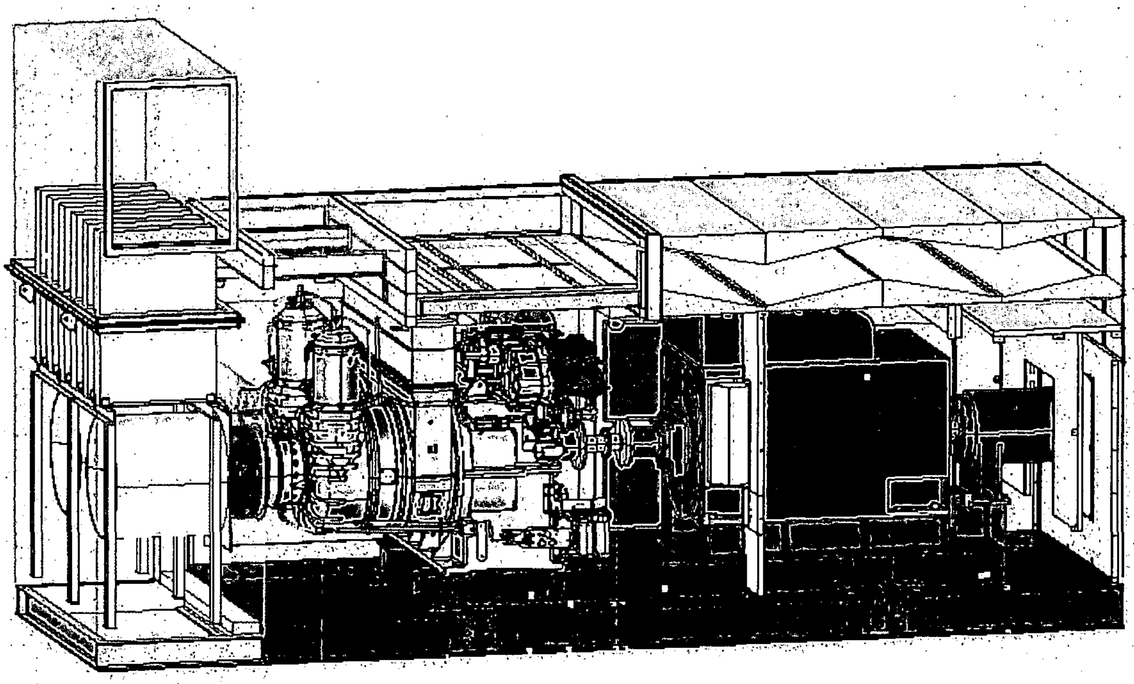
Qualification and Test Plan of Class 1E Gas Turbine Generator System



Non Proprietary Version

December 2007

Prepared: Shinji Niida 11/30/'07
Shinji Niida, Senior Engineer
Electrical Engineering Section
Water Reactor Engineering Department
Date

Prepared: Hideki Tanaka 12/04/'07
Hideki Tanaka, Engineer
Electrical Engineering Section
Water Reactor Engineering Department
Date

Reviewed: Yasutaka Eguchi 12/04/'07
Yasutaka Eguchi, Acting Manager
Electrical Engineering Section
Water Reactor Engineering Department
Date

Approved: Shigeru Hosokawa 12/04/'07
Shigeru Hosokawa, Section Manager
Electrical Engineering Section
Water Reactor Engineering Department
Date

Approved: Ryosuke Terada Dec./04/'07
Ryosuke Terada, General Manager
Water Reactor Engineering Department
Date

Revision History

Revision	Page	Description
0	All	Original issued

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

This technical report describes the design criteria, the design features, testing and qualification requirement for the Class 1E Gas Turbine Generator (GTG) units of US-APWR.
MHI will perform the qualification program including tests with two partner companies. One has many years of experience of supplying commercial grade GTG. The other has extensive experiences of supplying Class 1E Diesel Generator (DG) units to US conventional nuclear power plants, as well as Commercial Grade Dedication per EPRI NP5652.
This report provides reasonable assurance that GTG is highly reliable and dependable and very well suited to perform their safety functions as required by the US codes and Standards. These include:

Code of Federal Regulations
Regulatory Guides
Branch Technical Positions
NUREG-Series Publications
IEEE-Standards
Other Industry Standards

The GTG system requires no cooling water system. GTG is a very simple rotary engine which is much simpler than a diesel engine. There are also far fewer components, such as valves, pumps and pipes in the GTG support systems, compared to support systems for a DG. Thus, GTG is expected high reliability. The reliability of GTG system is expected to be higher than or at least equal to that the DG.

This technical report describes the followings
Design criteria
Design features, specification
Seismic analysis
Reliability
Class 1E qualification plan

MHI seeks NRC approval of this design criteria and qualification requirement for application to the Class 1E standby power supply system of the US-APWR.

Table of Contents

List of Tables

List of Figures

List of Acronyms

ac	Alternate Current
dc	Direct Current
CDP	Compressor Discharge Pressure
CPS	Control Protection and Surveillance systems
CPU	Central Processing Unit
CT	Current Transformer
DG	Diesel Generator
ECCS	Emergency Core Cooling System
EGT	Exhaust Gas Temperature
ESI	Engine System Inc.
ESFAS	Engineered Safety Features Actuation System
FMEA	Failure Modes and Effects Analysis
FOA	Fuel, Oil and Air
GTG	Gas Turbine Generator
I&C	Instrumentation and Control
I/O	Input/Output
IV&V	Independent Verification and Validation
KHI	Kawasaki Heavy Industries
LOCA	Loss of Coolant Accident
LOOP	Loss of Offsite Power
MCR	Main Control Room
MHI	Mitsubishi Heavy Industries
MTBF	Mean Time Between Failure
QA	Quality Assurance
RTD	Resistance Temperature Detector
SLS	Safety Logic System
UV	Under Voltage
VDU	Visual Display System
VT	Voltage Transformer

1.0 INTRODUCTION/OVERVIEW

The US-APWR uses Gas Turbine Generators (GTG), as Emergency Power Supply in lieu of the most commonly used Diesel Generators (DGs).

In a gas turbine, a pressurized gas spins the turbine. In all modern gas turbine engines, the engine produces its own pressurized gas, and it does this by burning its fuel. The heat that comes from burning the fuel expands air, and the high-speed rush of this hot air spins the turbine.

There are two (2) major advantages of the turbine over the diesel (a detailed comparison is presented in Table 1.0-1):

- Gas turbine engines have a great power-to-weight ratio compared to reciprocating engines. That is, the amount of power that comes out of the engine compared to the weight of the engine itself is very good.
- Gas turbine engines are smaller than their reciprocating counterparts of the same power.

The main disadvantage of gas turbines is that, compared to a reciprocating engine of the same size, they are expensive. Because they spin at such high speeds and because of the high operating temperatures, designing and manufacturing gas turbines is a tough problem from both the engineering and materials standpoint. Gas turbines also tend to use more fuel when they are idling. That makes gas turbines great for jet aircraft and power plants, but explains why they are not used in cars.
The Gas Turbine was selected for the US-APWR because the engines are, theoretically, extremely simple. They have three main parts:

- Compressor - Compresses the incoming air to high pressure
- Combustion area - Burns the fuel and produces high-pressure, high-velocity gas
- Turbine - Extracts the energy from the high-pressure, high-velocity gas flowing from the combustion chamber

In the engine, air is sucked in from the compressor. The compressor is basically a cone-shaped cylinder with small fan blades attached in rows. As the air is forced through the compression stage its pressure rises significantly. In some engines, the pressure of the air can rise by a factor of 30.

As a result:

- The Gas Turbine is a very simple rotating engine with few components
- The GTG System consists only of the gas turbine, generator, fuel transport system, starting system and control/instrumentation system
- Water cooling system is not required
- The GTG, as described below, presents a high level of reliability.

The application of an aircraft derivative gas turbine for electrical power generation was required in order that the "fast start" requirement for emergency core cooling could be met. This resulted in the combination of an extremely reliable aircraft component with equally reliable industrial components such as reduction gears, electrical generator, governor, voltage regulator, relays and similar components.

The GTG components have demonstrated a high degree of reliability in starting and continuous power operation in aircraft and commercial applications over a long period of time.
The Gas Turbine unit is maintained in a state of readiness through regular maintenance inspections and testing. The unit will be started and loaded once a month to demonstrate operational readiness. This requirement assures that the gas turbine unit is maintained in a state of functional readiness.

Mitsubishi Heavy Industries (MHI) applies the unit named GPS 6000. It is manufactured by Kawasaki Heavy Industries (KHI).

A brief comparison between a DG and a GTG is presented in the table 1.0-1 below:

Table 1.0-1 Gas Turbine and Diesel Engine Comparison

	Gas Turbine	Diesel	Comments
Weight, Size	Gas Turbine		The gas turbine size is approximately one-fourth by weight and one-seventh by volume compared with the same range diesel engine.
Space	Compact	Large	See above
Noise Level	Gas Turbine		The main component of noise is the high frequency wave, which is easily silenced . As a result it is easier to reduce the noise level of the gas turbine.
Vibration	Gas Turbine		A gas turbine produces little vibration because the engine is not reciprocating , and just has a rotary motion
Cooling Water	Not Required	Required	The gas turbine does not need cooling water because the engine is air-cooled.
Reliability of Starting	Gas Turbine		Since the combustion system is a continuous combustion system with spark plugs, the engine starting reliability is high
Power Supply	Gas Turbine		Deviation in frequency is small, therefore the gas turbine supplies high quality power.
Exhaust Gas	Gas Turbine		The combustion efficiency is high, and harmful substances like NOx included in exhaust gas are small. Therefore the gas turbine is clean.
Fuel Consumption		Diesel	The diesel is superior to the gas turbine, because the fuel consumption of a gas turbine is higher than that of a diesel.
Periodic Maintenance	Overhaul is done once or twice during plant life	Periodic Overhaul Required	The Gas Turbine requires fewer overhauls than the Diesel units.
Reliability	Higher than DG	10^{-2} (/d)	See Reliability report
Starting Time	40 sec	10 sec	The Gas Turbine unit requires a longer starting time but this time is within the core cooling requirements of the US-APWR. This starting time for the GTG is acceptable because the advance accumulator design of the US-APWR.

Note : The design and analysis of Emergency Core Cooling System (ECCS) permits 100 seconds. Design requirement of GTG starting time is within 100 seconds.

1.1 Scope

This Technical Report describes the application, qualification and testing of the GTG units as Class 1E standby power supplies in nuclear power generating stations (US-APWR). Figure 1.1-1 shows the boundaries of systems and equipment included in the scope of this report.

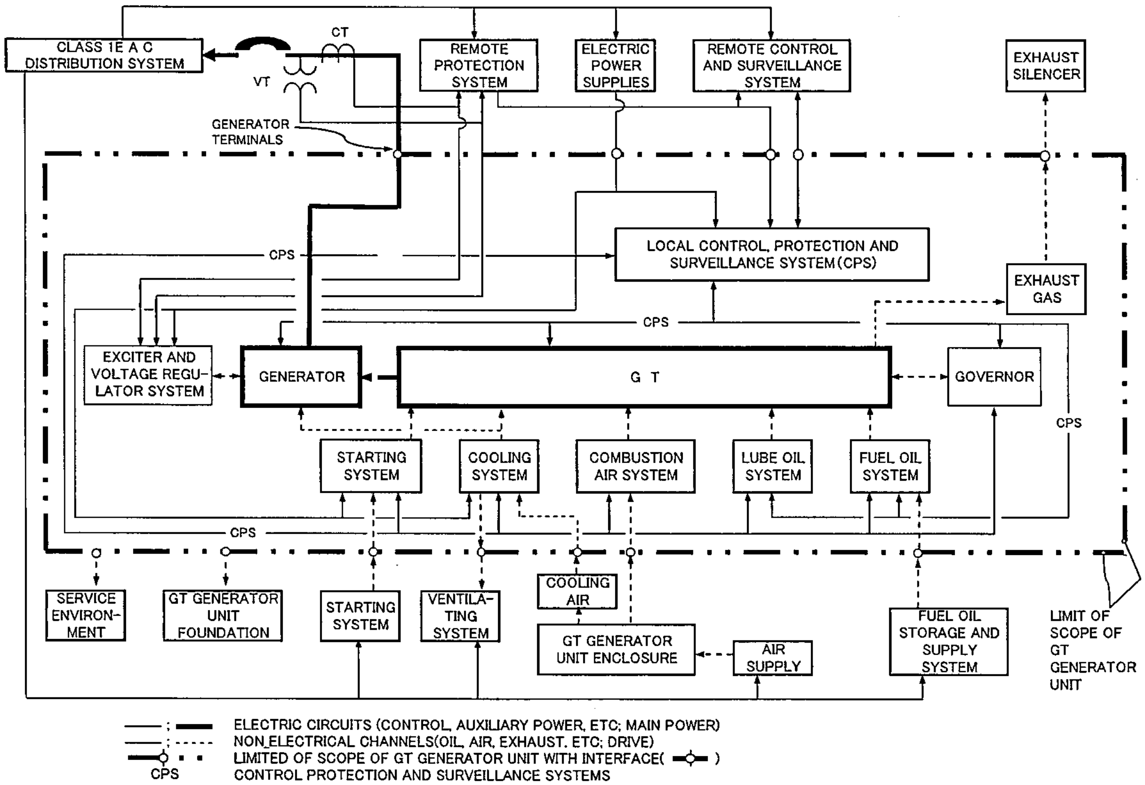


Figure 1.1-1 Scope Diagram

1.2 Purpose

The purpose of this Technical Report is to provide the principal design criteria, the design features, testing, and qualification requirements for the GTG units that enable them to meet their functional requirements as part of the standby power supply system for the US-APWR, under the conditions produced by the design basis events cataloged in the Plant Safety Analysis. It is also intended to provide reasonable assurance that these units are highly reliable and dependable and very well suited to perform their safety functions as required by the applicable regulations. This Technical Report proves that the GTG selected for use in the US-APWR is an excellent alternative to the commonly used DGs.

2.0 LIST OF STANDARDS AND REGULATIONS

The requirements of various standards and regulations presently used for DGs that are pertinent to a GTG will be implemented in US-APWR design.

2.1 NRC Documents

(1) Regulatory Guide 1.6 Rev 0. Independence Between Redundant Standby (Onsite) Power Sources and Between Their Distribution Systems (Safety Guide 6)
(2) Regulatory Guide 1.9 Rev. 4 Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants
(3) Regulatory Guide 1.28 Rev. 3 Quality Assurance Program Requirements
(4) Regulatory Guide 1.32 Rev. 3. Criteria for Power Systems for Nuclear Power Plants
(5) Regulatory Guide 1.38 Rev. 2 Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage, and Handling of Items for Water-Cooled Nuclear Power Plants (Rev. 2)
(6) Regulatory Guide 1.75 Rev. 3. Physical Independence of Electric Systems
(7) Regulatory Guide 1.93 Rev. 0. Availability of Electric Power Sources
(8) Regulatory Guide 1.118 Rev. 3. Periodic Testing of Electric Power and Protection Systems
(9) Regulatory Guide 1.137 Rev. 1. Fuel-Oil Systems for Standby Diesel Generators
(10) NUREG/CR-6928, Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power plant, February 2007
(11) NRC Information Notice 2006-22 New Ultra-low-sulfur Diesel Fuel Oil Could Adversely Impact Diesel Engine Performance
(12) 40CFR 50 NATIONAL PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS
(13) 40CFR 52 APPROVAL AND PROMULGATION OF IMPLEMENTATION PLANS
(14) 40CFR 60 STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES
(15) 40CFR 61 NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS
(16) 40CFR 63 NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS FOR SOURCE CATEGORIES
(17) 40CFR 68 CHEMICAL ACCIDENT PREVENTION PROVISIONS
(18) 40CFR 70 STAGE OPERATING PERMIT PROGRAMS
(19) 40CFR 71 FEDERAL OPERATING PERMIT PRGRAMS
(20) 40CFR 81 DESIGNATION OF AREAS FOR AIR QUALITY PLANING PURPOSES

2.2 Industry Standards – IEEE

(1) IEEE 1-2000, Recommended Practice - General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation
(2) IEEE 43-2000, Recommended Practice for Testing Insulation Resistance of Rotating Machinery
(3) IEEE Std 96-1969, General Principles for Rating Electric Apparatus for Short-Time, Intermittent, or Varying Duty
(4) IEEE Std 115-1995, Test Procedures for Synchronous Machines
(5) IEEE 142-1991, Recommended Practice for Grounding of Industrial and Commercial Power Systems

(6) IEEE 275-1992, Recommended Practice for Thermal Evaluation of Insulation Systems for Alternating-Current Electric Machinery Employing Form-Wound Preinsulated Stator Coils for Machines Rated 6900 V and Below
(7) IEEE Std 308-2001 - IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations
(8) IEEE Std 323-2003 - IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
(9) IEEE 336-2005 IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities
(10) IEEE 338-1987 – IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems
(11) IEEE-344-2004 IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
(12) IEEE-379-2000 IEEE Standard Application of the Single Failure Criterion to Nuclear Power Generating Stations Safety Systems
(13) IEEE Std 384-1992 IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits
(14) IEEE Std 387-1995 - IEEE Standard Criteria for Diesel Generator Units Applied as Standby Power Supply for Nuclear Power Generating Stations.
(15) IEEE-415-1986 IEEE Guide for Planning of Preoperational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations.
(16) IEEE-421.3-1997 IEEE Standard for High Potential Test Requirements for Excitation Systems for Synchronous Machines
(17) IEEE-421.4-2004 IEEE Guide for the Preparation of Excitation System Specifications
(18) IEEE 429-1972, Recommended Practice for Thermal Evaluation of Sealed Insulation Systems for AC Electric Machinery Employing Form-Wound Preinsulated Stator Coils for Machines Rated 6900 V and Below
(19) IEEE-493-1997, Recommended Practice for the Design of Reliable Industrial and Commercial Power System
(20) IEEE-494-2005 IEEE standard methods for identification of documents related to class 1E equipment and systems
(21) IEEE Std 500-1984 IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations
(22) IEEE-603-1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations
(23) IEEE-627-1980, IEEE Standard Criteria for Design Qualification of Safety Equipment Used in Nuclear Power Generating Stations

2.3 Other Industry Standards

(1) NEMA FU-1-2002 Low Voltage Cartridge Fuses
(2) NEMA MG-1-2006 Motors and Generators
(3) ANSI/ASME NQA-1-2004 Quality Assurance Requirements for Nuclear Facility Applicants
(4) ANSI B31.1-2001 Power Piping
(5) ANSI B37.20 Switchgear Assemblies including Metal Enclosed Bus
(6) ANSI C37-90.1-2002 IEEE Standard for Surge Withstand Capabilities (SWC) Tests foor Relays and Relay Systems Associated with Electric Power Apparatus
(7) ANSI C37-101-1993 IEEE Guide for Generator Ground Protection
(8) ANSI C37.102-2006 IEEE Guide for AC Generator Protection

(9) ANSI C50.10-1990 Rotating Electrical Machinery - Synchronous Machines
(10) ANSI C50.12 Requirements for Salient Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications
(11) ANSI C50.13-2005 IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above
(12) ANSI C50.14-1977 American National Standard Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators
(13) ANSI C57.13-1993 IEEE Standard Requirements for Instrument Transformers (if needed)
(14) ANSI C62.92.2-1989 IEEE Guide for the Application Guide for Neutral Grounding in Electrical Utility Systems, Pt II - Grounding of Synchronous Generator Systems.
(15) ANSI/ASME B16.11-2005, Forged Fittings, Socket Welding and Threaded.
(16) ANSI/ASME B16.25-1997, Buttwelding Ends.
(17) ANSI N195-1976, Fuel Oil Systems for Standby Diesel Generators
(18) ASTM D975-1981, Standard Specification for Diesel Fuel Oils
(19) ANSI/NFPA 37-2002, Combustion Engines and Gas Turbines, Stationary
(20) ASME Boiler and Pressure Vessel Code
(21) Standard Practices for Low and Medium Seed Stationary Diesel and Gas Engines, 6th Edition, p. 94, Diesel Engine Manufacturers Association (DEMA), 1972
(22) TEMA Standards of the Tubular Exchanger Manufacturers Association, 9th Edition
(23) ICEA S-19-81 (NEMA WC3) Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
(24) ICEA S-66-524 Cross-linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
(25) ICEA S-68-516 (NEMA WCB) Ethylene-Propylene-Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.
(26) NFPA Vol. 1 Flammable Liquids - Tank Storage
(27) NFPA No. 30 Flammable and Combustible Liquids Code
(28) NFPA No. 37 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines

3.0 DEFINITIONS

3.1 Acceptable:

Demonstrated to be adequate by the safety analysis of the plant.

3.2 Continuous Rating (of Unit):

The electric power output capability that the GTG unit can maintain in the service environment for 1,000 hrs of operation between overhauls only scheduled outages for maintenance.

3.3 Design Basis Events:

Postulated events used in the design to establish the performance requirements of the structures and systems.

3.4 Design Load:

That combination of electric loads (kW and kVAR), having the most severe power demand characteristic, which is provided with electric energy from a GTG unit for the operation of engineered safety features and other systems required during and following shutdown of the reactor.

3.5 Gas Turbine Generator Unit:

An independent source of standby electrical power that consists of a diesel-fueled internal combustion engine (or engines) coupled to an electrical generator (or generators) through a reducing gearbox; the associated mechanical and electrical auxiliary systems; and the control, protection, and surveillance systems.

3.6 Engine Equilibrium Temperature:

The conditions at which the lube oil temperatures are both within ± 5.5°C (10°F) of their normal operating temperatures established by the engine manufacturer.

3.7 Load Profile:

The magnitude and duration of loads (kW and kVAR) applied in a prescribed time sequence, including the transient and steady-state characteristics of the individual loads.

3.8 Qualified Gas Turbine Generator Unit:

A GTG unit that meets the qualification requirements of the applicable standards and regulations.

3.9 Redundant Equipment or System:

An equipment or system that duplicates the essential function of another equipment or system to the extent that either may perform the required function regardless of the state of operation or failure of the other.

3.10 Service Environment:

The aggregate of conditions surrounding the GTG unit in its enclosure, while serving the design load during normal, accident, and post-accident operation.

3.11 Short-Time Rating (of Gas Turbine Generator Unit):

The electric power output capability that the GTG unit can maintain in the service environment for 300 hrs , without exceeding the manufacturer's design limits and without reducing the maintenance interval established for the continuous rating.

3.12 Slave Equipment:

Equipment not permanently installed, used for testing only.

3.13 Standby Power Supply:

The power supply that is selected to furnish electric energy when the preferred power supply is not available.

3.14 Start Signal:

That input signal to the GTG unit start logic that initiates a GTG unit start and run sequence.

3.15 Surveillance:

The determination of the state or condition of a system or subsystem.

4.0 PRINCIPAL DESIGN CRITERIA

4.1 Capability

4.1.1 General

When in service, the GTG unit has the capability of performing as a redundant unit of a standby power supply, in accordance with the requirements stated in IEEE Std 308.

4.1.2 Mechanical and Electrical Capabilities

The GTG unit has each of the following specific capabilities to meet the design, application, and qualification requirements of pertinent standards and regulations:

(1) *Design conditions.* The unit is capable of operating during and after any design basis event without support from the preferred power supply. The following design conditions, including appropriate margins as required by subclause 6.3.1.5 of IEEE Std 323-1983, and shall include as a minimum:
   - (a) Operational cycles (6000 starts over a period of 60 years, unless otherwise specified , with scheduled maintenance activities)
   - (b) Operating hours (9,000 hrs over a period of 60 years, unless otherwise specified , with scheduled maintenance activities)
   - (c) Temperature at equipment locations (minimum and maximum with durations and average annual ambient)
   - (d) Seismic response spectra
   - (e) Radiation ($1X10^4$ rd of gamma integrated dose over a period of 60 years, unless otherwise specified)
   - (f) Humidity (minimum and maximum with durations)
   - (g) Load profile, including allowable voltage and frequency variations (Appendix A)
   - (h) Absolute barometric pressure (altitude and tornado depressurization, duration, and magnitude)
   - (i) Combustion air contaminants (salt, sand, etc.)
   - (j) Fuel type and quality
   - (k) Auxiliary electrical power supply requirements
   - (l) Effect of fire protection actuation

(2) *Starting and loading.* The unit is capable of starting, accelerating, and being loaded with the design load within the time required by the equipment specification (Appendix B).
   - (a) From the normal standby condition.
   - (b) On a restart with an initial engine temperature equal to the continuous rating full-load engine temperature.

(3) *Light-load or no-load operation.* The unit is capable of accepting design load following operation at light load or no load for the time required by the equipment specification (Appendix B).

(4) *Design load.* The unit is capable of carrying the design load for the time required by the equipment specification (Appendix B).

(5) *Quality of power.* The unit is capable of maintaining voltage and frequency at the generator terminals within limits that will not degrade the performance of any of the loads comprising the design load below their minimum requirements, including the duration of transients caused by load application or load removal.

4.2 Ratings

The US–APWR GTG is rated as follows:
4500 kW Continuous @ 1,000 hrs Engine Overhaul Interval, 115°F Air Intake Temperature
4950 kW Short Time @ 300 hrs Engine Overhaul Interval, 115°F Air Intake Temperature
6900 V, 3-phase, 60 Hz

4.2.1 Application

The GTG unit has continuous and short time ratings that reflect the output capabilities of the GTG unit in accordance with the requirements of Section 4.1 and the following:

(1) Inspections and scheduled maintenance are performed periodically using the manufacturer's recommendations and procedures.
(2) Unscheduled maintenance is performed in accordance with the need as indicated by the periodic inspections and operating experience.

4.2.2 Operation

The GTG units are utilized to the limit of their power capabilities, as defined by the continuous and short-time ratings. Unless time and load parameters for light-load and no-load operation are established by tests and documentation, the following precautions shall be taken:

(1) When 4 hrs operation at 30% or less of the continuous rating have been accumulated (without at least 0.5 hrs operation above 50% of the continuous rating), the unit shall be operated at a load of at least 50% of the continuous rating for a minimum of 0.5 hrs.
(2) Operating at 30% or greater of the continuous rating shall be restricted to the manufacturer's recommendations.

4.3 Starting Time

(1) Starting time of GTG is required within 100 seconds by safety design and analysis of US-APWR. GTG to be reached set voltage and frequency, and GTG breaker should be closed within 100 seconds after starting signal is initiated.
(2) GPS 6000 is reached set voltage and frequency within 40 seconds as its standard specification.

4.4 Interactions

Independence between units will not be compromised. Mechanical and electric system interactions between a particular GTG unit and other units of the standby power supply, the nuclear plant, the conventional plant, and the Class 1E electric system is coordinated in such a way that the GTG unit's design function, and capability requirements of Section 4.1, may be realized for any design basis event, except failure of that GTG unit.

4.5 Design Features

4.5.1 Mechanical and Electrical Design Features

4.5.1.1 Vibration

Vibration amplitudes are limited to be within the design capabilities of the GTG unit and auxiliary components. Solenoids, relays, and other devices are mounted in such a way to minimize vibration effects.

4.5.1.2 Torsional Vibration

Harmful torsional vibration stresses will not occur within a range from 10% above to 10% below rated idle speed and from 5% above to 5% below rated synchronous speed.

4.5.1.3 OverSpeed

Moving parts are designed to withstand that level of over-speed that results from a short-time rating load rejection. Margin is provided to allow the over-speed device to be set sufficiently high to guarantee that the unit will not trip on short-time rating load rejection. The generator rotor and exciter rotor are designed to withstand an over-speed of 25% without damage.

4.5.1.4 Governor Operation

The gas turbine engine is equipped to operate in both the isochronous and the droop mode. Provisions are included to automatically place the engine governor in the proper mode of operation when the GTG unit is required to operate automatically (see Subsection 4.5.2.2).

4.5.1.5 Voltage Regulator Operation

The voltage regulator is equipped to operate in the paralleled and non-paralleled modes. Provisions are included to automatically place the voltage regulator in the proper mode of operation when the GTG unit is required to operate automatically (see Subsection 4.5.2.2).

4.5.2 Control

4.5.2.1 Control Modes

The GTG unit is provided with control systems, permitting automatic and manual control.

4.5.2.2 Automatic Control

Upon receipt of an automatic start signal, the automatic control system provides automatic startup and automatic adjustment of speed and voltage to a ready-to-load condition.

(1) ECCS Actuation signal overrides all other operating modes and return control of the GTG unit to the automatic control system.
(2) An automatic start signal will not override any manual non-operating modes such as those for repair and maintenance.

4.5.2.3 Control Points

Provisions are made to control both from the control room and external to the control room.

4.5.3 Surveillance

4.5.3.1 Surveillance Systems

The GTG unit is provided with surveillance systems permitting remote and local alarms and indicating the occurrence of abnormal, pre-trip, or trip conditions.

4.5.3.2 Modes Surveyed

The following conditions are surveyed:

(1) Unit not running
(2) Unit running, not loaded
(3) Unit running, loaded
(4) Unit out of service

4.5.3.3 Surveillance Instrumentation

The following systems shall have sufficient mechanical and electric instrumentation to survey the variables required for successful operation and to generate the abnormal, pre-trip, and trip signals required for alarm of such conditions:

(1) Starting system
(2) Lubrication system
(3) Fuel oil storage and transfer system
(4) Combustion air intake and Exhaust system
(5) Generator
(6) Excitation system
(7) Voltage regulation system
(8) Governor system

4.5.4 Protection

The GTG unit shall be automatically tripped on an engine over-speed or generator differential current, or both and high exhaust gas temperature (EGT). Protective features, other than engine over-speed, generator differential current and high EGT, are blocked from automatically tripping the GTG unit during an accident condition, and are annunciated in the plant control room.

5.0 FACTORY PRODUCTION TESTING

5.1 General

This specification covers the requirements of the factory test including procedures for the gas turbine power section and the gas turbine engine assembly. The factory test for gas turbine power section is performed prior to assembling the Gas Turbine Generation System.
The test procedures are developed by the manufacturer in accordance with ISO 2314.

5.2 Gas Turbine Power Section Test

The factory test of the gas turbine power section is performed at the manufacturer's test facility. The scope of the Gas Turbine Power Section factory testing includes only the power section and accessories directly installed on the gas turbine power section. This does not include the reduction gear box, accessory gear box, accessories installed on accessory gear box, and external systems (fuel system, lubrication oil system and electric system, etc.).
The components not installed on the power section are not tested during the factory test of gas turbine power section. "Slave" equipment is used instead of these components.
The load used for the factory test of the gas turbine power section is absorbed by means of a water dynamometer. Liquid fuel is used during the factory test.

5.3 Gas Turbine Engine Assembly Test

The factory test of the gas turbine engine assembly is performed by using "slave" test equipment at the manufacturer test facility.
The scope of the gas turbine engine assembly test includes the power section, reduction gear box, accessory gear box, accessories installed on accessory gear box, and external system (fuel system, lubrication oil system and electric system, etc.).
The load during pass off test of the gas turbine engine assembly is absorbed by means of water dynamometer.

5.4 Test Contents for Gas Turbine Power Section

(1) Functional Test (refer to Subsection 5.4.1)
(2) Performance Test (refer to Subsection 5.4.2)
(3) Cycle Test (refer to Subsection 5.4.3)
(4) Test Report (refer to Subsection 5.4.4)

5.4.1 Functional Test

5.4.1.1 Visual Check Before Test

The gas turbine shall be correctly assembled and configured according to the design drawings without any damage.

5.4.1.2 Operation and Inspection

The standard operating ranges are shown in Table 5.4-1.

(1) Purge test

Check for smooth acceleration and deceleration, and no abnormal noise.

(2) Start-up test
Check the maximum indicated Exhaust Gas Temperature (EGT).
Measure the starting time.

(3) Engine shutdown
Measure the coast-down time.

5.4.1.3 Visual Inspection After Test

Check to ensure no leakage of fuel or lubricating oil inside the test unit.
Check to ensure the turning motor operate following shutdown.

5.4.2 Performance Test

5.4.2.1 Test

Engine shall be run at 100% corrected rotor speed and at 6 load cases (minimum load, 4/8, 5/8, 6/8, 7/8, and maximum load).

5.4.2.2 Monitoring Data

The monitored data shall not exceed standard operating ranges shown in Table 5.4-1.

5.4.2.3 Correction to Standard Performance

The standard performance specified in this specification is the corrected value under the following conditions.

(1) Ambient Pressure	0.1013 MPa (14.7 psia)
(2) Intake Air Temperature	15°C (59°F)
(3) Intake Air Pressure Loss	0 Pa (0 psi)
(4) Exhaust Pressure Loss	2 kPa (0.29 psi)

(The exhaust pressure loss represents the total pressure loss at the outlet flange of the exhaust duct of the power section with a tail cone of the outlet diameter 662 mm.)
The corrected fuel flow rate and EGT shall satisfy the requirements given in the following:

The fuel flow rate corrected at standard operating condition of 15°C (59°F) intake air temperature and 0.1013 MPa (14.7 psia) ambient pressure is shown in Fig. 5.4-1.
The measured fuel flow rate shall be corrected at standard operating condition. (refer to formula (3))
The corrected value shall be within the limit as shown in Fig. 5.4-1.
The EGT corrected at standard operating condition of 15°C (59°F) intake air temperature is shown in Fig. 5.4-2.
The measured EGT shall be corrected to standard operating condition. (refer to formula (4))
The corrected value shall be within the limit as shown in Fig. 5.4-2.

5.4.3 Cycle Test

The cycle test shall be performed for a total of three times.
Start – Loading – 30 minutes running at rated load – Unloading – Stop

5.4.4 Test Report

The test results consisting of the following test reports shall be kept in the Quality Assurance (QA) Department.

(1) Functional Test
(2) Performance Test
(3) Cycle Test

5.5 Test Contents for Gas Turbine Engine Assembly Test

(1) Functional Test
(2) Test Report

5.5.1 Functional Test

5.5.1.1 Visual Check Before Test

The gas turbine shall be correctly configured as shown in the design drawings without damage.

5.5.1.2 Operation and Inspection

Standard operating ranges is shown in Table 5.4-1.

(1) Purge test
Check for smooth acceleration and deceleration, and no abnormal noise.
(2) Start-up test
Check the maximum indicated EGT.
Measure the starting time.
(3) Engine test
The Gas Turbine shall run at 100% rotation speed and minimum load rating for 1 hr.
(4) Engine shutdown
Measure the coast-down time.

5.5.1.3 Visual Inspection After Test

Check to ensure no leakage of fuel or lubricating oil inside the test unit.
Check to ensure the turning motor operate following shutdown.

5.5.1.4 Test Report

The test results consisting of the following test reports shall be kept in the QA Department.

(1) Functional Test

Table 5.4-1 Standard Operating Ranges for Gas Turbine Power Section

Item		Range (SI unit)	Range (English unit)
Rotor Speed (100%: 18000 min^{-1})		95 - 104%	95 - 104%
Indicated EGT	During Startup	Max. 750°C	Max. 1382°F
	After Startup	Max. 605°C	Max. 1121°F
Startup Time		Max. 60 sec.	Max. 60 sec.
Lube Oil Pressure (at oil manifold)		0.26 – 0.39 MPa	37.7 – 56.6 psig
Lube Oil Temp. (at oil manifold)		Max. 80°C (Toil)	Max. 176°F (Toil)
No.2 BRG. Scavenge Oil Temp.		Max. Toil+30°C	Max. Toil+54°F
Vibration	P/S Shaft	Max. 50 µm	Max. 2 mil
	G/B HSG (engine assembly)	Max. 11 mm/s	Max. 0.43 inch/s
Coast-down Time		Min. 240 sec.	Min. 240 sec.

Figure 5.4-1 Corrected Fuel Flow Rate vs Corrected Output of Gas Turbine Power Section

Figure 5.4-2 Corrected EGT vs Corrected Output of Gas Turbine Power Section

6.0 SEISMIC ANALYSIS

This seismic analysis includes the power section (Gas Turbine Engine assembly), and the Reduction Gearbox.
The following conditions are considered:

- Seismic loads applied to the GPS6000-Type GTG set while the generator set is running and it is stopped respectively.
- Shock loading of magnitude 1g in the axial direction (parallel to a shaft), as well as Shock loading of magnitude 1g in the radial direction (right angles to the shaft) were applied.

Then it was concluded from the evaluation results that the GPS6000-Type GTG Set is operable continuously and successfully after receiving the subject seismic shocks.

6.1 Shock Loading Due to Seismic Events

The GPS6000-Type Gas Turbine (including the power section and Reduction gearbox) has been developed for industrial use. The construction of the Gas Turbine is sufficiently strong. However, the rotor of the Gas Turbine, as well as the gear shaft of the Reduction gearbox is supported by bearings at both shaft ends. Since the contact area of the bearing is small, the bearings are very vulnerable against stresses such as seismic shocks. Therefore, the anti-seismic capability of the major bearings of the Power section and of the Reduction gearbox was evaluated.
The "Seismic Evaluation" methods are described below:

(1) Load applied to bearings caused by seismic shocks are represented by "Shaft mass x Acceleration".
(2) Because the above seismic shocks are applied instantaneously, the shock loads applied to bearings are defined as static loads.
(3) Shock loads are applied to bearings in the axial direction (parallel to the shaft, magnitude 1g), and in the radial direction (at right angles to the shaft, magnitude 1g).
(4) Referring to the below equation, the static equivalent radial load "Po" is obtained as follows and the larger value is selected.

Equation

$$Po = Xo \times Fr + Yo \times Fa \quad \text{or} \quad Po = Fr \quad \text{(Larger value select)}$$

where, Po: Static equivalent radial load [kgf]
Fr: Radial load [kgf]
Fa: Axial load [kgf]
Xo: Static radial load coefficient
Yo: Static axial load coefficient

(5) Referring to the below equation, the Safety coefficient "So" is obtained.
If the Safety coefficient "So" of a ball bearing is 2, 3 or more, and of a roller bearing is 3 or more, the bearing is safe to operate during shock loads applied by seismic events.

Equation:
So = Co/Po

where, So : Safety factor
Po : Static equivalent radial load [kgf]
Co : Basic static rated load [kgf]

Note : 1 Xo, Yo and Co are characteristic values of bearings.
Note : 2 As for equations (4) and (5), for the larger safety factor, the bearing manufacturer's design standards are used.

6.2 Seismic Evaluation of the Power Section Bearings (Gas Turbines Engine Assembly)

The Seismic evaluation is provided on the No. 1 and No. 2 Bearings, which are shown in the Power section of Fig. 6.2-1.
The result of Seismic evaluation is presented in Table 6.2-1.
With the GTG Set both stopped and in running, the safety factor obtained are 2, 3 or more.
As a result, the Power section is proved to be acceptable to continuously and successfully operate after the termination of the seismic event.

6.3 Seismic Evaluation of Reduction Gearbox Bearings

The Reduction gearbox, shown in Fig. 6.3-1, the Seismic Evaluation was performed on the bearings of the output shaft and the intermediate shaft.
The result of Seismic Evaluation is presented in Table 6.3-1.
While the Reduction gearbox is both stopped and in running, the safety factor obtained are 2, 3 or more.
As a result, the Reduction gearbox is proved to be acceptable to continuously, successfully operate after the termination of the seismic event.

Table 6.2-1 Seismic Evaluation of Bearings Used for The Power Section (Gas Turbine Assembly) (When a Shock Load 1g is Applied Horizontally, and a 1g is Applied Vertically)

Item	Details	Factor and Equations	No1 Running	No1 Stop	No2 Running	No2 Stop
Characteristics value of bearing	Basic static load rating[kgf]	Co	5650	5650	9100	9100
	Static radial load factor	Xo	0.50	0.50	1.00	1.00
	Static axial load factor	Yo	0.33	0.33	0.00	0.00
weight	Weight of shaft[kgf]	w	300			
Loading conditions	Radial load	Fr=a+b	240	240	360	360
	Load by shaft self-weight[kgf]	a=w*0.4or0.6	120		180	
	Acceleration (radial)	Gradial	1	1	1	1
	Seismic load (radial) [kgf]	b=a×Gradial	120	120	180	180
	Axial load	Fa=c+d	300	1100	0	0
	Acceleration (axial)	Gaxial	1	1	1	1
	Seismic load (axial) [kgf]	c=w×Gaxial	300	300	0	0
	Thrust load in running[kgf]	d	0	800	0	0
	Static equivalent load[kgf]	Po=XoFr+YoFa or Po=Fr (large select)	240	483	360	360
Result	Safety factor	So=Co/Po	23.5	11.7	25.3	25.3
Evaluation	When the safety factor is more than below, there is no problem [2:ball bearing] [3:roller bearing]		○	○	○	○

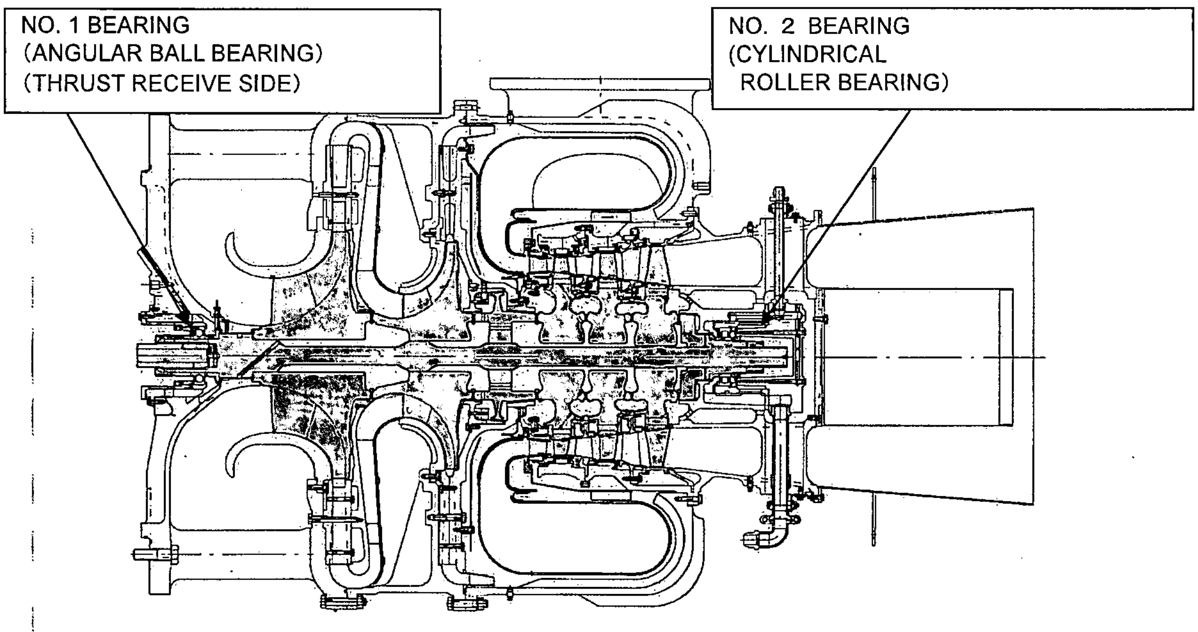


Figure 6.2-1 Sectional Drawing of Power Section (Colored Section Shows the Rotor)

Table 6.3-1 Seismic of Bearings Used for the Intermediate Shaft and the Output Shaft of the Reduction Gearbox

Inter mediate shaft

Item	Details	Factor and Equations	6324 Stop	6324 Running	NU324 Stop	NU324 Running
Charasteristic value of bearing	Basic static load rating[kgf]	Co	18800	18800	52000	52000
	Static radial load factor	Xo	0.6	0.6	1.0	1.0
	Static axial load factor	Yo	0.5	0.5	0.0	0.0
weight	Weight of shaft[kgf]	w	308.8			
Loading conditions	Radial load	Fr=a+b+c	205.9	1489.9	411.7	3185.7
	Load by shaft self-weight[kgf]	a	102.9		205.9	
	Acceleration (radial)	Gradial	1.0	1.0	1.0	1.0
	Seismic load (radial) [kgf]	b=a × Gradial	102.9	102.9	205.9	205.9
	Radial load in running[kgf]	c	0	1387	0	2774
	Axial load	Fa=d+e	308.8	4130.8	0.0	0.0
	Acceleration (axial)	Gaxial	1.0	1.0	1.0	1.0
	Seismic load (axial) [kgf]	d=w × Gradial	308.8	308.8	0	0
	Thrust load in running[kgf]	e	0	3822	0	0
	Static equivalent load[kgf]	Po=XoFr+YoFa or Po=Fr (large select)	277.9	2959.4	411.7	3185.7
Result	Safety factor	So=Co/Po	67.6	6.4	126.3	16.3
Evaluation	When the safety factor is more than below, there is no problem [2:ball bearing] [3:roller bearing]		○	○	○	○

Output shaft

Item	Details	Factor and Equations	6044 Stop	6044 Running	6228 Stop	6228 Running
Characteristic s value of bearing	Basic static load rating[kgf]	Co	29400	29400	15300	15300
	Static radial load factor	Xo	0.6	0.6	0.6	0.6
	Static axial load factor	Yo	0.5	0.5	0.5	0.5
weight	Weight of shaft[kgf]	w	608			
Loading conditions	Radial load	Fr=a+b+c	912.0	3716.0	304.0	508.0
	Load by shaft self-weight[kgf]	a	456.0		152.0	
	Acceleration (radial)	Gradial	1.0	1.0	1.0	1.0
	Seismic load (radial) [kgf]	b=a × Gradial	456.0	456.0	152.0	152.0
	Radial load in running[kgf]	c	0	2804	0	204
	Axial load	Fa=d+e	608.0	608.0	0.0	0.0
	Acceleration (axial)	Gaxial	1.0	1.0	1.0	1.0
	Seismic load (axial) [kgf]	d=w × Gradial	608.0	608.0	0	0
	Thrust load in running[kgf]	e	0	0	0	0
	Static equivalent load[kgf]	Po=XoFr+YoFa or Po=Fr (large select)	912.0	3716.0	304.0	508.0
Result	Safety factor	So=Co/Po	32.2	7.9	50.3	30.1
Evaluation	When the safety factor is more than below, there is no problem [2:ball bearing] [3:roller bearing]		○	○	○	○

Inter mediate shaft

			6324		NU324	
Item	Details	Factor and Equations	Stop	Running	Stop	Running
Charasteristic value of bearing	Basic static load rating[kgf]	Co	18800	18800	52000	52000
	Static radial load factor	Xo	0.6	0.6	1.0	1.0
	Static axial load factor	Yo	0.5	0.5	0.0	0.0
weight	Weight of shaft[kgf]	w	308.8			
Loading conditions	Radial load	Fr=a+b+c	205.9	1489.9	411.7	3185.7
	Load by shaft self-weight[kgf]	a	102.9		205.9	
	Acceleration (radial)	Gradial	1.0	1.0	1.0	1.0
	Seismic load (radial) [kgf]	b=a × Gradial	102.9	102.9	205.9	205.9
	Radial load in running[kgf]	c	0	1387	0	2774
	Axial load	Fa=d+e	308.8	4130.8	0.0	0.0
	Acceleration (axial)	Gaxial	1.0	1.0	1.0	1.0
	Seismic load (axial) [kgf]	d=w × Gradial	308.8	308.8	0	0
	Thrust load in running[kgf]	e	0	3822	0	0
	Static equivalent load[kgf]	Po=XoFr+YoFa or Po=Fr (large select)	277.9	2959.4	411.7	3185.7
Result	Safety factor	So=Co/Po	67.6	6.4	126.3	16.3
Evaluation	When the safety factor is more than below, there is no problem [2:ball bearing] [3:roller bearing]		○	○	○	○

Output shaft

			6044		6228	
Item	Details	Factor and Equations	Stop	Running	Stop	Running
Characteristics value of bearing	Basic static load rating[kgf]	Co	29400	29400	15300	15300
	Static radial load factor	Xo	0.6	0.6	0.6	0.6
	Static axial load factor	Yo	0.5	0.5	0.5	0.5
weight	Weight of shaft[kgf]	w	608			
Loading conditions	Radial load	Fr=a+b+c	912.0	3716.0	304.0	508.0
	Load by shaft self-weight[kgf]	a	456.0		152.0	
	Acceleration (radial)	Gradial	1.0	1.0	1.0	1.0
	Seismic load (radial) [kgf]	b=a × Gradial	456.0	456.0	152.0	152.0
	Radial load in running[kgf]	c	0	2804	0	204
	Axial load	Fa=d+e	608.0	608.0	0.0	0.0
	Acceleration (axial)	Gaxial	1.0	1.0	1.0	1.0
	Seismic load (axial) [kgf]	d=w × Gradial	608.0	608.0	0	0
	Thrust load in running[kgf]	e	0	0	0	0
	Static equivalent load[kgf]	Po=XoFr+YoFa or Po=Fr (large select)	912.0	3716.0	304.0	508.0
Result	Safety factor	So=Co/Po	32.2	7.9	50.3	30.1
Evaluation	When the safety factor is more than below, there is no problem [2:ball bearing] [3:roller bearing]		○	○	○	○

Figure 6.3-1 Sectional Drawing of Gear Box (Colored Section Shows the Rotor)

7.0 RELIABILITY ANALYSIS

7.1 General

More than 6000 units of GPS Gas Turbine series have been supplied in worldwide facilities. The GPS Gas Turbine series had been developed aiming at Emergency or Backup generator usage. They are designed so that not only performance for power operation may be ensured but also reliability required of emergency start be achieved. As a result, those Gas turbine series have been provided with capability to start within 40 seconds as standard specification and also with highly reliability for emergency standby usage based on the experiences even on commercial grade basis.

7.2 Reliability Derived from Industrial Field Data

GPS GTG Packages have industrial based field data available for estimating the starting reliability which has been collected from the required starting events confirmed, as shown in table 7.2-1.

Table 7.2-1 Field Data of GTG Starting Reliability

Number of Units (Generator Package Unit)	Start Attempts (Note)	Failed Starts
375	7394	2

Note : This includes testing and actual demand on Loss of Offsite Power (LOOP)

Result of this field data, starting reliability is estimated as below;

$$(1 - 2/7394)\times 100 = 99.97\%$$
$$3.0\times 10^{-4} \text{ per demand}$$

Two failed start events were caused respectively by a low voltage of starter batteries due to degradation of the battery and moisture interfusion in the liquid fuel system.

Although the field data regarding GTG are not sufficient the probability of failed start of the GPS GTG estimated above is lower in single figure than that of DGs (3.5 × 10^{-3} per demand) that is reported in NUREG/CR-6928 "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power plant, February 2007". For US-APWR application the Class 1E GTG is designed so as to use air starting system and also the control power for the GTG operation is designed to be supplied from the Class 1E station batteries so that the reliability of the GTG starting system may be improved. Therefore the Class1E-qualified GTG is expected to be provided with higher reliability than that of the existing DGs.

7.3 Analysis

Table 7.3-1 shows failure rate analysis for the GTG on the basis of its composites, where the GTG set was divided into subsystems and components for developing Failure Modes and Effects Analysis (FMEA). The portions attributed to electrical power systems such as station batteries for control power source, generator circuit breaker and its protective relays were excluded in the analysis because they are identical to those of DG. The failure rate available for the components relating to function of the GTG start are collected from IEEE Std 500-1984 "IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations". However for the components in the turbine power section itself such as compressor, combustor and speed reduction gear, no statistical failure rate data for emergency start are available as of now. Therefore for the purpose of addressing the failure rates conservatively to those components herein typical assumption was made based on insights of their failure mechanisms and engineering judgments that consider the characteristics similar to passive components.

Result of this, the probability of the failed start of GTG is estimated at approximately 1.51×10^{-3} per demand.
The failure rate of the GTG start resulting from the analysis is higher than the aforementioned actual field data. It is considered in common that analytical results provide conservative or adverse levels compared to those collected from actual operating events. Furthermore it should be noted that the analytical results of GTG failure rate that are considered conservative is nearly equal to or lower than the probability of the DG failed start (3.5×10^{-3} per demand) that are collected from actual operating experiences on nuclear plants.
Accordingly it is reasonable to expect that the reliability of the GTG is higher than that of the existing DGs.

7.4 Contributing Factor for Reliability

Major contributing factor for the difference of reliability between Gas Turbine and Diesel Engine is the quantity of their composite parts. Gas Turbine is a simple rotational engine with rotor, stator and driving shaft, while DG has multiple cylinder blocks each of which needs to convert its reciprocating piston movement to rotary driving shaft through piston rod, crank mechanism and pertinent bearings. This inevitably leads to increase in quantity of composite parts of the DG compared to GTG. In addition to the difference of the engine itself it is the contributing factor of the quantity of composite parts that no water cooling system is required of gas turbine system while vice versa for diesel engine.

Table 7.4-1 shows the comparison of the composite parts between GTG and DG.

Table 7.4-1 Comparison of Quantity of Parts between GTG and DG

	GTG	DG
1. Engine Generator	273 sorts of parts (for the type applied to US-APWR)	More than 3 times of GTG
2. Starting System	Almost same as DG	base
3. Fuel System	Almost same as DG	base
4. Lubricant Oil System	Slightly less than DG	base
5. Air Intake and Exhaust System	Almost same as DG	Base (Room Ventilation system included)
6. Cooling Water System	None	Required

The reliability contributor other than the quantity of parts would be operating condition and related parameters. From viewpoint of operating condition higher operating temperature of the GTG could be the only adverse aspect that could impact especially on the exhausting system. However this problem has to be resolved by design which reflects a lot of past operating experiences. Furthermore improved reliability can be achieved through implementing the class 1E qualification program scheduled in the near future.

Thus the GTG system can be expected more reliable as standby power supply than the DG System.

7.5 Quoted Reliability Data from Other Reference Documents

Some industrial basis data that addressed the reliability comparison of GTG and DGs are found in IEEE report as follows;

(1) IEEE Std 500-1984 "IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations".
  - (a) Failure Rate of Diesel Engine (4 stroke V Block; Page827): 4.67×10^{-3} per hour
  - (b) Failure Rate of Combustion Turbine (Over 5000Hp; Page841): 2.00×10^{-4} per hour

(2) IEEE Std 493-1997 "Reliability Survey of 600 to 1800kW Diesel and Gas turbine Generating Units"
  - (a) Mean Time Between Failure (MTBF) of GTG for Standby Usage: 27,874.6 hrs
  - (b) MTBF of DG with Auxiliary Support Systems for Standby Usage: 6,857.4 hrs
  - (c) Failure Rate of DG (4 stroke V Block; Page827): 4.67×10^{-3} per hour

The above industrial basis data also show advantage in reliability of GTG.

7.6 Conclusion

As described above the reliability of GTG is expected to be higher than or at least equal to that of the DG.

8.0 QUALIFICATION SCHEDULE

MHI plans to start the Class 1E qualification of GTG on January 2008, and will complete it by December 2009. Gas Turbine Assembly (engine and gear box) is fabricated in Japan, and the other components are procured in the U.S. The detailed schedule of detail is shown in Appendix F. After assembly, GTG will be tested in accordance with Appendix C to dedicate the unit as Class 1E. Basic schedule of Class 1E qualification is shown in Fig. 8.0-1.

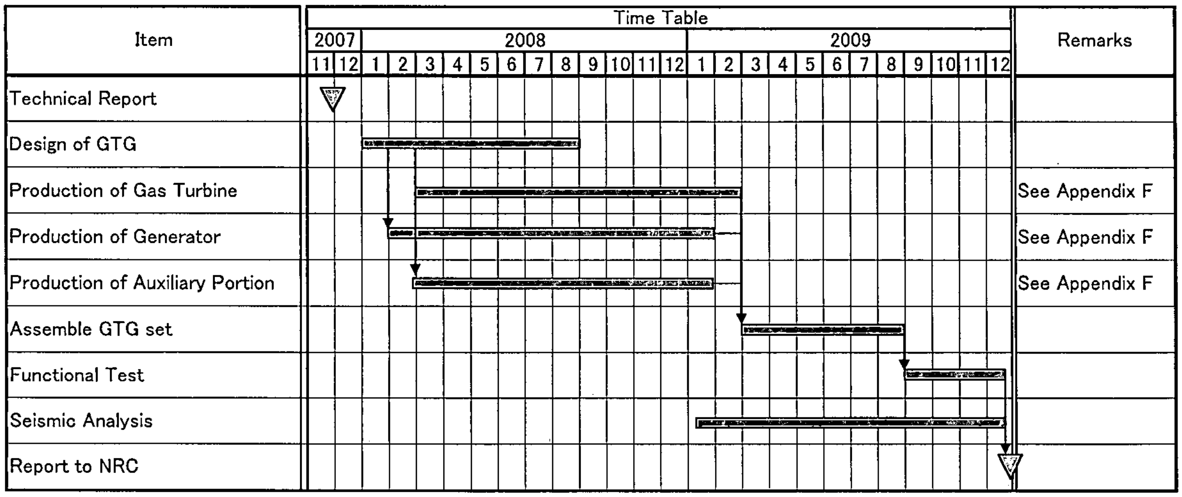


Figure 8.0-1 Qualification Schedule

9.0 CONCLUSIONS

Based on the analysis provided herein this Technical Report it is concluded that the GTG unit provided by KHI and Class 1E qualified by Engine System Inc. (ESI) is adequate to support the safe and reliable operation on the US-APWR.

10.0 REFERENCES

In this section, references in this technical report except for applicable codes, standards and regulatory guidance in section 2 are listed.

1. ISO 2314
2. MIL-PRF-23699
3. Underwriter's Laboratories Specification UL-142, Steel Aboveground Tanks for Flammable and Combustible Liquids
4. MIL-STD-705
5. AWS D1.1.
6. ASME Section IX
7. The requirements of MNES, Quality Assurance Administrative and System Requirements (Nuclear)
8. The requirements of MNES, Quality Assurance Administrative and System Requirements for Safety Related Electrical Equipment
9. MUAP-07004, Safety I&C System Description and Design Process
10. MUAP-07005, Safety System Digital Platform –MELTAC-

Appendix A US-APWR Typical Load Profiles

Typical load profiles of Loss of Coolant Accident (LOCA) and LOOP are shown in Table A.1.0-1 to A.1.0-10 and Fig. A.1.0-1 to A.1.0-8

Table A.1.0-1 Class 1E GTG - LOCA Load List

Load Group	Load Name	Rated Output (kW)	Load Factor (%)	Efficiency (%)	Power Factor (%)	Ratio of Starting Current to Normal Current (%)	Power Factor at Starting (%)	Load Starting Capacity (kW)	Load Necessary Input (kW)
1	Moter Control Center	861.0	—	—	—	—	30.0	258.3	77.0
		371.0	—	—	—	—	—	—	371.0
2	MOV Operated by SI Signal MOV Operated by SP Signal	109.1	—	90.0	85.0	6.5	30.0	278.1	—
3	Safety Injection Pump	900.0	95.0	90.0	85.0	6.5	25.0	1911.8	950.0
4	Componet Cooling Water Pump	610.0	95.0	90.0	85.0	6.5	25.0	1295.8	643.9
5	Service Water Pump	720.0	95.0	90.0	85.0	6.5	25.0	1529.4	760.0
6	Containment Spray/Residual Heat Removal Pump	400.0	95.0	90.0	85.0	6.5	25.0	849.7	422.2
7	Emergency Feed Water Pump	590.0	72.5	90.0	85.0	6.5	25.0	1253.3	475.0
8	Class 1E Electrical Room Air Handling Supply Fan	80.0	95.0	85.0	80.0	6.5	25.0	191.2	89.4
9	Safety Chiller Unit	290.0	95.0	85.0	80.0	6.5	25.0	693.0	324.1
10	Safety Chilled Water Pump	53.0	95.0	94.0	91.0	6.5	25.0	100.7	53.6

Table A.1.0-2 Class 1E GTG -LOOP Load List

Load Group	Load Name	Rated Output (kW)	Load Factor (%)	Efficiency (%)	Power Factor (%)	Ratio of Starting Current to Normal Current (%)	Power Factor at Starting (%)	Load Starting Capacity (kW)	Load Necessary Input (kW)
1	Moter Control Center	687.0	—	—	—	—	30.0	206.1	55.0
		326.0	—	—	—	—	—	—	326.0
2	Componet Cooling Water Pump	610.0	95.0	90.0	85.0	6.5	25.0	1295.8	643.9
3	Service Water Pump	720.0	95.0	90.0	85.0	6.5	25.0	1529.4	760.0
4	Containment Spray/Residual Heat Removal Pump	400.0	95.0	90.0	85.0	6.5	25.0	849.7	422.2
5	Charging Pump	820.0	95.0	90.0	85.0	6.5	25.0	1741.8	865.6
6	Emergency Feed Water Pump	450.0	95.0	90.0	85.0	6.5	25.0	955.9	475.0
7	Class 1E Electrical Room Air Handling Supply Fan	80.0	95.0	85.0	80.0	6.5	25.0	191.2	89.4
8	Safety Chiller Unit	290.0	95.0	85.0	80.0	6.5	25.0	693.0	324.1
9	Plessurizer Heater	562.0	100.0	100.0	100.0	—	—	562.0	562.0
10	Safety Chilled Water Pump	53.0	95.0	94.0	91.0	6.5	25.0	100.7	53.6

Table A.1.0-3 Class 1E GTG Starting Sequence Train A - LOCA

LOCA Signal Initiated Time [Sec]	LOCA Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	MOV Operated by SI Signal MOV Operated by SP Signal	2	0	907	907	448
		Moter Control Center	1				
105	5	A Safety Injection Pump	3	448	1912	2360	1398
110	10	A Component Cooling Water Pump	4	1398	1296	2694	2042
		A Safety Chilled Water Pump	10				
115	15	A Service Water Pump	5	2042	1529	3571	2802
130	30	A Containment Spray/Residual Heat Removal Pump	6	2802	850	3652	3224
140	40	A Class 1E Electrical Room Supply Air Handling Unit	8	3224	191	3415	3313
150	50	A Safety Chiller Unit	9	3313	693	4006	3637
	Manual Start	Moter Control Center		3637	102	3739	3739

Table A.1.0-4 Class 1E GTG Starting Sequence Train A - LOOP

LOOP Signal Initiated Time [Sec]	LOOP Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	Moter Control Center	1	0	532	532	381
105	5	A Charging Pump	5	381	1742	2123	1247
110	10	A Component Cooling Water Pump	2	1247	1296	2543	1891
115	15	A Service Water Pump	3	1891	1630	3521	2705
		A Safety Chilled Water Pump	10				
130	30	A Class 1E Electrical Room Supply Air Handling Unit	7	2705	191	2896	2794
140	40	A Safety Chiller Unit	8	2794	693	3487	3118
	Manual Start	Moter Control Center	1	3118	627	3745	3745
		A Plessurizer Heater	9				

Table A.1.0-5 Class 1E GTG Starting Sequence Train B - LOCA

LOCA Signal Initiated Time [Sec]	LOCA Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	MOV Operated by SI Signal	2	0	907	907	448
		MOV Operated by SP Signal					
		Moter Control Center	1				
105	5	B Safety Injection Pump	3	448	1912	2360	1398
110	10	B Component Cooling Water Pump	4	1398	1296	2694	2042
		B Safety Chilled Water Pump	10				
115	15	B Service Water Pump	5	2042	1529	3571	2802
120	20	B Emergency Feed Water Pump	7	2802	1253	4055	3277
130	30	B Containment Spray/Residual Heat Removal Pump	6	3277	850	4127	3699
140	40	B Class 1E Electrical Room Supply Air Handling Unit	8	3699	191	3890	3788
150	50	B Safety Chiller Unit	9	3788	693	4481	4112
	Manual Start	Moter Control Center		4112	102	4214	4214

Table A.1.0-6 Class 1E GTG Starting Sequence Train B - LOOP

LOOP Signal Initiated Time [Sec]	LOOP Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	Moter Control Center	1	0	532	532	381
110	10	B Component Cooling Water Pump	2	381	1296	1677	1025
115	15	B Service Water Pump	3	1025	1630	2655	1839
		B Safety Chilled Water Pump	10				
120	20	B Emergency Feed Water Pump	6	1839	956	2795	2314
130	30	B Class 1E Electrical Room Supply Air Handling Unit	7	2314	191	2505	2403
140	40	B Safety Chiller Unit	8	2403	693	3096	2727
	Manual Start	Moter Control Center	1	2727	627	3354	3354
		B Plessurizer Heater	9				

Table A.1.0-7 Class 1E GTG Starting Sequence Train C - LOCA

LOCA Signal Initiated Time [Sec]	LOCA Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	MOV Operated by SI Signal	2	0	907	907	448
		MOV Operated by SP Signal					
		Moter Control Center	1				
105	5	C Safety Injection Pump	3	448	1912	2360	1398
110	10	C Component Cooling Water Pump	4	1398	1296	2694	2042
		C Safety Chilled Water Pump	10				
115	15	C Service Water Pump	5	2042	1529	3571	2802
120	20	C Emergency Feed Water Pump	7	2802	1253	4055	3277
130	30	C Containment Spray/Residual Heat Removal Pump	6	3277	850	4127	3699
140	40	C Class 1E Electrical Room Supply Air Handling Unit	8	3699	191	3890	3788
150	50	C Safety Chiller Unit	9	3788	693	4481	4112
	Manual Start	Moter Control Center		4112	102	4214	4214

Table A.1.0-8 Class 1E GTG Starting Sequence Train C - LOOP

LOOP Signal Initiated Time [Sec]	LOOP Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	Moter Control Center	1	0	532	532	381
110	10	C Component Cooling Water Pump	2	381	1296	1677	1025
115	15	C Service Water Pump	3	1025	1630	2655	1839
		C Safety Chilled Water Pump	10				
120	20	C Emergency Feed Water Pump	6	1839	956	2795	2314
130	30	C Class 1E Electrical Room Supply Air Handling Unit	7	2314	191	2505	2403
140	40	C Safety Chiller Unit	8	2403	693	3096	2727
	Manual Start	Moter Control Center	1	2727	627	3354	3354
		C Plessurizer Heater	9				

Table A.1.0-9 Class 1E GTG Starting Sequence Train D - LOCA

LOCA Signal Initiated Time [Sec]	LOCA Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	MOV Operated by SI Signal	2	0	907	907	448
		MOV Operated by SP Signal					
		Moter Control Center	1				
105	5	D Safety Injection Pump	3	448	1912	2360	1398
110	10	D Component Cooling Water Pump	4	1398	1296	2694	2042
		D Safety Chilled Water Pump	10				
115	15	D Service Water Pump	5	2042	1529	3571	2802
130	30	D Containment Spray/Residual Heat Removal Pump	6	2802	850	3652	3224
140	40	D Class 1E Electrical Room Supply Air Handling Unit	8	3224	191	3415	3313
150	50	D Safety Chiller Unit	9	3313	693	4006	3637
	Manual Start	Moter Control Center		3637	102	3739	3739

Table A.1.0-10 Class 1E GTG Starting Sequence Train D - LOOP

LOOP Signal Initiated Time [Sec]	LOOP Sequence Time [Sec]	Invest Load	Refer Load Group	Base Load1 [KW]	Start Load [KW]	Max Load [KW]	Base Load2 [KW]
100	0	Moter Control Center	1	0	532	532	381
105	5	D Charging Pump	5	381	1742	2123	1247
110	10	D Component Cooling Water Pump	2	1247	1296	2543	1891
115	15	D Service Water Pump	3	1891	1630	3521	2705
		D Safety Chilled Water Pump	10				
130	30	D Class 1E Electrical Room Supply Air Handling Unit	7	2705	191	2896	2794
140	40	D Safety Chiller Unit	8	2794	693	3487	3118
	Manual Start	Moter Control Center	1	3118	627	3745	3745
		D Plessurizer Heater	9				

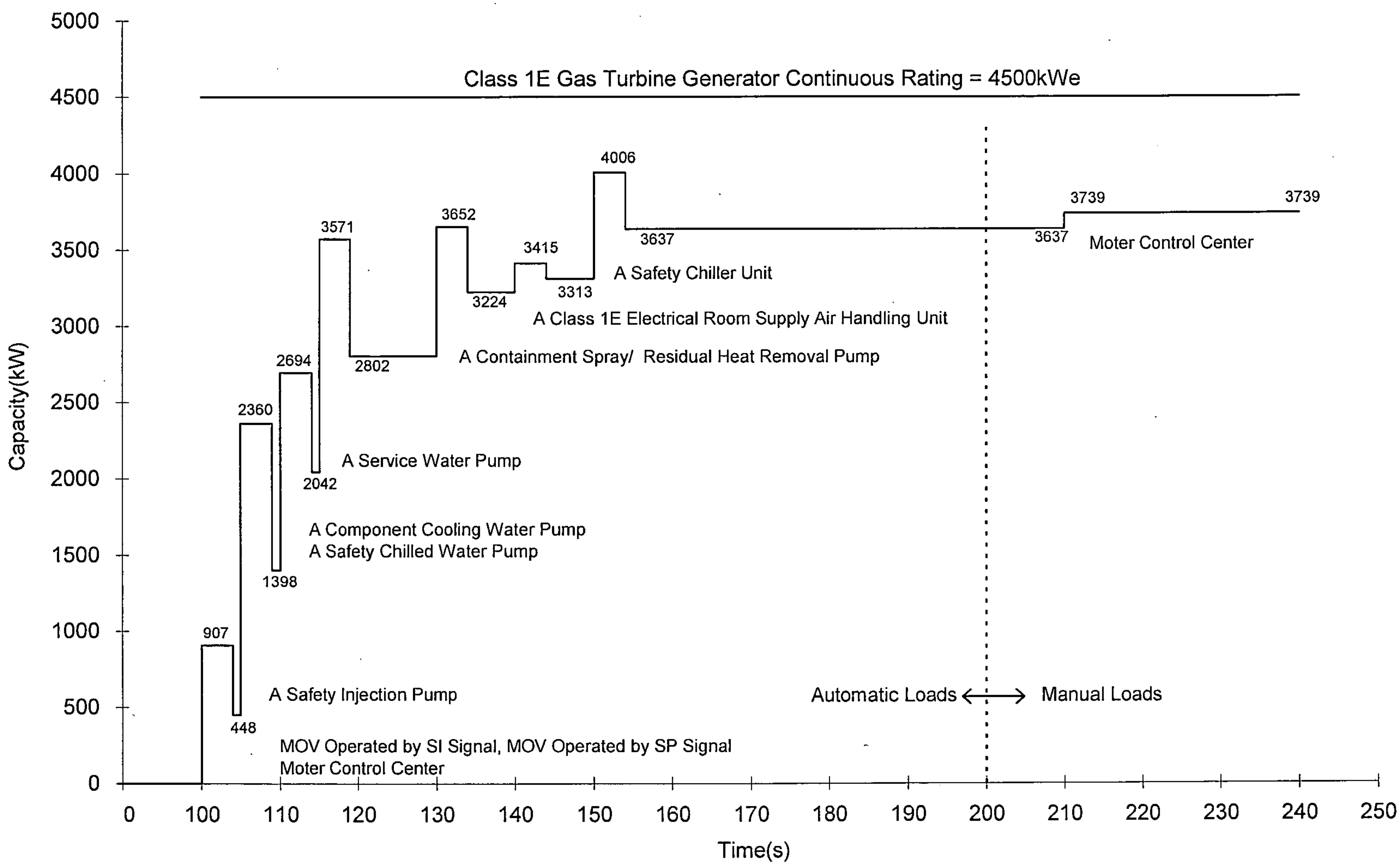


Figure A.1.0-1 LOCA Condition Class 1E GTG Load Profile (Train A)

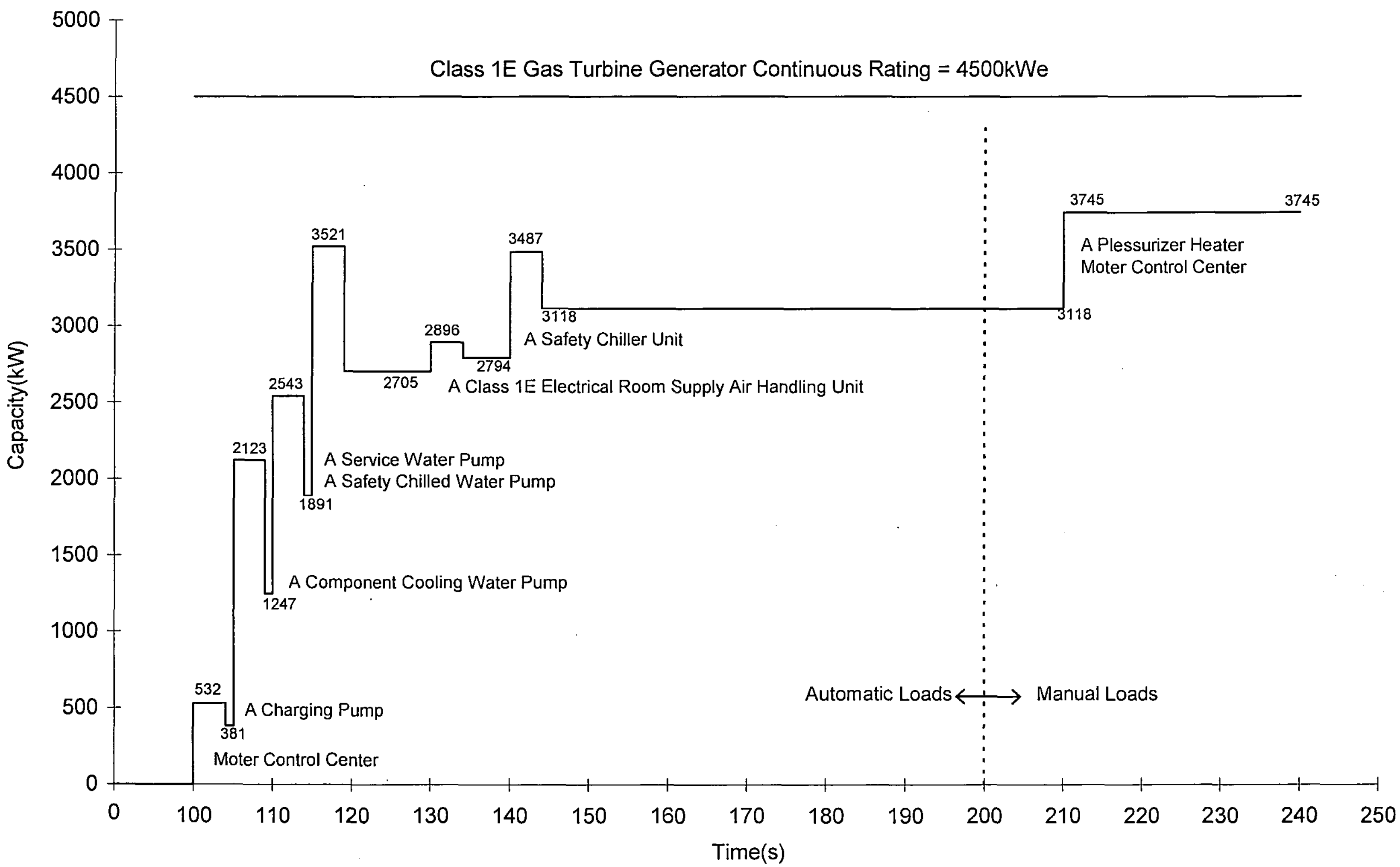


Figure A.1.0-2 LOOP Condition Class 1E GTG Load Profile (Train A)

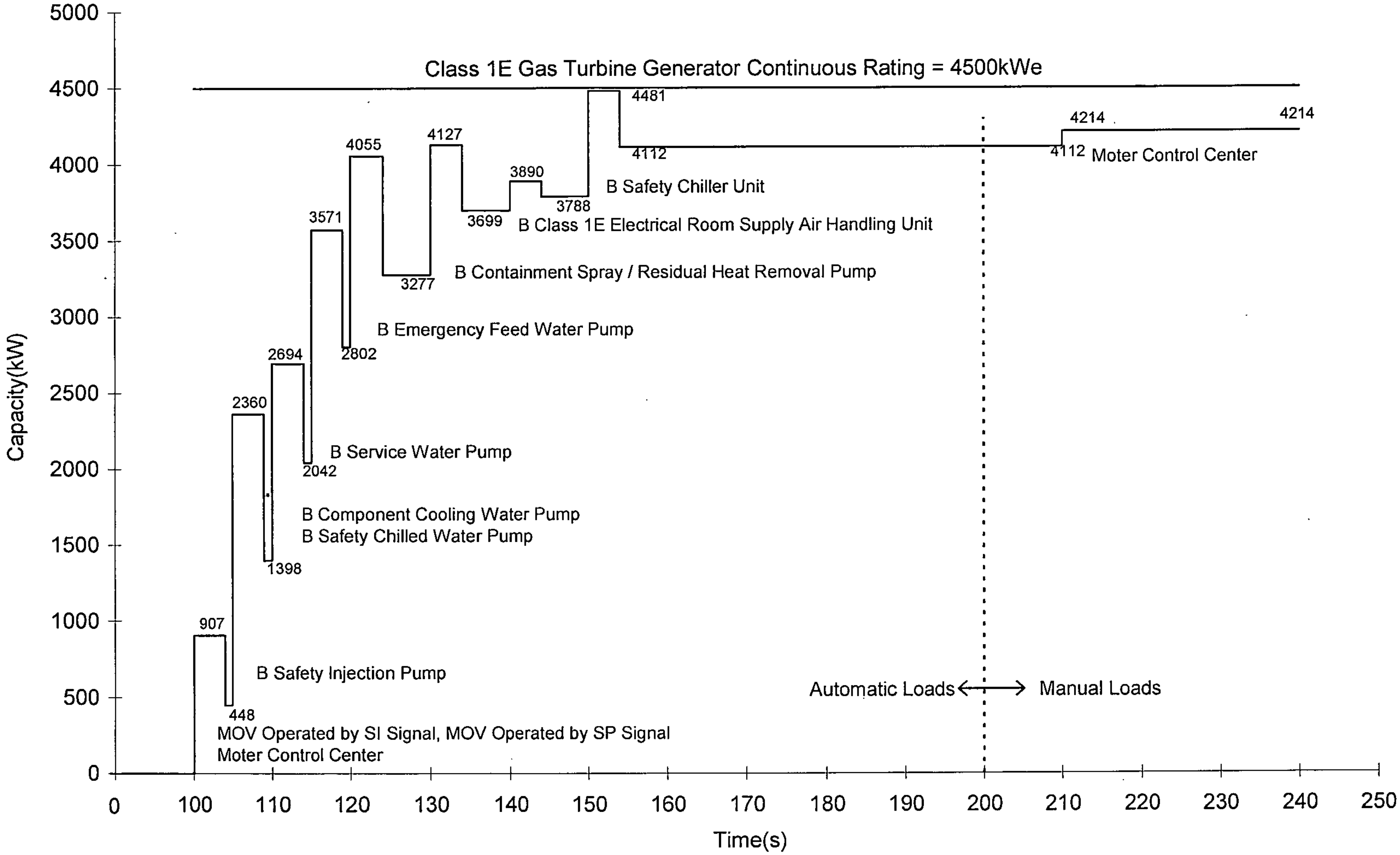


Figure A.1.0-3 LOCA Condition Class 1E GTG Load Profile (Train B)

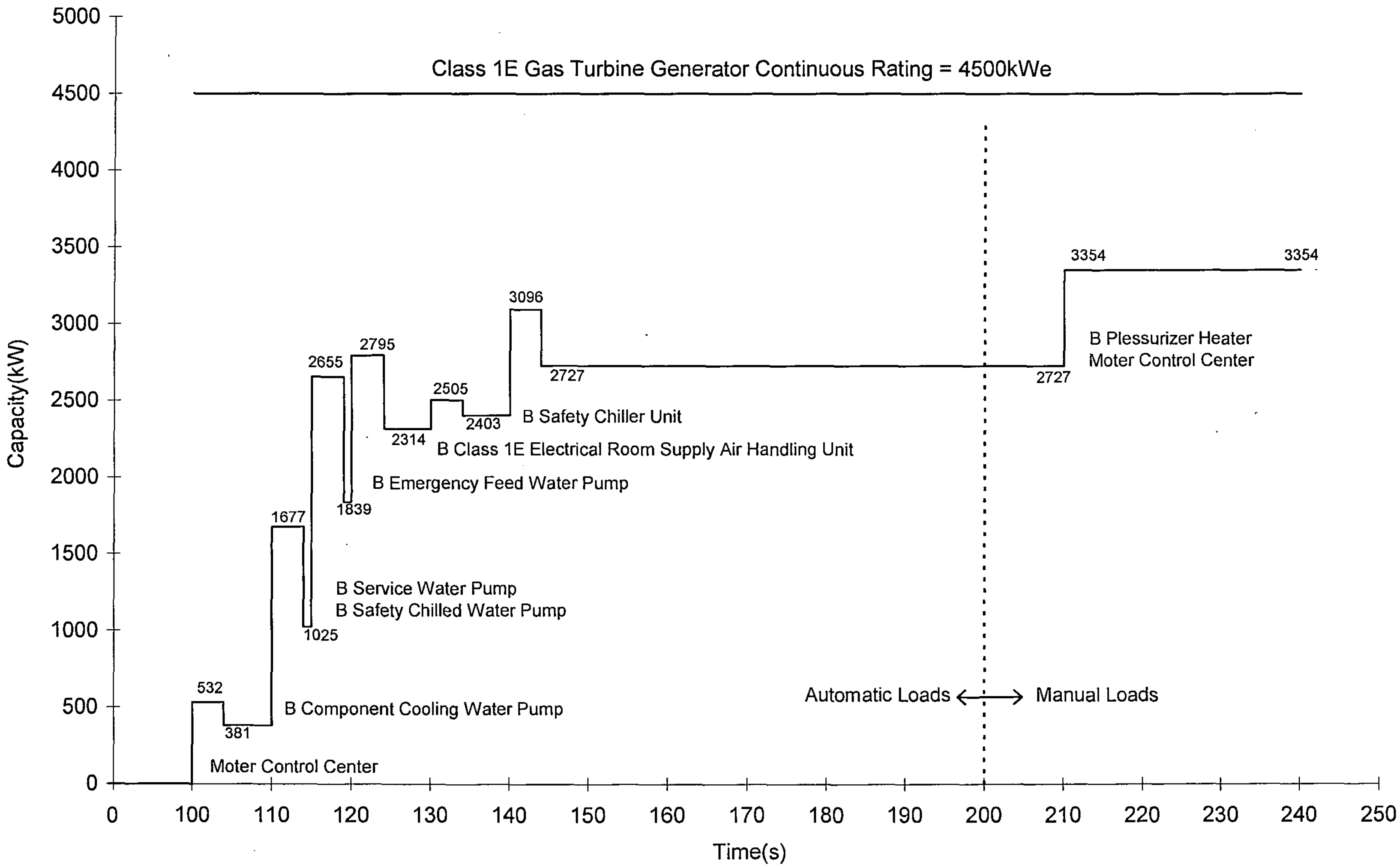


Figure A.1.0-4 LOOP Condition Class 1E GTG Load Profile (Train B)

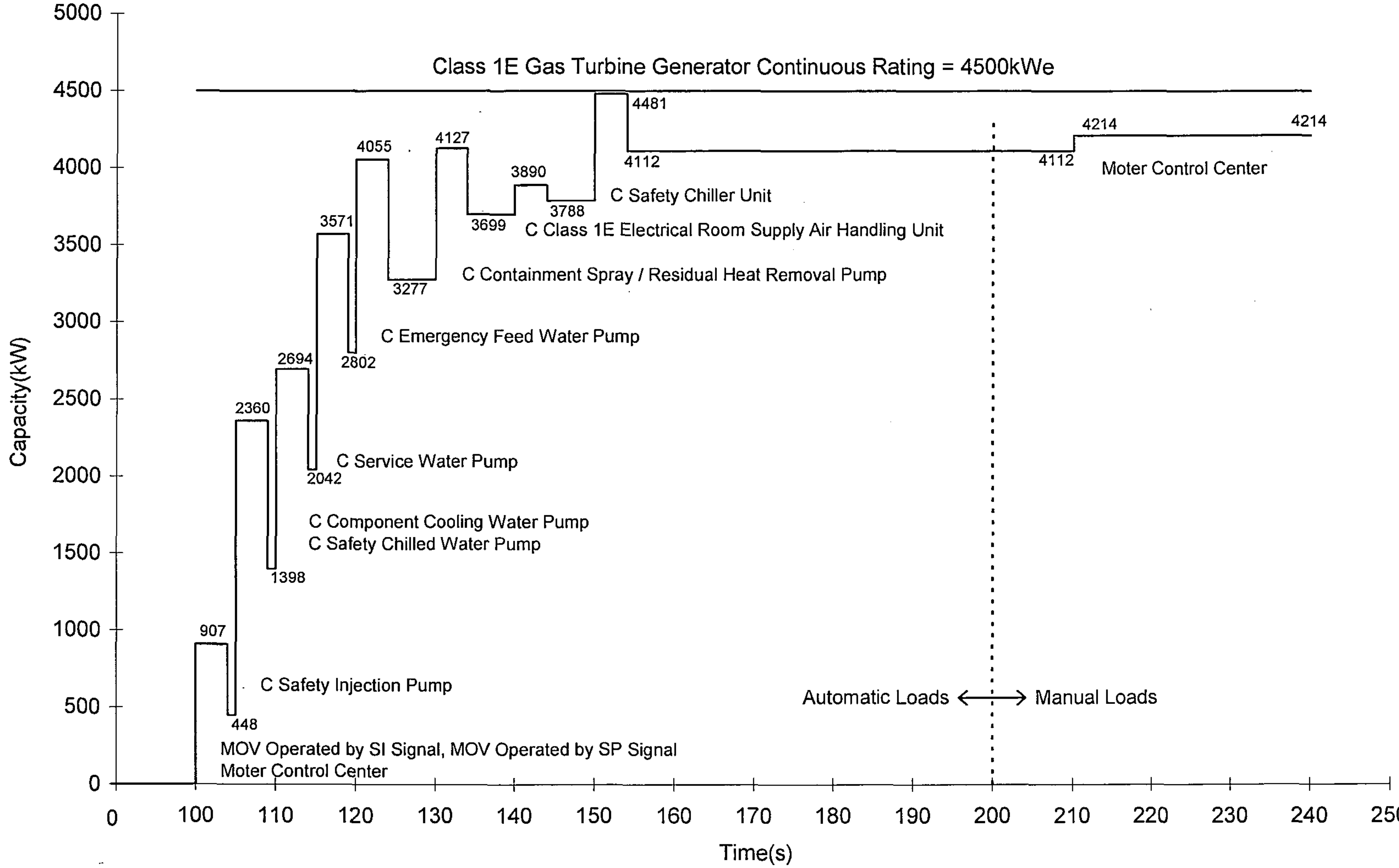


Figure A.1.0-5 LOCA Condition Class 1E GTG Load Profile (Train C)

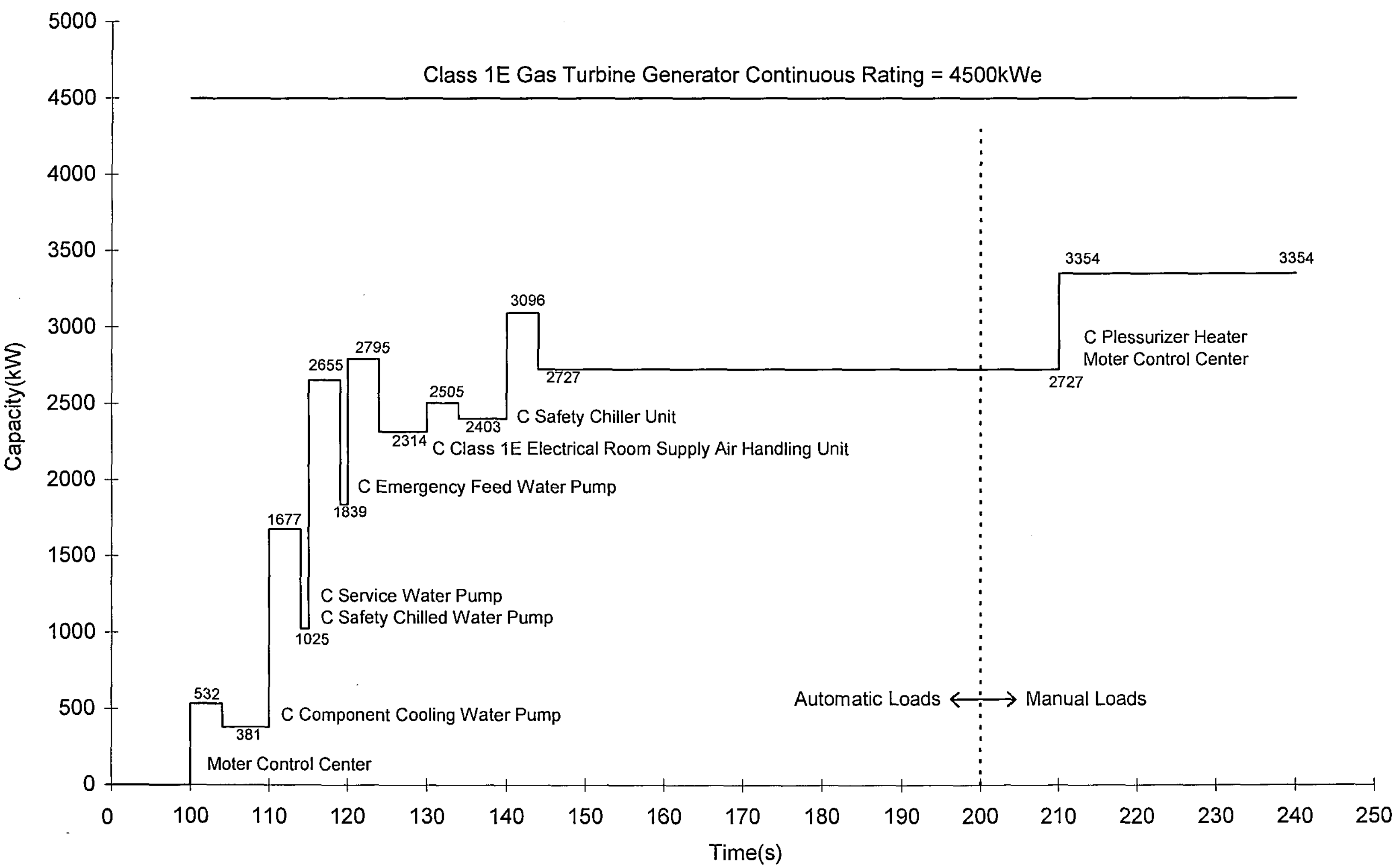


Figure A.1.0-6 LOOP Condition Class 1E GTG Load Profile (Train C)

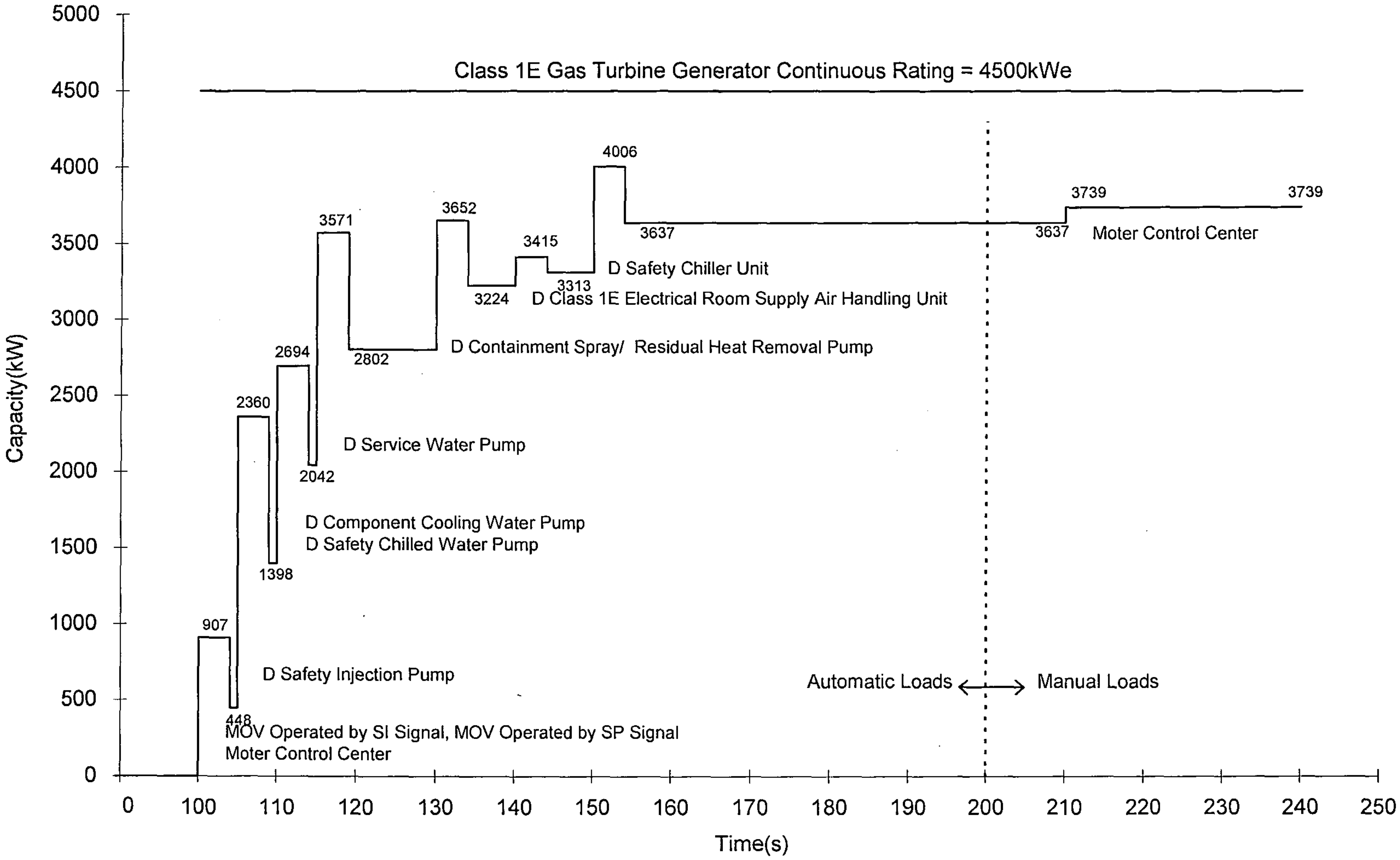


Figure A.1.0-7 LOCA Condition Class 1E GTG Load Profile (Train D)

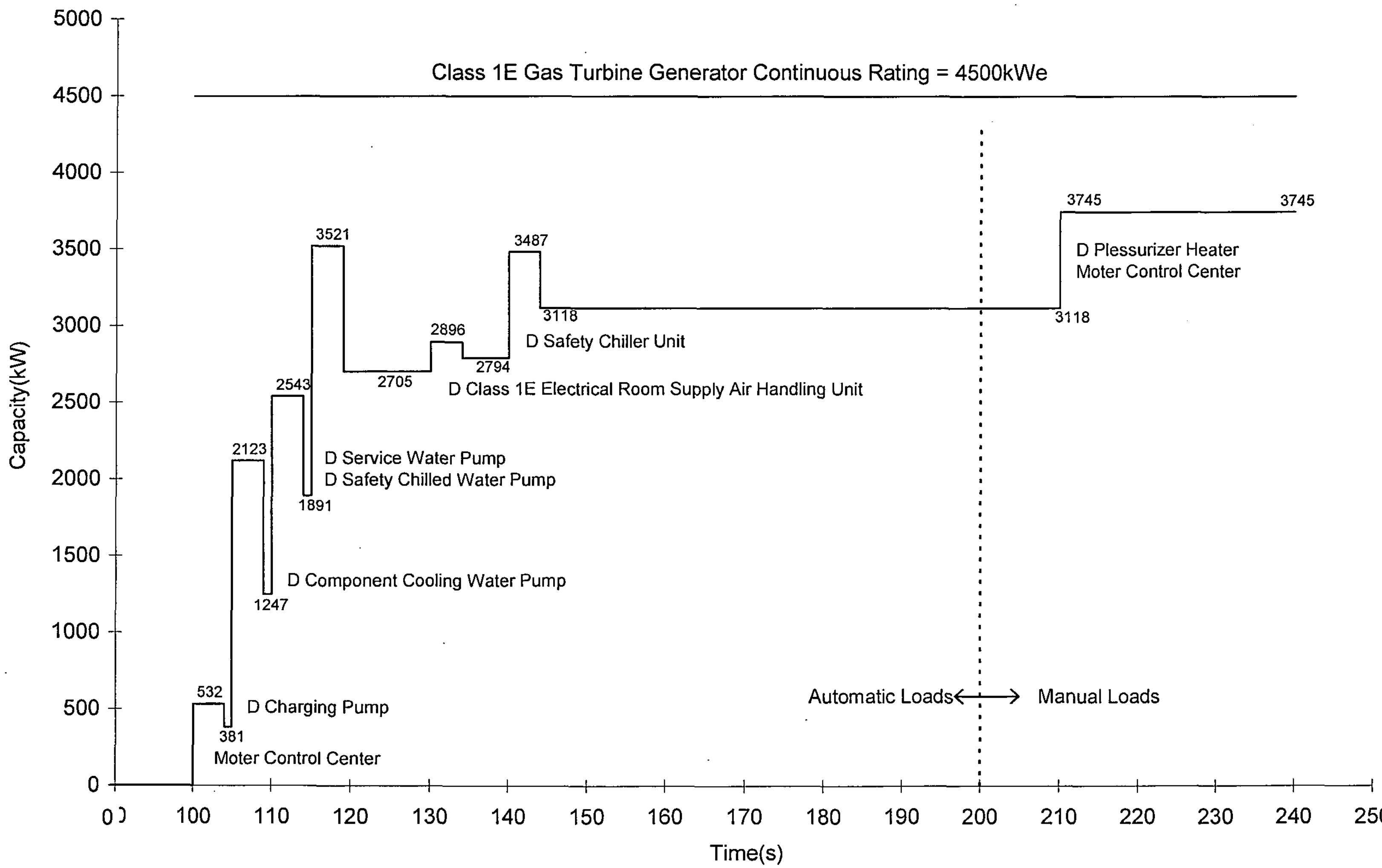


Figure A.1.0-8 LOOP Condition Class 1E GTG Load Profile (Train D)

Appendix B Gas Turbine Generator Technical Specification

B.1.0 Introduction

This Specification clearly specifies the performance, structure, etc. of GPS6000 GAS TURBINE, as well as describes data necessary for the driving units which are mainly available for generator system.

B.2.0 Engine Arrangement and Specification

B.2.1 Basic Arrangement

The engine of GPS6000 is a twin version of engine and two power sections are coupled to the reduction gearbox.
The following items are included in the engine:

(1) Engine Assembly

(a) Power Section:
This is so-called a gas turbine component which consists of the following parts:
- Simple & open cycle single-shaft-type gas turbine
- Two-stage centrifugal compressor
- Single can type combustor
- Three-stage axial turbine
- Double-end-support bearings, etc.

The cross-sectional view of the power section is shown in Fig. B.2.1-1

(b) Reduction Gearbox:
The reduction gearbox assembly provides support for the two power sections. It contains the reduction gearing with epicyclic gear and parallel gear train that enables the power section to drive accessories and output shaft at appropriate speed. The gear train of reduction gear box is shown in Fig. B.2.1-2.
Two types of output shaft speed are available. One is 1,800 rpm (reduction gear ratio: 9.969, for 60 Hz generator) and the other is 1,500 rpm (reduction gear ratio: 11.991, for 50 Hz generator).

(c) Fuel, Oil and Air (FOA) system:
The fuel, oil, and air system consists of the following components:
- Main fuel pump
-Electric starting fuel pump
- Starting fuel pump
- Fuel control valves
- Main lubricating oil pump
- Relief valve
- Pressure rising valve
- Air starter (in case of pneumatic starting system)
- Other small parts

The details of the main components are shown in Table B.2.1-1.

(d) Engine Electric System:

The engine electric system consists of the following components:
- Ignition system
- EGT harness
- Speed sensor
- Electric starter motor (in case of electric starting system)
- Turning motor
- Oil Temperature Sensor
- Oil Pressure Switch
- Other small parts

The main items of components are shown in Table B.2.1-2.

(e) Inlet collector:
This part composes a square-type air intake. The ignition exciter is mounted on its side panel.

B.2.2 Dimensions and Weight

(1) Dimensions (Details are referred to Fig. B.2.2-1):

- Overall length	: 2,877 mm
- Overall width	: 2,686 mm
- Overall height	: 2,275 mm

(2) Weight:

- Engine assembly (in case of electric starting system)
: 13,500 kg

- Power section	: 2,540 kg ×2
(- Rotor assembly	: 300 kg ×2)
- Main reduction gearbox	: 8,500 kg

(3) Rotational Speed and Direction:

(b) Rotational Speed:

- Rotor	: 17,944 rpm (60 Hz version)
	: 17,987 rpm (50 Hz version)
- Output shaft	: 1,800 rpm (60 Hz version)
	: 1,500 rpm (50 Hz version)

(c) Rotational Direction of Output Shaft:
Counter-clockwise, facing to the output shaft

(4) Rotational Inertia Moment: (GD^2 converted to the output shaft speed)
: 3,580 kgm^2 (60 Hz version)
: 5,120 kgm^2 (50 Hz version)

B.3.0 Performance

B.3.1 Major Performance

- Rated output	: 5,300 kW
- Fuel consumption	: 21,130 kW
- EGT	: 585°C

- Intake air flow : 25.4 kg/s
- Exhaust gas flow : 93.5 ton/hr
- Compressor discharge Pressure: 1.04×10^6 Pa, abs

Standard Operating Condition:
- Ambient pressure : 1.0133×10^5Pa
- Intake air temperature : 40 °C
- Humidity : 60 %
- Intake pressure loss : 0 Pa
- Exhaust pressure loss : 2×10^3 Pa
  (The exhaust pressure loss means the total pressure loss at the outlet flange of the exhaust duct of the power section with a tail cone of the outlet diameter 662 mm.)
- Fuel : Liquid fuel
- Bearing, power section : No.1 ball bearing & No.2 roller bearing

If the intake air temperature and output are varied, the applicable fuel flow rate, EGT, air flow rate and compressor discharge pressure are also varied as shown in Fig. B.3.1-1 and B.3.1-2. Performances at different operating conditions can be calculated according to Section B.3.2 (Performance Compensation Method).
Standard NOx value is shown in Fig. B.3.1-3. This value cannot be guaranteed, only for reference.

B.3.2 Performance Compensation Method

(1) Intake/exhaust Pressure Loss (See Fig. B.3.2-1)
The pressure loss corrections due to the pressure losses for the output power, fuel flow and EGT are shown in Fig. B.3.2-1. The intake air flow Ga [kg/s] is calculated from following equation:

$$Ga = Gao \times (1 - \Delta P / P)$$

where Gao = Intake air flow without intake pressure loss [kg/s]
ΔP = Intake pressure loss [Pa]
P = Ambient pressure [Pa]

(2) Ambient Pressure:
The ratio of the ambient pressure to the standard ambient pressure shall be specified as the elevation correction factor [δ] which is related to the altitude from the sea level. The variation of δ to the altitude shall be referred to Fig. B.3.2-2.
The output power, fuel flow and air flow, shall be corrected as follows:
Corrected value = Nominal value (output, fuel flow, air flow) × δ

(3) Intake air temperature:
Referring to Fig. B.3.1-1 and B.3.1-2, the applicable variation shall be read out.

B.3.3 Allowable Ambient Air Conditions

(1) Temperature : -20 to 50 °C

(2) Pressure : 795 to 1037.5 hPa (Equivalent altitude : 2000 to -200 m)

(3) Foreign matters in the intake air:

Grain size : less than 10μm (0.4μinch)
Salt concentration : 0.02ppm max

B.4.0 Specification of Components and Systems

B.4.1 Fuel System

Fuel system schematic is shown in Fig. B.4.1-1.

(1) Applicable fuel : Liquid fuel

(2) Fuel supply pressure : 0.01 to 0.03 MPa [gage]
(at the inlet port of the main fuel pump)

(3) Fuel nozzle cooling system
To prevent the fuel coaking. After engine stop, fuel nozzle must be cooled by air.
Air supply pressure : 0.49 to 0.69 MPa (Main)
0.84 kPa (Primary)
Air flow rate : Min. 4.25 Nm3/hr for Gas Turbine Assembly E/G
Purge operating time : see Fig. B.4.1-2

B.4.2 Main Lubricating Oil System

Main Lubricating oil system schematic is shown in Fig. B.4.2-1.

(1) Applicable oil : Synthetic base oil, MIL-PRF-23699 or equivalent oil

Recommended brands : Aero Shell ASTO 500
MOBIL JET-II
CASTROL AERO 5000
BP BPTO 2380
DAPHNY ALPHA Turbine Oil 26

(2) Working temperature range : 0 to 70°C

(3) Oil supply pressure:
During operation : see Table B.4.2-1.

(4) Oil consumption:
Approx. 0.2 L/hr (with KHI's oil mist separator)
Tank capacity : Allowable maximum level : 370 L
Allowable minimum level : 280 L

(5) Oil mist:
Allowable back pressure: 5000 Pa at the downstream from the gearbox port, including the pressure loss of oil mist separator.

(6) Oil filter : Pump suction section : 150 mesh
Pump discharging section : NOM. 10μm

B.4.3 Starting System

(1) Pneumatic starting system

Starter	: TDI, 51H-21 × 4 Turbine starter (gear ratio 9:1)
Compressed air pressure	: 0.98 MPa [gage] (10.0 kg/cm^{2}g) (at the inlet port of the starter)
Air consumption	: approx. 120 Nm^3 per starting
Limitation of generator	: The limitation is needed to be inquired to the engineering department.

B.5.0 Engine Assembly Installation

B.5.1 Overall Structure

The engine assembly installation shall be carried out in accordance with the requirements of the drawing refer to Fig. B.2.2-1.
In order to facilitate overhauling or repairing, the overall structure shall be designed to be able to remove the power section, accessory gearbox, upper case of the main reduction gearbox, and the internal gears.

B.5.2 Air Intake and Exhaust System

(1) Air Intake Duct System:
The amount of additional intake air pressure loss (at the upstream from the upper flange on the engine air intake duct) shall be less than 2000 Pa. If the air intake duct connected with the upper section of an enclosure is arranged transversely, special care shall be taken for the bent duct in order to maintain as uniform the airflow as possible.

(2) Exhaust Duct System:
The amount of additional exhaust pressure loss (at the down-stream from the rear flange on the engine exhaust duct) shall be less than 3000 Pa. The exhaust duct directly connected with this rear flange shall be removed easily so as to inspect the rear of the engine or to remove the power section.

B.5.3 Heat Radiation

(1) Lubricating oil : 140 kW

(2) Surfaces of engine : approx. 105 kW

B.5.4 Sound Power Level

The sound power levels of inlet,exhaust, and engine noises refer to Fig. B.5.4-1.
The sound power level is calculated as follow equation;

$$Lw = 10 \log_{10} (W/W0)$$

where Lw: sound power level (dB)
W : sound output (W)
W0: standard value of sound output 10^{-12} (W)

Table B.2.1-1 Main Parts of Fuel, Oil, and Air System

Table B.2.1-2 Main Parts of Electric System

Table B.4.2-1 Engine Operation Limit and Protective Device Set Value

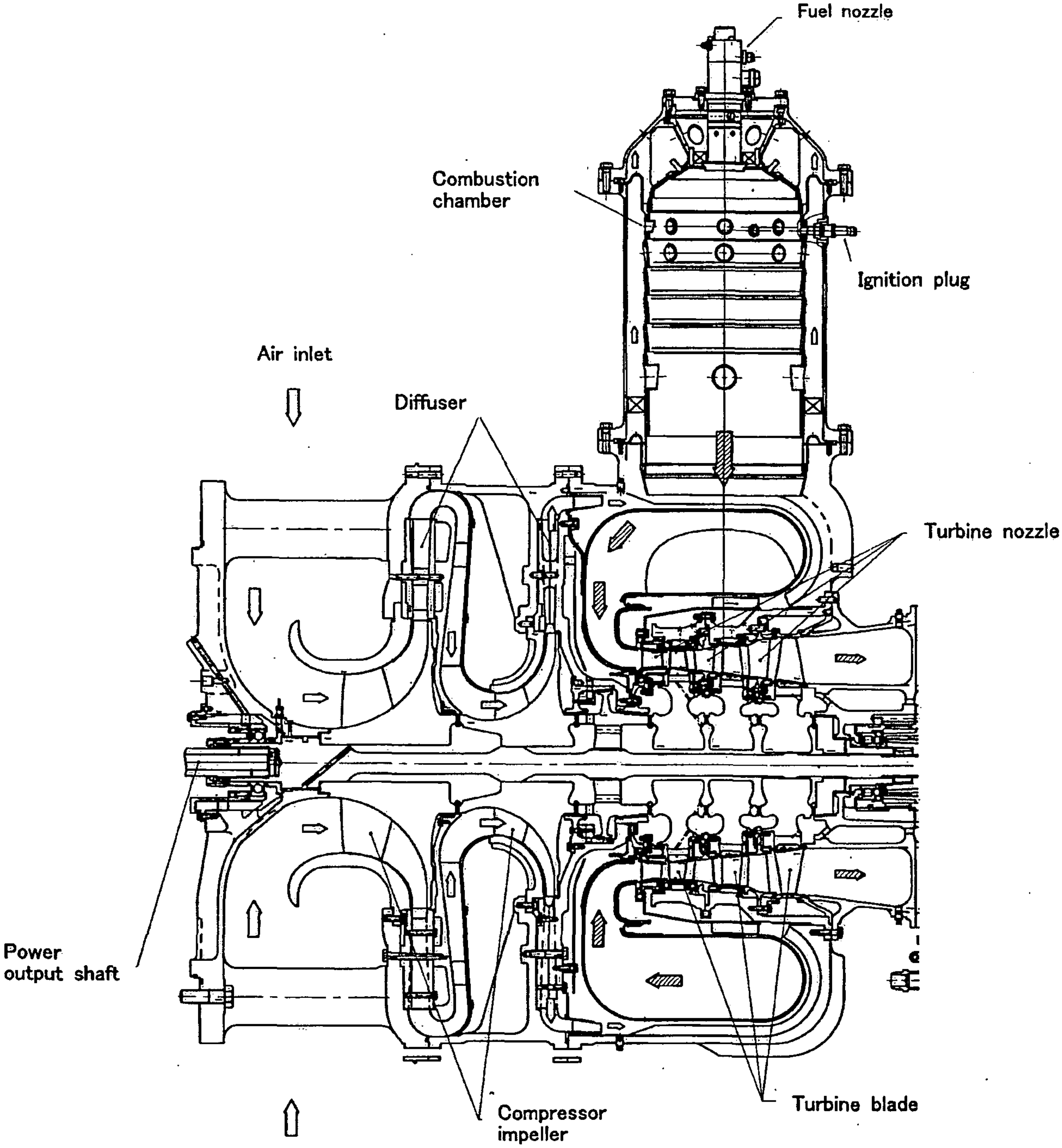
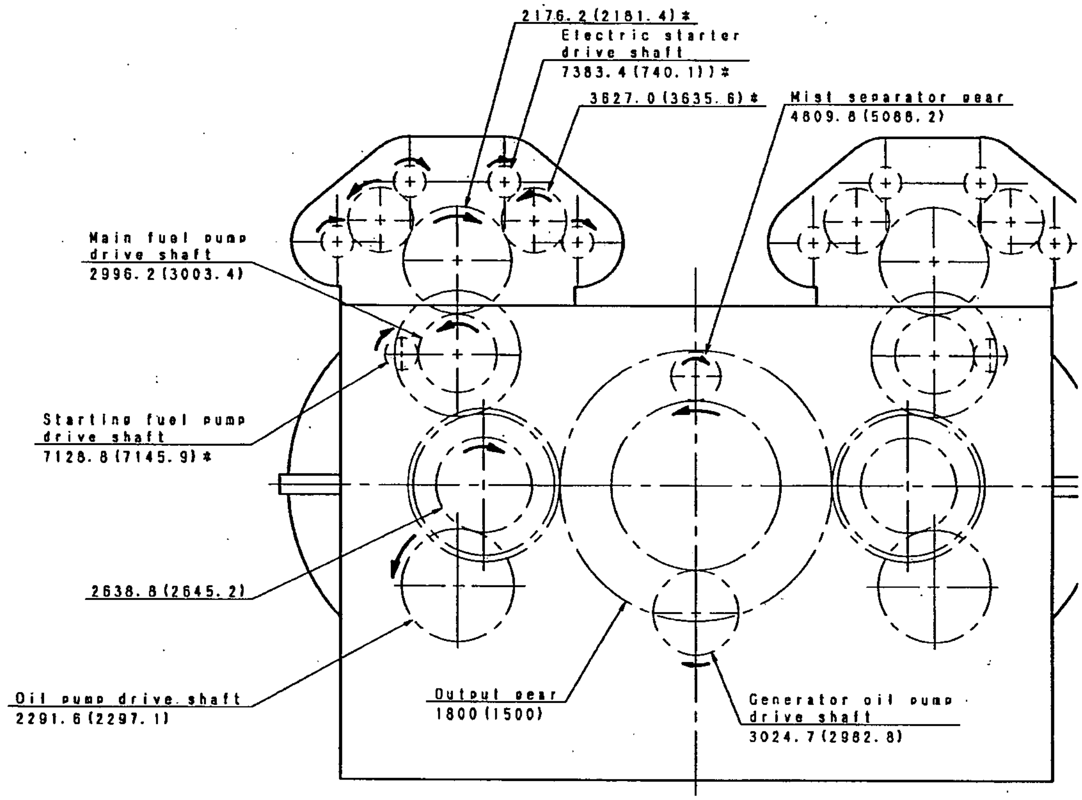


Figure B.2.1-1 Cross Sectional View of Power Section



Note : 1 Figures show the revolution speed (rpm).
The values are for 60Hz version machine and the values shown in parentheses are for 50Hz version machine.
: 2 The parts shown in asterisk * are intercepted by 55% revolution in case of electric starting system and by 50% revolution in case of pneumatic starting system.
That is, revolution speed at starter cut-off is 0.55 times of the above-mentioned value in case of electric starting system and 0.50 times of the above-mentioned value in case of pneumatic starting system.
: 3 The rotating direction is specified when it was viewed from the output shaft side.

Figure B.2.1-2 Gear Train of Reduction Gear Box

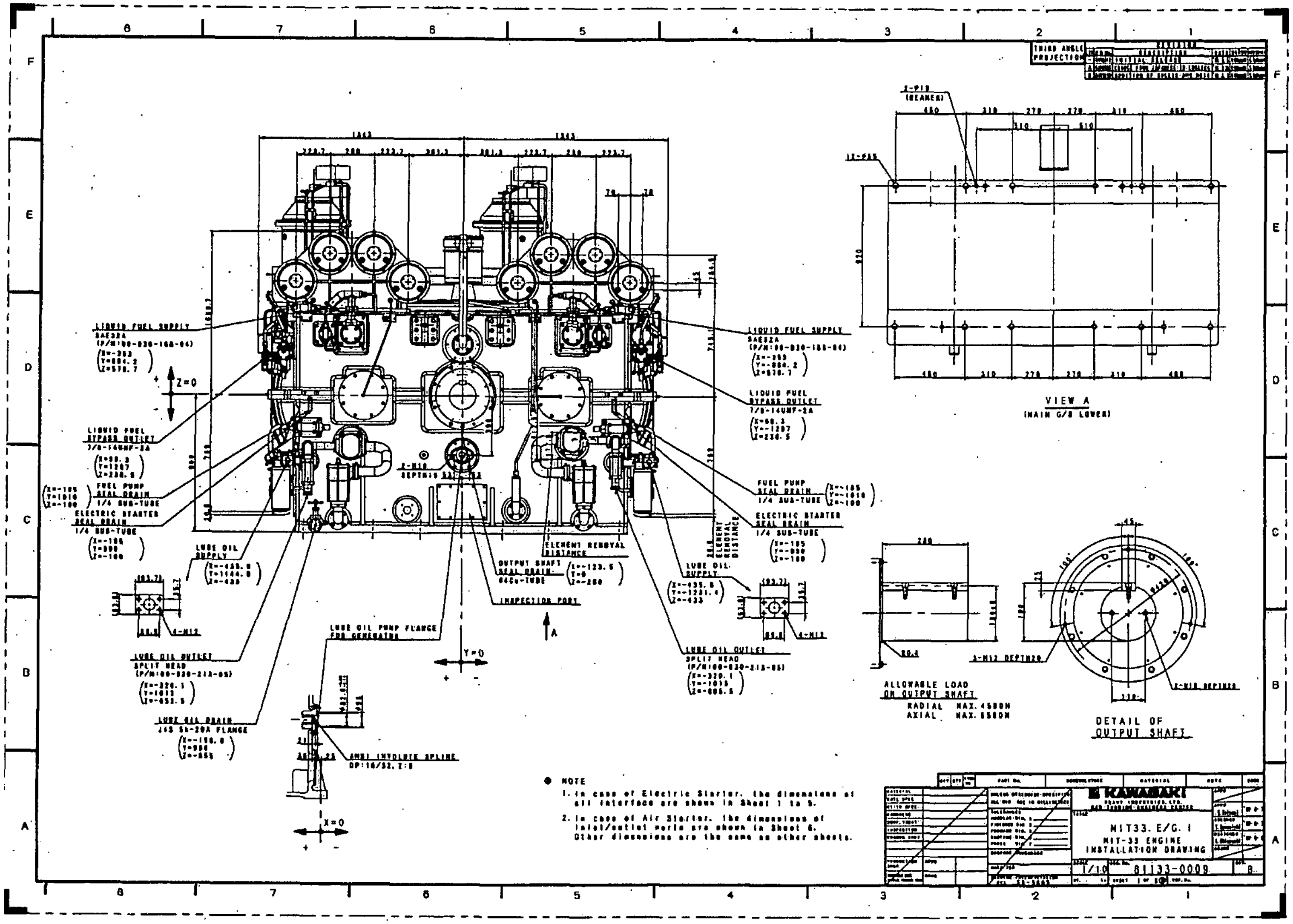


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 1)

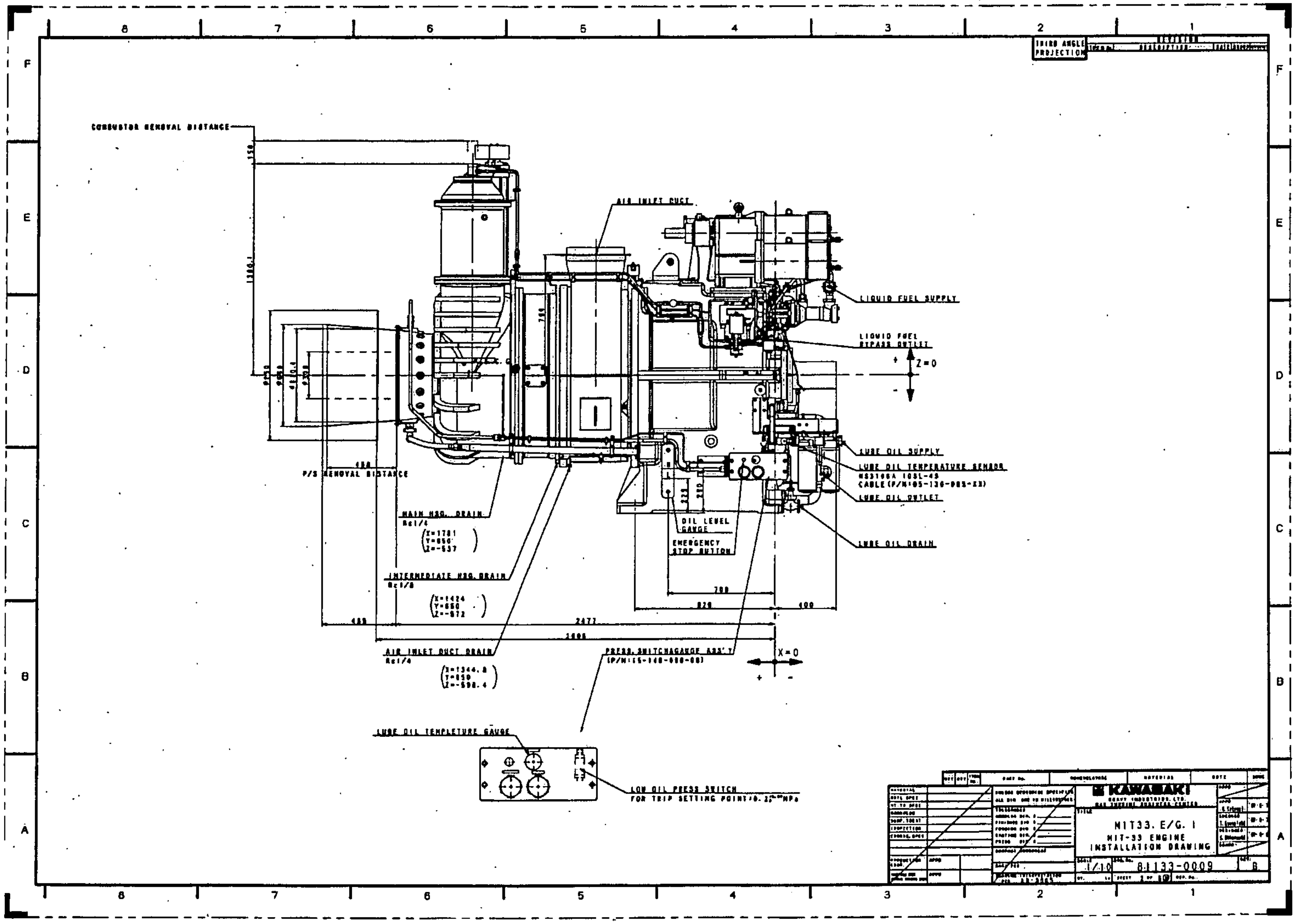


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 2)

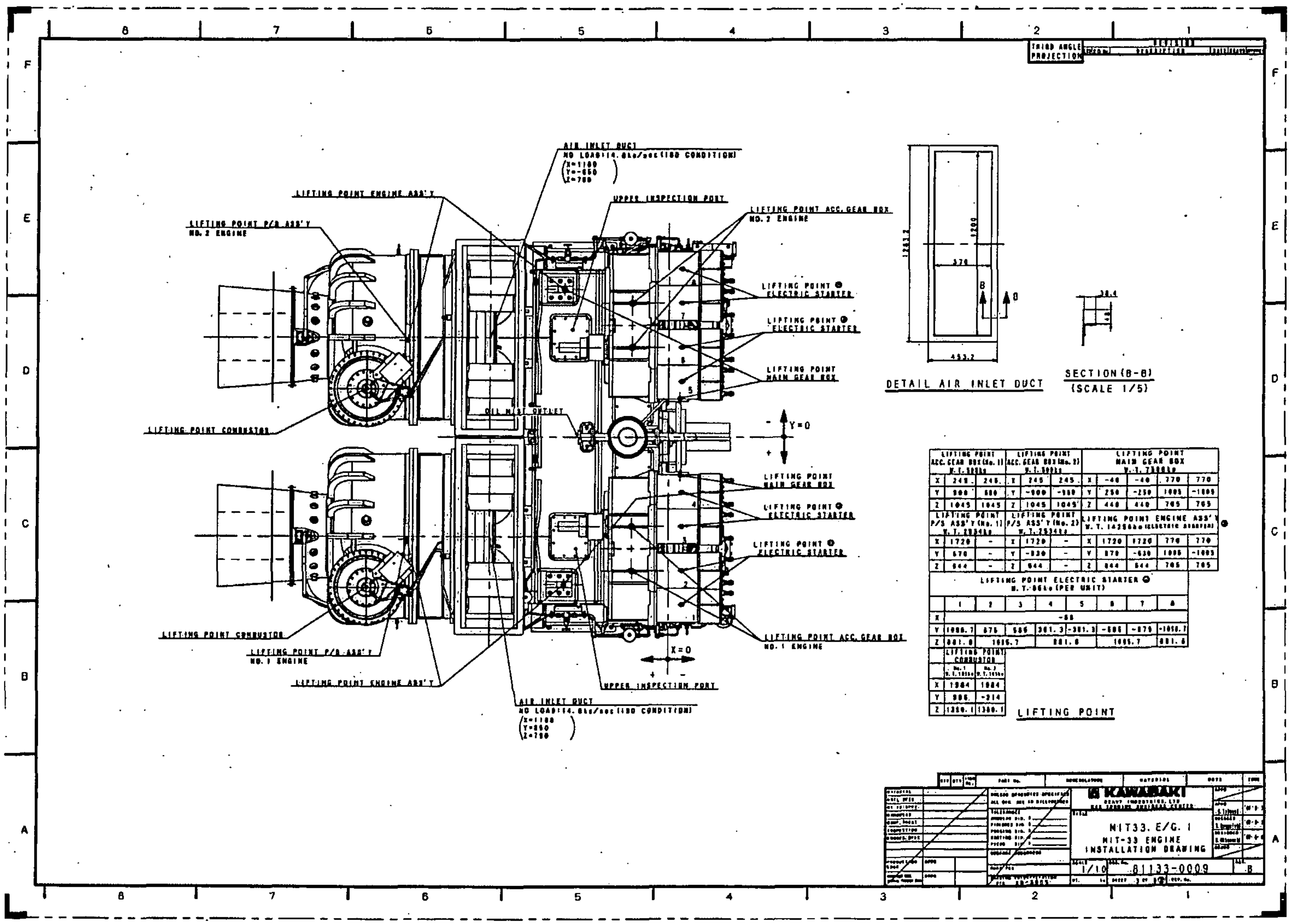


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 3)

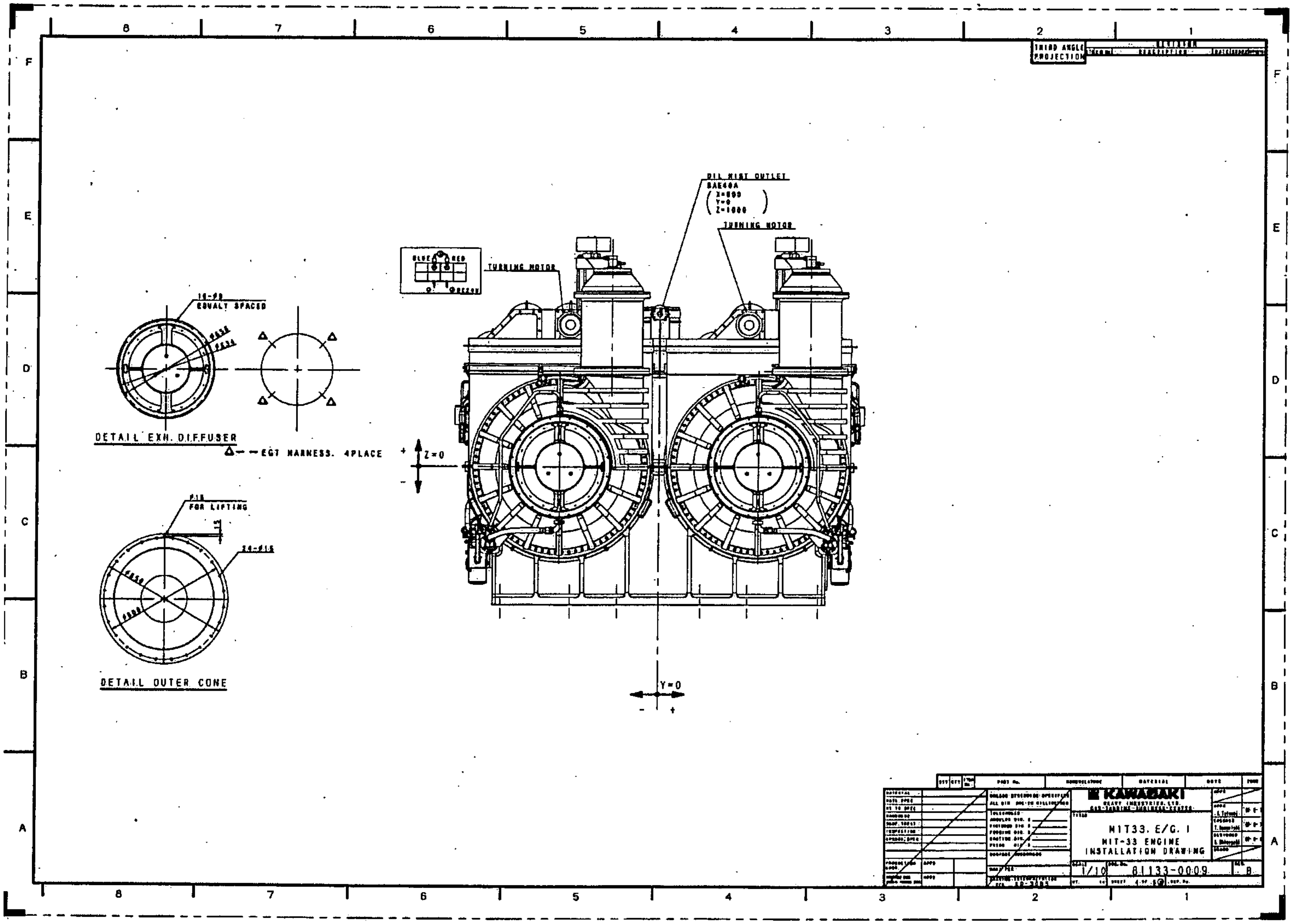


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 4)

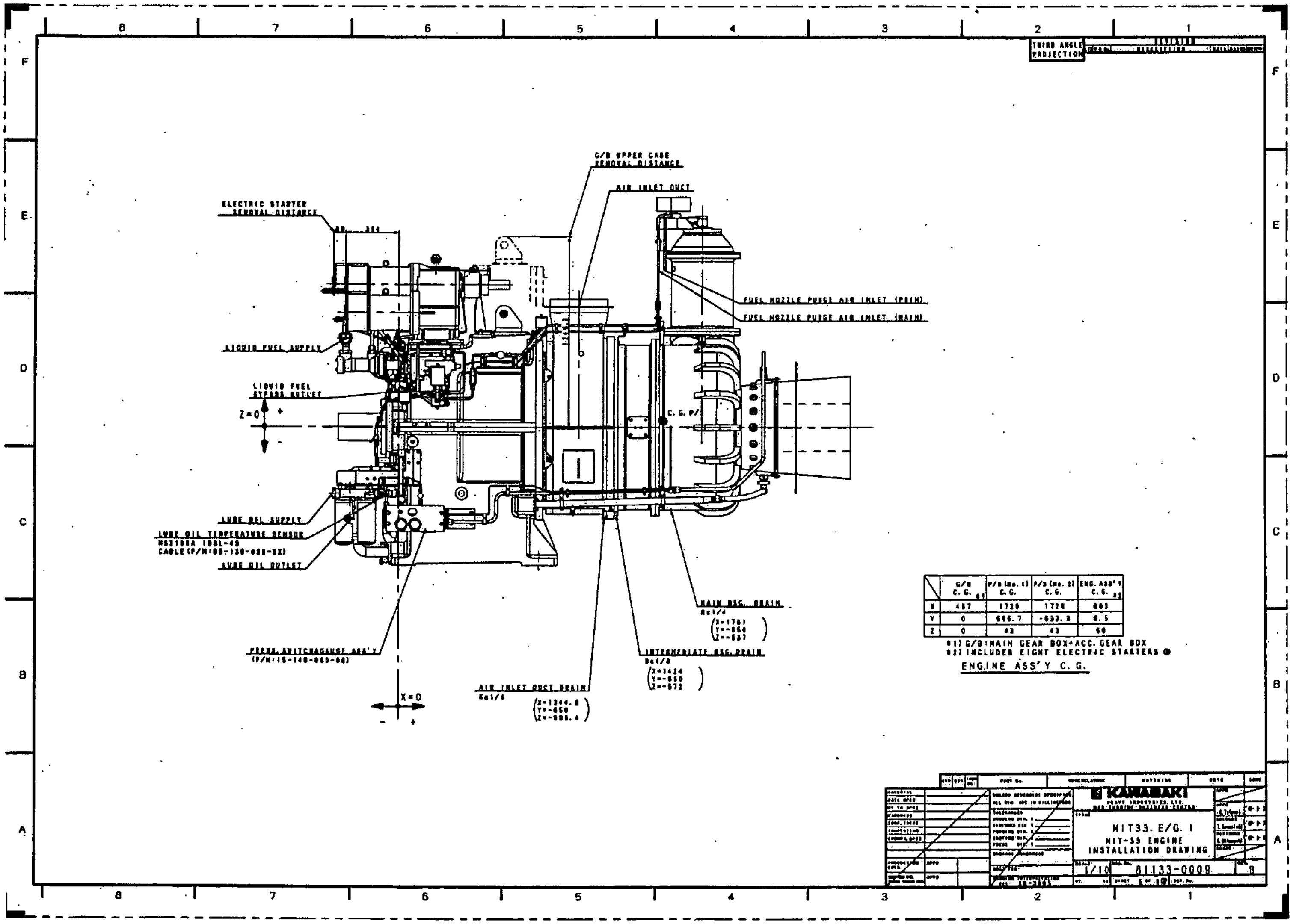


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 5)

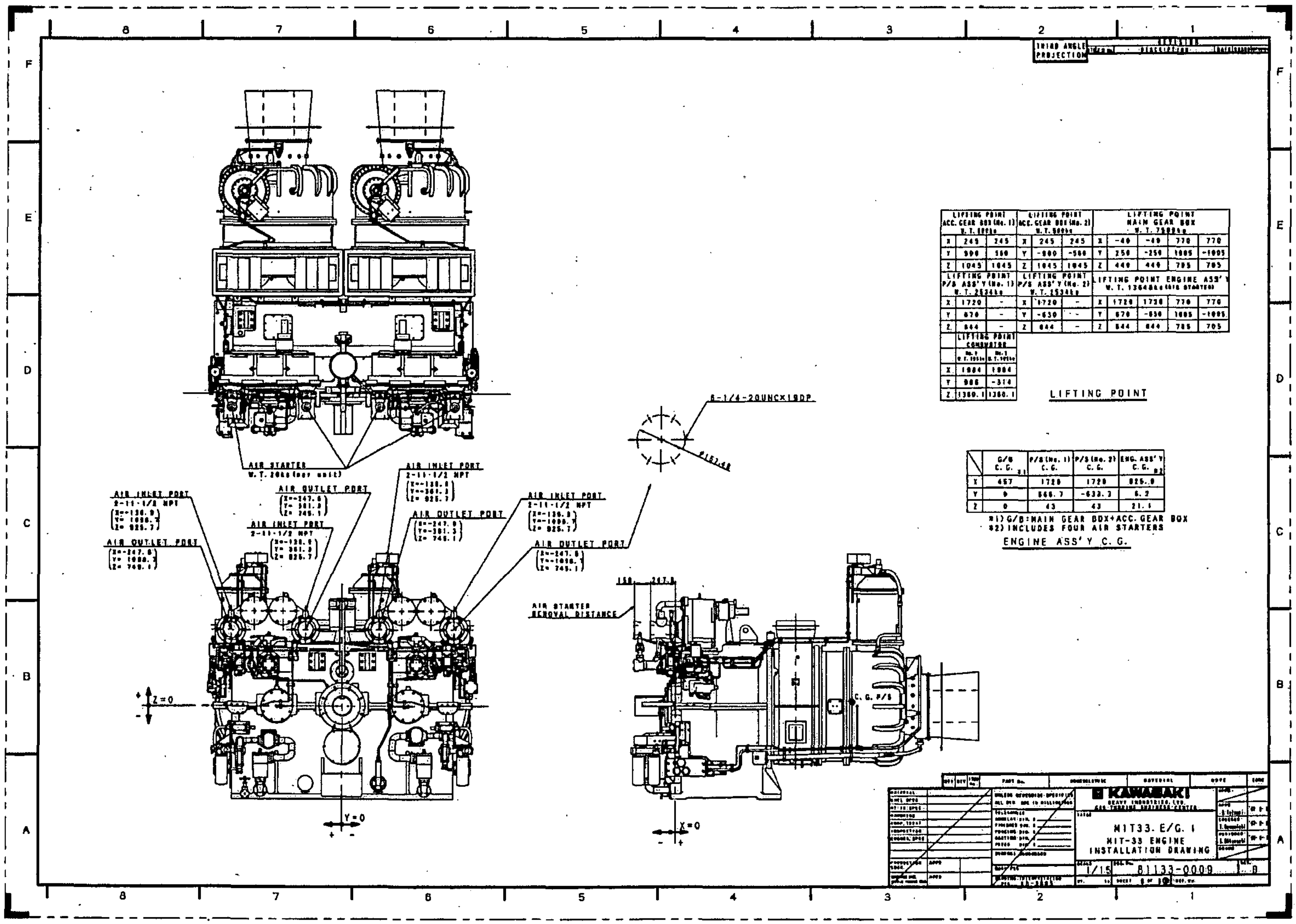


Figure B.2.2-1 Installation Drawing of Gas Turbine Assembly (sheet 6)

Figure B.3.1-1 Fuel Flow Rate and EGT of Gas Turbine Assembly Nominal Performance

Figure B.3.1-2 Air Flow Rate and Compressor Discharge Pressure (CDP) of Gas Turbine Assembly Nominal Performance

Figure B.3.1-3 Standard NOx Value

Figure B.3.2-1 Pressure Loss Correction of Gas Turbine Assembly

Figure B.3.2-2 Elevation Correction Factor

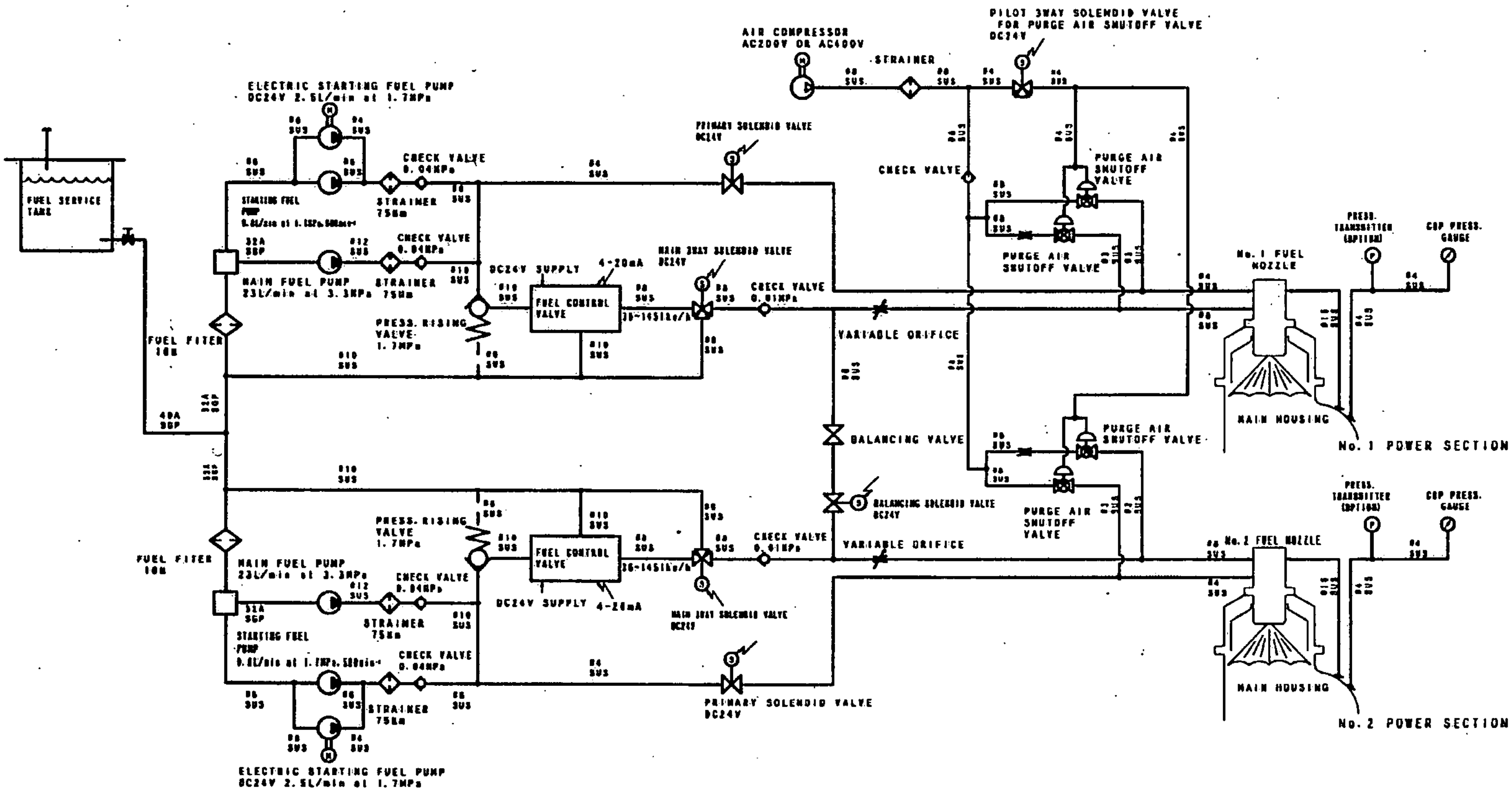
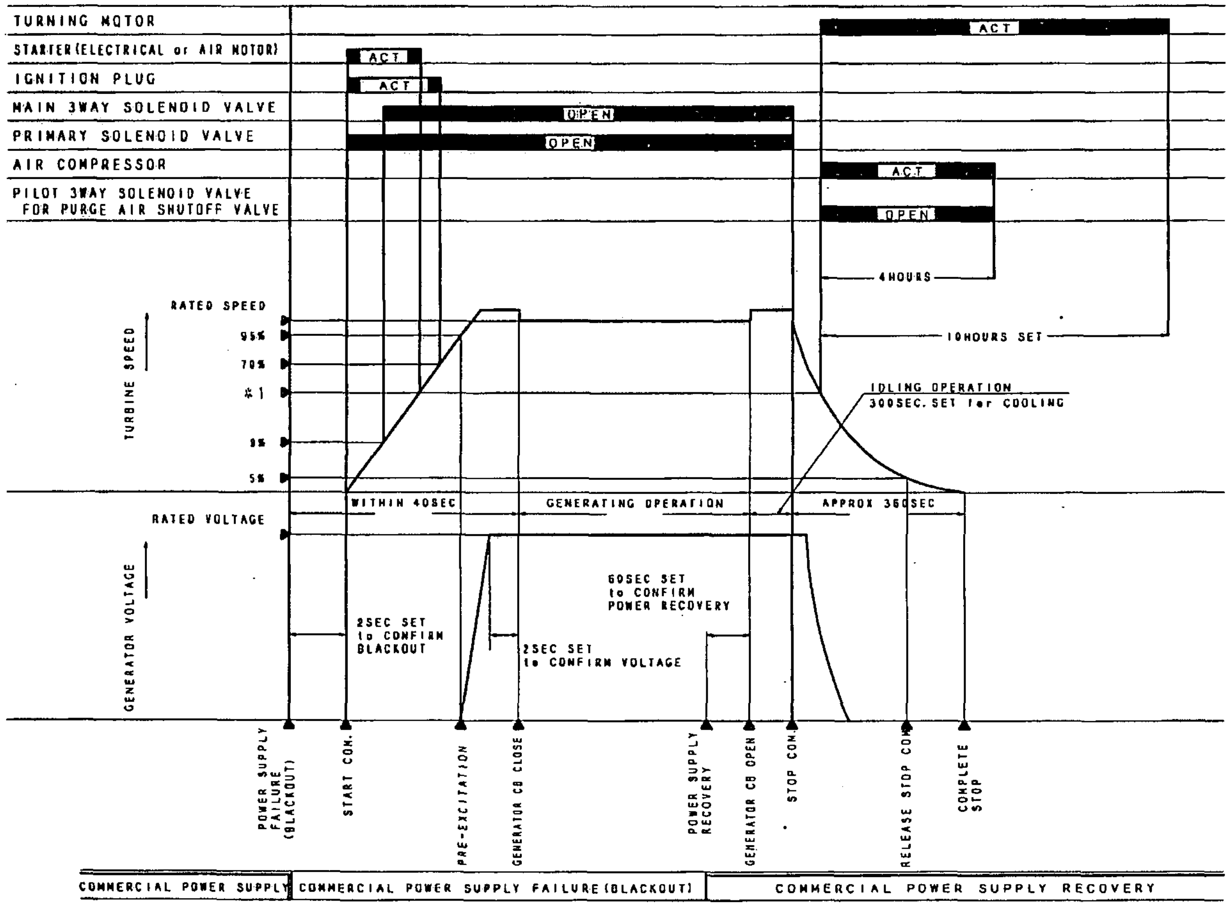


Figure B.4.1-1 Fuel System Schematic for Gas Turbine Assembly



Note : In case of Electric starting system, this speed is 55 %.
In case of Pneumatic starting system, this speed is 50 %.

Figure B.4.1-2 Timing Chart for GPS6000

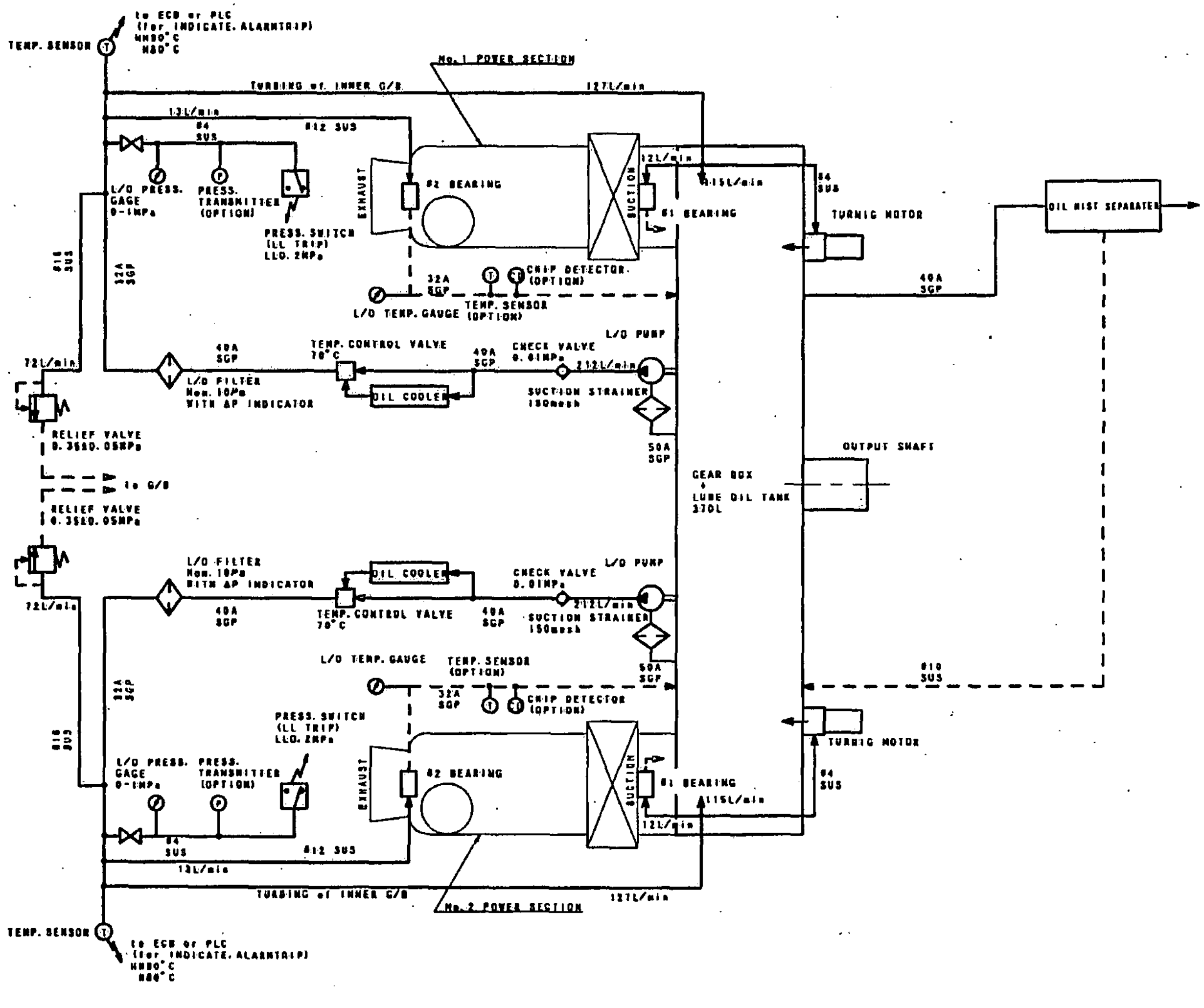


Figure B.4.2-1 Main Lubricating Oil System Schematic for Gas Turbine Assembly

(a) Sound Power Level (Inlet)

(b) Sound Power Level (Exhaust)

Figure B.5.4-1 Sound Power Level (sheet 1)

(c) Sound Power Level (Engine)

Figure B.5.4-1 Sound Power Level (sheet 2)

Appendix C Gas Turbine Generator Class 1E Qualification Plan

C.1.0 General Information

C.1.1 Description

The Class 1E GTG is part of the standby power system. This specification is for a GTG, having a rating of 4500 kW, 6900 V, 3-phase, 60 Hz. The design meets or exceeds the requirements of U.S. NRC Regulatory Guide 1.9 Rev. 4. This Regulatory Guides was provided for Diesel Engine powered generators used as Emergency Power Supplies. Since there is no guidance available for Gas Turbine engine power generators used for same purposes, the existing Regulatory Guides are used and applied accordingly. The engine, generator and all auxiliaries shall be classified as Seismic Category Class I, and shall also where applicable meet the requirements of the documents listed in Section C.2.0.

(1) The generator and other equipment whose operation is considered critical to the satisfactory starting and/or running of the GTG Unit shall be Class 1E. Furthermore, equipment whose operation is not considered critical to the satisfactory starting and/or running of the GTG Unit but which must maintain electrical integrity to prevent the compromising of a 1E circuit shall also be Class 1E.

(2) The above GTG provide standby power system for each unit. Each system will be used to supply onsite power to safely shut down the reactor in case the off site power becomes unavailable.

(3) No accessories or auxiliaries shall be shared between GTG systems.

(4) Each GTG set shall be furnished complete with all necessary component parts, accessories, auxiliaries and appurtenances, including but not limited to the following:

(a) Skid mounted assembly consisting of the following:
Dual Gas Turbine engine, reduction gear box, and generator.
Fuel System complete with engine driven pumps.
Lube Oil System complete with engine driven pumps, strainers, filter, instrumentation, etc.
Combustion Air System complete with flexible connections, silencer and bird screen.
Exhaust System complete with discharge expansion connector and silencer.
Starting Air System, to include air start motors, start and stop control solenoid valves, "Y" strainers, and flexible connectors.
All integral piping, valves, instrumentation, wiring of all Control, Auxiliary Power and Alarm Circuit.
(b) Starting Air Compressor System - shall consist of motor driven compressors, air receivers, integral piping, valves, wiring, etc.
(c) Control Panel, including turbine controls, exciter auxiliaries, voltage regulator, electrical accessories and instrumentation.
(d) Mounting and wiring of current transformers for generator differential protection.
(e) Two complete sets of any special tools required for maintenance of the two GTG sets.
(f) Recommended spare parts list and quotation.
(g) Shop tests, inspection and field tests.
(h) Special tools and instruments for shop and field tests. Services of a field installation representative.
(i) Certified drawings, Schematics, data sheets, instruction and maintenance

manuals, parts list, Seismic Qualification Reports and any other documentation required by Section VIII of ASME Boiler and Pressure Vessel Code.

(j) One copy of the manufacturers' data reports (required by the ASME Boiler and Pressure Vessel Code) shall be sent.

(k) Mild environmental qualification reports in accordance with IEEE 323-1983 to environmental parameters stated in section C.1.3 of this specification.

(l) Painting and protection for shipment and storage.

(m) Fuel oil day tank, located off skid. (See Subsection C.2.2.6.6)

C.1.2 Other Auxiliary Equipment

(1) Separate enclosure in Seismic Category Class I Building for housing each of the GTG units.
(2) Interconnecting piping and wiring between GTG set and remotely located auxiliary equipment.
(3) Fuel oil storage tanks (7 day) and fuel oil transfer pumps.
(4) Hoists required for maintenance.
(5) Furnishing and installation of cables for conveying power from the GTG units to the emergency busses.
(6) Current transformers for generator differential, for mounting and wiring.
(7) Distribution Panel for GTG auxiliaries.
(8) Air ducting for room ventilation.
(9) Remote control and surveillance stations.
(10) All labor, fuel oil, lube oil, test equipment and other supplies required for field testing.
(11) All cables required to interconnect the skid with motor control center, control panels and other remote equipment.
(12) Furnishing and installation of generator overcurrent, differential current, loss of field, reverse power, and bus fault protective relays.

C.1.3 Service Conditions

Typical ambient conditions considered are as follows and will be adjusted as required by specific site:

(1) Temperature during Storage — 0 to 88°F
(2) Temperature during Operation — 50 to 120°F
For mild environmental qualification purposes, the GTG Room peak temperature versus time profile is expected to be as follows for a 60 year service life:

197,000 hours	@ 80°F
2000 hours	@ 100°F
100 hours	@ 120°F

or use a weighted average temperature of 77°F

(3) Minimum Temperature during operation (at Building Heating System failure) — -10°F
(4) Elevation — +20 Feet above MSL
(5) Relative humidity range for environmental — 3% to 100%
For mild environmental qualification purposes use 10% to 95% RH
(6) Ambient air intake temperature range — -4 to 115°F
(7) Barometric design pressure — 29.92 inches Hg
(8) Radiation — $1x10^3$ Tads TID

The GTG unit shall be designed and be capable of performing at all ratings under the above service conditions:

C.2.0 Design Requirements-General

C.2.1 Summary

Each GTG set shall be capable of meeting the following conditions:

C.2.1.1 Type

(1) The GTG units shall be of the piped and wired, skid mounted, fast starting, high field forcing type; capable of operating in either the parallel or isochronous modes, and shall have an integral control, surveillance and protection system.
(2) The control, surveillance and protection system shall be housed on an off-skid control cabinet and shall be of the completely automatic type with provisions for semi-automatic and manual operation.

C.2.1.2 Rating - Gas Turbine Generator

(1) Ratings shall not be less than
 4500 kW Continuous @ 1,000 hrs Engine Overhaul Interval, 115°F Air Intake Temperature
 4950 kW Short time @ 300 hrs Engine Overhaul Interval, 115°F Air Intake Temperature
(2) Service Indoor
(3) Service Conditions - See Section C.1.3

C.2.1.3 Performance Criteria

The GTG units shall have the capability of performing in accordance with each of the following criteria, singly or in any combination; in the service conditions specified.

(1) Automatically or manually starting, being at set speed and voltage, and achieving a condition of "ready-to-load" within a maximum of 100 seconds after receiving a start signal in single operation.

(2) Compliance with Factory and Field Acceptance Tests discussed in Section C.4.0.

(3) Operating in parallel with the station 6.9 kV +10% auxiliary power system after being manually synchronized and manually loaded.

(4) Operate continuously at rated speed and voltage with no load on the generator terminals for a maximum of 72 hours without loss of performance.

(5) Providing a quality of power such that:
The maximum voltage dip on load acceptance shall not exceed 25 percent of rated voltage.
The maximum frequency dip on load acceptance shall not exceed 5 percent of rated frequency.
The maximum recovery time from 75 percent voltage to 90 percent voltage and from the lowest frequency to frequency at steady state, following the maximum load acceptance voltage and frequency dips, should be respectively three seconds after application of maximum load.

Under steady state operation the voltage shall be within ±2% of rated values and frequency shall be within ±1%.
During recovery from transients caused by step load increases, or resulting from the disconnection of the largest single load, the speed of the GTG shall not exceed 75% of the difference between nominal speed and the overspeed trip set point or 115% of nominal, whichever is lower.

(6) Providing a quantity of power such that:
The continuous rating may be utilized continuously and completely with no restrictions on duration except for scheduled outages for maintenance only.

(7) The unit shall be free of harmful critical speed vibration in the range of +5% of the synchronous speed (1800 RPM generator)

Appropriate speed control shall be provided to avoid the possibility of extended operation in a resonant condition near critical speeds.

C.2.1.4 Seismic Requirements

All equipment, including assemblies, sub-assemblies, supports, piping, control panel, etc., shall satisfy the seismic requirements of the specific site.

C.2.2 Design Requirements, Mechanical

C.2.2.1 Engine

The generator set shall be driven by two gas turbines. The gas turbine shall be the heavy-duty, single-shaft, simple open cycle, and air cooled type. The engine shall be the manufacturer's standard model for the intended service and shall be designed to applicable code requirements. The gas turbine shall be suitable for conformance with seismic and other operational requirements as stated herein. A flexible coupling shall be installed between the engine and generator. A suitable removable guard shall be mounted over the coupling. Also necessary operating and access platforms, steps, stairs, handrails, toe plates, etc. shall be provided all as per OSHA requirements.

C.2.2.2 Governor

The governor (ELV) is an electric fuel valve to control the fuel flow to a small industrial gas turbine. This is an all electric liquid fuel valve, which discharges fuel from output port in proportion to the input signal to the ELV driver. The control of the ELV driver is by electric load sensing and shall act instantly to adjust the Gas Turbine engine output to the electric load to maintain constant generator speed. Precise control shall be provided to assure compliance with the performance criteria stated in Subsection C.2.1.3. The valve goes to the minimum fuel position to shutdown the prime mover in case of power supply failure, feedback signal failure/short or actuator signal failure for fail-safe.
The governor response shall not be affected by the fluctuating service conditions indicated in Section C.1.3. Under all operating conditions the governors shall function primarily on automatic.

C.2.2.3 Engine Automatic Starting System

Each GTG set shall be capable of both manual and automatic starting. A completely independent and automatic start-up system shall be furnished for each engine requiring no operating personnel.

The engine shall be capable of being started by compressed air within 100 seconds after signal for start. The engine shall also start with all systems at 50°F.

There are six starting air compressors per engine and two receivers. The receivers capacity should be such that there is sufficient air at required pressure for three starts. The receivers are to be constructed in accordance with ASME Section VIII.

The manufacturer shall provide a set of receivers and compressors for each generating set piped. Compressors and receivers shall be furnished with all instrumentation, valving, relief valves, air dryer and other accessory equipment to provide a fully controlled and monitored air starting system.

Compressor final discharge shall be provided with a flexible connection to eliminate pipe vibrations caused by compressor operation.

The above air receivers, shall be designed, fabricated, and tested as per ASME Code for Pressure Vessels, Section VIII.

The starting system shall be designed to prevent rust within the receivers and piping, preferably with dryers, or proper selection of materials.

The compressor, receivers, valves, piping, and other accessory equipment shall be assembled on a common base. The air compressor and compressor motor shall be considered non safety related.

C.2.2.4 Air Intake System

Components:
Air intake system shall consist of duct, inlet duct, silencer, and bird screen.

Bird Screen:
A bird screen shall be furnished to prevent ingestion of foreign objects by the gas turbine.

Flexible Hose:
Flexible Hose with mounting clamps shall be furnished to absorb vibration and thermal expansion.

Silencer:
Silencer shall be furnished to absorb the gas turbine inlet noise.

C.2.2.5 Exhaust System

Components:
The exhaust outlet adapters, flexible connections and silencers for each generator set shall be furnished.

Flexible Connection:
Flexible metal, with flanged ends to assure expansion protection and vibration isolation.

Piping:
Interconnecting piping will be furnished by Purchaser.

C.2.2.6 Fuel System

C.2.2.6.1 General

A complete Gas Turbine engine fuel system shall be furnished in accordance with Section C.1.1.6.

C.2.2.6.2 Fuel

(1) Engine fuel will be commercial grade No. 2 fuel oil with limits as stated in ASTM Specification D-396 or kerosene.

C.2.2.6.3 Fuel Injection

(1) Pumps and nozzles shall require no adjustment while in service and shall be capable of quick replacement.

C.2.2.6.4 Fuel Oil Strainers and Filters

A full flow single strainer between the engine driven pump and header, a filter between the day tank and the engine driven pump and pressure gages on the skid panel to indicate fuel header pressure shall be provided.

High differential pressure switches shall be furnished across filter.

C.2.2.6.5 Main Fuel Oil Pump

(1) A direct engine/gearbox driven, pump that will pump fuel oil from the day tank to the fuel control valve under any condition of operation specified herein shall be provided.
(2) Pump inlet pressure shall be kept according to the gas turbine requirements

C.2.2.6.6 Fuel Tank

(1) Each GTG shall be provided with a welded steel day tank, to hold a total quantity of fuel required for 1.5 hours operation at the continuous rating (Approx. 2050 X 1.05 X 1.5 = 3229L = 853 Gal). Tanks shall be constructed in accordance with Underwriter's Laboratories Specification UL-142, Steel Aboveground Tanks for Flammable and Combustible Liquids.
(2) Tank shall be provided with fuel level gage, high and low level switches, automatic controls for maintaining tank fuel oil level, overflow, flame arrestor, vent, pressure relief vent, drain, engine supply, engine pressure return, and one fill connection.
(3) On normal low tank level, the automatic level controls shall be arranged to start the associated transfer pump that will pump the fuel from a 7-day storage tank to the day tank.
    (a) On pre-determined low-low tank level, a level alarm switch shall be actuated.
(4) On normal high level, the level control switch shall trip the fuel oil transfer pump.

(a) On high-high level a level switch shall be furnished to annunciate the condition.

C.2.2.7 Lubrication System

C.2.2.7.1 General

(1) A complete lube oil system shall be furnished to supply oil under pressure to the engine bearings and reducing gear bearings.
(2) Maximum stabilized oil temperature leaving the engine when the engine is carrying the overload in an ambient temperature of 115°F, shall not exceed the manufacturer's maximum safe value.

C.2.2.7.2 Main Lube Oil Pump

(1) Shall be engine-driven and a design which shall furnish lube oil at a constant pressure to all points requiring lubrication.

C.2.2.7.3 Filters

(1) The lube oil flow shall be continually filtered and strained.
(2) Filters (by-pass type) shall:
  (a) Be cotton waste or cellulose type conveniently located to maintain oil purity.
  (b) Have replaceable elements which can be changed without breaking the connecting piping.

C.2.2.7.4 Low Oil Pressure Protection

(1) A low oil pressure alarm shall be furnished in the system to signal when the lube oil pressure drops to the lowest safe operating level.

C.2.2.7.5 Lube Oil Cooler

(1) A lube oil cooler shall be supplied to remove heat from the engine and speed reducer oil during operation.
(2) The cooler shall be of the air to oil type and shall be driven by an electric motor driven fan, mounted close to the radiator core.
(3) Design pressure and cooler size shall be determined by engine manufacturer.

C.2.2.7.6 Controls

Automatic oil temperature controls with high oil temperature alarm shall be furnished.

C.2.2.7.7 Drain

The oil tank shall be provided with suitable sump and drain to remove the lube oil.

C.2.2.7.8 Lube System Pressure Gauge

Pressure gauge shall be provided for engine lube.

C.2.2.7.9 Lube System Temperature Gauges

Temperature gauges shall be provided at inlet and outlet of oil cooler.

C.2.2.7.10 Level Indicator

Shall be provided in the oil tank.

C.2.2.8 Bearings - (Generator)

(1) The generator shall be provided with two pedestal mounted sleeve bearing independent of the engine.
(2) Bearings shall be of the split ring type with integral oil lubrication.
(3) Close running shaft seals shall be provided on the generator shaft bearings to prevent oil leakage from the bearing area.
(4) The outboard generator bearing pedestal shall be insulated to prevent shaft current circulation and resultant bearing damage.
(5) Generator bearing oil lubrication system shall be provided with:
  (a) Oil sight level gages with clear and indelible oil level markings for standstill and running conditions.
  (b) Oil fill and drain plugs and inspection openings.
(6) One 100 ohm (at 0°C) Resistance type platinum temperature detector shall be provided in the generator pedestal mounted bearing. Three Leads shall be brought out and connected to terminals in a conveniently located terminal box mounted on the GTG unit skid. Extension wire shall be shielded, twisted, 3/c, No. 16 AWG. Resistance Temperature Detector (RTD) shall be ungrounded.

C.2.2.9 Skid

(1) The skid type base plate shall be fabricated of rolled steel sections welded together to form a rigid base for mounting the equipment and systems indicated in Subsection C.1.1.(4) (a) above and suitable for bolting to a reinforced concrete foundation.
(2) The skid and equipment mounted thereon shall be completely assembled, piped and wired in the factory.
  (a) Piping shall terminate in accessible positions for fitting-up of field connections.
  (b) Wiring shall terminate in terminal boxes in accessible locations on the skid.
(3) Walkways, platforms, ladders and/or stairways required for operator access to the skid mounted equipment shall be furnished and factory mounted.
  (a) Where items may require separate shipping they should be assembled in the largest possible components.
(4) Skid shall be equipped with lifting eyes and jacking provisions and shall be suitable for skidding in a direction parallel to or perpendicular to its longitudinal axis.

C.2.2.10 Piping

C.2.2.10.1 Scope

All integral piping systems for the GTG Skid Assembly as outlined in Section C.1.1.(4) (a) shall be furnished, fabricated and installed.
Also all interconnecting piping between each of above assemblies and also between the assemblies and remotely located equipment shall be furnished and installed.

C.2.2.10.2 Codes

All piping systems shall be designed, fabricated and erected in strict accordance as per listed below:

All on-skid, off-engine piping essential for starting and operating (portions of the starting air, lube oil and fuel oil systems) the seismic requirements of this specification

Remaining on-skid, off-engine piping non-essential for starting and operating, and all engine-mounted piping per Manufacturer's Standards

C.2.2.11 Air Starting System

Air stating system mainly consists of air starters, air compressors, starting valve units, and air tanks.

C.2.2.11.1 Air Starting Motor

Air starter is furnished with the engine. At starting of the generator set, this starter rotates the engine through the gear box. The following specification is the air starter for 6000kVA generator set.

(1) The number of starters	4
(2) Maximum limit pressure at inlet	142 PSIG (0.98MPaG)
(3) Necessary air volume for 1 start	4250 Standard ft^3 (120 Nm^3)

C.2.2.11.2 Starting Manifold

The starting manifold assembly consists of reduction valves, pipes, gauges, Y-strainer, and control valves. This unit reduces air pressure at the inlet of this unit to the specified pressure (the secondary air pressure). The secondary air pressure depends on air starter's maximum limit pressure at inlet. The following is the specification for 6000kVA generator set.

(1) The number of valve units	2
(2) The number of connecting ports	4 (2 for inlet and 2 for outlet)
(3) Port size (inner diameter)	2.6" (67.9 mm)

C.2.2.11.3 Air Tank

The air tank has starting air in itself. A pressure switch is furnished with this tank, and the switch sends signals when air pressure inside it drops or rises to the specified values. The following is the specification for 6000kVA generator set.

(1) Necessary air volume 3	4238 ft3 (120 Nm^3) / one start
(2) Air pressure at standby state (Normal pressure)	426 psig (2.94 MPa)
(3) Air pressure after 3 continuous starts	190 psig (1.31 MPa)

C.2.2.11.4 Air Compressor

The number of air compressors and capacity of each air compressor depends on air

compressor's specification and the required receiver recharge time.
The following specification is for reference.

(1)	Motor capacity	7.5 HP
(2)	Number of air compressors	6
(3)	Discharge rate of an air compressor	700 ft3/hr
(4)	Filling time (190 to 426 psig)	5 hrs

Pipes from air tanks to the generator set shall be zinc coated to prevent pipes from rusting.

C.2.2.12 Ventilation System

C.2.2.12.1 Air Supply

Supplied air from outside is used for combustion, cooling in the enclosure, and cooling in the generator room. This air is introduced into the room with a fan.

(1) Required air for combustion (6000kVA) 49,435 ft3/min (1,400 m3/min)
(2) Required air for lube oil cooler (6000kVA) 14,124 ft3/min (400 m3/min) (reference)
(3) Required air for cooling generator 17,655 ft3/min (500 m3/min) (reference)
(4) Required air for cooling the generator room is calculated from heat discharge from exhaust duct and the exhaust silencer. Therefore, this volume depends on layout plan.
(5) Exhaust gas volume and temperature 135,240 ft^3/min (3,830 m^3/min) (@ 595 °C)

C.2.2.12.2 Ventilation

Air for cooling in the enclosure is exhausted through duct with a ventilation fan. This volume is calculated supplied air volume and discharged heat in the enclosure.

C.2.2.12.3 Directly Connected Air Supply System

If fire suppression gas system in the generator room, combustion air for the turbine shall be taken through a separate duct connected to the inlet on the enclosure. This is to prevent the engine from ingesting the gas and disrupting the fire suppression system.

C.2.3 Design Requirements - Electrical

C.2.3.1 Generator

The generator is an alternating current synchronous generator of open drip proof construction, two bearing configuration, equipped with integral direct connected exciter and permanent magnet generator.

C.2.3.1.1 Rating of the Generator

The rating of the generator shall be as follows.

KVA:	6000 (6600 KVA overload capability for 2 hrs / 24 hrs)
PF:	0.8 Rated
Voltage:	6900V

Phase	3
Connection:	Wye
Wire:	6
Frequency:	60 Hz
Amperes:	502 (552 overload)
Speed:	1800 RPM
Rotation:	CW facing shaft extension end
Temp Rise:	70°C over 50°C ambient for embedded detectors
Insulation:	Class F
Enclosure:	Drip proof

C.2.3.1.2 Generator Frame

The frame of the generator is of open drip proof, fully guarded construction and is provided with removable covers on each end and the sides to facilitate maintenance and troubleshooting. The stator and coils assembly are an integral part of the frame with the stator laminations welded directly to the frame structure. The generator frame is equipped with removable end frames which provide support for the rotating field assembly and exciter components. Two grounding pads are provided at opposite corners of the generator frame. The grounding connections accept 2-hole standard bolted lugs.

C.2.3.1.3 Ventilation

The generator is designed for axial ventilation type cooling, with ambient air drawn into the generator through openings at the exciter end of the frame and hot air exhausted through openings in the drive end of the frame. Air flow is provided by a fan assembly installed on the shaft of the rotating field assembly.

C.2.3.1.4 Bearings

The generator is of two bearing construction. The rotating field and shaft assembly is supported by a self aligning bearing installed at each end. The bearings are either oil lubricated or grease lubricated. The bearing on the connection end of the generator is capable of carrying axial loads in addition to the design radial loads. The rotor shaft is locked at the connection end to allow for thermal growth towards the non-connection end. The bearing located at exciter end is installed in an electrically insulated housing to prevent circulating currents. The housings are equipped with seals and include provisions for addition of lubricant or re-greasing during operation. Each bearing housing is also equipped with a 100 ohm platinum resistive temperature device for temperature monitoring.

C.2.3.1.5 Stator and Coils Assembly

The stator and coils assembly consists of coil groups embedded in slots within the laminated steel core of the stator. The stator coils are of form wound construction and interconnected on the connection end of the stator. The stator of the generator is equipped with six 100-ohm platinum resistive temperature devices (two per phase) imbedded between the coils of the stator for temperature monitoring.

C.2.3.1.6 Rotating Field Assembly

The rotating field assembly consists of four salient poles connected in a series configuration. The field poles are bolted to the shaft assembly. The field poles consist of dc coils installed on laminated steel pole bodies. The field poles contain embedded copper amortisseur or damper windings that are interconnected between each pole.

C.2.3.1.7 Exciter Assembly

The exciter assembly consists of an exciter field, exciter armature and rotating rectifier, installed on the non connection end of the generator. The exciter field is stationary and secured to the generator end frame. The exciter field consists of dc coil assemblies installed on laminated poles. The exciter armature is installed on the shaft supporting the rotating field assembly. The exciter armature is constructed of Alternate Current (ac) coil groups installed on a rotating lamination stack and connected in a three phase, three wire, WYE configuration. The rotating rectifier is installed on the shaft supporting the rotating field assembly. The rotating rectifier consists of a three phase, full wave diode bridge mounted on a split plate.

C.2.3.1.8 Permanent Magnet Generator

The permanent magnet generator consists of a stator assembly and permanent magnet field assembly. They are installed outboard of the nonconnection end bearing. The permanent magnet generator stator is stationary and secured to the generator end frame. The permanent magnet generator stator consists of AC coils installed within a laminated steel core. The permanent magnet generator field is installed on the shaft supporting the rotating field assembly. The permanent magnet generator field consists of permanent magnets secured to a central hub.

C.2.3.1.9 Generator Electrical Characteristics

Generator reactance, exciter speed of response and field forcing voltage shall be sufficient to meet the starting and loading requirements. The maximum voltage dip during the design loading sequence shall be limited to 25% of nominal line-to-line voltage.

C.2.3.1.10 Prime Mover Connection

This generator is equipped with a solid circular input shaft for connecting to the output of the speed increaser through a flexible coupling.

C.2.3.1.11 Auxiliary Terminal Box

An auxiliary terminal box is mounted on the generator frame. The auxiliary terminal box provides terminal connections for the six stator resistive temperature devices, two bearing RTD's, space heaters, permanent magnet generator and exciter field.

C.2.3.1.12 Space Heaters

This generator shall be provided with space heaters to prevent moisture absorption in the generator windings when the machine is out of service. The space heaters are energized whenever the generator is not in use.

C.2.3.1.13 Power Output Leads / Terminal Box

The generator is equipped with six power output leads for bus connection. The leads are terminated to insulated standoffs within the generator load terminal box assembly. The terminal box is sized to allow for cable terminations at each phase and neutral connection. The three phases are labeled "T1", "T2", and "T3". The three neutrals are labeled "T4", "T5", and "T6".

C.2.3.1.14 Generator Assembly Manufacturer's Test

The assembled generator shall be tested at the manufacturer to confirm proper operability and conformance to standards. All tests shall be performed in accordance with accepted standards (IEEE 115 or MIL-STD-705) and shall include, at a minimum, the following:

- Air Gap Measurement
- Resistance Temperature Device Test
- Winding Resistance Test
- Space Heater Test
- Insulation Resistance & Polarization Index Test
- Bearing Insulation Resistance Test
- High Potential Test
- Generator Dynamic Balance Test
- Phase Sequence Test
- Open Circuit Saturation Test
- Short Circuit Saturation Test
- Phase Balance Test
- Shaft Current Test
- Current Balance Test
- Temperature Rise Test
- Overspeed Test
- Vibration Test
- Assembled Unit Weight
- Shaft TIR
- Efficiency Testing Including Bearing Friction and Windage, Open Circuit Core Loss, Stator Loss, Armature I^2R Loss, Field I^2R Loss & Stray Load loss.

C.2.3.2 Automatic Voltage Regulator

The generator shall be equipped with a static automatic voltage regulator with necessary rheostats, switches, and accessories to control the amount of current supplied to the exciter field under all loading conditions. The automatic regulator shall be capable of controlling the steady-state generator terminal voltage within ±2% for a load variation from no load to full load, power factor variation from 0.8 lagging to unity. The generator terminal voltage is adjustable over a ±10% range of rated voltage. The voltage regulation system shall be equipped with provisions for parallel operation with the utility during exercise operation of the generator set.

C.2.3.3 Backup Voltage Regulator

The generator controls include a backup voltage regulator with necessary rheostats, switches, and accessories to control the amount of current supplied to the exciter field under all loading conditions. The backup voltage regulator is field-selectable by the operator and is capable of performing as a fully functional unit. The controls of the backup voltage regulator does not allow for switching from the automatic unit to the backup unit while the unit is in operation.

C.2.3.4 Excitation and Voltage Regulation System

(1) The generator shall be equipped with an excitation and voltage regulation system providing high speed response to voltage and load changes to meet the requirements of these specifications, and shall work in conjunction with the specified governor to meet performance criteria, as stated in Subsection C.2.1.3. This system shall include necessary contactors and controls for manual and automatic field flashing from Owner's 125 volt dc source. There shall be minimum capability of 300 % field forcing and the system shall be sized to provide adequate excitation when the generator is operating at its short time rating and when it is operated in parallel with the station 6.9 kV bus.

(2) Current and potential signal input to the metering and relaying will be provided.

(3) All components including field forcing current transformers and power potential transformers shall be mounted and wired in the separate cubicle provided for the excitation and voltage regulation system.

(4) Each exciter and/or voltage regulator shall have the inherent capability to sustain generator excitation during a 3 phase fault or line to line fault without switching to a different mode.

(5) Each exciter and/or voltage regulator system shall be designed to fail "safe" to protect the generator from excessively high output voltages resulting from accidental interruption of the voltage-sensing network.

(6) Each exciter and/or SEVR system shall not include any electronic tubes or electrolytic capacitors.

(7) Precautions shall be taken to ensure that the silicon rectifiers are not subject to peak inverse voltages in excess of 80% of their rating under any condition of system operation, including transients. Surge protection shall be provided.

(8) Power diodes shall be provided in sufficient number to allow for 100% redundancy. The failure of any diode shall cause an indicating light to illuminate. Provisions shall be included for the replacement of a failed power diode without removing the exciter from service.

(9) The automatic voltage regulation system shall operate within +2% under steady state conditions for a load variation from no load to full load, power factor variation from 0.8 lagging to unity, and a generator field temperature rise from ambient (40°C) to the rated operating temperature rise.

(10) The voltage regulator shall be capable of accepting and responding to a signal from a remote and local "raise-lower" control switch, independent of the automatic voltage regulator control circuitry. The dc motor operated rheostat or similar device shall operate from 125V dc supply. The automatic voltage regulator shall override the manual voltage regulator whenever the GTG is in the automatic (emergency) mode.

(11) An exciter field circuit breaker or equivalent shall be provided to permit field de-energization when required. The breaker shall be operated manually with provision for remote tripping from a contact closure of a protective relay.

C.2.3.5 Control Panel

(1) One free standing control panel shall be furnished. The control panel and its components shall satisfy the seismic requirements of the system.

(2) The free standing control panel shall be comprised of the required number of cubicles to house the control, surveillance and protection logic, and the excitation and voltage regulation system.

(3) Equipment shall be completely wired and tested at the factory.

(4) One molded case, non automatic two pole, circuit breaker in each control panel, to serve as disconnect means for the incoming dc control power supply shall be furnished.

(5) Individual control circuits shall be isolated from the control power by means of fusible pullouts with cartridge type fuses.

C.2.3.6 Motor Control Center and Auxiliary Power

(1) The motor control center to supply power to motor driven auxiliaries will be provided. This motor control center will receive power from the GTG source under emergency conditions.

(2) Auxiliary power available from plant power distribution system will be:

(a) dc control power	125 volt nominal 90 volt minimum 140 volt maximum 2 wire ungrounded system
(b) ac power	460 Volt +10%, with a dip of -25% during motor starting ungrounded, 3 phase, 3 wire 60Hz, 115V ±10%

C.2.3.7 Auxiliary Motors

(1) All auxiliary drive motors required to drive equipment as specified shall be furnished.

(2) Motors shall be squirrel cage induction type, totally enclosed, non Class 1E and suitable for operation in the specified environment.

C.2.3.8 Space Heaters

C.2.3.8.1 Generator

(1) Generator shall be equipped with a means for heating which shall be adequate to maintain the internal temperature above the dew point when the equipment is idle.
(2) Space heaters shall be accessible for convenient inspection and replacement.
(3) Leads shall be brought out to a terminal block in a space heater conduit box.

C.2.3.8.2 Space Heater Voltages

Heater kw	Voltage
Below 2 kW	120V, single phase
2 kW and above	480V, three phase

C.2.4 Control, Surveillance And Protection System

C.2.4.1 General

A free-standing control panel enclosing excitation and voltage regulation equipment, control, surveillance, and protective systems and devices shall be designed and furnished. This unit will be installed in the GTG room and all interconnecting wiring to and from it from other points of control and surveillance will be furnished and installed. There shall be one control panel for each GTG unit.

(1) There will also be one control and surveillance station for each generator in the Main Control Room (MCR).

The GTGs are normaly set to automatic operation mode, and can be operated manually in MCR. Major condition signals of each GTG and associated buses are indicated and alerted in MCR. For an additional operation mode, when the GTG is paralleled with offsite source for load testing, the GTG breaker can be operated in only MCR.

(2) The control unit shall perform the following functions:

(a) Monitor and display all aspects of engine performance which would normally be required for attended or unattended operation of the unit, such as pressures, temperatures, speeds, loadings, voltage, frequency, etc. Unattended remote surveillance and operation will be from the MCR. The Seller's control shall be designed with sufficient terminal points to relay surveillance information to the MCR, and to permit complete remote operation of the unit.
(b) The modes of operation are as follows:
Automatic - In this mode the engine is started on ECCS actuation signal and/or Under Voltage (UV) signal.
Manual - In this mode the engine may be started locally or from the control room on a routine test basis, or in anticipation of accident conditions.

(3) A key operated "REMOTE-LOCAL " selector switch shall be incorporated in the local control panel to prevent starting the engine during maintenance or repair intervals. This locking device shall not override the engine barring device or other accessory equipment required for maintenance and repair. Wiring provision for remote indication of this condition shall also be made.

C.2.4.2 Protective Devices

(1) The protective devices designed to trip the GTG shall be limited to the following:

(a) Overspeed
(b) Generator differential current
(c) High EGT
(d) Failed to start
(e) Overcurrent
(f) Low pressure lube oil
(g) High temperature lube oil
(h) Anti motoring

These components are installed in the unit switchgear and are provided by others. The above devices will be bypassed during ECCS signal except for mechanical overspeed (1), generator differential current (2) and high EGT (3). The bypassed protective devices shall provide annunciation in any mode of operation.

(2) A GTG breaker trip is initiated by Items (a), (b), (c), (e), (f) and (g) with items (f), (g), (h), and (h) bypassed on ECCS signal.

An additional, operational only, trip of the GTG breaker assures isolation of the GTG on under frequency or ECCS signal if the GTG is paralleled with any of the offsite sources for load testing (i.e. with UAT or RAT breaker also closed).

C.2.4.3 Alarms

(1) Each alarm shall be locally signalled on an individual window of an annunciator located in the free standing control panel.

(2) The following alarm points shall be furnished.

Engine:
(a) Lubricating oil low pressure
(b) Lubricating oil high temperature
(c) Starting air low pressure
(d) Engine failure to start (after automatic attempt to start)
(e) Overspeed
(f) Low fuel oil day tank level
(g) High fuel oil day tank level
(h) High Fuel Oil Tank level
(i) Low Fuel Oil Tank level
(j) Governor Not Isochronous

Generator:
(a) Generator differential
(b) Overcurrent with voltage restraint, ground fault overcurrent (Inst.), reverse power**
(c) Loss of excitation**
(d) Stator high temperature
(e) Bearing high temperature
(f) Field ground fault

System status:
(a) Loss of control power supply
(b) Loss of 480V ac auxiliary power supply
(c) GTG automatic start
(d) GTG control-local
(e) Any fault or irregularity occurring during the standby (ready to start) and running modes shall be annunciated at the local annunciator. All conditions preventing the unit from starting shall be annunciated.

C.2.4.4 Manual Control

(1) The following manual controls shall be furnished:

(a) Start and stop switches for testing the Gas Turbine in the load test mode. Wiring provision for remote control shall also be made.
(b) An emergency stop switch is provided on gas turbine engine.
(c) Governor lower-off-raise selector switch wiring provisions for remote control shall be included.
(d) Voltage regulator selector switch with manual-auto positions and separate control switches for each regulator with lower-off-raise positions. These devices shall be wired to a terminal board for Purchaser's parallel remote devices.
(e) Field flashing and exciter shutdown pushbuttons.
(f) GTG and offsite power circuit breaker control switches with close-trip positions and provisions for wiring to remote switches.

C.2.4.5 Indicating Lights

(1) The following indicating lights shall be furnished and mounted on the local free standing control panel:

(a) GTG not ready for Auto Start-on; i.e., all systems necessary for automatic operation are normal when indicating light is off.
(b) Gas Turbine unit parallel with auxiliary power distribution system.
(c) GTG operating mode.
i) Emergency Start
ii) Remote Control
iii) Local Control
iv) Gas Turbine on maintenance
v) Voltage Regulator in Auto
vi) Voltage Regulator in Manual
(d) Circuit breaker position

(2) An independent initiating contact for duplicating the above indicating lights in the control room, except for (d) shall be furnished.

C.2.4.6 Instrumentation and Metering

The following is the partial list of instrumentation and metering to be furnished by the Seller. Certain instrumentation has been described in the specification and/or drawings under the various applicable systems and is not repeated here. The partial list provided here is a guide only and it is the responsibility of the seller to supply all instrumentation required for the safe, efficient and reliable operation of the GTG unit for automatic and manual operation.

(1) Kilowatt meter (0-1 MA transducer by others) with test provision*
(2) Ammeter and ammeter switch (three independent circuits with OFF position)*
(3) Voltmeter (0-1 MA transducer by others)
(4) Excitation amp transducer (with shunt) ammeter (with shunt)
(5) Excitation volt transducer and voltmeter*
(6) Frequency meter* (connected to transducer by others)
(7) Engine Exhaust Temperature Measuring System:
(8) Each engine shall be equipped with an exhaust temperature measuring system to measure the exhaust temperature leaving each engine.
(9) Kilovar meter (0-1 MA transducer by others) with test provision*

Terminal points shall be furnished for items marked with an asterisk (*) for connection to remote indicators.

C.2.5 Weights

The followings shall be furnished:

(1) Dry and operational weight and center of gravity of all assemblies and separate components.
(2) Foundation loadings for all equipment.
(3) Maximum weights of heaviest part for maintenance.

C.2.6 Welding

All structural welding shall be in accordance with AWS D1.1. All welders shall be qualified in accordance with ASME Section IX.

C.2.7 Cleaning

All equipment furnished shall be Grade C clean
Prior to shipment all equipment shall be given prime and finish coats of paint in accordance with manufacturer's standard procedure.
Corrosion resistant materials shall not be painted.

C.3.0 Quality Control

The requirements of MNES, "Quality Assurance Administrative and System Requirements (Nuclear)" and "Quality Assurance Administrative and System Requirements for Safety Related Electrical Equipment" apply to this specification in total, except where exempted by purchaser. The vendor shall certify in writing that all applicable codes, standards, and requirements of this specification are met.

C.4.0 Acceptance Tests

C.4.1 Acceptance Tests

C.4.1.1 Factory Test

Each GTG set shall be completely assembled in the plant. For the purpose of these tests a completely assembled engine-generator set shall consist of a Gas Turbine engine, governor, generator, exciter and voltage regulator, start air system plus all controls, auxiliaries and special equipment within the scope of this specification which determines the performance of the unit.

(1) Auxiliaries that do not affect the unit performance and are not mounted on the GTG skid may be other than those intended for use at the site of final installation.

(2) Break in runs shall be performed on each GTG set in accordance with the Seller's best procedure and practice.

(3) In addition to the manufacturer's standard tests, the following tests shall be performed on each unit prior to acceptance by the Purchaser.

(a) Reliability
Test results of a factory test consisting of 100 valid start & load tests on a prototype unit to demonstrate the ability of the GTGs to start, attain rated speed and voltage within 100 seconds and load to 50% of the continuous rating shall be submitted.
A valid start and load test is defined as a start with loading to at least 50% of the continuous rating within 100 seconds and continued operation until temperature equilibrium is obtained.
At least 90 of the starts shall be performed with the unit at warm standby conditions.
At least 10 of the starts shall be performed with the unit at normal operating temperatures.

Failure of the unit to successfully complete this series of tests will require further testing as well as a review of the System Design Adequacy.
The test as described above shall be performed on the first unit of the design

(b) Starting Test
Starting Test - A test consisting of 15 valid start and load test without failure, to demonstrate the capability to attain rated speed and voltage within 100 seconds and load to 50% of the continuous rating within 30 seconds. This test shall be performed in the same manner as described above. If a unit has been reliability tested, this test is omitted.

(c) Margin Test
To demonstrate the capability to accept the most severe load + 10% and to maintain voltage, speed, and frequency within limits specified in Subsection C.2.1.3. For this factory test, motor loads in combination with resistance loads shall be connected to the GTG to simulate the actual loading sequence indicated in Appendix A. This test shall be performed twice.

(d) Rated Load Test
To demonstrate the capability to carry the continuous rated load for 22 hours and to carry the 105% load rating (if applicable) for two hours. This test will be performed once.

(e) Load Rejection Test
To demonstrate the capability to reject the largest single load without exceeding the speed limits specified in Subsection C.2.1.3e). This test will be performed twice.

(f) Air Receiver Capacity and compressor test
Shall demonstrate that the air receivers are sized to provide a minimum of 3 successful unit starts. The air compressors pump up time for the air receivers will be confirmed during this test.

(g) Electrical Test
Shall demonstrate that the electrical properties of the generator, excitation system, voltage regulation system, engine governor system and the control and surveillance systems are acceptable for the intended application.

(h) Functional Test
To demonstrate the capability of the control, surveillance and protection systems to perform in accordance with the requirements.

(i) Overspeed Test
Shall demonstrate the ability of the independent overspeed governor to perform in accordance with the requirements.

(j) Additional Factory Tests
That are unrelated to proving the GTG for Purchaser's application, and that are not part of the manufacturers standard tests, shall not be performed on the units without written permission from the Purchaser.

(4) All the "Standard Factory Tests" both mechanical and electrical in written test procedures shall be listed and described.

(5) Test shall be arranged so that ac generator may be operated at the various loadings.

(6) All labor, fuel oil, lube oil, test equipment any other necessary supplies and load for the test shall be furnished.

C.4.2 Field Tests

(1) For the purpose of field tests all systems and auxiliaries shall be complete and all plant services shall be available. Tests shall be performed in accordance with IEEE Std 387-1995.

(2) All deficiencies shall be corrected.

(3) Special tools, equipment and instruments required for the test shall be furnished.

(4) During these tests the designated operating personnel in the operation, care and maintenance of the equipment shall be instructed.

(5) Load, fuel, initial lube oil and supplies will be furnished by the Purchaser for these tests.

C.4.3 Performance of Tests

(1) Tests shall be performed in accordance with the procedures in the documents listed in Section 2.0.

(2) Instruments used to measure and record tested variables and quantities shall be those which have been regularly and recently calibrated, using appropriate standards traceable to the National Bureau of Standards.

(a) Records of such calibration shall be available for inspection.
(b) In the event that test instruments used for performance testing specified in Section C.4.0, have not been calibrated within the six month period preceding testing, they shall be calibrated immediately before and after the testing.
(c) Purchaser reserves the right to compare such calibrations and reject results of testing if deviations in the calibrations are excessive, in his opinion.

C.4.4 Repair and Retesting

(1) If the various components or the assembled complete assembly fittings, auxiliary equipment and accessories fail to pass the tests specified, additional tests shall be made to locate the failure.

(2) After rework or repair of the failure, and subject work is inspected and accepted by Quality Control, the specified tests shall be repeated to insure that the reworked or repaired equipment will meet the Specification in all respects.

(3) A record of all failures detected during tests, rework or repair required, inspection reports and test data taken after rework or repairs have been completed shall be kept.

(4) Rework or repairs shall be made in accordance with an approved procedure signed by that party responsible to give in-process disposition of such rework or repairs.

C.4.5 Test Reports

Certified test reports shall be furnished for all tests in Section C.4.0 of this Specification.

C.4.6 Records and Documentation

All documents and test results called for in this specification as well as in the referenced documents shall be available for review prior to shipment of the equipment.
All material certification, code data forms, QA check lists, non destructive examination results etc. shall be available for review prior to shipment of the equipment.

Appendix D Gas Turbine Generator Failure Mode and Event Analysis

Reliability analysis is shown in Table D.1.0-1

Table D.1.0-1 FMEA of Starting Reliability for GTG Set

Appendix E I&C SYSTEM OF GAS TURBINE GENERATOR

E.1.0 Overall

The GTG is automatically started by ECCS and LOOP signals from ESFAS, and manually started and stopped by signals from the Main Control Room (MCR), the Remote Shutdown Room, and the GT Local Control Board. Stable operation of the GTG is maintained due to governor control by rotation speed. Also, an operation condition of the GTG is monitoring, and the necessary information for an operator is transmitted to the MCR. An emergency stop function of the GTG is also provided by protective signals.

The above GTG functions are provided from the following I&C system.

Safety VDU, Operational VDU and related equipment
- Manual GTG start/stop operation by operator
- Monitoring of GTG operating conditions (major parameters and typical alerts) by operator

ESF Actuation System (ESFAS)
- Generation of ECCS signal, LOOP signal

Safety Logic System (SLS) for GTG (GTG -SLS)
- Control circuit of incoming breaker to class 1E bus
- Monitoring of incoming breaker condition
- Control circuit (On-Off control) of component related to gas turbine start/stop operation
- Control circuit (continuous control) of component related to gas turbine continuous control
- Operation monitoring of gas turbine
- Generation of alert/interlock signals

Gas Turbine Local Control Board
- Manual GTG start/stop operation for maintenance
- Individual start/stop operation of related GTG components for maintenance
- Monitoring of GTG and related component parameters for maintenance

The overall configuration of the GTG I&C system is shown in Figure E.1.0-1.

E.2.0 System Description

The following systems are common to other I&C systems, and are described in the already submitted Topical Report (Safety I&C System description and Design: MUAP-07004), and detail descriptions refer to this TR.
- Safety VDU, Operational VDU and related equipment
- ESFAS

The GTG-SLS and the gas turbine local control board, which are I&C facilities unique to the GTG, are described here in detail.

E.2.1 GTG-SLS (One sub-group of SLS for GTG control and monitoring functions)

One group of the GTG-SLS for each GTG (4 sets in total) is installed in the safety I&C room.

These GTG-SLSs are classified into Class 1E according to their safety functions. The same digital platform (MELTAC) as for the safety I&C is applied. The following description applies to each GTG-SLS.

The GTG-SLS receives automatic start signals (ECCS, LOOP) from the ESFAS which is classified into the same train, and manual signals from the safety VDU or the operational VDU in the MCR, via a safety bus. Also, the controller receives the manual GTG start/stop signals and start/stop signals of individual components from the gas turbine local control board. When the controller receives automatic or manual signals, actual signals are transmitted to the related components (compressor air supply valve, fuel outlet valve, fuel pump etc.) of the GTG.

All parameters, alarms and component status that indicate GTG inoperability or inadequate safety performance can be monitored in the MCR. Other detail information and alarms for maintenance personnel (ie. conditions that indicate the need for preventative maintenance, but are not immediately critical to operations) are provided on the gas turbine local control board. Maintenance information will be used primarily by maintenance personnel, but should also be accessible to operators. Operators should also be informed of maintenance conditions via low priority summary alarms.

The GTG is stopped when equipment protective signals are received from the GTG monitoring functions. However, if the GTG is started by the ECCS or LOOP signal, the start signal has high priority and blocks the GTG protective signals which are initiated by several equipment protective circuits. But, the following equipment protection functions have high priority and the GTG is stopped by the following signals even when the ECCS or LOOP signal is initiated and so the GTG is automatically started, since the following equipment protective signals are suspected to cause catastrophic fault of the GTG.

- Generator Differential Current
- Mechanical Overspeed
- High Exhaust Temperature

The GTG-SLS performs the following functions which require high speed calculation.

- Governor control
- Detection of rotation speed

The GTG-SLS is a digital system, and almost all functions are provided by software logics, so the integrity of these software logics is continuously tested by self-diagnostic functions. Other functions including I/O units that are not checked by the self-diagnostic functions are confirmed of its integrity by the GTG actual operational test which is conducted once a month.

To enhance reliability, each train GTG-SLS consists of a duplex architecture using dual redundant CPUs. The GTG is controlled by the main CPU and automatically switches to the stand-by CPU if the main CPU fails. This architecture can provide continuous operation of the GTG even in the case of single failure.

The MELTAC Platform is applied to the GTG-SLS. The hardware (CPU module, Input/Output module, etc) of the MELTAC conforms to various requirements (seismic qualification, electromagnetic compatibility, etc), which is required for the Class 1E system.
The basic software of the MELTAC conforms to various requirements (single task processing, uninterruptible processing) which realize deterministic processing that assures response time, which is required to the Class 1E system.

The application software reliability of the GTG-SLS is assured by the independent Verification and Validation (V&V) process at each design stage. The application software is automatically produced from the visible composite block diagrams which are made by the I&C engineer by utilizing a special engineering tool so that factors of human error are further decreased.

Detail descriptions of the duplex architecture, hardware/software specification, application software V&V process and software life cycle process of the MELTAC Platform are described in the Topical Report (Safety System Digital Platform MELTAC MUAP-07005).

E.2.2 Gas turbine local control board

One set of the local control board for each GTG (4 sets in total) is installed in the each GTG room. The GTG can be manually started under maintenance. A maintenance GTG bypass switch is installed to prevent the manual start signal initiated from the MCR. A GTG start switch, operation switches of individual components, and various indicator and detail alarms are provided in the gas turbine local control board. Also, sensing units to monitor the detailed inner status of the GTG for maintenance purposes are provided.

The GTG bypass switch for maintenance is classified into class 1E, because it has a bypass function of the safety protective function. While it is selecting the bypass position, manual or automatic start functions of the GTG from the PSMS are disabled.
The bypass status of the GTG is displayed continuously in the MCR, in accordance with RG 1.47 Bypassed or Inoperable Status.

The emergency start switch classified into class 1E is provided to override the bypass condition in case that emergency start is needed during bypass for maintenance. Other functions are classified into the non-Class 1E because they have no safety functions. Operation signals (including the GTG start signal) from the gas turbine local control board maintains its function even while the above mentioned maintenance of the GTG bypass switch is under selection of bypass.

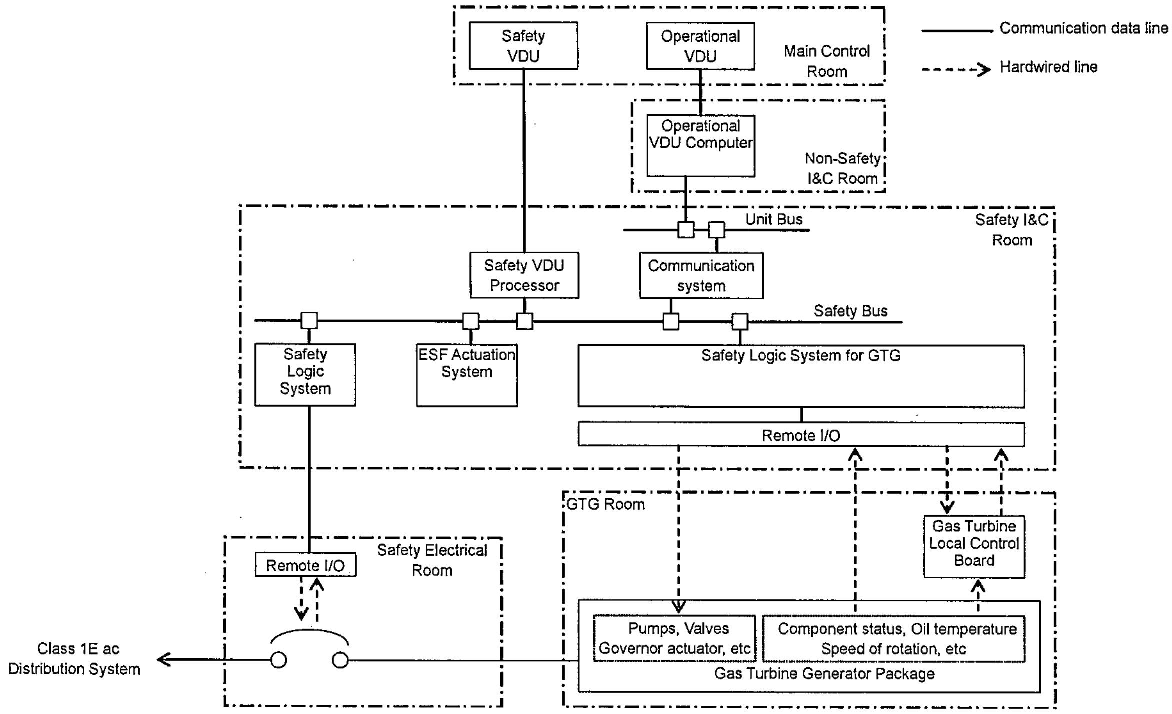
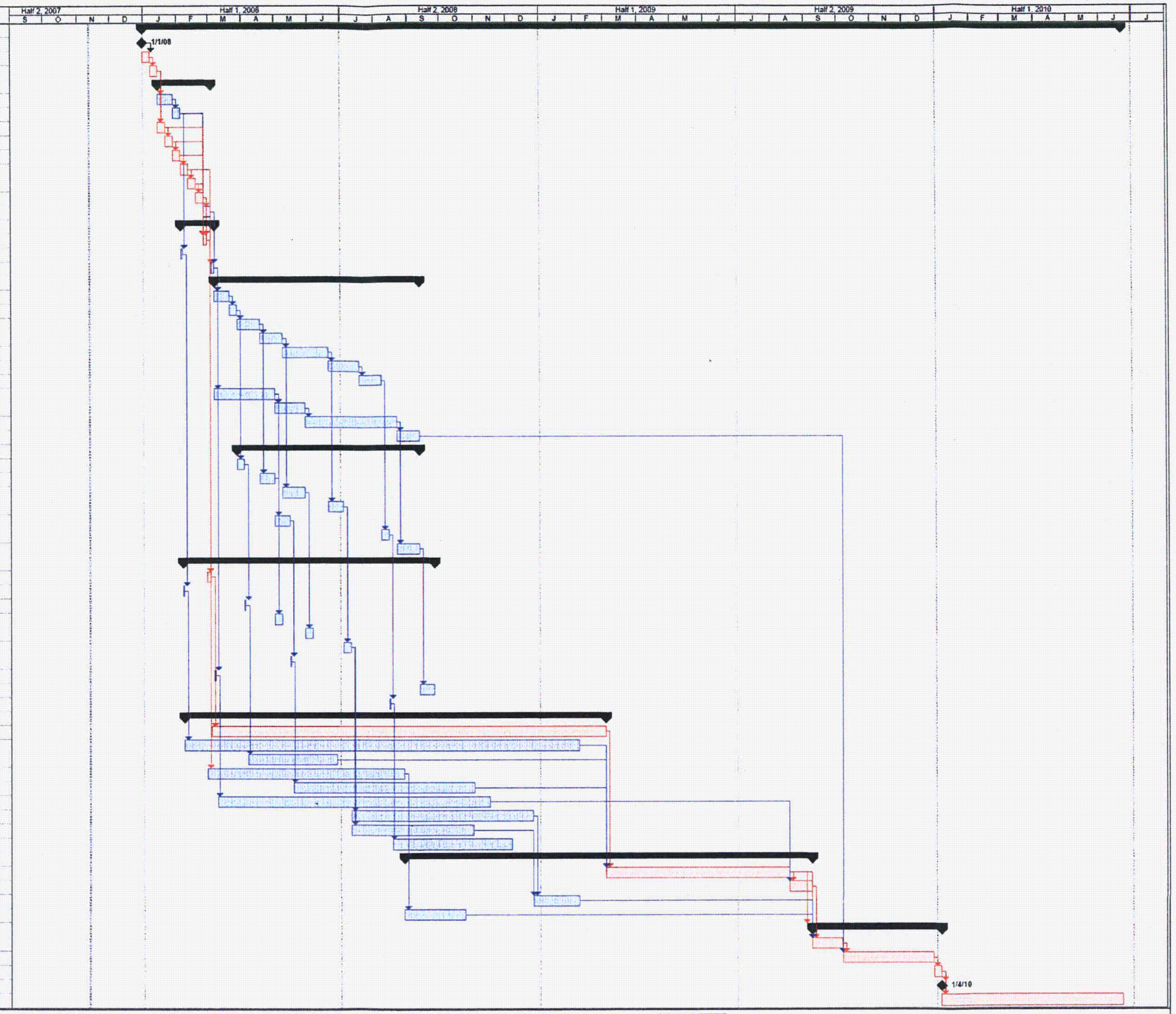


Figure E.1.0-1. Overall configuration of GTG I&C

Appendix F Production Schedule

Basic schedule of production and class 1E qualification as shown in Fig. F.1.0-1 and F.1.0-2

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Mitsubishi Combustion Turbine Generator**	**129 wks**	**1/1/08**	**6/21/10**	
2	Receive PO	0 days	1/1/08	1/1/08	
3	Accept PO	1 wk	1/1/08	1/7/08	2
4	Review Specifications	1 wk	1/8/08	1/14/08	3
5	**Engineering Preliminary Design / Drafting**	**7 wks**	**1/15/08**	**3/3/08**	
6	General Arrangement	2 wks	1/15/08	1/28/08	4
7	Driveline (gearbox, coupling, generator)	1 wk	1/29/08	2/4/08	6
8	Lubricating Oil System	1 wk	1/15/08	1/21/08	4
9	Fuel Oil System	1 wk	1/22/08	1/28/08	8
10	Air Start System	1 wk	1/29/08	2/4/08	9
11	Combustion & Ventilation Air System	1 wk	2/5/08	2/11/08	10
12	Exhaust System	1 wk	2/12/08	2/18/08	11
13	Skid	1 wk	2/19/08	2/25/08	12
14	Enclosure	1 wk	2/26/08	3/3/08	13
15	**Purchase Specs / Material Quotes**	**4.6 wks**	**2/5/08**	**3/6/08**	
16	Purchase Spec / RFQ Turbine & Gearbox	3 days	2/26/08	2/28/08	7,8,9,10,11,12,13
17	Purchase Spec / RFQ Generator	2 days	2/5/08	2/6/08	7
18	Purchase Spec / RFQ Enclosure & Ventilation	3 days	3/4/08	3/6/08	11,14
19	**Engineering Detail Design / Drafting**	**27 wks**	**3/7/08**	**9/11/08**	
20	General Arrangement	2 wks	3/7/08	3/20/08	18
21	Driveline (gearbox, coupling, generator)	1 wk	3/21/08	3/27/08	20
22	Lubricating Oil System	3 wks	3/28/08	4/17/08	21
23	Fuel Oil System	3 wks	4/18/08	5/8/08	22
24	Air Start System	6 wks	5/9/08	6/19/08	23
25	Combustion & Ventilation Air System	4 wks	6/20/08	7/17/08	24
26	Exhaust System	3 wks	7/18/08	8/7/08	25
27	Skid	8 wks	3/7/08	5/1/08	18
28	Enclosure	4 wks	5/2/08	5/29/08	27
29	Integrated Control System	12 wks	5/30/08	8/21/08	28
30	Engineering Procedures	3 wks	8/22/08	9/11/08	29
31	**Purchase Requisitions**	**24 wks**	**3/28/08**	**9/11/08**	
32	RFQ Coupling	1 wk	3/28/08	4/3/08	21
33	RFQ L.O. Components	2 wks	4/18/08	5/1/08	22
34	RFQ F.O. Components	3 wks	5/9/08	5/29/08	23
35	RFQ Air Start Components	2 wks	6/20/08	7/3/08	24
36	RFQ Skid	2 wks	5/2/08	5/15/08	27
37	RFQ Exhaust Silencer	1 wk	8/8/08	8/14/08	26
38	Engine Control Panel Components	3 wks	8/22/08	9/11/08	29
39	**Place Purchase Orders**	**33.2 wks**	**2/7/08**	**9/25/08**	
40	Turbine/gearbox	2 days	2/29/08	3/3/08	16
41	Generator	1 day	2/7/08	2/7/08	17
42	Coupling	1 day	4/4/08	4/4/08	32
43	L.O. System	1 wk	5/2/08	5/8/08	33
44	F.O. System	1 wk	5/30/08	6/5/08	34
45	Air Start System	1 wk	7/4/08	7/10/08	35
46	Skid	1 day	5/16/08	5/16/08	36
47	Enclosure	1 day	3/7/08	3/7/08	18
48	Control Panel Components	2 wks	9/12/08	9/25/08	38
49	Exhaust Silencer	1 day	8/15/08	8/15/08	37
50	**Vendor Production**	**55.4 wks**	**2/8/08**	**3/2/09**	
51	Turbine / Gearbox - Kawasaki	52 wks	3/4/08	3/2/09	40
52	Generator	52 wks	2/8/08	2/5/09	41
53	Coupling	3 mons	4/7/08	6/27/08	42
54	Controls - Kawasaki	26 wks	2/29/08	8/28/08	16
55	Skid	120 days	5/19/08	10/31/08	46
56	Enclosure	36 wks	3/10/08	11/14/08	47
57	Air Receivers	6 mons	7/11/08	12/25/08	45
58	Air Compressors	4 mons	7/11/08	10/30/08	45
59	Exhaust Silencer	4 mons	8/18/08	12/5/08	49
60	**ESI Production**	**53.4 wks**	**8/29/08**	**9/7/09**	
61	Assemble Genset (less Enclosure)	120 days	3/3/09	8/17/09	51,52,55,53
62	Install Enclosure	3 wks	8/18/09	9/7/09	61,56
63	Fabricate Air System Piping / Skid	6 wks	12/26/08	2/5/09	57,58
64	Integrated Control Panel	8 wks	8/29/08	10/23/08	54
65	**Test**	**17 wks**	**9/8/09**	**1/4/10**	61
66	Test Setup	1 mon	9/8/09	10/5/09	62,63,64,61
67	Test Genset	3 mons	10/6/09	12/28/09	66,30
68	Prepare for Shipment	1 wk	12/29/09	1/4/10	67
69	Delivery	0 wks	1/4/10	1/4/10	68
70	Project Closeout	6 mons	1/5/10	6/21/10	68



Project: Mitsubishi Combustion Turbine
Date: 11/12/07

Legend: Task; Critical Task; Progress; Milestone; Summary; Rolled Up Task; Rolled Up Critical Task; Rolled Up Milestone; Rolled Up Progress; Split; External Tasks; Project Summary; Group By Summary; Deadline

Page 1

Figure F.1.0-1 Generator and Class 1E Qualification

	1 Month	2 Month	3 Month	4 Month	5 Month	6 Month	7 Month	8 Month	9 Month	10 Month	11 Month	12 Month	13 Month
1. Purchasing Material, Manufacturing													
2. Assembling													
3. Factory Inspection and Test													
4.Transportation													

Note : After detail specifications are decided, purchasing is be started.

Figure F.1.0-2 Gas Turbine Engine

Appendix G Conformance to Regulatory Guide 1.9 Rev. 4

Table G.1.0-1 shows US-APWR GTG conformance to RG 1.9.

Table G.1.0-1 Conformance of US-APWR GTG to RG 1.9

Regulatory Guide 1.9	US-APWR
1.1 Clause 1.1.1, "Inclusions," of IEEE Std 387-1995 should be supplemented to include diesel generator auto controls, manual controls, and diesel generator output breaker.	This requirement is out of scope of this document.
1.2 When the characteristics of the required emergency diesel generator loads are not accurately known, such as during an early stage of design, each emergency diesel generator selected for an onsite power supply system should have a continuous load rating (as defined in Section 3.2 of IEEE Std 387-1995) equal to the sum of the conservatively estimated connected loads (nameplate rating) that the diesel generator would power at any one time, plus a 10- to 15-percent margin. In the absence of fully substantiated performance characteristics for mechanical equipment such as pumps, the electric motor drive ratings should be calculated using conservative estimates of these characteristics (e.g., pump runout conditions and motor efficiencies of 90 percent or less, and power factors of 85 percent or less).	Loading is addressed in item 1.3 below.
1.3 During the operating license or combined license stages of review, the maximum design-basis loads should be within the continuous rating (as defined in Section 3.2 of IEEE Std 387-1995) of the diesel generator with sufficient margin (i.e., not less than 5 percent).	US-APWR GTG complies with this requirement. The station maximum design-basis loads are known accurately (par. 1.3 Reg Guide 1.9 Rev. 4). However, the equipment was not yet specified and/or purchased. As a result for conservatism the loads are estimated and calculated per par. 1.2 Reg Guide 1.9 Rev. 4 (e.g., pump runout conditions and motor efficiencies of 90 percent or less, and power factors of 85 percent or less). Worse case loading channel B & C loading is 4198kW or 4236kW at higher frequency. Therefore there is about 6% load margin, acceptable per par. 1.3 Reg Guide 1.9 Rev. 4.

Regulatory Guide 1.9	US-APWR
1.4 Clause 4.1.2 of IEEE Std 387-1995 pertains, in part, to the starting and load-accepting capabilities of the diesel generator. In conformance with Clause 4.1.2, each diesel generator should be capable of starting and accelerating to rated speed, in the required sequence, all the needed engineered safety features and emergency shutdown loads. The diesel generator should be designed such that the frequency will not decrease, at any time during the loading sequence, to less than 95 percent of nominal and the voltage will not decrease to less than 75 percent of nominal. (A larger decrease in voltage and frequency may be justified for a diesel generator that carries only one large connected load.) Frequency should be restored to within 2 percent of nominal in less than 60 percent of each load-sequence interval for a stepload increase, and less than 80 percent of each load-sequence interval for disconnection of the single largest load. Voltage should be restored to within 10 percent of nominal within 60 percent of each load-sequence interval. The acceptance value of the frequency and voltage should be based on plant-specific analysis (where conservative values of voltage and frequency are measured) to prevent load interruption. (A greater percentage of the load-sequence interval may be used if it can be justified by analysis. However, the load-sequence interval should include sufficient margin for the accuracy and repeatability of the load-sequence timer.) During recovery from transients caused by disconnection of the largest single load, the speed of the diesel generator should not exceed the nominal speed plus 75 percent of the difference between nominal speed and the overspeed trip set point, or 115 percent of nominal (whichever is lower). Furthermore, the transient following a complete loss of load should not cause the diesel generator speed to reach the overspeed trip set point.	US – APWR GTG complies with this requirement as far as the voltage is concerned. The frequency variation of the Gas Turbine at rated load is within +/- 0.3%. Based on the available operating experience provisions are provided in the loading calculation to account for operation at higher frequency, (e.g 0.3%).
1.5 Emergency diesel generators should be designed so that they can be tested as described in Regulatory Position 2. The design should allow testing of the diesel generators to simulate the parameters of operation (e.g.,	US-APWR GTG fully complies with the testing requirements listed and these tested will be performed as part of the Class 1E qualification process. The GTG do not require jacket water cooling.

Regulatory Guide 1.9	US-APWR
manual start, automatic start, load sequencing, load shedding, operation time), normal standby conditions, and environments (e.g., temperature, humidity) that would be expected if actual demand were placed on the system. If prelubrication systems or prewarming systems designed to maintain lube oil and jacket water cooling at certain temperatures (or both) are normally in operation, this would constitute normal standby conditions for the given plant.	
1.6 Design provisions should include the capability to test each emergency diesel generator independently of the redundant units. Test equipment should not cause a loss of independence between redundant diesel generators or between diesel generator load groups. Testability should be considered in selecting and locating instrumentation sensors and critical components (e.g., governor, starting system components). Instrumentation sensors should be readily accessible and designed so that their inspection and calibration can be verified in place. The overall design should include status indication and alarm features.	US-APWR GTG fully complies with this requirement.
1.7 Clause 4.5.3.1 of IEEE Std 387-1995 pertains to status indication of diesel generator unit conditions. The following paragraphs should supplement the guidance in this clause: 1.7.1 A surveillance system should be provided with a remote indication in the control room to display emergency diesel generator status (i.e., under test, ready-standby, lockout). A means of communication should also be provided between diesel generator testing locations and the main control room to ensure that the operators know the status of the diesel generator under test. 1.7.2 To facilitate the diagnosis of failure or malfunction, the surveillance system should indicate which of the emergency diesel generator protective trips has been activated first.	US-APWR GTG fully complies with this requirement.

Regulatory Guide 1.9	US-APWR
1.8 The following should supplement Clause 4.5.4 of IEEE Std 387-1995, which pertains to bypassing emergency diesel generator protective trips during emergency conditions: The emergency diesel generator should be tripped automatically on engine overspeed and generator-differential overcurrent. A trip should be implemented with two or more measurements for each trip parameter with coincident logic provisions for trip actuation. The design of the coincident logic trip circuitry should include the capability to indicate individual sensor trips. The design of the bypass circuitry should include the capability to (1) test the status and operability of the bypass circuits, (2) trigger alarms in the control room for abnormal values of all bypass parameters (common trouble alarms may be used), and (3) manually reset the trip bypass function. The capability to automatically reset the bypass function is not acceptable. Clause 4.5.4(b) of IEEE Std 387-1995, which pertains to retaining all protective devices during emergency diesel generator testing, does not apply to periodic tests [safety injection actuation system (SIAS), combined with SIAS and LOOP, and protective trip bypass] that demonstrate diesel generator system response under simulated design-basis events.	US-APWR GTG fully complies with this requirement except for exhaust temperature which will trip the unit without being by passed in accident situation.
1.9 Clause 4.5.2.2 of IEEE Std 387-1995 should be modified to read as follows: Upon receipt of an emergency start-diesel signal, the automatic control system shall provide automatic startup and automatic adjustment of speed and voltage to a ready-to-load condition in the emergency (isochronous) mode.	US-APWR GTG fully complies with this requirements