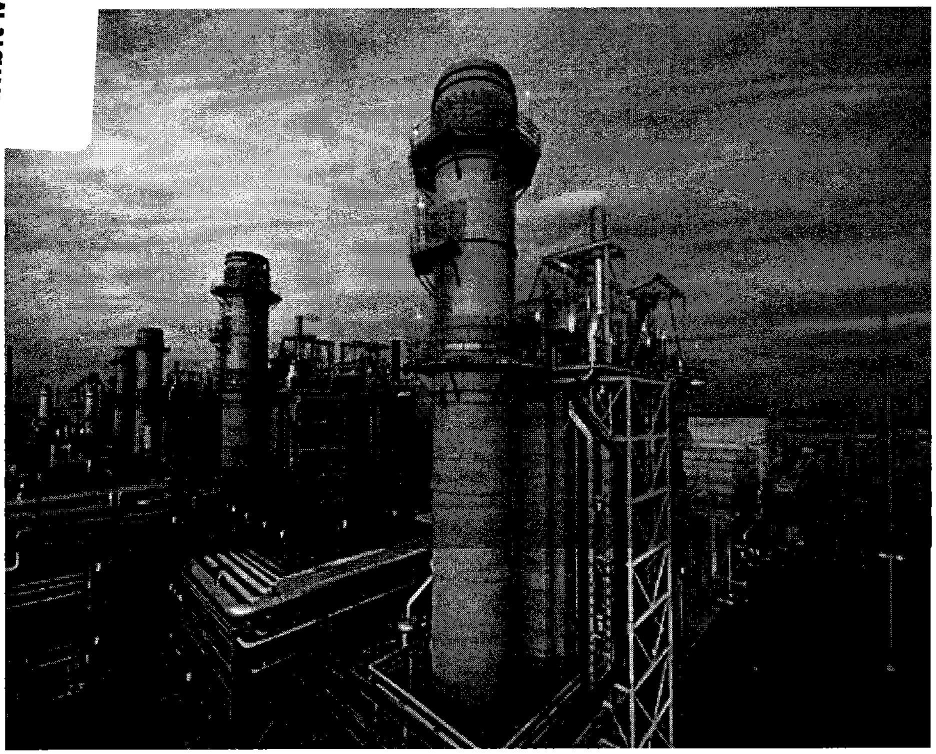
Exhibit MDT-1



Low Emission, Highly Fuel Efficient

Natural Gas-fired Combined-Cycle Generation

Investing in our Future

is dependent upon

Sustainable Energy Supply

which creates

Sustainable Jobs

and <u>**Creation of New Jobs**</u>

while focusing on a

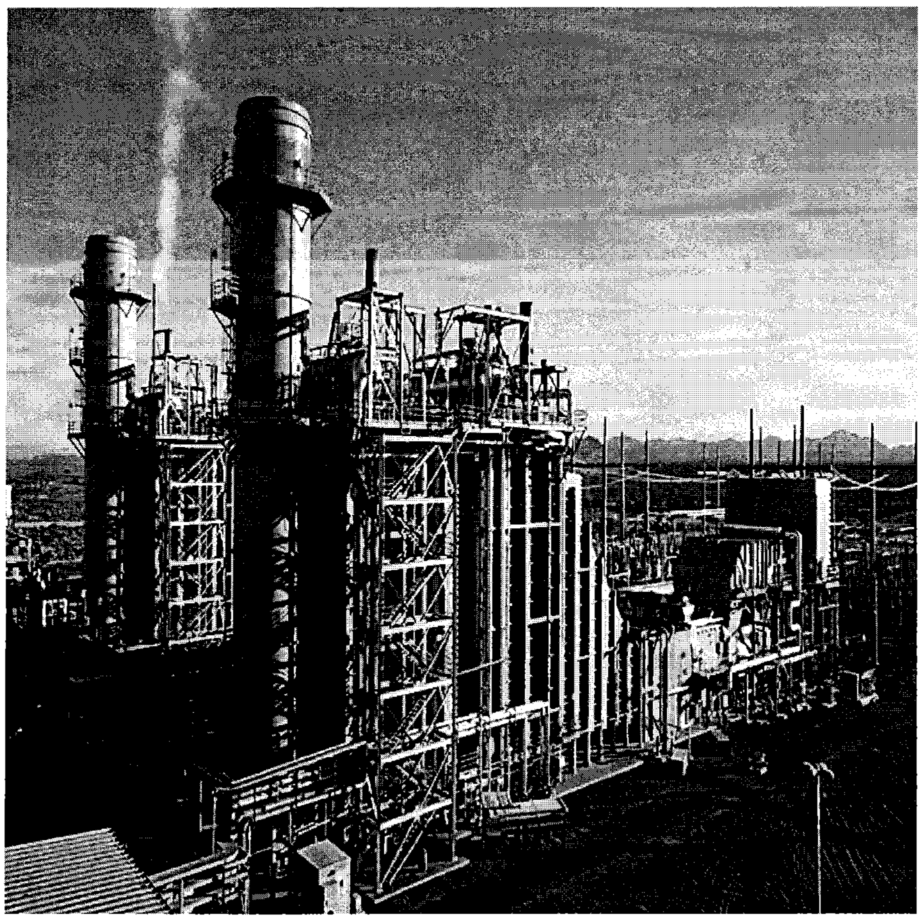
Sustainable Environment

such that the combined disciplined focus provides for a

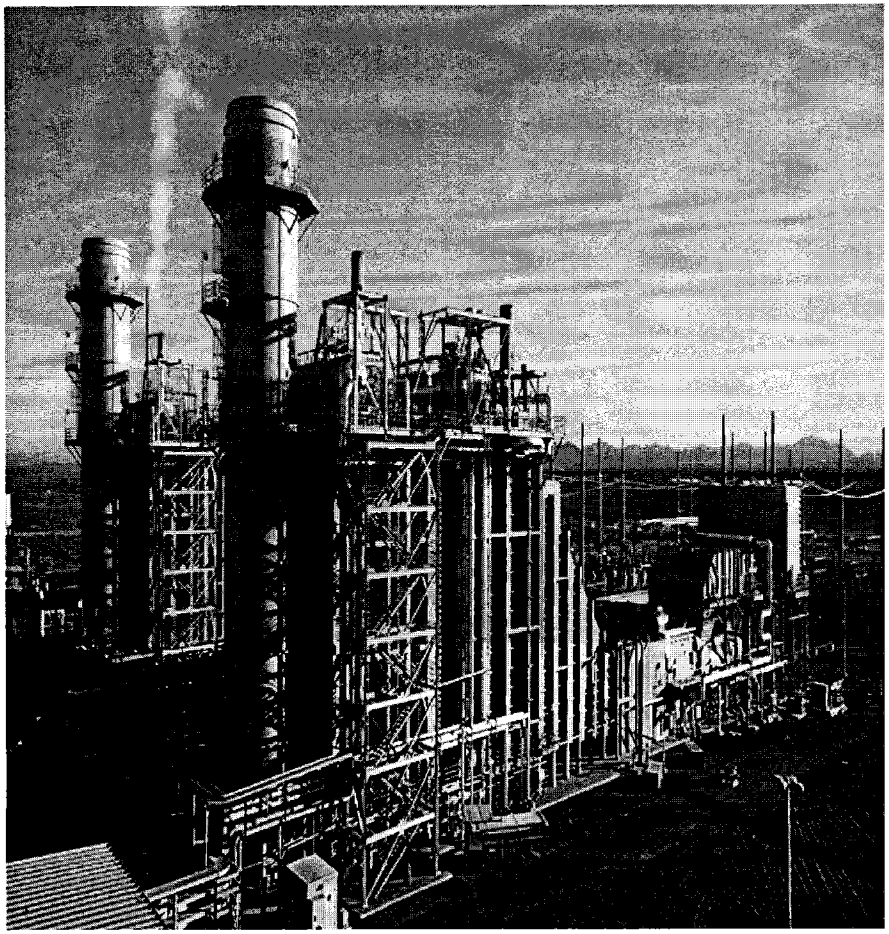
Sustainable Future

Investment Objective and Economic Development

Local Resources sustaining and creating local jobs



- Construction Jobs – 300 average (peaking to 600) skilled and unskilled jobs during 18 month construction
- Ongoing Operational Jobs – 41 full-time family wage power plant jobs
- Off-site service and community commercial business growth
- Local natural gas supply production, development and infrastructure jobs
- Stable Future for Core Operations – Sustainable energy costs will support core operations and secure the long-term viability of approximately 1,000 direct and indirect jobs at Ormet and potentially other major Ohio energy users



Reliable, Efficient and Low Emissions

Project capacity will be sufficient to meet Ormet and other major users' long-term energy requirements.

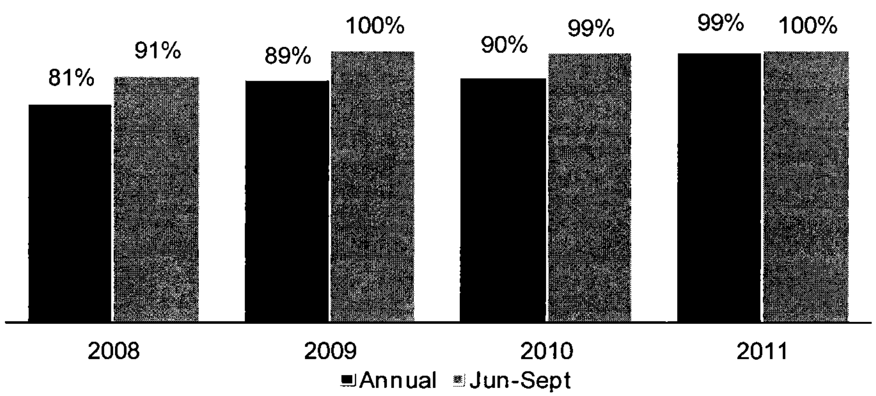
Project will be designed with low NOx combustion (with SCR controls) to meet EPA BACT emissions standards.

Location:	Hannibal, Ohio
Nominal Capacity:	600 MW
COD:	May 2015
Heat Rate:	7,250 Btu/kWh[1]
NERC Region:	PJM (AEP)
Pricing Point:	AEP-Dayton
Fuel:	Natural Gas
Gas Interconnection:	Dominion Pipeline
Electric Interconnection:	Ormet 138 kV
Facility Type:	Combined-Cycle
Configuration:	2x1 Power Block (2 CT x 2 HRSG x 1 ST)
Key Equipment:	2 GE 7FA CTs 4 Alstom HRSGs 1 GE D11STs
Site:	12- 24 acre site
O&M Provider:	Third Party O&M (41 on-site personnel)
Energy Manager:	EDF Trading North America

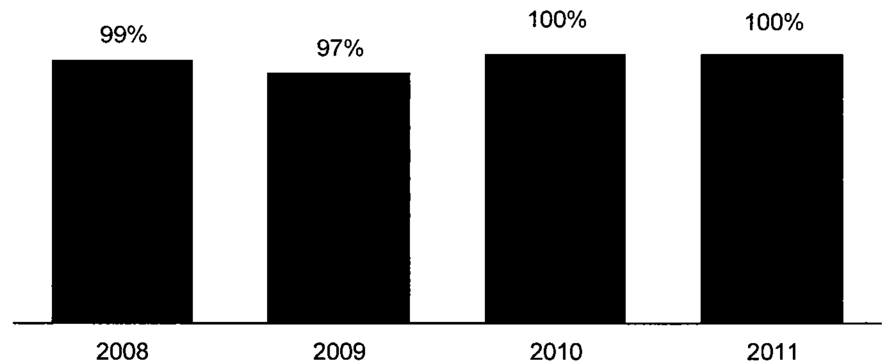
Power Resource: Highly Reliable & Efficient with Low Emissions

Demonstrated Technology Resource with Proven Track Record

•Availability Factors



•Annual Reliability Factors



Project capacity will be sufficient to reliably meet Ormet and other major users' long-term energy requirements.

<u>Project will be designed with low NOx combustion (with SCR controls) to meet EPA BACT emissions standards.</u>

•[1] All hours heat rate includes start fuel and the impact of electrical losses.

Source: Company

3. Exhibit D - Performance Data (Amended 3/25/02)

3.1 Guarantees

3.1.1 Gas Turbine Guaranteed Performance on Natural Gas Fuel

Measurement	Value	
	Evaporative Cooler Installed and Operating (Optional)	Evaporative Cooler Not Installed
Output – Base Load	160,800 kW	154,500 kW
Heat rate – Base Load	9,380 BTU/kWh	9,465 BTU/kWh
Exhaust Energy – Base Load	905,600,000 BTU/h	882,900,000 BTU/h
Output Incremental Increase – Base Load with Steam Injection (Optional)	Steam Inj. can not be used at this ambient	12,500 kW

3.1.1.1 Design Basis

Measurement	Value
Elevation	1830 ft
Ambient temperature	67 °F
Relative humidity	29 %
Exhaust system pressure loss at ISO conditions	18.98in. H2O
Natural gas fuel heating value (LHV) (Section 3.1.1.2)	20,522 Btu/lbm
Combustion system type	DLN 2.6
Evaporative Cooler	Optional
Fuel Gas Supply Temperature	365 °F
Generator Power Factor	0.85
Compressor Air Extraction From Gas Turbine	0
Steam Injection	Optional @ 3.5% of compressor flow

The following also apply to the performance guarantees:

- Performance is measured at the generator terminals and includes allowances for excitation power and the shaft-driven equipment normally supplied.
- Guarantees are based on new and clean condition of the gas turbine. If more than 250 fired hours have elapsed before a performance test is to be conducted, a GE representative shall have the right to inspect the unit to assure that the power plant is in new and clean condition. Degradation factors shall be applied if fired hours exceed 250 hours.
- The combustion turbine will operate on the dry base load control curve during steam injection for power augmentation.
- Performance and emissions guarantees are based on the Project Fuel.
- Performance guarantees shall be met while meeting emissions guarantees.
- Guarantees are based on a site test conducted as described in the Reference Documents chapter and per the Terms and Conditions of this offer.
- Exhaust energy shall be calculated per the "Gas Turbine Heat Balance Method" of ASME-PTC-4-4 as referenced in Reference Documents chapter.
- Performance curves for both the turbine and generator are included in the Performance Curves section of this proposal. From these curves it is possible to determine estimated performance at ambient temperatures, percent loads, and barometric conditions differing from those listed in the above design basis table. These curves are used during the site performance test to correct performance readings back to the site conditions at which the performance guarantee was provided.

3.1.1.2 Project Fuel Analysis (% by Volume)

Methane	97.17	Ethane	0.01
Propane	0.01	i-Butane	0.02
Carbon Dioxide	1.52	Nitrogen	0.29
Butane	0.02		

3.1.2 GT Generator Performance Specifications

3.1.2.1 Performance Rating Conditions

Measurement	Value
Elevation	1830 ft.
Stator insulation	Class F
Rotor insulation	Class F
Hydrogen gas temperature	40°C
Hydrogen pressure	30 psig
Required cooling water flow	1600 gal/min
Required temperature of inlet cooling water	33.3° C rated
Coolant type	100% fresh water
Fouling factor	0.001
Rating and dielectric test standards	ANSI

3.1.2.2 Performance Rating, Synchronous Generator

Note	Design
Following values based on generator design number	91465G

Measurement	Base
KVA	215,700
Power Factor	0.85
kW	183,345
Number of poles	2
Number of phases	3
Frequency (Hz)	60
Voltage	18.0 kV
Amperes	6,919

Connection	WYE
Short Circuit Ratio	0.52

Temperature Rating (total temperature at base load, with temp stabilized)	Value
Armature coils (by temperature detector)	100°C
Collector (by thermometer)	125°C
Field coils (by resistance)	110°C

Dielectric Tests (between coils and frame, ac voltage for 1 minute)	Value
Armature	37,000 V
Field	3,500 V

Excitation (maximum required)	Value
kW	476
Voltage	300

Calculated Generator Reactances (base load)	Value
Xdi	1.972
X'di	0.297
X'dv	0.219
X"dv	0.153
X2v	0.146
X0i	0.129

3.1.3 Steam Turbine Performance

3.1.3.1 Steam Turbine-Generator Unit (Base Load with GT Evap. Cooler On and No Steam Augmentation)

Rating	Type	LSB (in.)
178,197 kW	TC 2F	33.5

Operating Conditions:

Inlet Steam Pressure (psia)	Inlet Steam Temperature (Degrees °F)	Reheat Steam Temperature (Degrees °F)	Exhaust Pressure (in Hga)
1013.4	1032.4	1025.7	1.48

PERFORMANCE SUMMARY

Generator Output (kW)	Throttle Flow (lb/hr)	Exhaust Flow (lb/hr)	Heat Balance Number
178,197	860,843	1,042,819	91465S2-2

g = Guaranteed point (under new and clean conditions)

SYNCHRONOUS GENERATOR

Performance Rating at ISO; at sea level and 46°C cold gas

Design No. 91465S1*

*Design based on 105°F cooling water.

kVA	Power Factor	kW	rpm	No. Poles	Phase	Freq. (Hz)	Volts	Amperes	Con-nection	Cooling	Short Circuit Ratio
367,500	.85	312,375	3600	2	3	60	18000	11,788	WYE	H2	0.48

3.1.3.2 Steam Turbine-Generator Unit Estimate (With GT. Evap. Cooler On and no Steam Augmentation) – Peak Load Case

Rating	Type	LSB (in.)
306,058 kW	TC 2F	33.5

Operating Conditions:

Inlet Steam Pressure (psia)	Inlet Steam Temperature (Degrees °F)	Reheat Steam Temperature (Degrees °F)	Exhaust Pressure (in Hga)
1906	1050	1049.2	3.55

PERFORMANCE SUMMARY

Generator Output (kW)	Throttle Flow (lb/hr)	Exhaust Flow (lb/hr)	Heat Balance Number
308,058	1,639,242	1,659,862	91465S2-8

g = Guaranteed point (under new and clean conditions)

SYNCHRONOUS GENERATOR

Performance Rating at ISO; at sea level and 46°C cold gas

*Design based on 105°F cooling water.

Design No. 91465/S1*

kVA	Power Factor	kW	rpm	No. Poles	Phase	Freq. (Hz)	Volts	Amperes	Con-nection	Cooling	Short Circuit Ratio
367,500	.85	312,375	3600	2	3	60	18000	11,788	WYE	H2	0.48

3.1.4 Emissions Guarantees

Gas turbine exhaust gas emissions shall not exceed the following concentrations during steady-state gas fuel operation as specified in the table below.

Measurement	Value	Range for Guarantee	
		Load	Ambient Temperature
NOx @15% 0_2	9 ppmvd	50% - 100%	7°F – 107°F
CO	9 ppmvd	50% - 100%	7°F – 107°F
VOC	1.4 ppmvw	50% - 100%	7°F – 107°F
PM_{10}	18 lb/hr	50% - 100%	7°F – 107°F

Steam Injection Power Augmentation (option)

Measurement	Value	Range for Guarantee	
		Load	Ambient Temperature*
NOx @15% 0_2	12 ppmvd	Power Aug	59°F – 107°F
CO	15 ppmvd	Power Aug	59°F – 107°F
VOC	1.4 ppmvw	Power Aug	59°F – 107°F
PM_{10}	18 lb/hr	Power Aug	59°F – 107°F

3.1.4.1 Basis for Emissions Guarantees

- The natural gas fuel is in compliance with Seller's Gas Fuel Specification, GEI-41040F and supplementary fuel, air and steam purity requirements as defined in this proposal
- Testing and system adjustments are conducted in accordance with Seller's GEK-28172F, Standard Field Testing Procedure For Emissions Compliance.
- PM_{10} emissions are based on 0.0 wt% sulfur content in the gas fuel.
- 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.

*Steam injection is only permissible for compressor inlet temperatures greater than 59°F

SEMPRA – Copper Mountain **EVAP COOLER NOTINSTALLED**

ESTIMATED PERFORMANCE PG7241(FA)

Load Condition		BASE	BASE
Exhaust Pressure Loss	in H2O	16.2	17.1
Ambient Temperature	deg F	67.	67.
Output	kW	154,500.	167,000.
Heat Rate (LHV)	Btu/kWh	9,465.	9,115.
Heat Cons. (LHV)	MBtu/hr	1,462.3	1,522.2
Exhaust Flow x10^3	lb/hr	3325.	3439.
Exhaust Temperature	deg F	1128.	1104.
Exhaust Energy (Heat Bal)	MBtu/hr	882.9	916.9
Steam Flow	lb/hr	0.	113,180.

EMISSIONS

NOx	ppmvd @ 15% O2	9.	12.
NOx AS NO2	lb/hr	53.	74.
CO	ppmvd	9.	15.
CO	lb/hr	27.	45.
UHC	ppmvw	7.	7.
UHC	lb/hr	13.	14.
VOC	ppmvw	1.4	1.4
VOC	lb/hr	2.6	2.8
Particulates	lb/hr	9.0	9.0
(PM10 Front-half Filterable Only)			
Particulates (PM/PM10)	lb/hr	18.0	18.0

EXHAUST ANALYSIS % VOL.

Argon	0.89	0.84
Nitrogen	74.70	70.79
Oxygen	12.77	11.81
Carbon Dioxide	3.73	3.68
Water	7.91	12.88

SITE CONDITIONS

Elevation	ft	1830.0
Site Pressure	psia	13.77
Inlet Loss	in H2O	3.0
Exhaust Loss	in H2O	18.98 @ ISO Conditions
Relative Humidity	%	29
Fuel Type		Cust Gas – Mfarrel Email 050301
Fuel LHV	Btu/lb	20522 @77F
Fuel Temperature		365 °F
Application		Hydrogen-Cooled Generator
Combustion System		9/42 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(c)(1). NOx levels shown will be controlled by algorithms within the SPEEDTRONIC control system.

PM/PM10 Emissions based 0.0% fuel Sulfur content.

IPS- 91462 Version Code - 3.1.1/34A1/2.2.8/PG7241UF-1200

FERREIFE 2/1/2002 11:07 020102 67F NO Evap Steam.dat

General Electric Proprietary Information

SEMPRA – Copper Mountain **EVAP COOLER INSTALLED**

ESTIMATED PERFORMANCE PG7241(FA)

Load Condition		BASE
Inlet Loss	in H2O	4.
Exhaust Pressure Loss	in H2O	17.0
Ambient Temperature	deg F	67.
Evap. Cooler Status		On
Evap. Cooler Effectiveness	%	85
Fuel Type	Cust Gas	MFarrel Email 050301
Fuel LHV @ 77F	Btu/lb	20,522
Fuel Temperature	deg F	365
Output	kW	160,800.
Heat Rate (LHV)	Btu/kWh	9,380.
Heat Cons. (LHV)	MBtu/hr	1,508.3
Exhaust Flow x10^3	lb/hr	3412.
Exhaust Temperature	deg F	1113.
Exhaust Energy (Heat Bal)	MBtu/hr	905.6
Steam Flow	lb/hr	0.

Steam Injection can not be run at this ambient condition with the evaporative cooler on. Steam injection is only allowed at compressor inlet temperatures (CIT) greater than 59F, at this ambient condition with the evap cooler on the CIT is 53F.

EMISSIONS

NOx	ppmvd @ 15% O2	9.
NOx AS NO2	lb/hr	55.
CO	ppmvd	9.
CO	lb/hr	28.
UHC	ppmvw	7.
UHC	lb/hr	13.
VOC	ppmvw	1.4
VOC	lb/hr	2.6
Particulates	lb/hr	9.0
(PM10 Front-half Filterable Only)		
Particulates (PM/PM10)	lb/hr	18.0

EXHAUST ANALYSIS % VOL.

Argon	0.89
Nitrogen	74.31

Oxygen		12.64
Carbon Dioxide		3.74
Water		8.42

SITE CONDITIONS

Elevation	ft	1830.0
Site Pressure	psia	13.77
Exhaust Loss	in H2O	18.98 @ ISO Conditions
Relative Humidity	%	29
Application		Hydrogen-Cooled Generator
Combustion System		9/42 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(c)(1). NOx levels shown will be controlled by algorithms within the SPEEDTRONIC control system.

PM/PM10 Emissions based 0.0% fuel Sulfur content.

IPS- 91462 Version Code - 3.1.1/34A1/2.2.8/PG7241UF-1200

FERREIFE 2/1/2002 10:57 020102 67F Evap Steam.dat

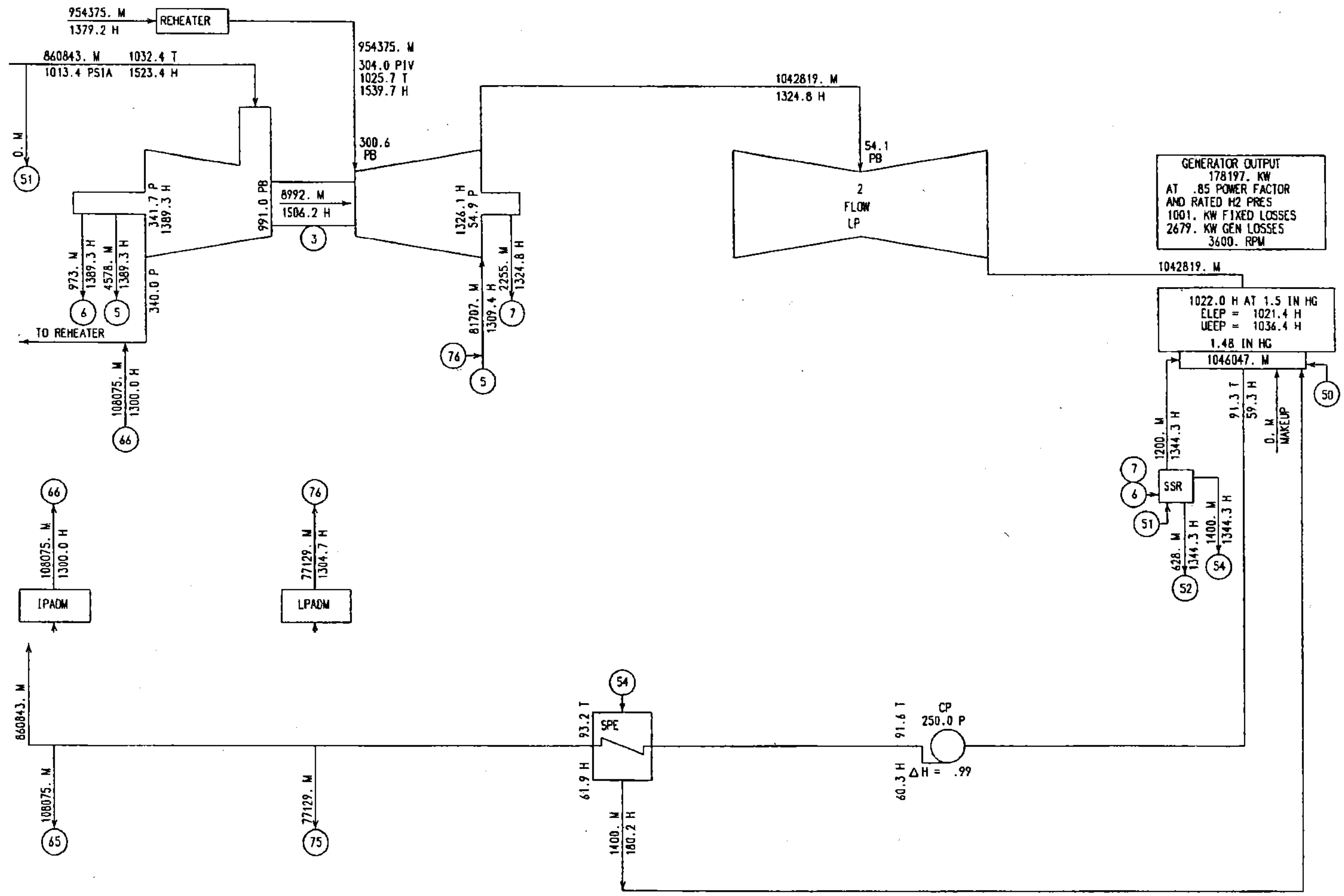
General Electric Proprietary Information

TURBINE AND EXTRACTION ARRANGEMENT IS SCHEMATIC ONLY

UNFIRED GUARANTEE

THE VALUE OF GENERATOR OUTPUT SHOWN ON THIS HEAT BALANCE IS AFTER ALL POWER FOR EXCITATION AND OTHER TURBINE-GENERATOR AUXILIARIES HAS BEEN DEDUCTED

PROGRAM NO 8.260



2GT@100% 67F UNFRD G'TEE

LEGEND - CALCULATIONS BASED ON 1967 ASME STEAM TABLES
M - FLOW-LB/HR
P - PRESSURE-PSIA
H - ENTHALPY-BTU/LB
T - TEMPERATURE-F DEGREES

306288. KW   3.55 IN HG ABS   0. PCT MU
TC2F 33.5 IN LSB   3600 RPM
1906.1 PSIA   1050. / 1049. T
GEN- 365000. KVA   .85 PF LIO

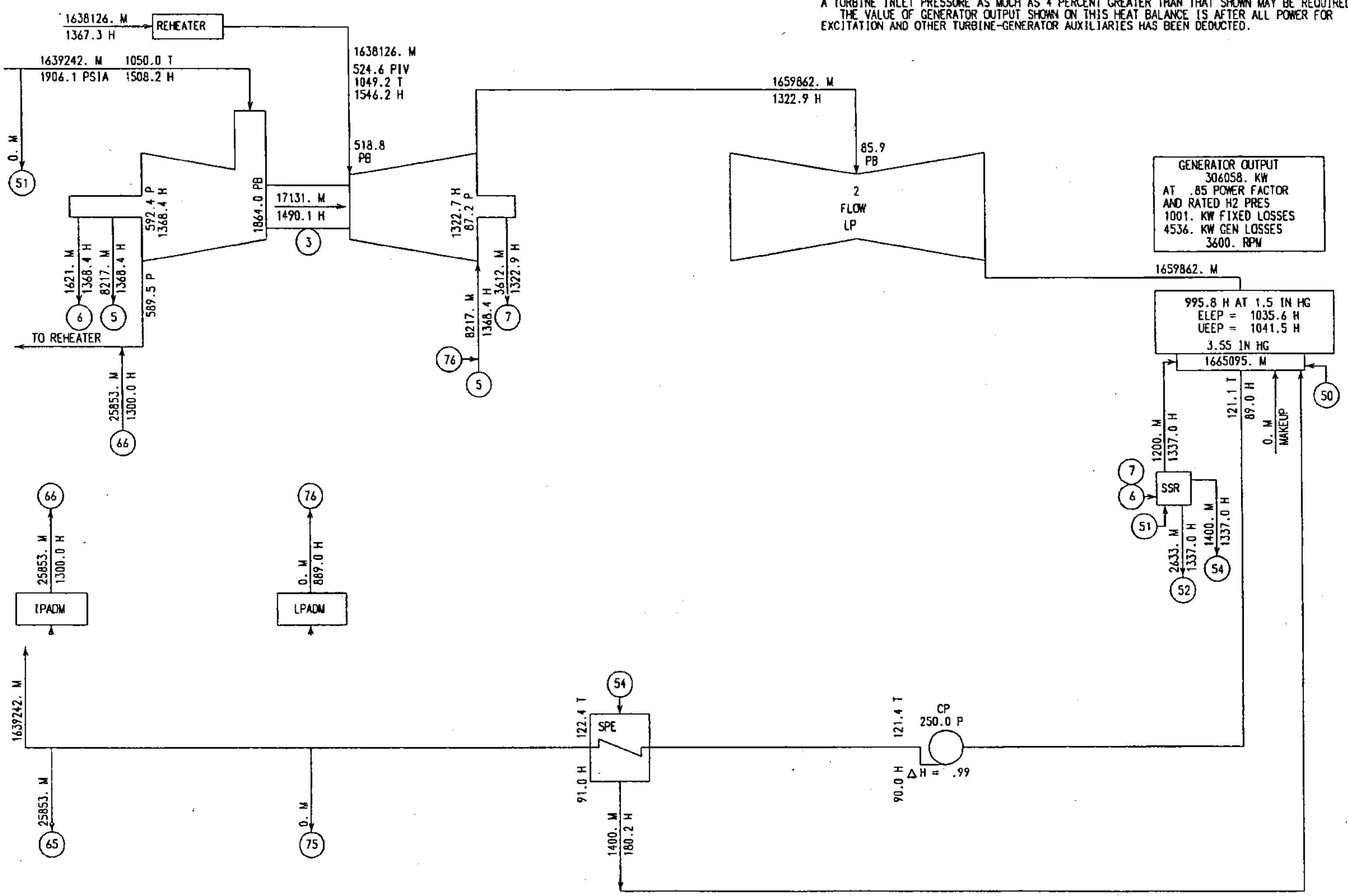
91465S2_8

TURBINE AND EXTRACTION ARRANGEMENT IS SCHEMATIC ONLY

FIRED GUARANTEE

THIS HEAT BALANCE REPRESENTS THE MAXIMUM EXPECTED FLOW AT THE INITIAL CONDITIONS SHOWN. TO ASSURE THAT THE TURBINE WILL PASS THIS FLOW, CONSIDERING VARIATIONS IN FLOW COEFFICIENTS FROM EXPECTED VALUES, MANUFACTURING TOLERANCE, ECT, WHICH MAY AFFECT THE FLOW A TURBINE INLET PRESSURE AS MUCH AS 4 PERCENT GREATER THAN THAT SHOWN MAY BE REQUIRED.
THE VALUE OF GENERATOR OUTPUT SHOWN ON THIS HEAT BALANCE IS AFTER ALL POWER FOR EXCITATION AND OTHER TURBINE-GENERATOR AUXILIARIES HAS BEEN DEDUCTED.

PROGRAM NO 8.260



2GT@100% 95F FIRED G'TEE

LEGEND - CALCULATIONS BASED ON 1967 ASME STEAM TABLES
M - FLOW-LB/HR
P - PRESSURE-PSIA
H - ENTHALPY-BTU/LB
T - TEMPERATURE-F DEGREES

306288. KW 3.55 IN HG ABS 0. PCT MU
TC2F 33.5 IN LSB 3600 RPM
1906.1 PSIA 1050. / 1049. T
GEN- 365000. KVA .85 PF LIQ

5. Exhibit D - Gas Turbine Scope Summary

5.1 Gas Turbine Systems

5.1.1 Gas Turbine

Base-mounted gas turbine including:

- Modulating IGV

5.1.2 Combustion System

- Dry Low NOx combustion system
  - With inlet heating
- Compressor inlet humidity sensor
- Compressor inlet temperature thermocouple

5.1.3 Fuel Systems

5.1.3.1 Gas Fuel System

- Natural gas only
- Stainless steel gas piping
- Orifice type gas flow measurement system
- Single gas strainer
- Gas fuel valves on accessory base
- Gas fuel temperature < 365°F

5.1.4 Lubricating and Hydraulic Systems

5.1.4.1 Pumps

- AC motor driven dual lube oil pumps
- AC motor driven dual hydraulic pumps
  - Used for jacking (lifting) oil also

- DC motor driven, emergency lube oil pump
- AC/DC motor driven auxiliary generator seal oil pump

5.1.4.2 Filters and Coolers

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

5.1.4.3 Lube Oil Piping

- 304L stainless steel lube oil feed pipe
- Carbon steel lube oil drain pipe
- Lube system valve stainless steel trim

5.1.4.4 Oil Reservoir

- With heater for -20°F
- Lube vent demister

5.1.4.5 Instrumentation

- Pressure switches for lubrication and hydraulic oil filters

5.1.5 Inlet System

- Inlet system arrangement
  - Up and forward inlet system arrangement
  - Inlet compartment supports straddle ductline
  - Support steel and monorail to lift the front end of the generator rotor clear of the filter house and allow removal with a crane up to $30,000 cost

- Inlet filtration
  - Self-cleaning inlet filter
  - Compressor bleed air supply for filter cleaning
  - Moisture resistant filter media (high humidity environments)
  - APU with galvanized steel piping
  - APU heat tracing kit
  - APU NEMA 4X kit
  - Weather protection on inlet filter compartment
  - Inlet system differential pressure indicator
  - Inlet system differential pressure alarm
  - Inlet filter compartment support steel (Seismic Zone 4, <= 120 mph wind speed)
  - Stairway to inlet filter compartment
  - Left hand access to inlet filter compartment
  - Inlet filter compartment light kit
  - Inlet plenum windows
- Inlet heating
  - Bleed heat manifold located in duct
  - DLN premix turndown inlet bleed heat control
  - Compressor pressure ratio operating limit bleed heat control
  - Inlet bleed heat control valve(s)
- Inlet ducting
  - Inlet silencing
  - Inlet duct section arrangement per proposed mechanical outline
  - Inlet expansion joint
  - Inlet 90 degree elbow
  - Inlet transition piece
  - Inlet ducting support steel (Seismic Zone 4, = 120 mph wind speed)
- Inlet system atmospheric protection
  - Zinc rich paint inside and outside of inlet filter compartment
  - Zinc rich paint on inlet filter compartment support steel
  - Zinc rich paint inside and outside of inlet ducting
  - Galvanized inlet silencing perforated sheet
  - Zinc rich paint on inlet ducting support steel

5.1.6 Exhaust System

5.1.6.1 Arrangement

- Exhaust diffuser with an axial exit
- Exhaust expansion joint

5.1.6.2 Exhaust System Features

- Exhaust system materials and atmospheric protection
  - Carbon steel exhaust system shell and stiffeners
  - 409 stainless steel internal lagging
  - Inorganic zinc primer
    - Duct exterior

5.1.7 Couplings

- Rigid load coupling
- Load coupling guard

5.1.8 Gas Turbine Packaging

- Lagging and enclosures
  - On-base accessory compartment lagging
  - Load coupling compartment lagging
  - Off-base acoustic enclosure for turbine only
  - Acoustic barrier wall around exhaust diffuser
- Compartment ventilation, pressurization and heating
  - Dual turbine compartment vent fans
  - Single accessory compartment vent fan
  - Single load compartment vent fan
  - Heated turbine and accessory compartments for humidity control
- Plant arrangement
  - Turbine designed for installation outdoors
  - Right hand accessory module
  - Unit walkways by customer, mounting pads by GE

- Turbine and accessory base painting
  - Standard primer
- UBC seismic zone #4
- Hazardous area classification
  - NEC Class 1, Group D, Division 2
    - Turbine compartment
    - Gas fuel compartment
- Special features
  - Dual (metric-English) indicators and gauges

5.1.9 Fire Protection System

- Fire detection system
  - Turbine and accessory compartments
- Smoke detection system
  - Control cab/PEECC
- Compartment warning signs
- CO2 supply system
  - One low pressure CO2 tank per unit
  - Tank suitable for 0-120°F (-18 to 49°C)
  - Two dump tank capacity
- Fire protection piping
- Hazardous atmosphere detectors in turbine and gas fuel compartments
- Hazardous atmosphere detector readout

5.1.10 Cleaning Systems

- On base piping for on and offline compressor water wash system
- Water wash skid
  - Water storage tank and freeze protection
  - Skid enclosure
  - Single skid for multiple units (one skid for 2 units).

5.1.11 Cooling Water System

- Cooling system temperature regulating valve

5.1.12 Starting Systems

- Static start
  - Generator start with inverter/regulator
  - Static start isolation transformer
    - Oil filled
  - Shared hardware within a power block
  - Isolation transformer fed from auxiliary bus
  - 12-pulse, water cooled LCI
  - One static start for every two gas turbines
  - Single dc link reactor
  - Water-to-water heat exchanger, shipped loose
- Rotor turning systems
  - AC motor driven turning gear for rotor cooldown
  - Rotor indexing (borescope inspection)

5.1.13 Miscellaneous Systems

5.1.13.1 Special Systems

- Exhaust frame blowers on turbine compartment roof

5.2 Generator

5.2.1 General Information

- Hydrogen cooled generator with conventionally cooled armature
- Outdoor installation
- 60 Hz generator frequency
- Generator voltage 18.0 kV
- 0.85 power factor (lagging)

- Capability to 1.00 power factor (leading)
- Class "F" armature and rotor insulation
- Class "B" temperature rise, armature and rotor winding
- Generator bearings
  - End shield bearing support
  - Elliptical journal bearings
  - Roll out bearing capability without removing rotor
  - Insulated collector end bearing
  - Online bearing insulation check
  - Offline bearing insulation check with isolated rotor
- Monitoring Devices
  - Two BN3300 probes per bearing at 45° angle
  - Two (2) velocity vibration probes at turbine end, one (1) at collector end
  - Provisions for key phaser-generator
  - Permanently mounted flux probe
  - Proximity vibration sensors
- Generator Field
  - Direct cooled field
  - Two-pole field
  - Finger type amortissuers

5.2.2 Generator Gas Coolers

- Coolers shipped installed
- Generator gas cooler configuration
  - Five (5) horizontally mounted simplex coolers
  - Coolers located in generator base
  - Cooler piping connections on left side as viewed from collector end
  - ASME code stamp
  - Single wall cooler tubes
  - Victaulic cooler couplings
  - Plate fins
  - Cooling water manifold and isolation valves

- Generator gas cooling system characteristics
  - Coolant temperature
    - 105°F maximum
  - TEMA class C coolers
  - Generator capacity with one section out of service 80% with Class "F" rise
  - 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 waterbox and coupling flanges with epoxy coating
  - Aluminum cooler tube fins

5.2.3 Generator Lube Oil Systems and Equipment

- Bearing lube oil system
  - Generator lube oil system integral with turbine
  - Sight flow indicator
- Bearing lift oil system
  - Stainless steel lift oil piping and tubing
  - Lift oil supplied from turbine oil system
- Lube oil system piping materials
  - Stainless steel lube oil feed pipe
  - Carbon steel lube oil drain pipe
  - Welded oil piping
  - Flexible pipe as permitted by ANSI 31.3

5.2.4 Generator Grounding Equipment

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

5.2.5 Generator Temperature Devices

- Stator winding temperature devices
  - 100 ohm platinum RTDs (resistance temperature detector)
  - Single element RTDs
  - Grounded RTDs
  - Twelve(12) stator slot RTDs – 9 active, 3 spares wired to teminals
- Gas path temperature devices
  - 100 ohm platinum gas path RTDs
  - Single element temperature sensors
  - Four (4) cold gas
  - Two (2) hot gas
  - GTG-2 (common cold gas)
- Bearing temperature devices
  - Chromel alumel (type K) thermocouples
  - Dual element temperature sensors
  - Two (2) bearing metal temperature sensors per bearing
- Collector temperature devices
  - 100 ohm platinum RTDs
  - Single element temperature sensors
  - Collector air inlet temperature sensor
  - Collector air outlet temperature sensor
- Lube oil system temperature devices
  - Chromel alumel (type K) thermocouples
  - Dual element temperature sensors
  - One (1) bearing drain temperature sensor per drain

5.2.6 Packaging, Enclosures, and Compartments

- Paint and preservation
  - Standard alkyd beige primer
- Generator terminal enclosure (GTE)
- Acoustical requirement of 85 dBA

- Line-side terminal enclosure
  - Terminal enclosure shipped separate
  - High voltage bushings shipped installed
  - Six (6) ambient air cooled, high voltage bushings
  - Isolated phase bus duct connection
  - Phase sequence R-C-L when looking at enclosure terminals
  - Outgoing power connection on right side when viewed from collector end
  - Lightning arrestors
  - Voltage transformers, fixed
- Current transformers
  - Relaying Class C800
  - Line CTs
    - CT16, CT17, CT18
    - CT21, CT22, CT23
    - CT19A, CT19C
- Neutral terminal enclosure
  - Integral with line-side terminal enclosure
  - Neutral tie
  - Neutral CTs
    - CT1, CT2, CT3
    - CT4, CT5, CT6
    - CT7, CT8, CT9
- Collector compartment
  - Collector compartment shipped separate
  - Outdoor
- Generator fire detection
  - Thermal detector in generator collector compartment
- Compartment lighting and outlets
  - AC lighting
    - Collector compartment

- Foundation hardware
  - Generator shims
  - Generator alignment key(s) - collector end
  - Generator alignment key(s) - turbine end
  - Generator alignment key(s) - axial

5.2.7 Hydrogen Systems and Accessories

- Hydrogen control panel
  - NEMA 1 panel in collector compartment
- Hydrogen gas manifolds
  - Auto purge gas purge control manifold
  - Hydrogen/CO2 control manifold in collector compartment
- Seal oil system
  - Control unit mounted in collector compartment
  - Stainless steel seal oil feed pipe
  - Carbon steel seal oil drain pipe
- Hydrogen accessories
  - Pyrolysate collector in collector compartment
  - Core monitor in collector compartment

5.2.8 Electrical Equipment

- Motors
  - TEFC motors
  - Coated with antifungal material for protection in tropical areas
- Heaters
  - Generator stator heaters
  - Generator collector heaters

5.2.9 Generator Excitation Systems, Static Components

- Static excitation with hot backup bridge, auxiliary bus fed

5.2.9.1 Excitation Module Features

- Control/monitor/display through TCP
  - Power factor controller in turbine control system
  - Var controller in turbine control system
  - Selection of automatic or manual regulator
  - Raise-lower of the active regulator setpoint
  - Enter setpoint command
  - Display field amps
  - Display field volts
  - Display transfer volts
  - Display field temperature
- Built-in diagnostic display panel
  - Automatic voltage regulator (AVR)
  - Manual voltage regulator (FVR)
  - Automatic and manual bi-directional tracking
  - Reactive current compensation (RCC)
  - Volts per hertz limiter (V/Hz LIM)
  - Volts per hertz protection (24EX) (Backup to 24G)
  - Over excitation limiter (OEL)
  - Offline/online over excitation protection (76EX)
  - Loss of excitation protection (40EX)
  - Bridge ac phase unbalance protection (47EX)
  - Under excitation limiter (UEL)
  - Generator overvoltage protection (59EX)
  - Generator field ground detector (64F)
  - VT failure detector (VTFD) (60EX)
- Dual source internal bulk power supply
- Millivolt shunt for field
- Surge protection
  - VT disconnect and CT shorting switches
  - Two phase current sensing (CTs A, C)
  - Three phase voltage sensing
  - Single pole dc field contactor/bridge

- Thyristor bridge circuit filtering
- Shaft voltage suppressor circuit (mounted in panel)
  - Field de-excitation circuit (with field discharge inductor)
  - Bridge disconnect; ac no load
- Power system stabilizer

5.2.9.2 Performance

- 2.0 response ratio and 160% VFFL (100°C) ceiling @ Vt = 1.0pu

5.2.9.3 Exciter Panel Location

- Installed in LCI/EX compartment for unit A
- Installed in excitation compartment for unit B

5.2.9.4 LCI Features

- LCI located in LCI/EX compartment
- LCI disconnect switch (89SS)
  - located in generator terminal enclosure
- LCI fuse
  - Located in compartment with LCI

5.2.9.5 PPT Features

- Freestanding oil-filled PPT
- PPT fed from auxiliary bus

5.3 Gas Turbine-Generator Controls and Electric Auxiliaries

5.3.1 Control Cab/Packaged Electric and Electronic Control Compartment (PEECC)

- Control panels mounted on a common skid
- Weatherproof, climate controlled, base mounted enclosure
- Supplemental wall-mounted air conditioner
- Provide egress/ingress access at each end of the PEECC, 1 of which will be away from the gas turbine or accessory compartment module

5.3.2 Gas Turbine Control System Panel Features

- Triple modular redundant (TMR) Mark VI Panel
- Skid mounted control panels
- Auto/manual synchronizing module with synchronizing check function
- Generator stator overtemperature alarm (49)
- Droop control
- Load limiter
- Purge cycle
- Customer alarm/trip contact for CRT display
- Additional customer input contacts
- Additional customer output contacts
- Provision for 8 selectable analog inputs from customer
- Provision for 8 selectable analog output to customer
- Vibration alarm readout and trip
- Electrical overspeed protection
- Constant settable droop

- Power factor calculation and display
- Power factor control
- VAR control
- Manual set point preselected load
- One (1) IRIG-B interface (time signal by buyer)(one per site)

5.3.3 Local Operator Station

- Multi unit control capability via single local operator interface<HMI>
- Commercial grade personal computer
- Color monitor
  - Table top
  - 15 in. screen
- Trackball cursor control
- Table top AT 101 keyboard
- Printer
  - 24 pin dot matrix
- Display in English language
- 50 ft of Arcnet cable between gas turbine control system panel and local operator interface /HMI for indoor use
- RS232C two way serial link (MODBUS) via local <HMI>

5.3.4 Remote Control and Monitoring Systems

- RS232C two way serial link (MODBUS) to DCS via remote <HMI>
- Multi-unit remote operator interface <HMI>
  - Three per site
  - Commercial grade personal computer
  - Color monitor
    - Table top
    - 20 in. screen
  - Trackball cursor control

- Table top AT 101 keyboard
- Printer
  - 24 pin dot matrix
- Power 120Vac 60 Hz

5.3.5 Rotor, Bearing and Performance Monitoring Systems

- Performance monitoring systems
  - Performance monitoring sensors wired to gas turbine control system
- Vibration sensors
  - Velocity vibration sensors
  - Proximity vibration sensors
- Bearing thermocouples
  - Bearing drain thermocouples
  - Bearing metal thermocouples
- Borescope access holes

5.3.6 Generator Control Panel

5.3.6.1 Generator Control Panel Hardware

- Mounted in PEECC
- Skid mounted with turbine panel
- DGP without test plugs
- DGP without ModBus communication interface
- DGP with communication interface
- DGP with oscillography capture
- DGP with printer port
- DGP with redundant internal power supply
- DCP powered from 2 sources allowing a back-up source of DC power for the DGP (second source by Buyer)
- Generator breaker trip switch (52G/CS)

- Humidity sensor readout
- Hazardous atmosphere detector readout
-

5.3.6.2 Digital Generator Protection System (DGP)

- Generator overexcitation (24)
- Generator undervoltage (27G)
- Reverse power/anti-motoring (32-1)
- Reverse power/anti-motoring (32-2)
- Loss of excitation (40-1,2)
- Current unbalance/negative phase sequence (46)
- System phase fault (51V)
- Generator overvoltage (59)
- Stator ground detection (64G1)/(59GN)
- Stator ground detection, third harmonic (27TN)
- Generator over frequency (81O-1,2)
- Generator under frequency (81U-1,2)
- Generator under frequency (81U-3,4)
- Generator differential (87G)
- Voltage transformer fuse failure (VTFF)

5.3.6.3 Generator Protection Discrete Relays

- Synchronizing undervoltage relay (27BS-1,2)
- Reverse/inadvertent energization protection relay (50RE/86RE)
- Breaker or lockout trip coil monitor relay (74)
- DC tripping bus, blown fuse protection relay (74-2)
- Generator differential lockout relay (86G-1)

- Second generator lockout relay (86G-2)

5.3.6.4 Main Transformer Discrete Relays

- Main transformer lockout relay (86T-1)

5.3.6.5 Features Integrated Into Gas Turbine Control System

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

5.3.6.6 Generator Control Panel Metering

- Generator digital multimeter
  - VM - Generator volts
  - AM - Generator Amps: Phase 1,2,3 and Neutral
  - MW - Generator MegaWatts
  - MVAR - Generator MegaVARs
  - FM - Generator frequency
  - MVA - Generator MVA
  - PF - Generator power factor
  - MWH - Generator MegaWatt-Hours
  - MVAH - Generator MVA Hours

5.3.6.7 Generator Control Panel Transducers

- Generator watt/VAR transducer 4-20 mA output for input to TCP (96GG-1)
- Generator TCP/droop control transducer 4-20 mA output (96GW-1)

5.3.7 Generator Protection

- Generator electrical protection equipment
  - Ground brush rigging

5.3.8 Batteries and Accessories

- Lead acid battery
- Single phase battery charger
- Battery and charger mounted in the PEECC
- 2nd battery charger

5.3.9 Motor Control Center

- MCC mounted in control cab/PEECC
- Tin-plated copper bus-work
- 42 kA bracing
- 480V 60 Hz auxiliary power

5.3.10 Motor Features

- TEFC motors (200 hp
- Coated with antifungal material for protection in tropical areas
- High ambient motor insulation
- Energy saver motors
- Extra severe duty motors
- Cast iron motor housings
- All redundant motors to be lead/lag
- Motor heaters
  - Rated 110/120 volts, 50/60 Hz
- WP motors >200 hp

5.4 Services

- Technical advisory services

- Start-up spare parts
- Transportation
  - Domestic freight
  - Generator shipped with rotor installed
- Documentation
  - Up to 10 sets of English language service manuals per station, including Operation, Maintenance and Parts volumes
- Turbine maintenance tools
  - Guide pins (for removal or replacement of bearing caps, compressor casing and exhaust frame)
  - Fuel nozzle wrenches
  - Fuel nozzle test fixture
  - Spark plug electrode tool
  - Clearance tools
  - Fuel nozzle staking tool
  - Combustion liner tool
  - Bearing and coupling disassembly fixture
- Generator maintenance tools (1 set per site)
  - Rotor lifting slings
  - Rotor removal equipment including shoes, pans, pulling devices
  - Rotor jacking bolts
- Installation equipment
  - Trunions for generator
    - On loan basis only
  - Jacking bolts for generator
  - Foundation/installation washer and shim packs
- Power System Studies
  - Provided by customer
  - Settings for generator; DGP, 27BS, and 59BN relays
  - Exciter power system stabilizer tuning study
  - PSS field tuning

6. Exhibit D - Gas Turbine-Generator

6.1 Gas Turbine Systems

6.1.1 Gas Turbine

The MS7001(FA) gas turbine has a single shaft, bolted rotor with the generator connected to the gas turbine through a solid coupling at the compressor or "cold" end. This configuration improves alignment control and provides an axial exhaust -- optimal for combined cycle or waste heat recovery applications. The major features of the MS7001(FA) gas turbine are described below:

6.1.2 Compressor Section

The axial flow compressor has 18 stages with modulating inlet guide vanes and provides a 15.2 to 1 pressure ratio. Interstage air extraction is used for cooling and sealing air for turbine nozzles, wheelspaces, and bearings, and for surge control during start up.

6.1.2.1 Compressor Rotor

The compressor rotor consists of a forward stub shaft with the stage zero rotor blades, a sixteen blade and wheel assembly for stages 1 to 16, and an aft stub shaft with the stage 17 rotor blades. Rotor blades are inserted into broached slots located around the periphery of each wheel and wheel portion of the stub shaft. The rotor assembly is held together by fifteen axial bolts around the bolting circle. The wheels are positioned radially by a rabbeted fit near the center of the discs. Transmission of torque is accomplished by face friction at the bolting flange.

Selective positioning of the wheels is made during assembly to reduce the rotor balance correction. The compressor rotor is dynamically balanced after assembly and again after the compressor and turbine rotors are mated. They are precision balanced prior to assembly into the stator.

6.1.2.2 Compressor Blade Design

The airfoil shaped compressor rotor blades are designed to compress air efficiently at high blade tip velocities. Compressor blades are made from high corrosion resistance material which eliminates the need for a coating. These forged blades are attached to their wheels by dovetail connections. The dovetail is accurately machined to maintain each blade in the desired location on the wheel.

Stator blades utilize square bases for mounting in the casing slots. Blade stages zero through four are mounted by axial dovetails into blade ring segments. The blade ring segments are inserted into circumferential grooves in the casing and are secured with locking rings. Stages 5 through 16 are mounted on individual rectangular bases that are inserted directly into circumferential grooves in the casings. Stage 17 and the exit guide vanes are cast segments.

6.1.2.3 Compressor Stator

The casing is composed of three major subassemblies: the inlet casing, the compressor casing, and the compressor discharge casing. These components in conjunction with the turbine shell, exhaust frame/diffuser, and combustion wrapper form the compressor stator.

The casing bore is maintained to close tolerances with respect to the rotor blade tips for maximum aerodynamic efficiency. Borescope ports are located throughout the machine for component inspection. In addition all casings are horizontally split for ease of handling and maintenance.

6.1.2.3.1 Inlet Casing

The primary function of the inlet casing, located at the forward end of the gas turbine, is to direct the air uniformly from the inlet plenum into the compressor. The inlet casing also supports the number 1 thrust bearing assembly and the variable inlet guide vanes, located at the aft end.

6.1.2.3.2 Compressor Casing

The compressor casing contains compressor stages zero through 12. Extraction ports in the casing allow bleeds to the exhaust plenum during start-up and extraction of air to cool the second and third stage nozzles.

6.1.2.3.3 Compressor Discharge Casing

The compressor discharge casing contains 13th- through 17th- stage compressor stators and one row of exit guide vanes. It also provides an inner support for the first-stage turbine nozzle assembly and supports the combustion components. Air is extracted from the compressor discharge plenum to cool the stage one nozzle vane, retaining ring, and shrouds.

Similarly, air extracted from the compressor discharge plenum is used to provide the following:

- Fuel system purge air
- Inlet bleed heat
- Compressor surge control

The compressor discharge casing consists of two cylinders connected by radial struts. The outer cylinder is a continuation of the compressor casing and the inner cylinder surrounds the compressor aft stub shaft. A diffuser is formed by the tapered annulus between the outer and inner cylinders. The compressor discharge casing is joined to the combustion wrapper at the flange on its outermost diameter.

6.1.3 Turbine Section

In the three stage turbine section, energy from hot pressurized gas produced by the compressor and combustion section is converted to mechanical energy. The turbine section is comprised of the combustion wrapper, turbine rotor, turbine shell, exhaust frame, exhaust diffuser, nozzles and diaphragms, stationary shrouds, and aft (number 2) bearing assembly.

6.1.3.1 Turbine Rotor

The turbine rotor assembly consists of a forward shaft, three turbine wheels, two turbine spacer wheels, and an aft turbine shaft which includes the number 2 journal bearing. The forward shaft extends from the compressor rotor aft stub shaft flange to the first stage turbine wheel. Each turbine wheel is axially separated from adjacent stage(s) with a spacer wheel. The spacer wheel faces have radial slots for cooling air passages, and the outer surfaces are machined to form labyrinth seals for interstage gas sealing.

Selective positioning of rotor members is performed during assembly to minimize balance corrections of the assembled rotor. Concentricity control is achieved with mating rabbets on the turbine wheels, spacers, and shafts. Turbine rotor components are held in compression by bolts. Rotor torque is accomplished by friction force on the wheel faces due to bolt compression.

The turbine rotor is cooled by air extracted from compressor stage 17. This air is also used to cool the turbine first- and second-stage buckets plus the rotor wheels and spacers.

6.1.3.2 Turbine Bucket Design

The first-stage buckets use forced air convection cooling in which turbulent air flow is forced through integral cast-in serpentine passages and discharged from holes at the tip of the trailing edge of the bucket. Second-stage buckets are cooled via radial holes drilled by a shaped tube electromechanical machining process. Third-stage buckets do not require air cooling.

Second- and third-stage buckets have integral tip shrouds which interlock buckets to provide vibration damping and seal teeth that reduce leakage flow. Turbine buckets are attached to the wheel with fir tree dovetails that fit into matching cutouts at the rim of the turbine wheel. Bucket vanes are connected to the dovetails by shanks which separate the wheel from the hot gases and thereby reduce the temperature at the dovetail. All turbine buckets are coated to provide corrosion resistance.

The turbine rotor assembly is arranged to allow buckets to be replaced without having to unstack the wheels, spacers and stub shaft assemblies. Similarly, buckets are selectively positioned such that they can be replaced individually or in sets without having to rebalance the wheel assembly.

6.1.3.3 Turbine Stator

The turbine stator is comprised of the combustion wrapper, turbine shell, and the exhaust frame. Like the compressor stator, the turbine stator is horizontally split for ease of handling and maintenance.

6.1.3.3.1 Combustion Wrapper

The combustion wrapper, located between the compressor discharge casing and the turbine shell, facilitates removal and maintenance of the transition pieces and stage one nozzle.

6.1.3.3.2 Turbine Shell

The turbine shell provides internal support and axial and radial positions of the shrouds and nozzles relative to the turbine buckets. This positioning is critical to gas turbine performance. Borescope ports are provided for inspection of buckets and nozzles.

6.1.3.3.3 Exhaust Frame

The exhaust frame is bolted to the aft flange of the turbine shell and consists of an outer and an inner cylinder interconnected by radial struts. The inner cylinder supports the number 2 bearing. The tapered annulus between the outer and inner cylinders forms the axial exhaust diffuser. Gases from the third-stage turbine enter the diffuser where the velocity is reduced by diffusion and pressure is recovered, improving performance.

Cooling of the exhaust frame, number 2 bearing, and diffuser tunnel is accomplished by motor-driven blowers. These motor driven blowers are located on the top of the gas turbine enclosure.

6.1.3.4 Turbine Nozzle Design

The turbine section has three stages of nozzles (stationary blades) with air cooling provided to all three stages. The first- and second-stage nozzles are cooled by a combination of film cooling (gas path surface), impingement cooling, and convection cooling in the vane and sidewall regions. The third stage uses convection cooling only.

All turbine nozzles consist of multi-vane segments. First-stage turbine nozzle segments are contained by a retaining ring which remains centered in the turbine shell. The second- and third-stage nozzle segments are held in position by radial pins from the shell into axial slots in the nozzle outer sidewall.

6.1.3.5 Bearings

The MS7001(FA) gas turbine contains two journal bearings to support the turbine rotor and one dual direction thrust bearing to maintain the rotor-to-stator axial position. The bearings are located in two housings: one at the inlet and one at the center of the exhaust frame. All bearings are pressure lubricated by oil supplied from the main lubrication oil system. The number 1 bearing (journal and thrust) is accessed by removing the top half of the compressor inlet casing. The number 2 bearing is readily accessible through the tunnel along the centerline of the exhaust diffuser. (Removal of the turbine casing is not required for bearing maintenance.) Bearing protection includes vibration sensors and drain oil temperature thermocouples.

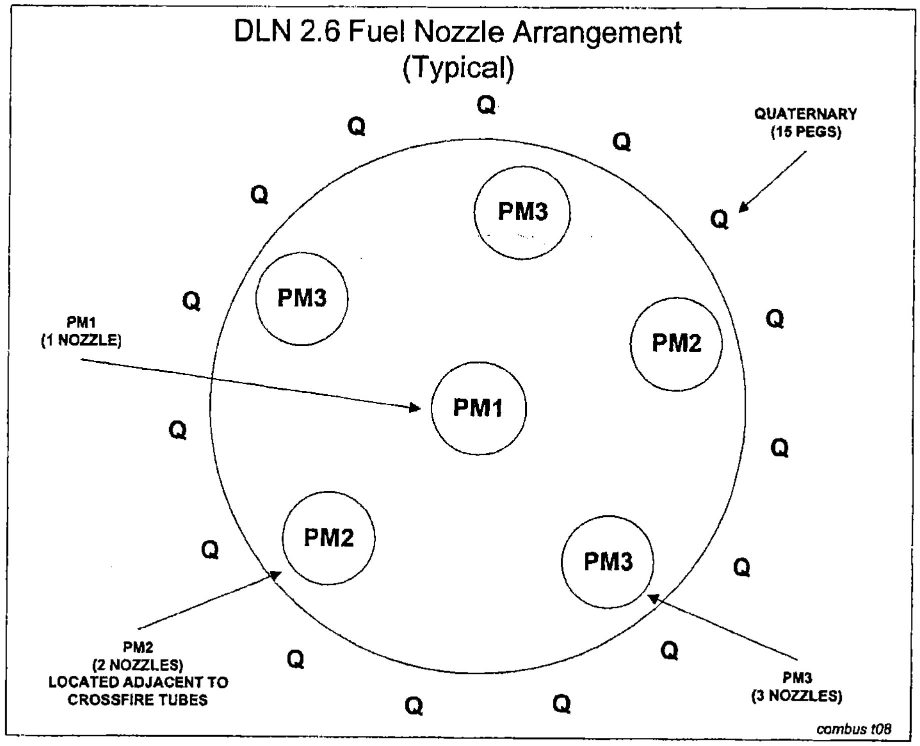
6.1.4 Combustion

6.1.5 Dry Low NOx 2.6 Combustion System

The Dry Low NOx 2.6 combustion system (DLN 2.6) was designed to minimize emissions when operating on gas fuel. Optimal emissions are achieved through the regulation of fuel distribution to a multi-nozzle, total premix combustor arrangement. The fuel flow distribution to each fuel nozzle assembly is calculated to maintain unit load and fuel split which optimizes turbine emissions.

6.1.5.1 Fuel Nozzle Arrangement

The DLN 2.6 combustion system consists of six fuel nozzles per combustion can, each operating as a fully premixed combustor. One fuel nozzle is located in the center of the combustion can with five nozzles located radially from the first as shown in the illustration below. The center nozzles is identified as PM1 (Pre Mix 1). Two outer nozzles located adjacent to the crossfire tubes are identified as PM2 (Pre Mix 2). The remaining three outer nozzles are identified as PM3 (Pre Mix 3). Another fuel passage is located in the airflow upstream of the premix nozzles, circumferentially around the combustion can. This passage is identified as the quaternary fuel pegs.



Fuel flow to the six fuel nozzles and quaternary pegs is controlled by independent control valves, each controlling flow split and unit load. The gas fuel system consists of the gas fuel stop/ratio valve, gas control valve one (PM1), gas control valve two (PM2), gas control valve three (PM3), and gas control valve four (Quat).

The stop/ratio valve (SVR) is designed to maintain a predetermined pressure at the inlet of the gas control valves. Gas control valves one through four regulate the desired gas fuel flow delivered to the turbine in response to the command signal fuel stoke reference (FSR) from the gas turbine control panel. The DLN 2.6 control system is designed to ratio FSR into a Flow Control Reference. The flow control philosophy is performed in a cascading routine, scheduling a percentage flow reference for a particular valve, and driving the remainder of the percentage to the next valve reference parenthetically downstream in the control software.

6.1.5.2 Chamber Arrangement

The gas turbine employs fourteen combustors designated as combustion chambers. There are two spark plugs and four flame detectors in selected chambers with crossfire tubes connecting adjacent chambers. Each combustor consists of a six nozzle/endcover assembly, forward and aft combustion casings, flow sleeve assembly, multi-nozzle cap assembly, liner assembly and transition piece assembly. A quaternary nozzle arrangement penetrates the circumference of the combustion chamber, porting fuel to casing injection pegs located radially around the casing.

6.1.5.3 Spark Plug Ignition System

Two spark plugs located in different combustion chambers are used to ignite fuel flow. These spark plugs are energized to ignite fuel at firing speed during start-up only. Flame is propagated to those combustion chambers without spark plugs through crossfire tubes connecting adjacent combustion chambers around the gas turbine.

6.1.5.4 Flame Detectors

Reliable detection of flame location in the DLN 2.6 system is critical to the control of the combustion process and to protection of the gas turbine hardware. Four flame detectors are mounted in separate combustion chambers around the gas turbine to detect flame in all modes of operation. The signals from these flame detectors are processed in control logic and used for various control and protection functions.

6.1.5.5 Gas Fuel Operation

The DLN 2.6 fuel system operation is fully automated, sequencing the combustion system through a number of staging modes prior to reaching full load. The primary controlling parameter for fuel staging is the calculated combustion reference temperature. Other DLN 2.6 operation influencing parameters available to the operator are inlet guide vane (IGV) temperature control "ON" or "OFF" and inlet bleed heat "ON" or "OFF". To achieve maximum exhaust temperature, as well as an expanded load range for optimal emissions, both IGV temperature control and inlet bleed heat should be selected "ON".

6.1.5.6 Inlet Guide Vane Operation

The DLN 2.6 combustor emission performance is sensitive to changes in fuel/air ratio. The combustor was deigned according to the airflow regulation scheme used with IGV temperature control. Optimal combustor operation is dependent upon proper operation along the predetermined temperature control scheme. Controlled fuel scheduling is dependent upon the state of IGV temperature control.

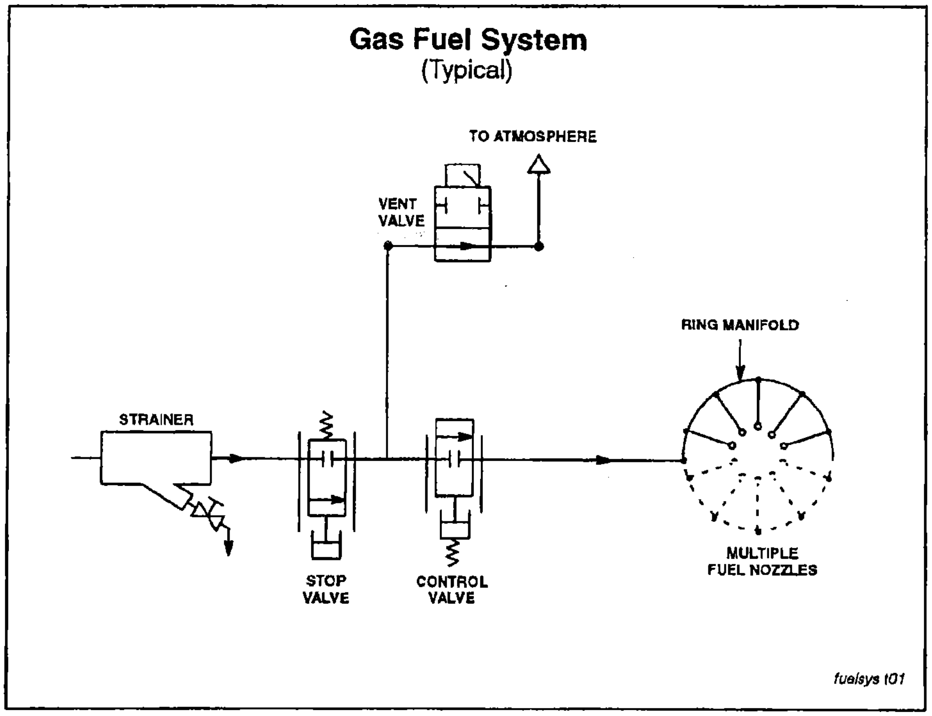
IGV temperature control "ON" is also referred to as a combined cycle operation while IGV temperature control "OFF" is referred to as simple cycle operation.

6.1.5.7 Inlet Bleed Heat

6.1.6 Fuel System

6.1.6.1 Gas Fuel System

The gas fuel system modulates the gas fuel flow to the turbine. Proper operation of the gas fuel system requires that the gas be supplied to the gas fuel control system at the proper pressure and temperature. The pressure is required to maintain proper flow control. The fuel gas temperature must ensure that the required hydrocarbon superheat is maintained. For discussion of fuel gas supply requirements in the Reference Documents - Process Specification Fuel Gases for Combustion in Heavy-Duty Gas Turbines. Major system components, as shown in the illustration which follows, are described below.



6.1.6.1.1 Strainer

A single strainer is used to remove impurities from the gas. A pressure switch which monitors the differential across the strainer will signal an alarm through the gas turbine control system when the pressure drop across the strainer indicates cleaning is required.

6.1.6.1.2 Fuel Gas Stop/Speed Ratio and Control Valves

The fuel gas stop/speed ratio and control valves allow fuel flow when the turbine starts and runs, control the fuel flow, and provide protective fuel isolation when the turbine is shut down. In systems with multiple control valve configuration, the control valves also maintain the fuel split among the fuel nozzles.

6.1.6.1.3 Vent Valve

When the gas fuel system is shut off, both the stop valve and the control valve(s) are shut. A vent valve is opened between the stop valve and the control valve(s). The vent valve permits the fuel gas to exit to the atmosphere when the turbine is shut down or switched to an alternate fuel.

6.1.6.1.4 Flow Measurement System

The gas fuel flow measurement system uses a flow metering tube with precision orifice. The pressure drop across the orifice is used to determine the fuel flow. To accommodate the large flow turndown, two delta-pressure transducers with different, but over-lapping ranges, are used.

6.1.6.1.5 Fuel Flow Monitoring Equipment

The following fuel flow equipment is provided for integration by the customer into the fuel supply line. The meter shall meet the requirement of EPA 40 CFR if installed in accordance with 40 CFR:

- Gas
  - Meter tube and orifice with delta P transducers for flow indication
  - Transmitter for supply temperature indication
  - Static pressure transducer

6.1.6.1.6 Fuel Manifold and Nozzles

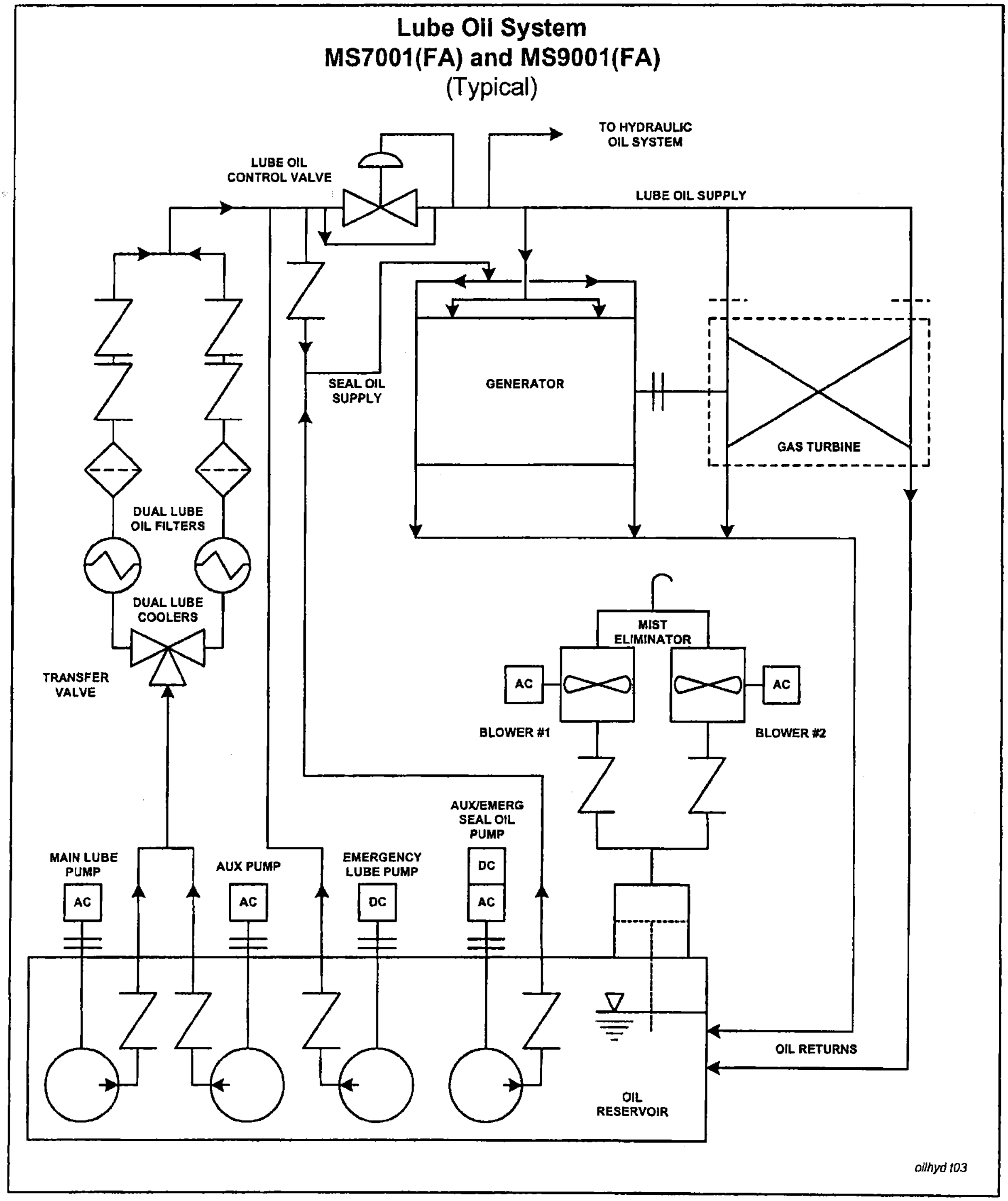
The fuel manifold connects the gas fuel nozzles which distribute the gas fuel into the combustion chambers. For staged combustion systems, more than one manifold is used.

6.1.6.1.7 Piping

The gas fuel system uses stainless steel fuel gas piping with carbon steel flanges.

6.1.7 Lubricating and Hydraulic Systems

The lubricating provisions for the turbine and generator are incorporated into a common lubrication system. Oil is taken from this system, pumped to a higher pressure, and used in the hydraulic system for all hydraulic oil control system components. The lubrication system includes oil pumps, coolers, filters, instrumentation and control devices, a mist elimination device and an oil reservoir as shown in the system illustration below. Following the illustration is a brief description of the major system components.


Lube Oil System
MS7001(FA) and MS9001(FA)
(Typical)
TO HYDRAULIC OIL SYSTEM
LUBE OIL CONTROL VALVE
LUBE OIL SUPPLY
SEAL OIL SUPPLY
GENERATOR
GAS TURBINE
DUAL LUBE OIL FILTERS
DUAL LUBE COOLERS
TRANSFER VALVE
MIST ELIMINATOR
AC
AC
BLOWER #1
BLOWER #2
AUX/EMERG SEAL OIL PUMP
MAIN LUBE PUMP
AUX PUMP
EMERGENCY LUBE PUMP
AC
AC
DC
DC
AC
OIL RETURNS
OIL RESERVOIR
oilhyd t03

6.1.7.1 Pumps

The lubrication system relies on several pumps to distribute oil from the oil reservoir to the systems which need lubrication. Similarly, redundant pumps are used to distribute high pressure oil to all hydraulic oil control system components. These and other oil pumps are listed below.

- Lubrication oil pumps
  - Dual redundant ac motor-driven main lubrication oil pumps are provided.
  - A partial flow, dc motor-driven, emergency lubrication oil centrifugal pump is included as a back up to the main and auxiliary pumps.
- Hydraulic pumps
  - Dual redundant ac motor-driven variable displacement hydraulic oil pumps are provided.
- Seal oil pump
  - An auxiliary generator seal oil pump driven by piggyback ac/dc motors is provided as backup to distribute seal oil to the generator.
- Oil Pump for pressure lift journal bearings
  - Oil for the pressure lift bearings is provided by the hydraulic oil pump.

6.1.7.2 Coolers

The oil is cooled by dual stainless steel plate/frame oil-to-coolant heat exchangers with transfer valve. The coolers have an ASME code stamp.

6.1.7.3 Filters

Dual, full flow filters clean the oil used for lubrication. Each filter includes a differential pressure transmitter to signal an alarm through the gas turbine control system when cleaning is required. A replaceable cartridge is utilized for easy maintenance. Filters have an ASME code stamp.

Dual filters clean the oil for the hydraulic system. Each filter includes a differential pressure transmitter to signal an alarm through the gas turbine control system when cleaning is required. A replaceable cartridge is utilized for easy maintenance. Filters have an ASME code stamp.

6.1.7.4 Mist Elimination

Lubrication oil mist particles are entrained in the system vent lines by sealing air returns of the gas turbine lubricating system. In order to remove the particles, a lube vent demister is used as an air-exhaust filtration unit. The demister filters the mist particles, and vents the air to atmosphere while draining any collected oil back to the reservoir.

The lube vent demister assembly consists of a holding tank with filter elements, motor-driven blowers, and relief valve. One assembly is provided for the vent line from the lubrication oil reservoir.

6.1.7.5 Oil Reservoir

The oil reservoir has a nominal capacity of 6200 gallons (23,470 liters) and is mounted within the accessory module. It is equipped with lubrication oil level switches to indicate full, empty, high level alarm, low level alarm, and low level trip. In addition the following are mounted on the reservoir:

- Oil tank thermocouples
- Oil heaters
- Oil filling filter
- Oil reservoir drains

6.1.8 Inlet System

6.1.8.1 General

Gas turbine performance and reliability are a function of the quality and cleanliness of the inlet air entering the turbine. Therefore, for most efficient operation, it is necessary to treat the ambient air entering the turbine and filter out contaminants. It is the function of the air inlet system with its specially designed equipment and ducting to modify the quality of the air under various temperature, humidity, and contamination situations and make it more suitable for use. The inlet system consists of the equipment and materials defined in the Scope of Supply chapter of this proposal. The following paragraphs provide a brief description of the major components of the inlet system.

6.1.8.2 Inlet Filtration

6.1.8.2.1 Inlet Filter Compartment

The self-cleaning inlet filter compartment utilizes high efficiency media filters which are automatically cleaned of accumulated dust, 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. Appropriate filter media is provided based on the site specific environmental conditions.

Dust-laden ambient air flows at a very low velocity into filter modules which are grouped around a clean-air plenum. The filter elements are pleated to provide an extended surface. The air, after being filtered, passes through venturis to the clean air plenum and into the inlet ductwork.

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 setpoint 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 high pressure air into a blowpipe which has orifices located just above the filters. This pulse shocks the filters and causes a momentary reverse flow, disturbing the filter cake. 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 setpoint. 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.

The filter elements are contained within a fabricated steel enclosure which has been specially designed for proper air flow management and weather protection.

Self-cleaning filters require a source of clean air for pulse-cleaning. Compressor discharge air is used as the pulse air source for filter cleaning. It is reduced in pressure, cooled and dried. This air is already clean because it has been filtered by the gas turbine's inlet air filter. When compressor discharge air is used to pulse the filter, cleaning is possible only when the gas turbine is running.

6.1.8.3 Inlet System Instrumentation

6.1.8.3.1 Inlet System Differential Pressure Indicator

Standard pressure drop indicator (gauge) displays the pressure differential across the inlet filters in inches of water.

6.1.8.3.2 Inlet System Differential Pressure Alarm

When the pressure differential across the inlet filters reaches a preset value, an alarm is initiated. This alarm may signify a need to change the filter elements.

6.1.8.4 Inlet Acclimatization

6.1.8.4.1 Inlet System Anti-Icing Protection

Dry Low Nox (DLN) combustion systems can require adjustment of the Inlet Guide Vane (IGV) angle during certain operational modes and load conditions. Reduced IGV angles can cause a higher pressure drop and a resultant temperature depression of the air flow. This effect could lead to ice formation on the first stage stator blades under certain ambient conditions. To address this situation, compressor discharge air is extracted from the compressor and recirculated to a mixing manifold in the inlet system. Recirculating the compressor discharge air to the inlet air stream prevents conditions necessary for the formation of ice on the first stage stator blades by warming the incoming inlet air. The inlet bleed heat system is controlled as a function of IGV angle.

When inlet bleed heating systems are required, the inlet bleed heat is also used for compressor pressure ratio operating limit control. The inlet bleed heat is used to control the amount of compressor bleed to limit the pressure ratio and adapt the existing system regulation for all compressor bleed protection designs.

6.1.9 Exhaust System

The exhaust system arrangement includes the exhaust diffuser. After exiting the last turbine stage, the exhaust gases enter the exhaust diffuser section in which a portion of the dynamic pressure is recovered as the gas expands. The gas then flows axially into the exhaust system.

6.1.10 Gas Turbine Packaging

6.1.10.1 Enclosures

Gas turbine enclosures consist of several connected sections forming an all weather protective housing which may be structurally attached to each compartment base or mounted on an off-base foundation. Enclosures provide thermal insulation, acoustical attenuation, and fire extinguishing media containment. For optimum performance of installed equipment, compartments include the following as needed:

- Ventilation
- Heating
- Cooling

In addition, enclosures are designed to allow access to equipment for routine inspections and maintenance.

The following illustration of the MS7001(FA) shows the gas turbine-generator as it is packaged in adjoining weather protective enclosures.

6.1.10.2 Acoustics

Lagging consists of glass mineral wool protected with perforated metal is used on the interior of the side and roof panels of the turbine and accessory compartments for acoustical attenuation.

The average estimated near field noise level of a single gas turbine generator package operating at base load is 85 dBA at 3 feet laterally from the turbine package, and measured 5 feet above the machine base (not adjacent to inlet compartment, inlet or exhaust ducting, openings, or any operating off-base equipment).

Measuring procedures will be in accordance with ASME PTC 36 (near field) and/or ANSI B133.8 (far field).

6.1.10.3 Painting

The exteriors of all compartments and other equipment are painted with two coats of alkyd primer prior to shipment. The exterior surfaces of the inlet compartment and inlet and exhaust duct are painted with one coat of inorganic zinc primer, or hot dip galvanized.

Interiors of all compartments are painted as well with the turbine compartment interior receiving high-temperature paint. The interior and exterior of the inlet system is painted with zinc rich paint.

6.1.10.4 Lighting

AC lighting on automatic circuit is provided in the accessory compartment. When ac power is not available, a dc battery-operated circuit supplies a lower level of light automatically.

For units with off-base enclosures, GE provides ac/dc lights in the turbine compartments.

Fluorescent lighting is also provided in the PEECC.

Incandescent lighting in the inlet filter house.

6.1.10.5 Wiring

The gas turbine electrical interconnection system includes on-base wiring, terminal boards, junction boxes, etc. as well as compartment interconnecting cables. Junction boxes are selected to meet the environmental requirement of the Customer but are, in general, of steel or cast aluminum construction. Terminal boards within junction boxes are of the heavy duty industrial type selected for the particular environment in which the junction box is located. On-base gas turbine wire termination uses spring tongue crimped type terminals. Generator wire termination are ring type. Control panel wiring is General Electric type SIS Vulkene insulated switchboard wire, AWG #14-41 Strand SI-57275. Ribbon cables are used as appropriate.

6.1.11 Fire Protection System

Fixed temperature sensing fire detectors are provided in the gas turbine, accessory and liquid fuel/atomizing air compartments, and #2 bearing tunnel. The detectors provide signals to actuate the low pressure carbon dioxide (CO_2) automatic multi-zone fire protection system. Nozzles in these compartments direct the CO_2 to the compartments at a concentration sufficient for extinguishing flame. This concentration is maintained by gradual addition of CO_2 for an extended period.

The fire protection system is capable of achieving a non-combustible atmosphere in less than one minute, which meets the requirements of the United States National Fire Protection Association (NFPA) #12.

The supply system is composed of a low pressure CO_2 tank with refrigeration system mounted off base, a manifold and a release mechanism. Initiation of the system will trip the unit, provide an alarm on the annunciator, turn off ventilation fans and close ventilation openings.

6.1.12 Cleaning Systems

6.1.12.1 On-Line and Off-Line Compressor Water Wash

Compressor water wash is used to remove fouling deposits which accumulate on compressor blades and to restore unit performance. Deposits such as dirt, oil mist, industrial or other atmospheric contaminants from the surrounding site environment, reduce air flow, lower compressor efficiency, and lower compressor pressure ratio, which reduce thermal efficiency and output of the unit. Compressor cleaning removes these deposits to restore performance and slows the progress of corrosion in the process, thereby increasing blade wheel life.

On–line cleaning is the process of injecting water into the compressor while running at full speed and some percentage of load. Off–line cleaning is the process of injecting cleaning solution into the compressor while it is being turned at cranking speed. The advantage of on–line cleaning is that washing can be done without having to shut down the machine. On–line washing, however, is not as effective as off–line washing; therefore on–line washing is used to supplement off–line washing, not replace it.

The on–base compressor washing features are described and illustrated below.

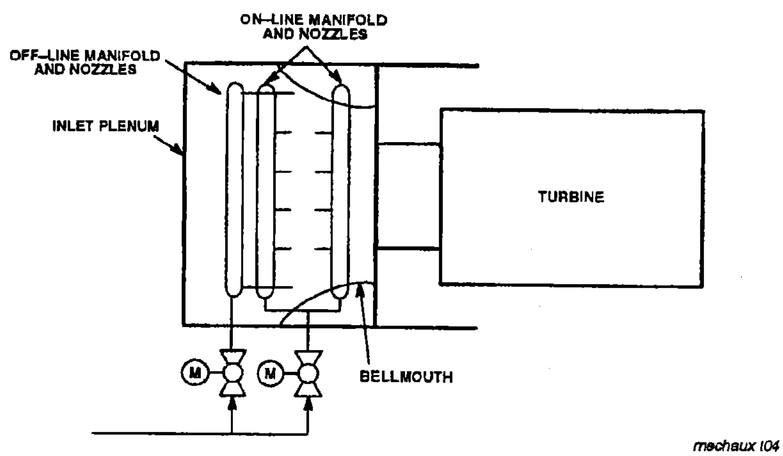
6.1.12.1.1 On–Line Manifold and Nozzles

The on–line washing components consist of two piping manifolds, spray nozzles (one in the forward bellmouth and one in the aft bellmouth), and an on/off control valve which is also controlled by the turbine control panel. The turbine control system is equipped with software to perform an automatic on–line wash by simply initiating the wash from the turbine control panel.

6.1.12.1.2 Off–Line Manifold and Nozzles

The off–line washing components consist of a piping manifold, spray nozzles in the forward bellmouth, and an on/off control valve controlled by the turbine control panel. Off–line washing is a manual operation because of the large number of manual valves on the turbine which need to be manipulated in order to perform an off–line wash.

Water Wash Off and On–Line Manifold and Nozzles
(Typical)



6.1.12.1.3 Water Wash Skid

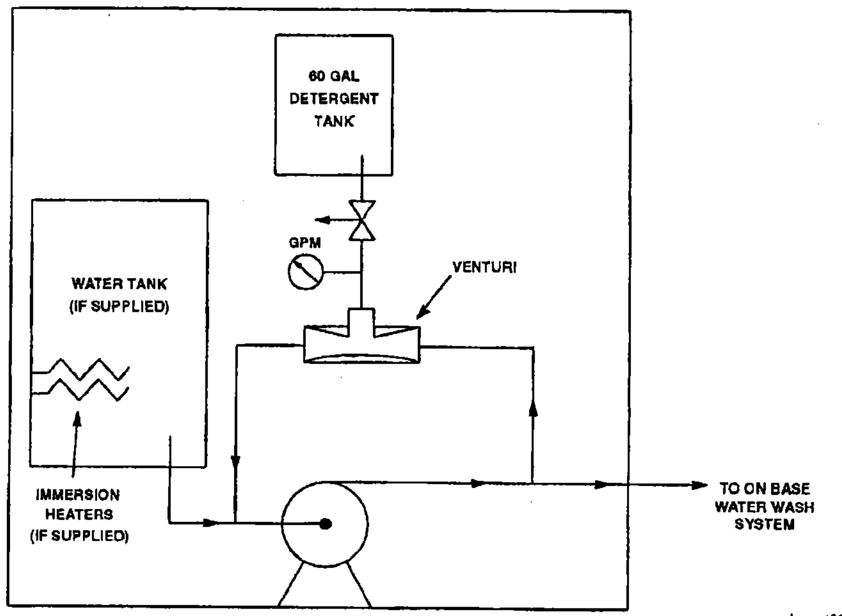
The off–base water wash skid is used for injecting cleaning solution into the compressor for off–line cleaning. The skid contains a water pump, a detergent storage tank, piping, and a venturi eductor capable of delivering solution at the proper flow, pressure and mix ratio.

In addition, the water wash skid is equipped with the following features:

- Water storage tank with freeze protection
- Enclosure for outdoor installation

Typical water wash skid features are shown in the illustration which follows.

Compressor Water Wash Skid
(Typical)



6.1.13 Starting System

6.1.13.1 Cooldown System

The cooldown system provides uniform cooling of the rotor after shutdown. A low speed turning gear with motor is used for the cooldown system.

6.1.13.2 Static Start System

6.1.13.2.1 Operation

The static start system uses a Load Commutating Inverter (LCI) adjustable frequency drive as the starting means for the gas turbine. By providing variable frequency power directly to the generator terminals, the generator is used as a synchronous motor to start the gas turbine. The generator will be turning at approximately 6 rpm, via a low speed turning gear, prior to starting. With signals from the turbine control, the LCI will accelerate or decelerate the generator to a self-sustaining speed required for purge, light-off, waterwash etc. Deceleration is a coast down function.

The system can accelerate the gas turbine-generator without imposing high inrush currents, thereby avoiding traditional voltage disturbances on the ac station service line.

Conventional three phase, 12-pulse bridge circuits are used for the rectifier and inverter and are connected through a dc link inductor. An isolation transformer is required to provide three phase power, impedance for fault protection, and electrical isolation from system disturbances to ground.

Starting excitation is provided by the generator excitation system.

6.1.13.2.2 System Protection

The customer should provide a high level of fault protection for the major equipment. The protective relaying should include phase overcurrent ground fault and motor protection

The drive system protective strategy is to provide a high level of fault protection for the major equipment. The protective relaying includes phase overcurrent ground fault and motor protection. The rectifier inverter includes voltage surge protection and full fault suppression capability for internal faults or malfunctions. A drive system monitor and diagnostic fault indications continuously monitor the condition and operation of the LCI.

6.1.13.2.3 **Equipment**

6.1.13.2.3.1 **Low Speed Turning Gear**

The turning gear assembly is located on the collector end of the generator and is used for slow speed operation (approximately 6 rpm), cooldown and standby turning, and rotor breakaway during startup.

6.1.13.2.3.2 **LCI Power Conversion Equipment**

The LCI power conversion equipment is mounted in a NEMA 1 ventilated enclosure and consists of the following:

- 12-pulse converter with series redundant thyristor cells to rectify ac line power to controlled voltage dc power.
- Inverter with series redundant cells to convert dc link power to controlled frequency ac power.
- Cooling system using a liquid coolant to transfer heat from heat producing devices, such as SCRs and high wattage resistors, to a remote liquid-liquid heat exchanger. The system is closed-loop with a covered reservoir for makeup coolant. Coolant circulates from the pump discharge to the heat exchanger to the power conversion bridges and returns to the pump. A portion of the coolant bypasses to a deionizer system to maintain coolant resistivity. Redundant pumps are provided.
- LCI control panel containing microprocessor system control logic for firing, drive sequencing, diagnostics and protective functions, acceleration (ramping function), excitation system interface, and input/output signal interfacing.

  Note: The control panel is located in the LCI enclosure and includes door mounted panel meters and operator devices.

6.1.13.2.3.3 **DC Link Reactor**

The dc link reactor helps smooth the dc current to eliminate coupling between the frequencies of the converter and inverter and provides protection during system faults by limiting the current.

The dc link is a dry-type, air core reactor which is convection cooled. It is located in an outdoor protective enclosure and electrically connected between the converter and the inverter.

6.1.13.2.3.4 Isolation Transformer

The isolation transformer provides electrical isolation and impedance for system protection against notching and harmonic distortion. The transformer has two secondary windings and is designed for service with a three phase, six pulse power converter connected to each secondary winding. One transformer is provided for each LCI and is located in an outdoor weather-protected enclosure.

6.1.13.2.3.5 Motorized Disconnect Switch

A motorized disconnect switch is provided to disconnect the static start system during normal generator operation. The disconnect switch is electrically connected between the LCI and the feed for the generator stator.

6.1.14 Miscellaneous Parts

As a service to the customer and to facilitate an efficient installation of the gas turbine, GE provides for shipment of miscellaneous parts needed during field installation.

Shipment is in a single 96" x 96" x 192" (2438 mm x 2438 mm x 4877 mm) weather-tight cargo container. The plywood container, which can be opened from one end, is outfitted with shelves and bins for parts storage. The container comprises what amounts to a "mobile stockroom" and is designed for transport by truck or rail.

Within the container, each part is packed, identified with its own label or tag, and stowed in an assigned bin or shelf. A master inventory list furnished with the container provides the location of each part for ease in locating the item.

An additional box approximately 60" x 60" x 216" (1524 mm x 1524 mm x 5486 mm) is furnished for the interconnecting piping.

6.2 Generator

6.2.1 Electrical Rating

The generator is designed to operate within Class "B" temperature rise limits, per ANSI standards, throughout the allowable operating range. The insulation systems utilized throughout the machine are proven Class "F" materials.

The generator is designed to exceed the gas turbine capability at all ambient conditions between 0 and 120°F.

6.2.2 Packaging

The 7FH2 generator is designed for compactness and ease of service and maintenance. Location permitting, the unit ships with the rotor, gas shields and end shields factory assembled. The high voltage bushings, bearings, oil deflectors, hydrogen seals, and coolers are also factory assembled. The collector cab ships separately for assembly to the generator at the customer's site. Clearances of the bearings, rub rings, fans, hydrogen seals and deflectors are factory fitted and only require a minimum amount of field inspection of these components.

All generator wiring, including winding and gas RTDs, bearing metal and drain TCs, and vibration detection systems are terminated on the main unit with level separation provided.

Prior to full assembly, the generator stator receives a pressure test at 150% of operating pressure followed by a leakage test at 100% of operating pressure.

Feed piping between the bearings are stainless steel and mounted on the units in the factory to a common header. All connections to the end shields are assembled. All assembled piping is welded without backing rings and a first pass TIG weld. A full oil flush is performed prior to shipping.

Some amount of field assembly is required but should be limited to the following:

- Factory fitted bearing drain piping and bearing drain enlargement (BDE)
  - Matched, marked, and shipped separate
  - Loop seal between BDE and drain tank are stainless steel and ship loose
- Water manifolds are factory fitted and shipped separate
- Collector compartment:
  - Collector end housing and brush rigging are shipped as part of the collector compartment and require some assembly and alignment
  - Interconnecting piping from cab to generator
  - Interconnecting wiring from cab to generator

The average estimated near field noise level of a single gas turbine generator package operating at base load is 85 dBA at 3 feet laterally from the turbine package, and measured 5 feet above the machine base (not adjacent to inlet compartment, inlet or exhaust ducting, openings, or any operating off-base equipment).

6.2.3 Frame Fabrication

The frame is a stiff structure, constructed to be a hydrogen vessel and to be able to withstand in excess of 200PSI. It is a hard frame design with its four-nodal frequency significantly above 120Hz. The ventilation system is completely self contained, including the gas coolers within the structure. The gastight structure is constructed of welded steel plate, reinforced internally by radial web plates and axially by heavy wall pipes, bars and axial braces.

A series of floating support rings and core rings are welded to keybars which in turn support the core, allowing the entire core to be spring mounted at twenty locations. 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 standard practices and experience with similar frame designs which have proven to be very effective and reliable.

The stator frame is supported on four welded-on feet attached at the lower portion of the fabrication. All the weight of the unit and the operating loads are carried through the structure by the web plates and the wrapper to the feet. The machined portion of the feet are located 85" below the centerline of the unit.

6.2.4 Core

The core is laminated from grain oriented silicon steel to provide maximum flux density with minimum losses, thereby providing a compact electrical design. The laminations are coated on both sides to ensure electrical insulation and reduce the possibility of localized heating resulting from circulation currents. A hydrogen system core monitor is located in the collector compartment.

The overall core is designed to have a natural frequency in excess of 170 hertz, 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.

6.2.5 Rotor

The rotor is machined from a single high alloy steel forging. The two pole design has 24 axial slots machined radially in the main body of the shaft. The axial vent slots machined directly into the main coil slot are narrower then the main slots and provide the direct radial cooling of the field copper.

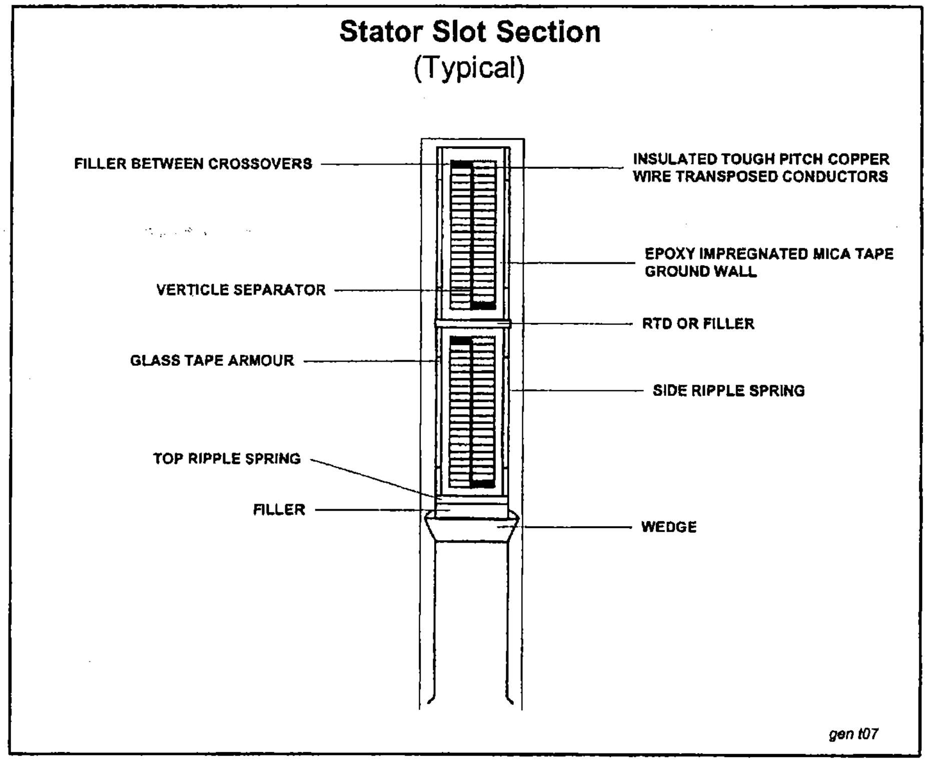
The two retaining rings are of the body mounted design. The rings are made of 18 Mn - 18 Cr forged material which offers excellent protection against stress corrosion cracking.

The coil wedges are segmented stainless steel. Radial holes are drilled in the wedges for ventilation passages.

A shrunk-on coupling is assembled after the collector rings are on, and provides the interface point to the flex-coupling connection to the turning gear. This arrangement is used with a static start system.

6.2.6 Field Assembly

The field consists of six 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. An insulated cover is positioned on the bottom of each slot armor and on top of the subslot vent. The cover will provide the required creepage between the lower turn 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 currents to flow. The rotor is designed to accommodate static start hardware utilizing full length slot amortisseurs.

The collector assembly incorporates all the features of GE proven generator packages with slip on insulation over the shaft and under the rings. The collector rings use a radial stud design to provide electrical contact between the rings and the field leads. The rings are designed to handle the excitation requirements of the design (approximately 2200 amps on cold day operation and 1900 amps at rated conditions).

The entire rotor assembly, weighing 74,000 pounds is balanced up to 20% over operating speed.

6.2.7 End Shield/Bearing

The unit is equipped with end shields on each end designed to support the rotor bearings, to prevent gas from escaping, and to be able to withstand a hydrogen explosion in the unlikely event of such a mishap. In order to provide the required strength and stiffness, the end shield is constructed from steel plate and is reinforced. The split at the horizontal joint allows for ease of assembly and removal.

The horizontal joints, as well as the vertical face which bolts to the end structure, are machined to provide a gas tight joint. Sealing grooves are machined into these joints. These steps are taken to prevent gas leakage between all the structural components for pressures up to 45 psig.

The center section of the end shields contain the bearings, oil deflectors and hydrogen seals. The lower halves of the bearings are equipped with dual element thermocouples. The leads are connected through a quick disconnect through the end shield to allow ease of bearing removal.

Vertically split inner and outer oil deflectors are bolted into the end shield and provide sealing of the oil along the shaft. The deflectors are either fabricated or cast aluminum. All faces of the deflectors have "O" ring grooves to provide additional protection from oil leaks. All annular areas formed between the set of teeth are designed to provide minimum pressure drops and have oil gutters machined in to prevent oil from backdripping on the shaft.

The hydrogen seal casing and seals, which prevent hydrogen gas from escaping along the shaft, utilize steel babbitted rings. Pressurized oil for the seals is supplied from the main oil system header to the seal oil control unit, where it is regulated. The seal oil control unit is factory assembled packaged system and is located in the collector end compartment and includes the following components:

- Differential pressure regulator valve with bypass
- Differential pressure gage (seal oil pressure vs. casing gas pressure) and two differential pressure switches: one for alarm and one for actuating the dc emergency seal oil pump
- Shut-off and isolation valves for operation and maintenance

The collector end bearing and hydrogen seals are insulated from the rotor to prevent direct electrical contact between the rotor and the end shield. Both end shields have proximity type vibration probes. These are located axially at the bearing. Mounting for velocity type vibration sensors is also provided on the surface of the bearing caps.

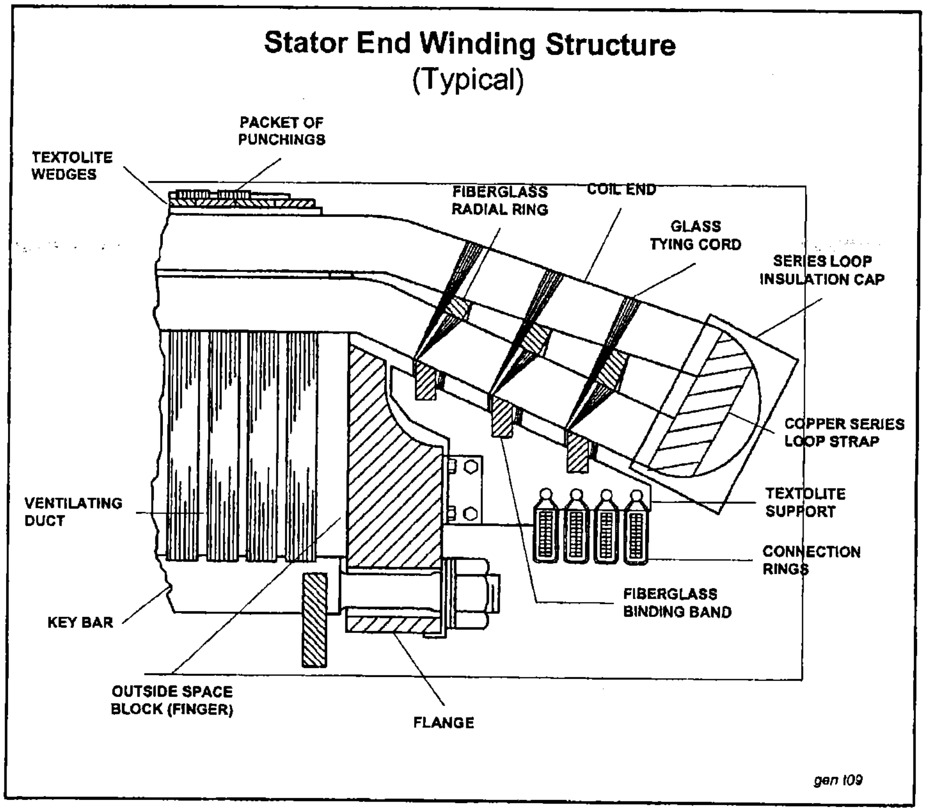
All exiting wiring from the temperature indication devices and the insulating test leads are brought out of the unit through gas tight conex type seals to prevent any chance of a hydrogen leak.

6.2.8 Winding

The armature winding is a three phase, 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 GE's well proven voltage grading system on the end 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. An epoxy resin filled insulation cap is used to insulate the end turn connections.

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 system electrical transients.



6.2.9 Lead Connections

All the lead connection rings terminate at the top of the excitation end of the unit and the six high voltage bushings (HVBs) exit at the top of the frame.

Each of the circuits are connected to the high voltage bushings (HVBs.) The bushings, which provide a compact design for factory assembly and shipment, are positioned in the top of the frame and are offset to allow proper clearances to be maintained. This configuration also allows connections to the leads to be staggered and provides ease of bolting and insulation.

The bushings are made up of a porcelain insulators containing silver plated copper conductors which form a hydrogen tight seal. The bushings are assembled to non-magnetic terminal plates to minimize losses. Copper bus is assembled to the bushings within an enclosure. Customer connections are made beyond the terminal enclosure and the specific mating arrangements are provided within the enclosure, not inside the generator.

6.2.10 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.

6.2.11 Hydrogen Cooling System

The generator is cooled by a recirculating hydrogen gas stream cooled by gas-to-water heat exchangers. Cold gas is forced by the generator fans into the gas gap, and also around the stator core. The stator is divided axially into sections by the web plates and outer wrapper so that in the center section cold gas is forced from the outside of the core toward the gap through the radial gas ducts, and in the end section it passes from the gas gap toward the outside of the core through the radial ducts. This arrangement results in substantially uniform cooling of the windings and core.

The rotor is cooled externally by the gas flowing along the gap over the rotor surface, and internally by the gas which passes over the rotor and windings, through the rotor ventilating slots, and radially outward to the gap through holes in the ventilating slot wedges.

After the gas has passed through the generator, it is directed to five horizontally mounted gas-to-water heat exchangers. After the heat is removed, cold gas is returned to the rotor fans and recirculated.

6.2.12 Hydrogen Control Panel

To maintain hydrogen purity in the generator casing at approximately 98 percent, a small quantity of hydrogen is continuously scavenged from the seal drain enlargements and discharged to atmosphere. The function of the hydrogen control panel is to control the rate of scavenging and to analyze the purity of the hydrogen gas. The panel is divided into two compartments, the gas compartment and the electrical compartment, which are separated by a gas-tight partition.

6.2.12.1 Control Panel Functions

The GE hydrogen control panel is designed for use on hydrogen cooled generators with scavenging systems. The panel functions are described below:

- The hydrogen control panel allows manual control of the continuous scavenging rate, both turbine end and collector end, via metering valves.
- Hydrogen from the generator turbine end and generator collector end is continuously monitored for purity. At predetermined time intervals, the purity of the generator core gas is also checked. Two independent, switchable, triple range hydrogen purity analyzers are used, thus providing total redundancy, for two out of two voting. Each display and control panel will include three digital displays providing real time readout of gas purity, gas temperature and the status of the analyzers operating parameters. All information is provided to the station DCS via contact inputs and 4-20 milliamp analog signals.
- In the event that one of the analyzers detect a drop in purity, a confirmation by the other gas analyzer is performed. Time for the measurement, which requires reconfiguration of the valves, as well as the handling of possible disagreements in measurement results, is also negotiated between the analyzers.
- In the event that either analyzer indicates a low purity alarm, the rate of scavenging is increased automatically and an alarm is annunciated.
- All components used in the hydrogen control panel are specifically designed and / or third party approved for use in an Class I, Division I, Group B environment.

6.2.12.2 Control Panel Devices

6.2.12.2.1 Differential Pressure Gas Transmitter

The differential pressure gas transmitter measures the generator fan differential gas pressure. It provides a 4-20 mA DC signal proportional to differential gas pressure and includes a 316L stainless steel diaphragm all housed in a Factory Mutual approved explosion proof enclosure.

6.2.12.2.2 Differential Gas Pressure Gage

The differential gas pressure gage provides local indication of the generator fan differential gas pressure. The gage is flush mounted, waterproof, dual range and stainless steel movements.

6.2.12.2.3 Gas Pressure Transmitter

The gas pressure transmitter measures the generator core gas pressure or machine gas pressure as it is sometimes called. It provides a 4-20 mA DC signal proportional to gas pressure and includes a 316L stainless steel diaphragm all housed in a Factory Mutual approved explosion proof enclosure.

6.2.12.2.4 Gas Pressure Gage

The gas pressure gage provides local indication of the generator core gas pressure. The gage is flush mounted, water proof, dual range and stainless steel movements.

6.2.12.2.5 Total Gas Flowmeter

The total gas flowmeter provides local indication of the total flow of scavenged gas. The flowmeter is a flush mounted, in line, direct read flowmeter with stainless steel body.

6.2.12.2.6 Gas Analyzer Flowmeters (2)

Gas analyzer flowmeters provide local indication and control of the gas flow through each of the gas analyzers. Each flowmeter is a flush mounted, in line, direct read flowmeter with stainless steel body.

6.2.12.2.7 Gas Purifiers (3)

Gas purifiers remove oil, water and foreign particles from each of the gas sampling lines (turbine end, collector end and core gas).

6.2.12.2.8 Moisture Indicators (3)

Moisture indicators provide local indication relating to the operating condition of the gas purifiers in each of the gas sampling lines (turbine end, collector end and core gas).

6.2.12.2.9 Control Panel

The standard panel is NEMA 1 rated and fabricated from #10 standard gauge, sheet steel. Gas piping and electrical field connections can be located at either the top, bottom or rear of the cabinet per customer request.

6.2.12.2.10 Solenoid Valves

All solenoid valves have stainless steel bodies with class H temperature rated coils. The solenoids are also third party approved for use in a Class 1, Division 1, Group B environment.

6.2.12.2.11 Gas Analyzers

The gas purity analyzer utilizes the principle of fixed geometry diffused flow thermal conductivity to measure the purity of a known component of a binary gas mixture. Digital acquisition at the sensor level by precision components, rather than the previous Wheatstone bridge arrangement, increases measurement accuracy. A novel aspect of the analyzer is its ability to operate in a redundant configuration; the two, identical, microcontroller based subsystems which comprise the analyzer are interconnected by a communications channel to enable the analyzer to confirm an alarm condition, (i.e. two out of two voting). This communications channel also allows the analyzer to negotiate and report possible malfunctions in the measurement system.

6.2.12.3 Fault Detection and Reporting

Each subsystem within the analyzer is self-supervising and continuously checks itself for acceptable processor functioning, internal voltages, analog to digital conversion accuracy, integrity of cabling and relay operation. Any faults are immediately annunciated at the cabinet and a contact signal indicating analyzer trouble is opened. A faults log, which maintains a date/time stamp of detected failures can be viewed at any time. The analyzer can also execute detailed self-diagnostics.

6.2.13 Detraining System

The air-side seal oil and the generator bearing oil drain to a bearing drain enlargement mounted under the generator casing. This bearing drain enlargement is a detraining chamber and provides a large surface area for detraining the oil before it is returned to the main oil tank.

Two seal drain enlargements are provided for removing entrained hydrogen from the oil which drains from the hydrogen-side seal rings. They are drained through a common line to a float trap which then drains to the bearing drain enlargement for further detraining. A high liquid level alarm switch is provided to detect abnormal oil level in the seal drain enlargement.

Piping is factory fitted and the system is well-proven to assure that no hydrogen can enter into the oil system.

6.2.14 Generator Collector Compartment

An exciter-end, enclosure is provided with the generator. It will contain the following assemblies:

- Hydrogen control panel
- Seal oil control unit, regulator and flowmeter
- Seal oil drain system, float trap and liquid level detector
- H2 and CO2 feed and purge system, valves and gauges
- Switch and gauge, block and porting system
- Collector housing and brush rigging assembly
- Collector filters and silencers
- Level-separated electrical junction boxes
- Turning gear
- Fire/heat detectors

The above items are packaged in the enclosure. The completed enclosure is assembled to the generator at the customer site. The enclosure has been designed to simplify interconnecting wiring and piping between the enclosure and the generator.

The enclosure is designed with a removable end wall section and roof to allow ease of rotor removal without moving the housing. Position of all the above hardware is spaced to allow easy access for maintenance and to prevent any unnecessary disassembly during rotor removal. Two doors are provided on the end wall to allow access from either side. Safety latches are provided on the inside of the doors to provide easy exit from the enclosure. AC lighting is standard.

6.2.15 Generator Terminal Enclosure

The Generator Terminal Enclosure (GTE) is a reach–in weather–protected enclosure made of steel and/or aluminum and is located on the generator. The GTE is convection cooled through ventilation louvers to the outside of the enclosure. The louvers are designed to inhibit debris from entering into the compartment.

The GTE houses the following major electric components:

- Neutral current transformers (CTs)
- Line CTs
- Lightning arresters
- Neutral grounding transformer with secondary resistor
- Fixed voltage transformers (VT)
- 89SS LCI disconnect switch
- Motor operated neutral disconnect switch

6.2.15.1 Interface Points

The primary interface points to the GTE are:

- The line bus exits the GTE on the right side as viewed from the collector end of the generator
- The orientation of the line bus is right-center-left as viewed from the side of the GTE from which the bus exits

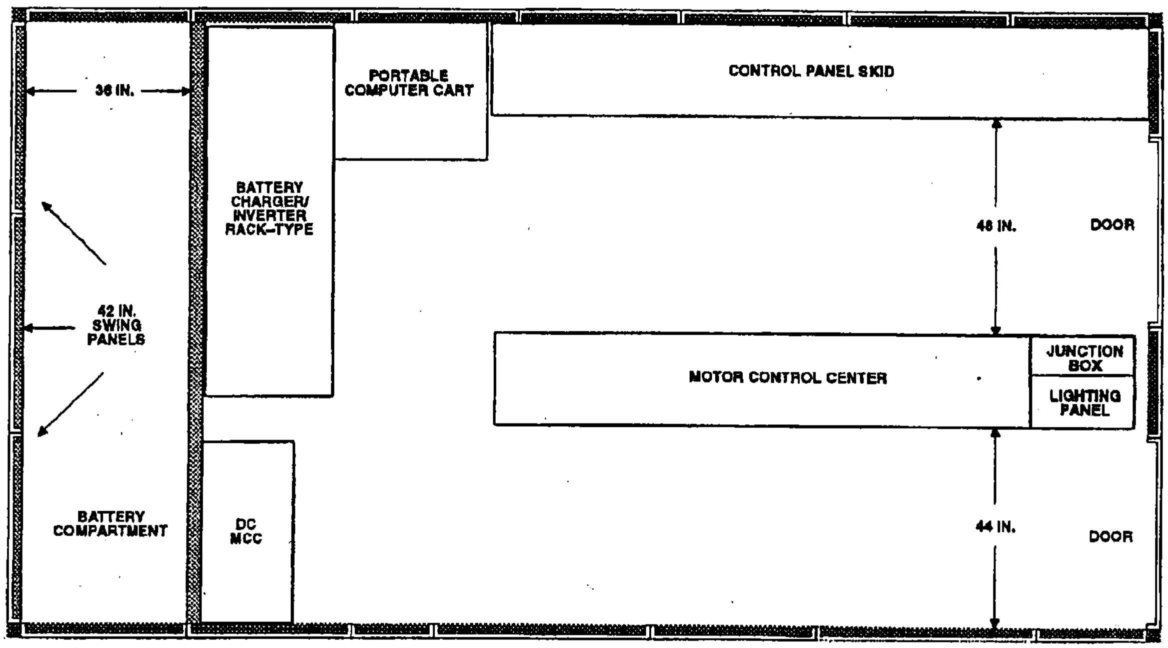
6.3 Gas Turbine-Generator Controls and Electric Auxiliaries

6.3.1 Packaged Electronic and Electrical Control Compartment (PEECC)

The PEECC is a completely enclosed compartment suitable for outdoor installation. Heating, air conditioning, compartment lighting, power outlets, temperature alarms, and smoke detectors are provided for convenience and protection of the equipment in the PEECC.

Electrical monitoring and control of the unit are accomplished by the turbine control panel and the generator control panel, which are mounted on a common skid and located in the PEECC. The customer control local interface <HMI> is also located in the PEECC. In addition to the control systems, the PEECC also houses the gas turbine motor control centers and batteries, rack and charger (s). The arrangement of the equipment is shown in the typical compartment layout below.

Packaged Electronic and Electrical Control Compartment (PEECC)
(Typical)



6.3.2 SPEEDTRONIC™ Mark VI Control System

The gas turbine control system, is a state-of-the-art Triple Modular Redundant (TMR), microprocessor based control system. The core of this system is the three separate but identical control modules <R>, <S>, and <T>. Each controller contains its own power supply, processor, communications, and I/O

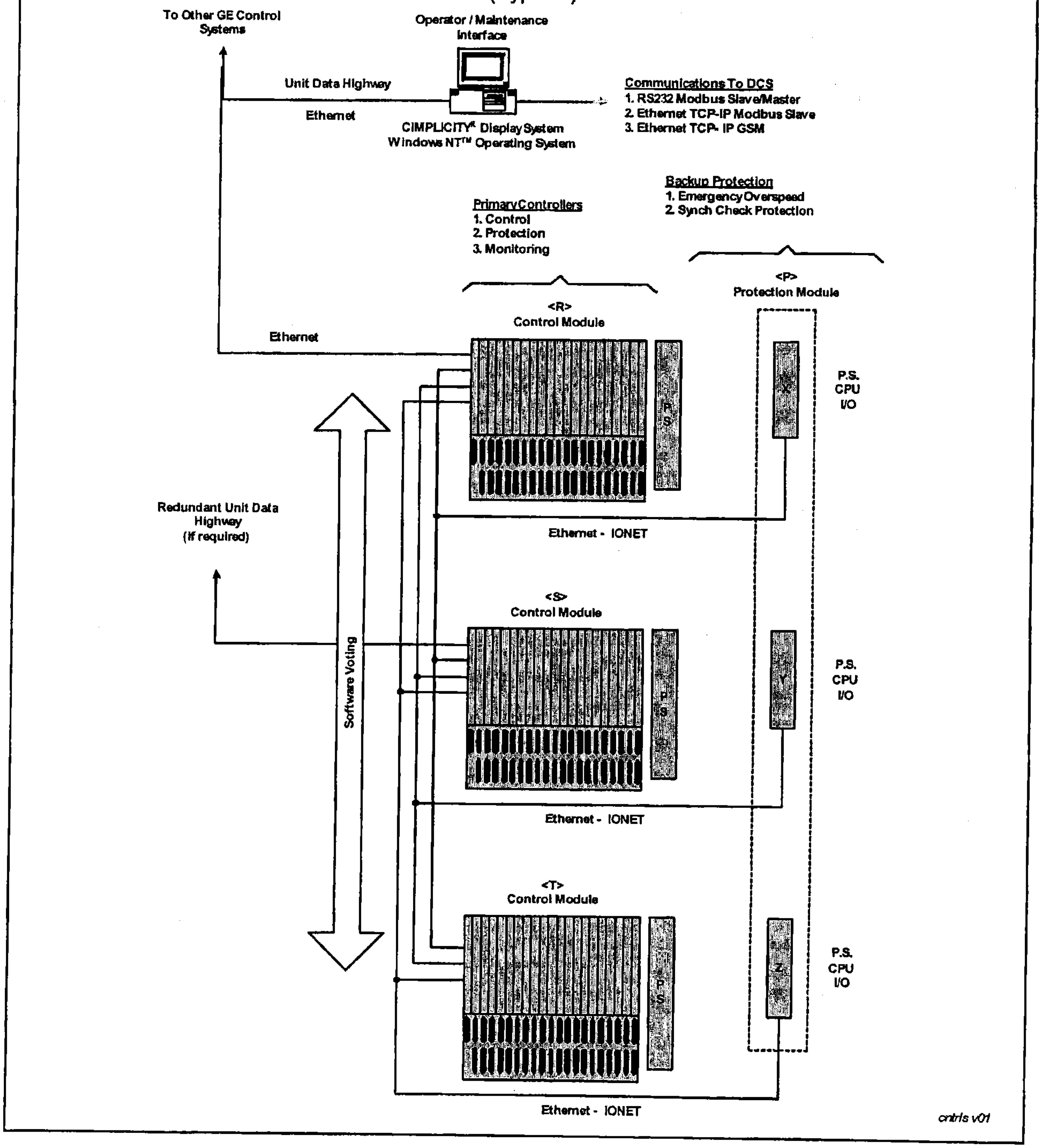
™ A trademark of the General Electric Company for all of the critical control, protection and sequencing of the gas turbine. Some backup protection devices interface with the <P> protection module which consists of triple redundant sections labeled <X>, <Y>, and <Z>. These sections provide independent backup protection for certain critical functions such as emergency overspeed protection and the phase-slip windows for synch check protection

The three control modules, <R>, <S>, and <T>, acquire data from triple–redundant sensors as well as from dual or single sensors. All critical sensors for control loops and trip protection are triple redundant. A major factor in the high reliability achieved by TMR control systems is due in considerable measure to the use of triple redundant sensors for all critical parameters.

6.3.2.1 Electronics

All of the micro-processor based electronics have a modular design for ease of maintenance. Each control module consists of a 21 slot VME type card rack with a processor card, communication card, and I/O cards. The I/O cards are connected to individual termination boards by computer type cables with 37 pin "D" type connectors. The termination boards have pluggable, barrier type termination blocks. Cards and termination boards can be arranged in various combinations and added in the field for future expansion. Ethernet based local area networks (LANs) are used to communicate between the control modules, the backup protection module, any expansion modules, and the operator interface. A real-time, multi-tasking operating system is provided with floating point data.

SPEEDTRONIC Mark VI Control Configuration
(Typical)



6.3.2.2 Shared Voting

An important part of the fault tolerant control architecture is the method of reliably "voting" the inputs and outputs without any single point failures. Each control module reads its inputs and exchanges the data with the other two control modules every time the application software is executed - 40ms.

The voted value of each contact input and the median value of each analog input is calculated within each control module and then used as the resultant control parameter for the application software. Diagnostic algorithms monitor these inputs and initiate a diagnostic alarm if any discrepancies are found between the three sets of inputs. In addition, a 1ms time stamp is assigned to each contact input to provide a built-in Sequence Of Events (SOE) monitor.

Redundant contact inputs for trip functions are connected to three separate termination points and then individually voted. This enables the control system to survive multiple failures of contact or analog inputs without causing an erroneous trip command as long as the failures are not from the same circuit.

An equally important part of the fault tolerance is the hardware voting of analog and contact outputs. Three coil servos on the valve actuators are separately driven from each control module, and the position feedback is provided with redundant LVDTs. Contact outputs to the hydraulic trip solenoids are voted with three magnetic relays on each side of the floating 125Vdc feeder to the solenoids.

6.3.2.3 PC Based Operator Interface

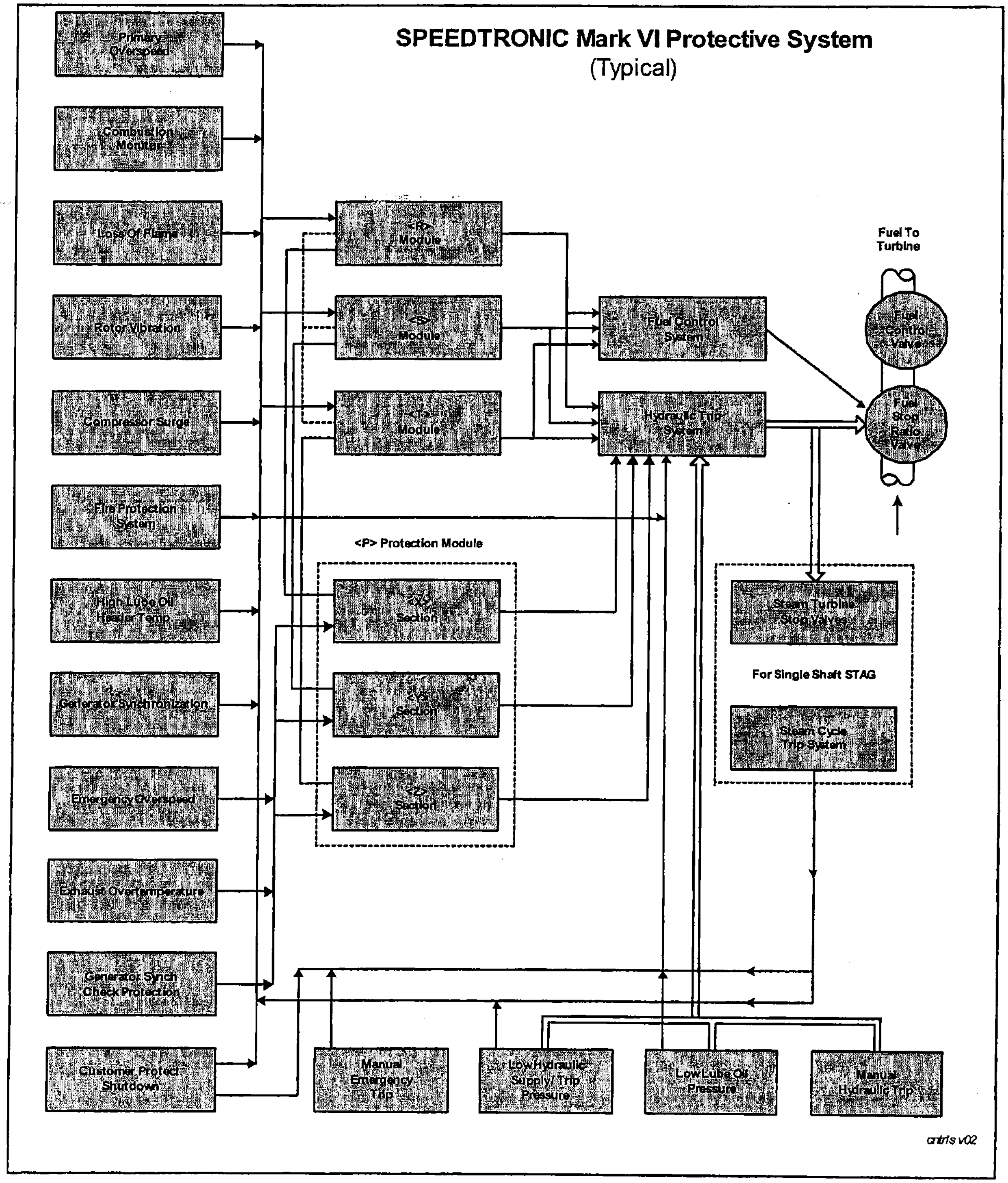
The operator interface consists of a PC with a GE Fanuc CIMPLICITYR graphics display system and a MicrosoftTM Windows NTTM operating system. A color monitor and keyboard are included. Client/server capability is inherent with Windows NTTM and redundant server configurations are supported for multi-unit applications.

The PC can be used as either an operator interface or as a maintenance workstation with all operator control and monitoring coming from communication links with a plant distributed control system (DCS).

Remote access by the Human Machine Interface (HMI) is provided for monitoring and/or control.

6.3.2.4 Direct Sensor Interface

The input/output (I/O) is designed for direct interface to turbine and generator devices such as vibration sensors, flame sensors, LVDTs, magnetic speed pickups, thermocouples, and RTDs. Direct monitoring of these sensors eliminates the need for interposing instrumentation with its associated single point failures, reduces long term maintenance, and enables the SPEEDTRONIC Mark VI diagnostics to directly monitor the health of the sensors on the machinery. This data is then available to local operator/maintenance stations and to the plant digital control system via the optional communications links.


SPEEDTRONIC Mark VI Protective System
(Typical)
Primary Overspeed
Combustion Monitor
Loss Of Flame
Rotor Vibration
Compressor Surge
Fire Protection System
High Lube Oil Header Temp
Generator Synchronization
Emergency Overspeed
Exhaust Overtemperature
Generator Synch Check Protection
Customer Protect Shutdown
<R> Module
<S> Module
<T> Module
Fuel Control System
Hydraulic Trip System
Fuel To Turbine
Fuel Control Valves
Fuel Stop Ratio Valve
<P> Protection Module
<X> Section
<Y> Section
<Z> Section
Steam Turbine Stop Valves
For Single Shaft STAG
Steam Cycle Trip System
Manual Emergency Trip
Low Hydraulic Supply/ Trip Pressure
Low Lube Oil Pressure
Manual Hydraulic Trip
cntrls v02

In addition, the communication link enables the resultant data to be accessible from a plant Distributed Control System (DCS) system.

- Contact inputs are powered from the 125Vdc battery bus through the SPEEDTRONIC Mark VI termination boards. Each contact input is optically isolated and has a 1 ms time stamp for SOE monitoring.
- Contact outputs are from plug-in, magnetic relays with dry form "C" contact outputs. The control provides a floating 125Vdc source and suppression to each solenoid with a 3.2A slow-blow fuse on each side of the 125Vdc feeder.
- Analog I/O can be configured for 4-20ma, 0-1ma, +/-5Vdc, +/-10Vdc inputs and 4-10ma or 0-200ma outputs.
- Thermocouple inputs can be grounded or ungrounded, and software linearization can be used to select type E, J, K (standard), or T thermocouples on each point.
- RTD inputs can be grounded or ungrounded, and software linearization can be used to select 10 ohm copper, 100 ohm platinum (standard), or 120 ohm nickel RTDs on each point.
- Flame inputs are normally the Reuter Strokes type or UV scanners.
- Servo valve interface: each of the SPEEDTRONIC Mark VI controllers directly drives one of three coils on a servo valve actuator. Redundant LVTDs are monitored by the control for regulation of the servo loop in software.
- Seismic (velocity) vibration inputs are monitored directly by the SPEEDTRONIC Mark VI for trip protection of the turbine and generator.
- Proximiter probes are provided for monitoring only.
- Proximiter monitoring system is provided.
- Proximiter output wired to MK-6. The system provides buffered outputs to BN connectors to facilitate plug-in analysis instrumentation.

6.3.2.5 Built-in Diagnostics

The SPEEDTRONIC Mark VI control system has extensive built-in diagnostics and includes "power-up", background, and manually initiated diagnostic routines capable of identifying both control panel, sensor, and output device faults. These faults are identified down to the board level for the panel, and to the circuit level for the sensors and actuators.

6.3.2.6 SPEEDTRONIC Mark VI Generator Excitation Interface

An Ethernet based Unit Data Highway (UDH) provides peer-to-peer communications between the SPEEDTRONIC Mark VI turbine control, the generator digital static excitation control and the static starter (if applicable). The SPEEDTRONIC Mark VI is used to control megawatt output, and the digital static excitation is used to control megavar output. The generator protection panel (GPP) is used to provide primary protection for the generator. This protection is further augmented by protection features located in the digital static excitation and the SPEEDTRONIC Mark VI.

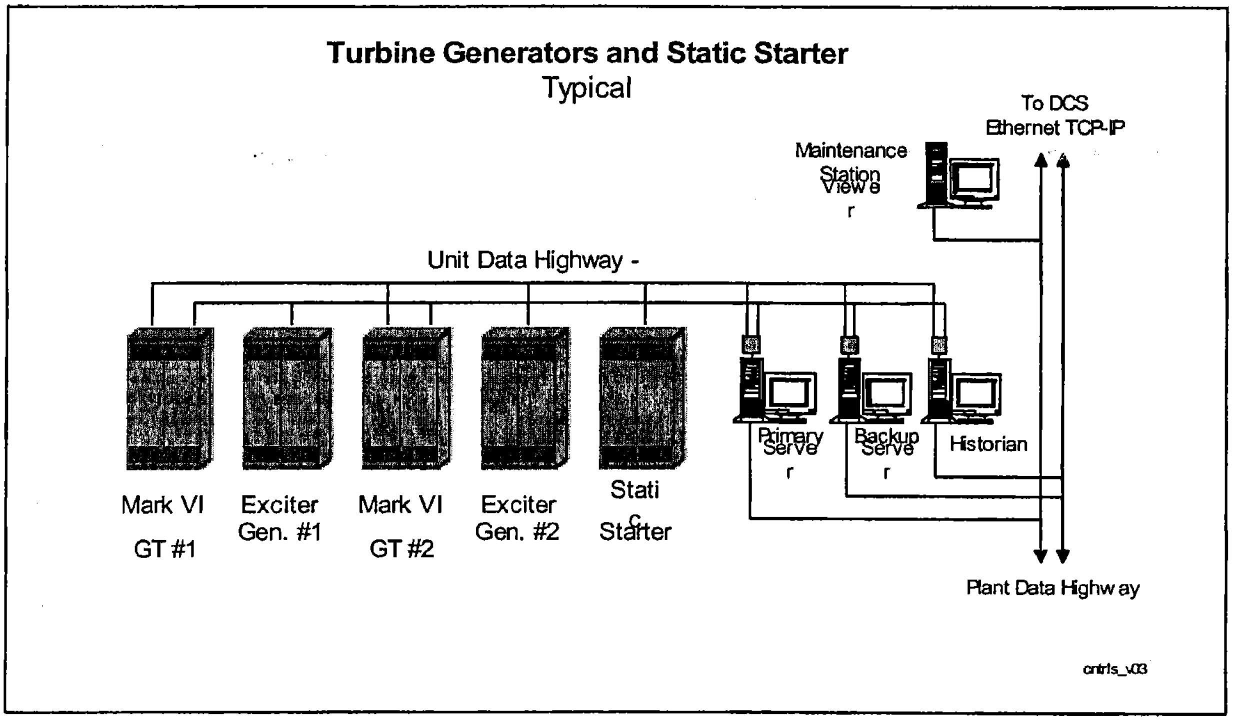
6.3.2.7 Synchronizing Control and Monitoring

A pair of single phase VTs are monitored by the control modules which match the turbine speed to the line frequency and match the generator and line voltages via the LAN to the generator excitation system. A command is issued to close the breaker based on a calculated breaker closure time. Diagnostics monitor the actual breaker closure time and self-correct each time the breaker closes. The single phase VTs are paralleled to the triple redundant protection module for the backup synch check protection. The synch check protection is used to backup the automatic synchronizing and the manual synchronizing which is implemented from a synchroscope display on an operator station (HMI) server. Three phase VT inputs from the generator and line, and single phase CT inputs are normally monitored by the generator excitation control and transmitted to the turbine control on the network

6.3.2.8 Control System Overview

The control system consists of several networks. IONET is an Ethernet based network for communication between the three control modules, the three sections of the protection module and any expansion modules. IONET uses Asynchronous Drives Language (ADL) to "pole" the modules for data instead of using the typical "collision detection" techniques used in Ethernet LANs.

The Unit Data Highway (UDH) is an Ethernet based network which provides peer-to-peer communications between the turbine and generator controls. This network 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. Data can be transmitted unicast, multicast, or broadcast to peer control systems on the network. Data (4K) can be shared between up to 10 nodes at 25Hz, and global time synchronization and time stamped data is supported.



Servers/workstations (CIMPLICITY with Windows NT) isolate the unit data highway from the Plant Data Highway. These servers and clients can be used as local or remote operator and/or maintenance stations and configured in a variety of arrangements. The primary server can be provided with a time synchronization interface to a Global Time Source (GTS) which is typically implemented with IRIG-B. A backup time master can be provided in a backup server. Network Time Protocol (NTP) is used for internal time synchronization with a +/-1ms time coherence.

The Plant Data Highway (PDH) is used to communicate data to the plant distributed control system or other third party platforms. A variety of optional protocols are supported including RS232 Modbus RTU master/slave, Ethernet TCP-IP Modbus slave, and Ethernet TCP-IP with GSM (GEDS Standard Messages).

The GSM Protocol provides:

- Administration messages
- Spontaneous event driven messages with local time tags

- Periodic group data messages at periodic rates down to 1 second
- Common request messages

6.3.2.9 Scope of Control

The SPEEDTRONIC Mark VI control system provides complete monitoring, control, and protection for gas turbine-generator and auxiliary systems. The scope of control is divided into three sections: control, sequencing and protection.

- Control
  - Start-up
  - Speed/load setpoint and governor
  - Temperature control
  - Guide vane control
  - Fuel control
  - Generator excitation setpoints
  - Synchronizing control (speed/voltage matching)
  - Emissions control
- Sequencing
  - GT auxiliary systems (MSS starters)
  - Start-up, running, and shutdown
  - Purge and ignition
  - Alarm management
  - Synchronizing
  - Turning gear
  - Static start
  - H2 sequencing
  - Maintain starts, trips, and hours counters
  - Event counters
    - Manually initiated starts
    - Fired starts
    - Emergency trips
    - Time meters
    - Fired time
    - DCS interface

- Protection
  - Overspeed, redundant electronics
  - Overtemperature (including generator)
  - Vibration
  - Loss of flame
  - Combustion monitor
  - Redundant sensor CO2 fire protection
  - Low lube oil pressure, high lube oil temperature, etc.

6.3.2.10 Gas Turbine Plant Operating Modes

6.3.2.10.1 Starting/Loading

All starting is done automatically, with the operator given the opportunity to hold the start-up sequence at either the crank (pre-ignition) or fire (post-ignition, pre-accelerate) points of the start-up. 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:

1. Select or disable the automatic synchronization capability of the turbine control. The auto synchronizing system provides extremely accurate and repeatable breaker closures based on phase angle, slip, the rate of change of slip and the response time of the breaker which is in the system memory.
2. Select preselected 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" automatically upon synchronization; be it automatic or manual. The turbine governor is automatically regulated to maintain the megawatt setting assigned to "Spinning Reserve".

6.3.2.10.2 Operating

Once the unit is on line, it may be controlled either manually or automatically from the SPEEDTRONIC Mark VI operator interface. Manual control is provided by the governor raise/lower control displayed on the operator interface screen. Automatic operating is switched on when the operator selects a load point from the turbine control interface. The control is capable of either droop or isochronous governing.

For a fully automatic start with automatic loading to base load, the operator selects "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.

6.3.2.10.3 Shutdown

On shutdown, the system will automatically unload and return to turning gear operation. The unit will stay on turning gear until an operator turns it off. (Note: the operator must insure the unit is sufficiently cool before shutting off turning gear to avoid temporary rotor bow due to heat.)

6.3.2.11 Operating System and Application Software

The SPEEDTRONIC Mark VI control 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. Floating point data (IEEE-854) can be run at frame rates down to 10ms. Changes to the application software can be made with password protection and downloaded to the control module while the turbine is running. All application software is stored in the control module in non-volatile (flash) memory. Application software is executed sequentially and represented in a ladder diagram format. A library of software building blocks allows maintenance personnel to add or change analog loops, sequencing logic, etc. Math blocks are also available. Application software documentation is created directly from the source code, and it can be printed at the site. This includes the primary elementary diagram, I/O assignments, the settings of tuning constants, etc.

6.3.3 Typical Speedtronic Mark VI Redundancy List and I/O

6.3.3.1 Typical Redundant and Multiple Sensors

Device	Parameter	Function	Device Type	Qty	Redundancy
26QA/T	Lube oil temp high	A/P	Temp switch	3	S
28FD	Flame detector	A/P	UV scanner	8	S
28FD	Flame detector	A/P	UV scanner	4	S
39VX	Vibration sensor	A/P	Velocity p.u.	2	S
45FX	Fire detector	A/P	Temp switch	2#	S
63HG	Gas fuel trip oil pressure	A/P	Press switch	3	D

63QA/T	Lube oil hydraulic pres.	A/P	Press switch	3	S
63TF	Inlet filter pressure	C/P	Press switch	3	D
65GC	Gas control valve servo	C	3 coil servo	1	D
77NH	Speed magnetic pick-up	C	Magnetic pu	3	D
77NT	Speed magnetic pick-up	A/P	Magnetic pu	3	D
90SR	Gas ratio valve servo	C	3 coil servo	1	D
90TV	Inlet guide vane servo	C	3 coil servo	1	D
96FG-2	Gas fuel control pressure	C	Transducer	3	D
96GC	Gas control valve	C	LVDT	2	S
96SR	Gas ratio valve	C	LVDT	2	S
96TV	Inlet guide vane	C	LVDT	2	S
CTDA	Compressor discharge temperature	M	TC	2	S
CTIF	Compressor inlet temp.	M	TC	2	S
FTGI-x	Fuel gas supply temp.	C	TC	3	D
TTWS-x	GT wheelspace temp.	A/P	TC	2/w	S
TTXD-x	GT exhaust temp.	C/P	TC	18#	D/S

Notes:

All channels/locations except 1 are redundant by means of two sensors per location. The non-redundant location has one sensor.

The number of exhaust TCs varies with the GT model from 13 to 27. Each control processor reads 1/3 of the TCs directly and then all TC data is shared by all processors.

Legend:

S = Shared	D = Dedicated	A = Alarm
M = Monitor	P = Protection	C = Control

6.3.3.2 Typical Non-redundant (partial listing)

Device	Parameter	Function	Device Type	Qty
20FG	Gas fuel trip oil	C	Solenoid vlv	1
26QL/M	Lube oil temperature low / moderate	C	Temp switch	1 each
26QN	Lube oil temperature normal	P	Temp switch	1
39FC	Cooler fan vibration	A	Vibration sw	1/fan
63FG	Gas fuel pressure	A *	Pressure sw.	1
63QA	Lube oil pressure	P	Pressure sw.	1
63QL	Lube oil pressure	P	Pressure sw.	1
63TK	Exhaust frame cooling pressure	A/P	Pressure sw.	1/fan

71QH	Lube tank high level	A	Level switch	1
71QL	Lube tank low level	A	Level switch	1
96FF-1	Gas fuel flow pressure	C	Transducer	1
96FG1	Gas fuel supply pressure	C	Transducer	1

Notes:

* Can be used to initiate a transfer from primary to backup fuel.

Legend:

S = Shared D = Dedicated A = Alarm

M = Monitor P = Protection C = Control

6.3.3.3 Human Machine Interface (HMI)

The Human Machine Interface is a single powerful, flexible and user friendly operator interface which brings together all of the displays and functions needed for real-time control and monitoring of turbomachinery processes, auxiliary equipment, driven devices and process alarms associated with power plant control.

The HMI system provides the infrastructure needed to meet the demanding requirements of delivering process information from a broader spectrum of controllers and compute platforms as well as accessing and delivering information to a customer enterprise system and balance of plant control system.

Designed with an open system concept, the system uses standard open hardware and operating system software. The HMI software system uses the Windows NT client-server architecture from Microsoft which provides built-in multi-tasking, networking and security features. The ability to run the system on conventional PC based platforms minimizes cost, promotes open interfaces, permits system scalability, and ensures longevity of investment and future enhancement.

6.3.3.3.1 HMI Product Structure

The GE Fanuc CIMPLICITY HMI system serves as the basic core system, which is enhanced by the addition of power plant control hardware and software from GE Industrial Systems. The HMI configuration consists of several distinct elements:

- HMI Server/Engineering Workstation with a Toolbox - This interface is the hub of the system and provides data support and system management.

The HMI server also has the responsibility for device communication for both internal and external interchanges. In most instances this is the 'local' HMI.

- HMI Viewer /Client/Operator Control and Monitoring - (If provided) the viewer provides the visualization function for the system and is the client of the distributed client-server system. The viewer contains the operator interface application software for issuing commands, viewing screen graphics, data values, alarms and trends, and providing system logs and reports. The gas turbine control system can have redundant communications with up to four HMI servers and/or viewers. The first HMI will be a server; additional HMIs can be a server or viewer depending on the plant control configuration.

6.3.3.3.2 HMI Product Features

- Graphics - 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 using CimEdit, a graphics editing package, and CimView, a high performance runtime viewing package.

- Alarm Viewer - The alarm management functions of the HMI system are provided by Alarm Viewer. Alarm Viewer handles routing of alarms to the operator.

- Short Term Trending - HMI trending, based on object linking and embedding technology, provides powerful data analysis capabilities. Trending capabilities include graphing collected data and making data comparisons between current and past variable data for quick identification of process problems.

- Point Control Panel - The HMI point panel provides a listing of points in the system with dynamically updating point values and alarm status. Operators have the ability to view and set local and remote points and modify alarm limit, displays selectively.

- Basic Control Engine - The basic control engine allows users to define control actions to take in response to system events. It monitors event occurrence and executes configured actions in response. The basic control engine is supported by an event editor for defining actions in response to system events and a program editor for programming more complex actions.

- User Roles and Privileges - CIMPLICITY allows configuration of system users to control access and privileges.

6.3.3.3.3 Operator Functions

- Display Management - Display management provides overall display functions to meet the needs of the turbine plant. Displayed data is a combination of data received over Ethernet from the other gas turbine controllers. Alarm display includes connection to gas turbine alarm queues.

- Hold List Display - The hold list is a set of conditions which must be met at certain times, speeds and operating modes in the turbine startup for systems which have Automatic Turbine Startup functions. The HMI provides for creation, modification, display, printing, down and uploading, compiling and reverse translation of a hold list of up to 64 points.

- Timer, Counter, Accumulator Display - This function shows the settings and totals in the turbine controllers.

- Screen Copy - Screen copy makes a copy of screen image and stores it in the Window clipboard for display, printing, directing to a file, or electronic transmission

- Trip History - Trip history data collected from each turbine controller can be plotted, printed as tabular data, or transmitted electronically for remote analysis.

- Process Alarm Management - The features of process alarm management help the operator to make a proper response to alarms and include the following:
  - Alarm queue display for each turbine unit controller
  - Alarm lockout for toggling alarm conditions
  - Alarm notepad function for adding explanatory notes to each active alarm drop number for each panel
  - Linking alarms to pre-selected display screens
  - Alarm help utilities for storing more detailed descriptions of alarms and their intended functions
  - Distinguishing display of control system diagnostic alarms from regular alarm or events

6.3.3.3.4 Maintenance and Tool Support

- Remote, On-Plant Maintenance Access - The HMI system supports plant wide maintenance access for field installation, troubleshooting, and resolving general maintenance problems of the controller and HMI systems. In remote access, a computer in the remote location appears as a view node on the site system. Capabilities include operation displays, configuration of the HMI, real-time and historical data retrieval, and diagnostic alarms.

- Diagnostic Alarms - Diagnostic alarms specifically pertain to the control system and help operators and maintenance personnel respond to control system problems. Functions associated with diagnostic alarms include sorting and grouping capabilities, printing alarms on optional HMI alarm printer (if selected), and help utilities to identify alarm and intended response.

- View Programs - This special short term data collection programs provide collection of data necessary to troubleshoot the turbine unit control systems. These programs create diagnostic data files that are stored for later analysis. Files can be displayed, trended, printed, faxed or transferred.

- Logic Forcing - The HMI supports logic forcing and maintains the identity and status of forced points.

- Control Constants - Control constants are tune-up parameters and variables that change with each application and may change from time to time during the life of an installation. The HMI displays control constants values for a given control unit and allows adjustment of the values with appropriate ramp rates and min and max values. A tool is included to create and maintain a control constant file on a unit basis which can be downloaded to the unit controller.

- Configuration Tools - The HMI system provides tools to configure a turbine control panel including:
  - Control Sequence Program (CSP) editor to edit existing control program segments and to create new program segments
  - I/O configurator for embedded turbine control I/O software
  - Panel configuration including maintenance of the Data Dictionary File System (DDFS) and the Control Signal Data Base (CSDB)
  - Ability to configure the turbine control unit trip logs

6.3.3.3.5 Operator Displays

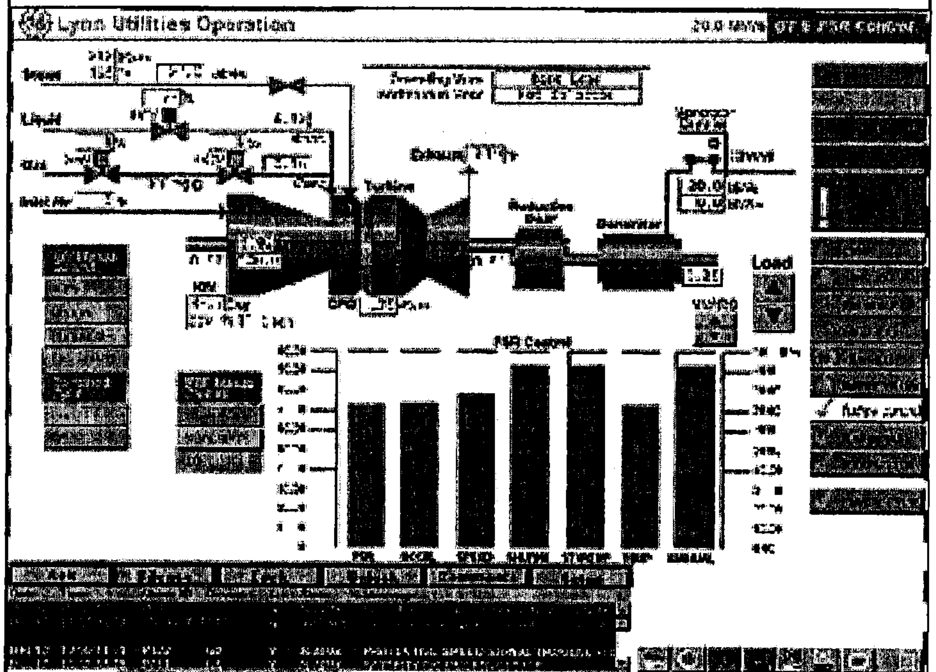
The operator/maintenance interface is commonly referred to as the Human Machine Interface (HMI). It is a PC with a GE CIMPLICITYR graphics display system and a MicrosoftR Windows NTR operating system. It can be applied as:

- The primary operator interface for one or multiple units
- A backup operator interface to the plant DCS operator interface
- A gateway for communication links to other control systems
- A permanent or temporary maintenance station
- An engineer station

All control and protection is resident in the turbine control which allows the HMI to be a non-essential component of the control system. It can be reinitialized or replaced with the turbine running with no impact on the control system. The HMI communicates with the processor card in the turbine control via the Ethernet based Unit Data Highway (UDH). The Main Display shows all of the pertinent control data on one screen to minimize the need for operators to change screens. A typical Main display is shown below. Data is displayed in either English or Metric engineering units with a 1 second refresh rate and a maximum of 1 second to repaint a typical display graphic. Operator commands can be issued by either incrementing / decrementing a setpoint with the up/down arrows or entering a numerical value for the new setpoint. Responses to these commands can be observed on the display one (1) second from the time the command was issued.

Some areas of the display have templates assigned to them. For example, some control valves show a rectangle around the graphic when the mouse is moved to the graphic symbol for that device. This identifies the underlying template that can be selected by the mouse as a pop-up. These pop-ups can be moved or resized on the Main Display and used to issue a command to the valve and observe the response of the valve via a numerical value, a bar chart, or a trend. Trend windows can be resized or moved to convenient locations on the display. Operators can select as many parameters as they feel comfortable viewing and trend at the control frame rate. Specific events can be pre-selected to trigger a trend with either pre-event data or post-event data.

Operator Interface Graphics
(Typical)



cntrls v04

An alarm field is provided in the lower left-hand corner of the Main Display. Each alarm message contains a 40ms time tag which originates in the turbine control, not in the HMI; therefore, the time tag resolution is the "frame rate" which the application software is running. Similarly, Sequence Of Events (SOE) time tagging for contact inputs originates in the turbine control contact input cards to enable the HMI to display 1ms resolution. Some alarms can become nuisance alarms such as an intermittent field ground. These types of alarms can be locked out / filtered by the Alarm Management system to avoid filling up the queue or logging numerous undesirable points. Operators can also add comments to alarm messages or link specific alarm messages to supporting graphics. Various methods of sorting alarms are supported including sorting by ID, Resource, Device, Time, and Priority.

Future growth to approximately 200 total graphics pages is available per operator station with up to 200 dynamic fields per display without impacting update time for multi unit sites. Displays have a maximum of 65k foreground and background colors, and the graphics are stored on the PC hard disk.

Security for the users of the HMI 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 NT User Manager administration program that supports five (5) user account levels.

6.3.3.3.6 Communications Interfaces

The HMI uses the Unit Date Highway (UDH) as its mechanism for communication with GE turbine controllers and ancillary equipment. The UDH allows the HMI to be located remotely at the plant site and enables a single HMI to communicate with up to eight turbine controllers. Since this network is intended to provide external interface, it uses open and widely used communication interfaces such as TCP/IP.

The Ethernet Plant Data Highway (PDH) serves to integrate the unit turbine control systems with the overall plant communications requirements. The HMI viewer stations connect to the PDH and receive their data from the servers over this network.

The HMI allows Modbus interfaces with other systems such as DCS.

6.3.4 Performance Monitoring Package

In conjunction with a centralized control system, the performance monitoring instrumentation package provides signals which may be used to compare turbine performance.

- Algorithms provided via the Mark V control panelturbine control operator interface <HMI>
-

6.3.5 Transducers

- Barometric pressure transmitter (96AP)
- Compressor bellmouth differential pressure transmitter (96BD)
- Compressor inlet air total pressure transmitter (96CS)
- Compressor discharge pressure transmitter (96CD)

- Exhaust pressure transmitter (96EP)
- Compressor temperature inlet flange (CT-IF-3/R)

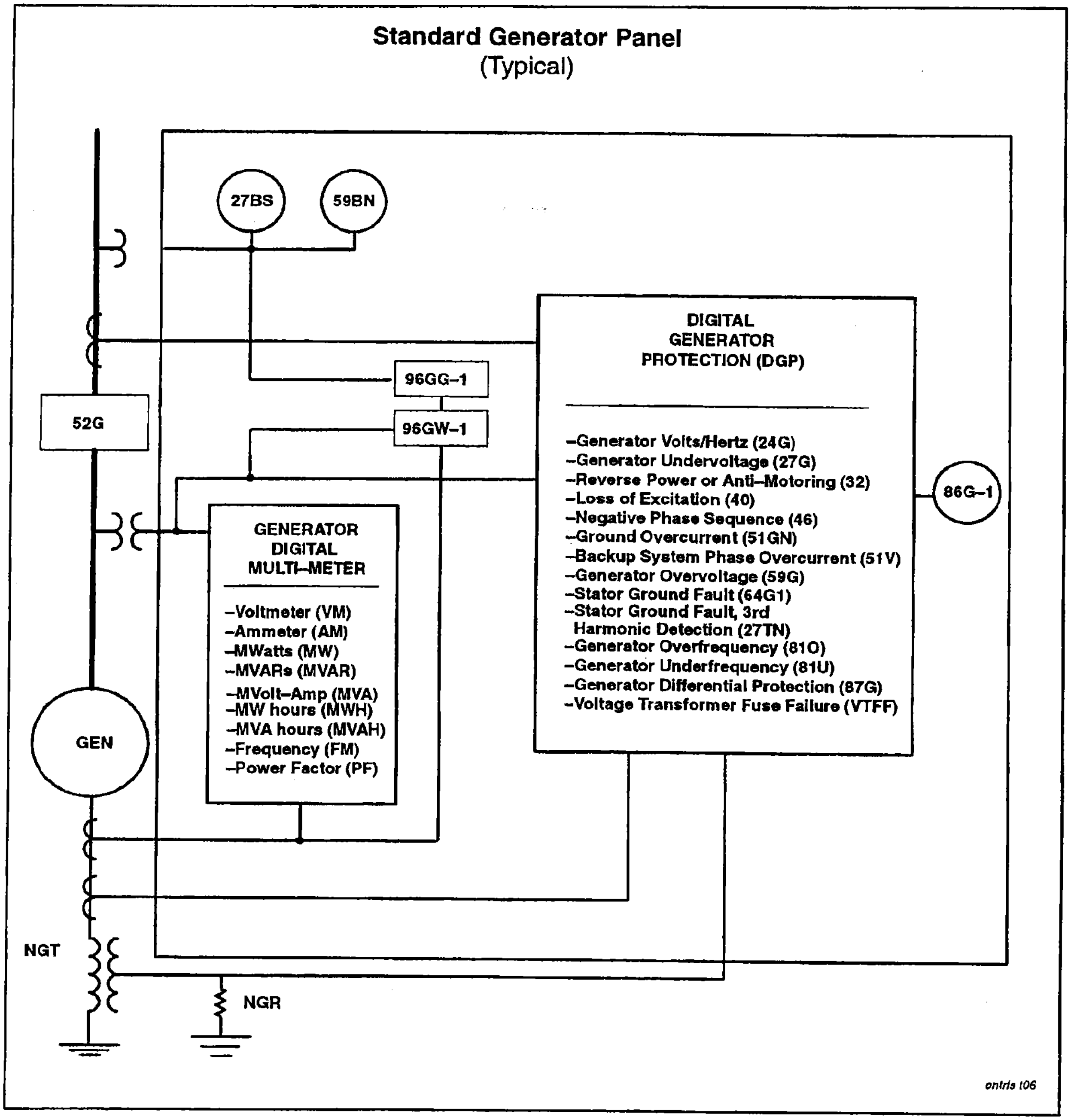
6.3.6 Motor Control Center

The motor control center contains circuit protective devices and power distribution equipment to supply electrical power to all packaged power plant devices as defined on the electrical one line diagram. The motor control center is manufactured and tested in accordance with NEMA ICS–2 and UL Standard No. 845. Vertical sections and individual units will be UL (CSA) Labeled where possible. The motor control center is located in the PEECC.

6.3.7 Generator Protection Panel

The heart of the generator protection panel is the digital multifunction relay integration with the gas turbine control system panel. The generator protection panel incorporates this feature along with generator metering and watt and VAR transducers for turbine control.

The following page presents a typical one-line diagram for the generator protection panel. The diagram and the tables which follow it illustrate the digital protection features and metering. For job-specific details please refer to the oneline diagram in the drawings section of the proposal.



6.3.7.1 Digital Generator Protection (DGP) Features

Measurement	Value
Overexcitation	24

Generator Undervoltage	27G
Reverse Power / Anti-Motoring	32-1
Reverse Power / Anti-Motoring	32-2
Loss of Excitation	40-1,2
Current Unbalance / Negative Phase Sequence	46
System Phase Fault	51V
Generator Overvoltage	59
Stator Ground Detection	64G/59GN
Stator Ground Detection, 3rd Harmonic	27TN
Generator Over Frequency	81O-1,2
Generator Under Frequency	81U-1,2
Generator Differential	87G
Voltage Transformer Fuse Failure	VTFF

6.3.7.2 Generator Digital Multimeter

Measurement	Value
Generator Volts	VM
Generator Amps	AM
Generator megawatts	MW
Generator megaVARs	MVAR
Generator MVA	MVA
Generator frequency	FM
Generator Power Factor	PF

6.3.7.3 Digital Generator Protection (DGP)

The digital generator protection system uses microprocessor technology to obtain a numerical relay system for a wide range of protection, monitoring, control and recording functions for the generator. Redundant internal power supplies and extensive diagnostic and self-test routines provide dependability and system security.

The DGP provides the commonly used protective functions in one package, including 100% stator ground fault detection using third harmonic voltage monitoring. Adaptive frequency sampling is used to provide better fault protection during off-normal frequencies such as startup.

The DGP can store in memory the last 100 sequence of events, 120 cycles of oscillography fault recording, and the last three fault reports

The system features a local Human-Machine Interface with integral keypad, 16 character display, and target LEDs for entering settings, displaying present values, viewing fault target information, and accessing stored data. In addition, two RS-232 serial communication ports are provided for local and remote computer access. (Please Note: The Personal Computer (PC) is not part of this offering.)

6.3.7.4 Gas Turbine Control System Integration

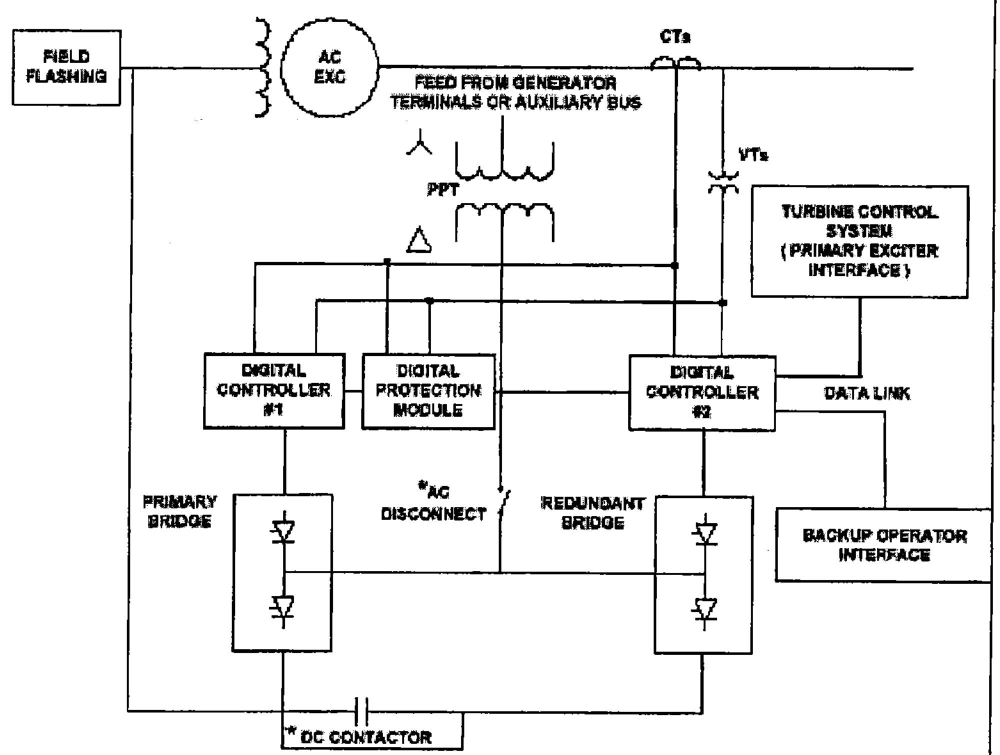
In addition to the relaying mounted in the generator protection panel, the gas turbine control system handles protective functions such as generator temperature protection, synchronizing check, backup frequency and reverse power.

Generator control and monitoring are primarily accomplished via the gas turbine control system operator interface. The operator interface handles manual and auto-synchronizing, speed raise/lower, voltage raise/lower, and generator breaker control. Also displayed are frequency and voltage for the generator and bus, breaker status, field current and voltage, along with the status of permissives.

6.3.8 Static Voltage Regulator for Bus Fed Excitation

The exciter is a digital, static, potential source excitation system. The system comes equipped with a full-wave thryristor bridge, which supplies excitation power to the rotating field winding of the main ac generator. In addition, all control and protective functions are implemented in the system software. Digital technology allows the exciter to maintain 99.98% availability. The following is a one-line diagram of the excitation system.

Static Excitation System with Redundant Bridge and Control (Typical)



* An AC disconnect/breaker or DC contactor will be supplied as required.

6.3.8.1 System Components

The exciter is comprised of the following four basic components as described below:

1. Power conversion module
2. Digital controller
3. Excitation transformer
4. Communication interface

6.3.8.1.1 Power Conversion Module

A three phase, full-wave thyristor bridge is the standard conversion module for the digital excitation system. The standard current capability of the bridge is 6% above the calculated rated full load field current of the generator.

The thyristor bridge assembly is forced air cooled. The cooling assemblies are all energized during normal operation. Thermostats are used to monitor the power conversion module temperature. An alarm is provided for a high temperature level and a trip is provided at a higher temperature level.

6.3.8.1.2 Excitation Transformer

The excitation transformer (power potential transformer) is separate from the exciter. The power to the transformer is obtained from a station auxiliary bus. The purpose of this transformer is to step the voltage down to the required level for the excitation system.

With the use of a regulator in the static exciter, it is not necessary to specify transformer full capacity taps above and below normal on the primary winding. The transformer rating is chosen so that the transformer can deliver the excitation required for the application at 110% rated generator terminal voltage on a continuous basis.

6.3.8.1.3 Digital Controller

The digital controller consists of several microprocessor I/O boards, and a power supply. Cell gating of the SCRs is controlled by one of the microprocessors. If redundant controls are provided, each controller section has its own power supply to ensure backup in the event of a power supply failure.

6.3.8.1.4 Communication Interface

The turbine control interface <HMI> is the primary interface with the exciter. Communication between the turbine control and exciter utilizes a single or redundant datalink. All exciter control logic and display data utilize this datalink. The exciter trip contact (94EX) is hardwired directly to the generator lockout relay and a single global alarm contact (30EX) is hardwired to the turbine control.

6.3.8.2 System Features

Following are descriptions of selected features of the exciter system. For a complete list of system features and accessories, please refer to the Scope of Supply section of the proposal.

6.3.8.2.1 Interface with the Gas Turbine Control System

The exciter is connected to the gas turbine control system through a digital datalink. This enables the gas turbine control system to provide a digital window into the exciter through which all pertinent variables can be monitored and controlled.

6.3.8.2.2 Protection Controller

The protection controller is separate from the main controller(s) and serves as a backup to the limiters located within the controller. The output of the protection controls transfer to backup control/bridge. The protection features provided are as follows:

- Volts/Hertz, dual level (24EX)
- Loss of excitation (40EX)
- Bridge ac phase unbalance (47EX)
- Generator overvoltage (59EX)
- Off/on-line overexcitation (76EX)

6.3.8.2.3 Spare Power Conversion Module as Redundant Bridge

A complete digital controller and rectifier bridge are provided as backup to the primary controller and bridge. If the protection module senses a condition that would normally initiate a trip signal, it will force a transfer to the redundant system before the trip contact is necessary. The transfer to the redundant system occurs with the generator on-line and does not affect generator output.

6.3.8.2.4 Power System Stabilizer (PSS)

The power system stabilizer function is incorporated into the exciter software. A signal representing the integral of accelerating power is introduced into the automatic voltage regulator algorithm to enable the generator to produce and transmit large power levels in a stable manner by reducing low frequency rotor oscillations

6.3.8.2.5 Enclosure

The exciter, located in a NEMA-1 stand-alone enclosure, contains the SCR power conversion module and regulator with all standard control and protection functions, plus auxiliary functions such as the de-excitation module and shaft voltage suppression circuit.

6.3.8.3 Related Services

6.3.8.3.1 Power System Stabilizer Tuning Study

GE provides engineering consulting services for tuning the power system stabilizer for optimal performance at the installation site. This includes studies to determine the optimum settings and producing computer models for use in transient stability analysis.

In order to complete the analyses described, GE typically requires data on the system strength at the HV bus (short circuit MVA) and data on the step-up transformer impedance. Copies of any pertinent interconnection specifications or performance requirements for the AVR/PSS should also be provided for use in determining the proper tuning.