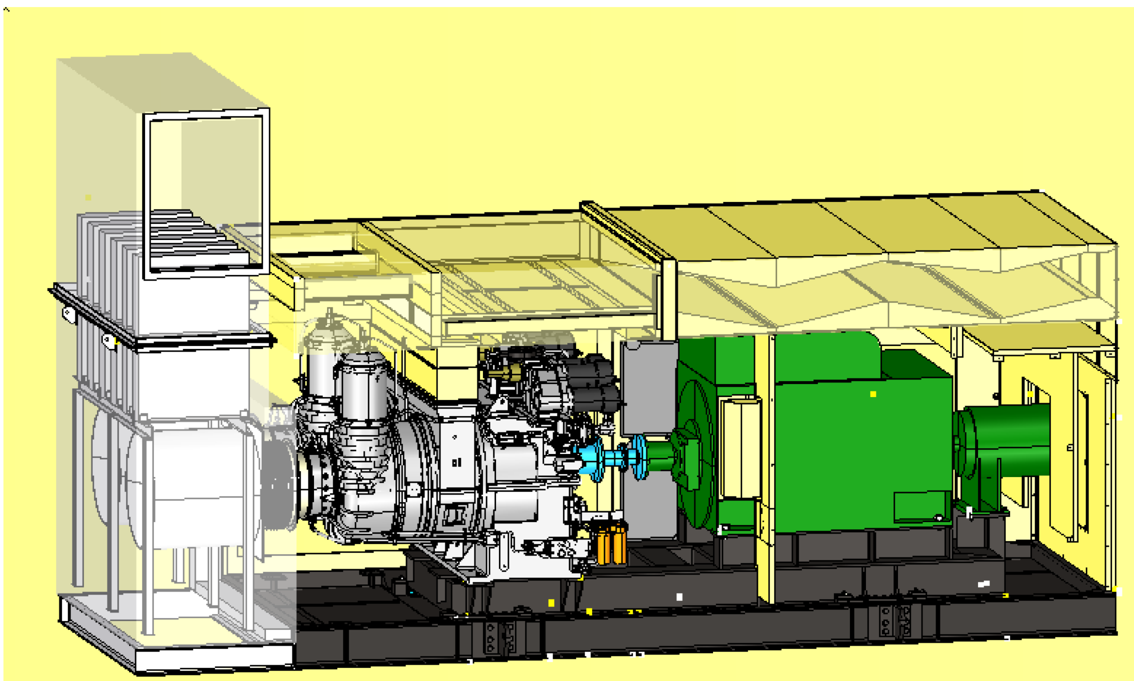
Initial Type Test Result of Class 1E Gas Turbine Generator System



Non Proprietary Version

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Revision History

Revision	Page	Description
0	All	Original issued
1	6-2	Added unit of parameters of Tables 6.2-1 and 6.2-2
	6-3	Added unit of parameters of Table 6.2-3.
	6-4	Added unit of parameters of Tables 6.3-1 and 6.3-2.
	7-1	Added title of Section 7.1 Added Section 7.2.
	7-2	Added Section 7.3.
	Appendix E-1 – E-8	Added Appendix E (Sections E.1.0 – E.3.0)
	Appendix F-1 – F-6	Added Appendix F (Sections F.1.0 – F.4.0)
2	2-1―2-3	Added title of list of standards and regulations
	4-1	Changed number of Figure for reference
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	5-3―5-4	Changed name of Table 5.3-1, 5.3-2, 5.3-3 and 5.3-4
	6-2	Changed number from Section 6.2.3 to 6.2.4
	6-2	Revised parameter of Tables 6.2-1 and 6.2-2
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2	6-4	Added description of Section 6.3.3 for clarification
	6-4	Revised Section 6.3.4
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	Appendix B-17－B-37	Changed number of Figures (Figure B.1.0-5－B.1.0-12)
	Appendix B-19－B-22	Changed Figures B.1.0-6 (Sheet1－4)
	Appendix B-29－B-32	Changed name of Figures B.1.0-10 from “Configuration” to “Drawing”
	Appendix B-31－B-32	Added Figure B.1.0-10 (Sheet3－4)
	Appendix B-33	Changed name of Figure from “Drawing of Inlet Air / Exhaust System” to “Drawing of Intake / Exhaust Air System”
	Appendix B-35－B37	Added Figure B.1.0-12 (Sheet2－4)
	Appendix C-2－C-156	Added Figure C.1.0-1－C.1.0-156.
	Appendix C-158－C-159	Added Figure C.1.0-157

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2	Appendix C-160－C-161	Added Figure C.1.0-158
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	Appendix G-1	Added Appendix G
	Appendix H-1 – H-220	Added Appendix H
	Appendix I-1 – I-28	Added Appendix I
	Appendix J-1 – J-28	Added Appendix J
3	Appendix B-13	Deleted Figure B1.0-4 (Sheet2)
4	-	Minor editorial changes to Abstract and minor typographical corrections in various sections
	5-4	Added Section 5.3.7 and Table 5.3-5
	6-1 – 6-5	Revised Section 6.0
	8-2	Deleted Table 8.2.1 and removed to Table 5.3-5
	Appendix B-27	Revised Figure B.1.0-9

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4	Appendix D-56 – D-57	Added Table D.2.0-1 and Table D.2.0-2
	Appendix E-2	Minor editorial clarification
	Appendix E-5	Revised Table E.2.0-1
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	Appendix K-1	Added Appendix K
	Appendix L-1	Added Appendix L
5	6-3	Minor editorial clarification
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	Appendix L-3	Added Section L.3.0

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Abstract

This technical report describes the summary of result of initial type test and seismic test of Class 1E Gas Turbine Generator (GTG) unit of US-APWR.
MHI has performed initial type test required in IEEE Std 387-1995 as part of Class 1E qualification program of Class 1E GTG units of US-APWR.
This report documents and concludes that the GTG passed the initial type test required and verified the acceptability for use for Class 1E emergency power units.
MHI also has performed seismic testing for a part of the GTG components as defined in IEEE Std 344 as part of Class 1E qualification program of Class 1E GTG units of US-APWR. This report documents that specific GTG components are successfully qualified by the seismic test.

This technical report describes the following:

Scope of qualification
Specification of components tested
Procedures, acceptance criteria and test conditions of tests
Summary of results
Considerations

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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
EUT	Equipment Under Test
FMEA	Failure Modes and Effects Analysis
FOA	Fuel, Oil and Air
GTG	Gas Turbine Generator
ISRS	In – Structure Response Spectra
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
OBE	Operating–Basis Earthquake
QA	Quality Assurance
RRS	Required Response Spectra
RTD	Resistance Temperature Detector
SSC	Structures, Systems and Components
SSE	Safe-Shutdown Earthquake
SLS	Safety Logic System
TRS	Test Response Spectra
UV	Under Voltage
VDU	Visual Display System
VT	Voltage Transformer

1.0 INTRODUCTION/OVERVIEW

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

Since GTG has not been applied for Class 1E Emergency Power Sources (EPSs) of nuclear power plants in US, there is no regulatory requirement for Class 1E GTG. MHI decided to perform the Class 1E qualification in accordance with IEEE Std 387 endorsed by R.G1.9. MHI performed Initial Type Test of US-APWR's GTG system required in IEEE Std 387. NRC has issued Interim Staff Guidance ISG-21 which is requirement about design and qualification of Class 1E GTG. ISG-21 seems to be regulatory guideline in future. MHI also reflects the requirement of ISG-21 in qualification. This report describes and concludes the result of initial type test of GTG.

Initial type test consists of three kinds of test, “Load capability test”, “Start and load acceptance test” and “margin test”. MHI performed all the three tests and this report summarizes those test results. Also, MHI performed the seismic qualification Test in accordance with IEEE Std 344 endorsed by R.G.1.100.

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. Criteria for Independence of Electrical Safety 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) Regulatory Guide, 1.100, Rev. 3, Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants.
(11) NUREG/CR-6928, Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power plant, February 2007
(12) NRC Information Notice 2006-22 New Ultra-low-sulfur Diesel Fuel Oil Could Adversely Impact Diesel Engine Performance
(13) 40CFR 50 NATIONAL PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS
(14) 40CFR 50 Earthquake Engineering Criteria for Nuclear Power Plants, Domestic Licensing of Production and Utilization Facilities, Energy.
(15) 40CFR 52 APPROVAL AND PROMULGATION OF IMPLEMENTATION PLANS
(16) 40CFR 60 STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES
(17) 40CFR 61 NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS
(18) 40CFR 63 NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS FOR SOURCE CATEGORIES
(19) 40CFR 68 CHEMICAL ACCIDENT PREVENTION PROVISIONS
(20) 40CFR 70 STAGE OPERATING PERMIT PROGRAMS
(21) 40CFR 71 FEDERAL OPERATING PERMIT PRGRAMS
(22) 40CFR 81 DESIGNATION OF AREAS FOR AIR QUALITY PLANING PURPOSES
(23) DC/COL-ISG-021, Interim Staff Guidance on the Review of Nuclear Power Plant Designs using a Gas Turbine Driven Standby Emergency Alternating Current Power System

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 142-2007, 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 338-2006 – 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 384-2008 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 429-1994, 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-493-2007, Recommended Practice for the Design of Reliable Industrial and Commercial Power System
(20) 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
(21) IEEE-603-1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations
(22) 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-1-2008 Quality Assurance Requirements for Nuclear Facility Applicants
(4) ANSI B31.1-2007 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 for Relays and Relay Systems Associated with Electric Power Apparatus
(7) ANSI C37-101-2006 IEEE Guide for Generator Ground Protection
(8) ANSI C37.102-2006 IEEE Guide for AC Generator Protection
(9) ANSI C50.13-2005 IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above
(10) ANSI C50.14-1977 American National Standard Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators
(11) ANSI C57.13-1993 IEEE Standard Requirements for Instrument Transformers (if needed)
(12) 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.
(13) ANSI/ASME B16.11-2009, Forged Fittings, Socket Welding and Threaded.
(14) ANSI/ASME B16.25-2007, Butt welding Ends.
(15) ASME Code, Section III, Class 1, 2, ad 3, Components and Core Support Structures, American Society of Mechanical Engineers, 2001 Edition thru 2003 Addenda.
(16) ANSI/ANS-59.51-1997, Fuel Oil Systems for Standby Diesel Generators
(17) ASTM D975-1981, Standard Specification for Diesel Fuel Oils
(18) ANSI/NFPA 37-2006, Combustion Engines and Gas Turbines, Stationary
(19) ASME Boiler and Pressure Vessel Code
(20) Standard Practices for Low and Medium Seed Stationary Diesel and Gas Engines, 6th Edition, p. 94, Diesel Engine Manufacturers Association (DEMA), 1972
(21) TEMA Standards of the Tubular Exchanger Manufacturers Association, 9th Edition
(22) ICEA S-19-81 (NEMA WC3) Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
(23) ICEA S-66-524 Cross-linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
(24) ICEA S-68-516 (NEMA WCB) Ethylene-Propylene-Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.
(25) NFPA Vol. 1 Flammable Liquids - Tank Storage
(26) NFPA No. 30 Flammable and Combustible Liquids Code
(27) NFPA No. 37 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
(28) Boiler and Pressure Vessel Code. Section iii, Division 1, Nuclear Power Plant Components, ASME, 2001 Edition including Addenda through 2003.

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 SCOPE

4.1 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.

IEEE Std 387 defines the boundaries of systems and equipment included its scope. Although there is no regulatory requirement for Class 1E GTG system, MHI decided the scope of systems and equipment to be tested in Class 1E GTG qualification same with IEEE Std 387 shown in Figure 4.0-1. MHI manufactured prototype system based on Figure 4.0-1 and tested.

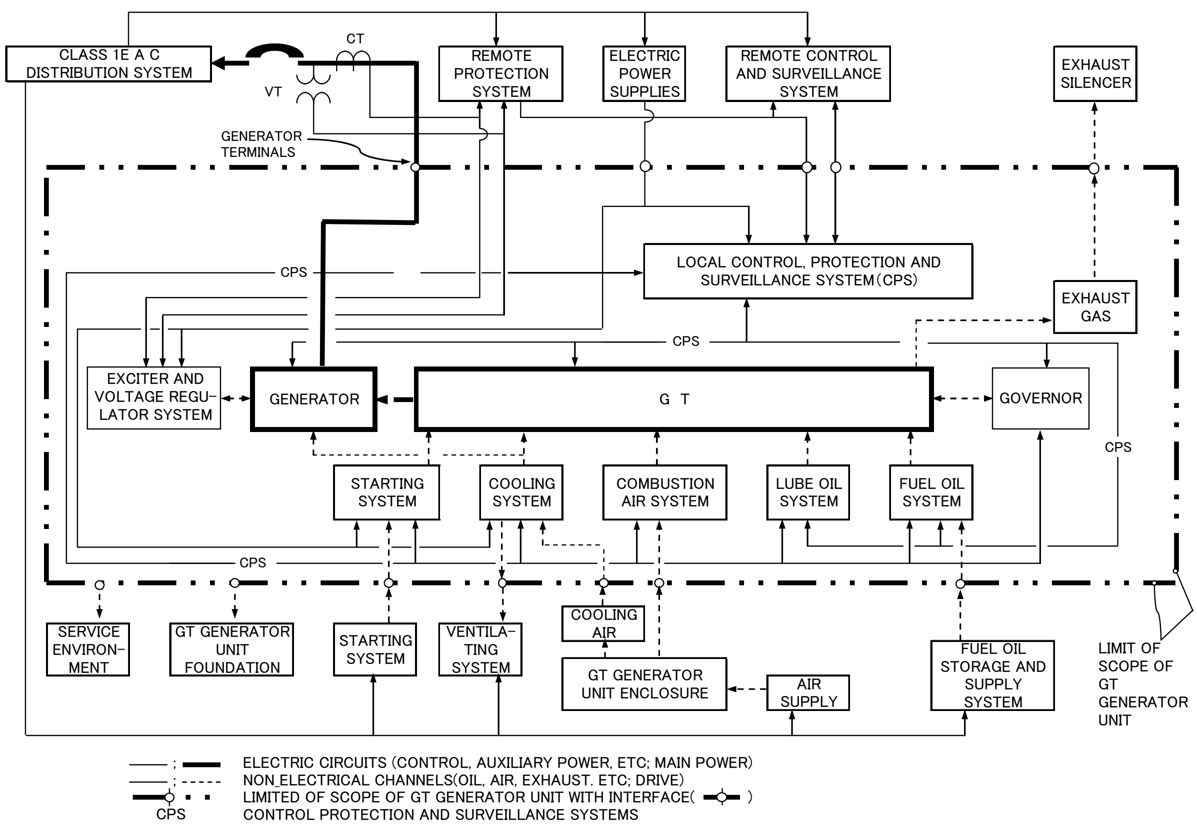


Figure 4.0-1 Scope Diagram

4.2 Prototype System Tested

Table 4.0-1 shows the list of systems, components and equipment of prototype system to be performed initial type test.

Systems or components of prototype GTG system inside the broken line in the previous figure were designed and manufactured in the same design conditions as actual plant system. The other systems or components outside the line are temporary and commercial and only supplied for these tests.

Table 4.0-1 Design Condition of Prototype GTG System

Component	Condition
Gas Turbine Engine With gearbox	Same with actual plant design
Generator	Same with actual plant design
Generator Bearing Lubrication Oil Unit	Same with actual plant design
Lube Oil Cooler Fan Assembly	Same with actual plant design
Enclosure	Same with actual plant design
Skid	Same with actual plant design
Fuel day tank	Same with actual plant design
Starting air receiver	Same with actual plant design
Air start valve unit	Same with actual plant design
Air intake/ exhaust air duct	Temporary equipment for test
Local control cabinet	Same with actual plant design
Plant control cabinet	Temporary equipment for test
Power supply	Temporary equipment for test
Fuel storage and transfer system	Temporary equipment for test
Starting air compressor	Temporary equipment for test

5.0 PROTOTYPE SYSTEM

5.1 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. Also GTG system should be designed in accordance with IEEE Std 387.

5.2 System Specification

5.2.1 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) US-APWR GTG is reached set voltage and frequency within 40 seconds as its standard specification.

5.2.2 Rating

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

5.2.3 Fuel Oil System

(1) Engine fuel will be commercial grade No. 2 fuel oil with limits as stated in ASTM Specification D-396.
(2) A direct engine/gearbox driven pump that pumps fuel oil from the day tank to the fuel control valve is provided.
(3) The welded steel day tank, to hold a total quantity of fuel required for 1.5 hours operation at the continuous rating (1250 gallon rated) is provided. Tank is constructed in accordance with ASME Section Ⅲ, Class 3.

The system configuration is shown in Figure B.1.0-9.

5.2.4 Lubrication Oil System

(1) One complete lube oil system is furnished to supply oil under pressure to the engine bearings and reducing gear bearings, and the other is furnished to supply oil to generator bearings and also have oil pumps to lift up the shaft.

(2) A lube oil cooler is shared for Lubrication Oil System for the engine/gear box and Generator Lubrication Oil System, which is supplied to remove heat from the engine and speed reducer oil during operation. 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.

The system configuration is shown in Figure B.1.0-8.

5.2.5 Starting Air System

The engine shall be capable of being started by compressed air within 100 seconds after signal for start.

There are two air receivers in prototype system tested. In the actual plant design, four receivers capacity is designed that there is sufficient air at required pressure for three starts. The receivers are to be constructed in accordance with ASME Section Ⅲ, Class 3.

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 air compressor and compressor motor are designed as non safety related components.

The system configuration of starting air system is shown in Figure B.1.0-10.

5.2.6 Intake/Exhaust Air System

Air intake and exhaust systems consist of duct, silencer and ventilation fans. Drawing of tested system is shown in Figure B.1.0-11. Those will be designed in accordance with the site specific condition at actual plant project stage.

5.2.7 Enclosure/Skid

The skid type base plate is provided of rolled steel sections welded together to form a rigid base for mounting the engine and generator systems above and suitable for bolting to a reinforced concrete foundation.

5.2.8 Control system

One free standing local control panel having following function is furnished.

- 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 local control cabinet is actuated by sent signal from safety logic system of GTG which is digital control cabinet and not within the qualification scope.

5.2.9 Load Profiles

The load profiles of US-APWR used as test condition are shown in Appendix A.

5.3 Component Specification

5.3.1 Gas Turbine Engine & Gearbox

Specification of gas turbine engine & gearbox is shown in Table 5.3-1.

Table 5.3-1 Specification for GT

Item		Specification
Gas Turbine Engine	Product	Kawasaki M1T-33 (twin engines with one gearbox) ✓ Two-stage Centrifugal Compressor ✓ Single Can Type Combustor ✓ Three-stage Axial Turbine
	Type	Simple & Open Cycle Single-shaft type
	Rotation Speed	17,944 min^{-1}
	Dimension Size (L, W, H)	3,398 mm, 2,679 mm, 2,403 mm (with Gearbox)
	Weight	14,000 kg (with Gearbox)
Gearbox	Type	Epicyclic Gear + Parallel Gear,
	Rotation Speed	1800 min^{-1}
Drawing		Figure B.1.0-1 to -3

5.3.2 Generator

Specification of generator is shown in Table 5.3-2.

Table 5.3-2 Specification for Generator

Item	Specification
Rating	5625 kVA
Power Factor	0.8 Rated
Rated Voltage	6900 V
Phase	3
Connection	Wye
Wire	6
Frequency	60 Hz
Insulation	Class F
Enclosure	Drip proof
Drawing	Figure B.1.0-4

5.3.3 Enclosure

Drawings of enclosure are shown in Figure B.1.0-7.

5.3.4 Skid

Drawings of skid are shown in Figure B.1.0-7.

5.3.5 Fuel Day Tank

Table 5.3-3 Specification for Fuel Day Tank

Item	Specification
Quantity	1
Capacity	1250 gallon (4.73 cubic meter)
Drawings	Figure B.1.0-5

5.3.6 Air Receiver

Table 5.3-4 Specification for Air Receiver

Item	Specification
Quantity	2
Capacity	2000 gallon
Drawings	Figure B.1.0-6

5.3.7 Lubrication Oil System

Table 5.3-5 Specification of Lubrication Oil System

Item		Specification
Lubrication Oil System for the engine bearings and reducing gear bearings	Total flow	424 L/min
	Lube Oil Supply Pressure	0.34±0.05 MPa [G] at Manifold
Generator Bearing Lubrication Oil System	Total flow	2 USGPM ±15% [7.6 L/min]
	Lube Oil Supply Pressure	14 PSI[1 bar Max] at the bearing
	Voltage	480 VAC (lubricating oil), 125 VDC (hydraulic jacking)
Lube Oil Cooler Fan Assembly	Temperature	up to 50°C (122°F)
	Radiation	1.0×10^4 rads gamma T.I.D.
	Voltage	230/460 VAC

6.0 INITIAL TYPE TEST

6.1 General

The testing was in accordance with the initial type test portion of IEEE Std 387-1995 (Section 6.2) and ISG-021 for application to gas turbine generator sets. The Initial Type Test basic requirements are provided in MUAP-07024-P. The objectives, basic requirements and acceptance criteria presented in MUAP-07024-P are repeated here for convenience.

6.2 Load Capability Test

6.2.1 Objective

These tests demonstrate the capability of the GTG unit to carry rated loads at rated power factor for the period of time indicated, and to successfully reject load. One successful completion of the test sequence shall satisfy this requirement.

6.2.2 Basic Requirements

a) Load equal to the continuous rating shall be applied for the time required to reach engine temperature equilibrium.
b) Immediately following step 7.2.1.2.a), the short-time rated load shall be applied for a period of 2 consecutive hours and the continuous rated load shall be applied for 22 consecutive hours. The short-time rating load rejection test shall be performed.

The detailed test procedure is provided in Appendix D.

6.2.3 Acceptance Criteria

1) Supply 110% rated output for 2 hrs and 100% for 22 consecutive hours while maintaining normal temperature limits.
2) The increase in speed of the engine does not exceed 75% of the difference between nominal speed and the overspeed trip set point, or 15% above nominal, whichever is lower, when rejecting a load equal to 110% of rated output.

6.2.4 Result

Parameters measured during the test are shown in Tables 6.2-1 to 6.2-3. The GTG was operated in the stable condition without incident, failures or abnormal conditions. All the parameters remained almost constant.

Upon rejection of 110 % load, the engine did not over speed trip. At the end of the full load operation, the load was increased to 110% of rated and immediately removed to verify the frequency excursion was within acceptable values. The allowable frequency excursion is 9 Hz above the nominal frequency of 60 Hz. The frequency did not exceed 63 Hz as shown in Figure C.1.0-1 which satisfies the acceptance criteria.
It is concluded that these tests were successful.

Table 6.2-1 Engine Lubricant Oil Parameters

		Engine #1			Engine #2		
		Oil Pressure [psi]	Oil Temp Engine In [°F]	Oil Temp Bug Drain [°F]	Oil Pressure [psi]	Oil Temp Engine In [°F]	Oil Temp Bug Drain [°F]
Average during 100% 1 hour operation		46	150	157	46	155	142
Average during 110% operation		45	154	160	46	154	148
Average during 100% 22 hour operation	Minimum	44	150	144	46	150	135
	Average	46	151	154	48	151	141
	Maximum	47	155	162	50	155	145

Table 6.2-2 Engine Temperature Parameters

		Ambient Temp [°F]	Engine #1			Engine #2		
			Exhaust Temp [°C]	Intake Air Restriction [inches of water]	Compressor Discharge Pressure [psi]	Exhaust Temp [°C]	Intake Air Restriction [inches of water]	Compressor Discharge Pressure [psi]
Average during 100% 1 hour operation		81	388.8	6.5	126	385.4	6.1	128
Average during 110% operation		78	496.1	6.3	135	497.7	6.1	140
Average during 100% 22 hour operation	Minimum	56	441.0	6.5	135	438.0	6.1	140
	Average	64	452.9	6.5	142	448.8	6.4	144
	Maximum	73	467.0	6.5	150	462.0	6.5	150

Table 6.2-3 Generator Parameters

		AC Volts [V]	AC Amps [A]	Exciter Field DC Amps [A]	Exciter Field DC Volts [V]
Average during 100% 1 hour operation		6.94	292.6	1.85	41.25
Average during 110% operation		6.96	537.4	2.8	64.75
Average during 100% 22 hour operation	Minimum	6.90	452.3	2.6	56
	Average	6.91	469.2	2.6	57.5
	Maximum	6.92	477.6	2.6	58

6.3 Start and Load Acceptance Tests

6.3.1 Objective

A series of tests shall be conducted to establish the capability of the GTG unit to start and accept load within the period of time necessary to satisfy the plant design requirement.
Total 150 starts were performed.

A total of 150 starts shall be performed.

6.3.2 Basic Requirements

a) Engine cranking shall begin upon receipt of the start signal, and the GTG unit shall accelerate to specified frequency and voltage within the required time interval.
b) Immediately following step a), the GTG unit shall accept a single-step load of ≧50% of the continuous kilowatt rating. Load may be totally resistive load or a combination of resistive and inductive loads.
c) Twenty starts were performed under the cold condition, and 131 starts were performed under the hot condition. The GT engine manufacturer defines the cold condition as being at or near ambient air temperature. Hot starts are defined as being at or near normal operating temperature. Hot starts may be performed immediately following shutdown of the previous test. The engine manufacturer recommended maintenance at recommended intervals shall be performed during the testing sequence. Following the maintenance activity, the GTG shall be started to conduct post maintenance testing and verify proper maintenance activities. This run shall not be considered part of the 150 start tests. IEEE Std 387-1995 Section 6.2.2.e) permits such scheduled maintenance to be performed during start and load acceptance testing.

The detailed test procedure “Factory Test Procedure for Emergency Gas Turbine Generator,” which covers the Start and Load Acceptance Test is included in Appendix D.
The test results in Appendix C contain notations of the fuel nozzle cleaning.

6.3.3 Acceptance Criteria

All starts shall be achieved within 100 seconds. 150 starts should be performed with no failures. The GTG shall continue to operate at greater than 50% rated load until lube oil and exhaust gas temperatures are within ±5.5°C (±10°F) of the normal engine operating temperatures for the corresponding load.

6.3.4 Results

Data charts for the start and load acceptance test sequence of 151 starts are provided in Figures C.1.0-2 through C.1.0-156. Minimum, average and maximum starting times are shown in Table 6.3-1. Additional significant parameters measured during the test are shown in Table 6.3-2.

During Test No. 128 a load bank failure occurred. The load bank is part of the test setup and not part of the permanent installation. Therefore, Test No. 128 was disregarded in accordance with IEEE Std 387-1995 Section 6.2.2.e).5). The load bank failure resulted in a large load transient being applied to the GTG for a short period. The sudden 200 to 300% of rated load caused an under frequency trip of the GTG prior to completion of the test. The detail of this event is described in Appendix L. In summary, MHI has determined the cause of the load bank failure associated with Test No. 128 and subsequent dislodging of the sound insulating component (assembly). A design change to the GTG was determined not to be necessary because dislodging of the assembly was caused by a manufacturing defect, revealed by the load bank failure. Based on IEEE Std 387-1995, the initial Test No. 128 was disregarded and the test sequence was then successfully completed.

MHI has performed a total of 151 starts, and all the starts were conducted successfully without failures or abnormal conditions. All the starts achieved the “ready to load condition” within 30 seconds.

The data indicates that the acceptance criteria were met or exceeded, therefore, the start and load acceptance test was successfully completed.

Table 6.3-1 Starting Time

	Minimum[sec.]	Average[sec.]	Maximum[sec.]
Cold (20 times)	26.0	26.5	27.0
Hot （131 times）	26.0	28.0	29.0

Table 6.3-2 Engine Parameters

		Cold	Hot
Intake Air [°F]		60.1	64.5
Engine #1	EGT[°C]	322.9	357.7
	Lube Oil temperature[°C]	32.4	67.1
	Lube Oil Pressure[psi]	56.8	46.4
Engine #2	EGT[°C]	322.4	358.1
	Lube Oil temperature[°C]	32.4	66.8
	Lube Oil Pressure[psi]	57.8	46.5

6.4 Margin Tests

6.4.1 Outline

Tests shall be conducted to demonstrate the GTG unit capability to start and carry loads that are greater than the magnitude of the most severe step load within the plant design load profile, including step changes above base load.

6.4.2 Procedure, Test Condition

At least two margin tests shall be performed using either the same or different load arrangement. A margin test load shall be at least 10% greater than the magnitude of the most severe single-step load within the load profile. The most severe load step is the 3rd load group of the LOCA sequence loads identified in table A.1.0-3. The test requires that the unit be initially loaded to 448 kW, 0 kVAR. A large transient load with a peak of 8144 kVAR, 3352 kW is then applied to the unit. The frequency and voltage excursions recorded may exceed those values specified for the plant design load. The detail test procedure is shown in Appendix D.

6.4.3 Acceptance Criteria

a) Accept the margin test load (the low power factor, high inrush, and high starting current of a pump motor) without experiencing instability resulting in generator voltage collapse, or significant evidence of the inability of the voltage to recover.
b) There is sufficient engine torque available to prevent engine stall, and to permit the engine speed to recover, when experiencing the margin test load.
c) Remove the load in one step and confirm GTG frequency does not exceed 69 Hz.

6.4.4 Result

Charts of two margin tests are shown in Figures C.1.0-159 to C.1.0-160.
The GTG met the acceptance criteria in both of two tests.
The first margin test had a peak load of 8818 kVar and 4127 kW. During the first margin test, the maximum voltage variation was approximately 25.40% and the maximum frequency variation was approximately 3.28%. The GTG was able to recover voltage to 10% of nominal within 850 milliseconds and it recovered to nominal voltage in 4 seconds. The GTG recovered to nominal speed (frequency) in 2.5 seconds as shown in Figures C.1.0-159.
The second margin test had a peak load of 8812 kVar and 4645 kW. During the second margin test, the maximum voltage variation was approximately 25.30% and the maximum frequency variation was approximately 3.35%. The GTG was able to recover voltage to 10% of nominal within 850 milliseconds and it recovered to nominal voltage in 4 seconds. The GTG recovered to nominal speed (frequency) in 3 seconds as shown in Figures C.1.0-160.

It is concluded that the margin test were successfully completed based upon observation and the data recorded.

6.5 Load Transient Tests

6.5.1 Outline

This test is not required in IEEE Std 387 endorsed by R.G1.9. MHI performed this test as internal test in accordance with recommendation of manufacture. This test confirms capability for load transient and rejection.

6.5.2 Procedure, Test Condition

Three load transient tests were performed using condition with 25% to 100 % load.
The detail test procedure is shown in Appendix D.

6.5.3 Acceptance Criteria

Demonstrate that there is sufficient engine torque available to prevent engine stall, and to permit the engine speed to recover.

6.5.4 Result

Charts of the tests are shown in Figures C.1.0-161 to C.1.0-164. The variation of voltage and frequency is shown in Table 6.5-1.

The GTG did not stall during any of transients and rejections. The voltage and frequency fluctuations during the load transients and rejections, the frequency recovered within 4.5.

The data indicated that the acceptance criteria were met; therefore the test was successful.

Table 6.5-1 Voltage and Frequency Variation

Load Step	kW	kVar	Parameters	Rejection		Transient	
				Variation (%)	Recovery Time (sec.)	Variation (%)	Recovery Time (sec.)
25%	1125	844	Voltage	2.93	0.88	-3.77	0.88
			Frequency	0.89	3.00	-0.92	2.38
50%	2250	1688	Voltage	5.70	0.93	-6.57	1.19
			Frequency	1.74	3.82	-1.78	3.06
75%	3375	2531	Voltage	8.61	1.15	-9.37	1.60
			Frequency	2.63	4.25	-2.70	3.46
100%	4500	3375	Voltage	11.34	2.00	-11.94	2.00
			Frequency	3.63	4.25	-3.72	3.79

7.0 CONSIDERATION

7.1 Test Result Consideration

Based on the test results provided in this Technical Report it is concluded that the GTG unit provided by KHI and Class 1E qualified by Engine System Inc. (ESI) was successful in the initial type test.

(1) US-APWR GTG system was successful in all three initial type tests, “Load Capability Test”, “Start and Load Acceptance Test” and “Margin Test”.

(2) During “Load Capability Test”, GTG was operated without failures or abnormalities. Each parameter such as engine lubricant oil temperature, engine compressor pressure, exhaust gas temperature (EGT) and others was almost constant during 100% operation. During 110% operation EGT remained stable although it was operating beyond its rating.

(3) The 150 start test was carried out without a failure. “Ready to Load” time of all starts was less than 30 seconds. The rotation speed increased at consistent linier rate between all the tests conducted. When comparing the starting time between cold and hot conditions, the average starting time was slightly shorter at the cold condition. This is because the governor based upon EGT is designed to supply more fuel in the cold condition. This results in a shorter time to reach rated speed and the “Ready to Load” condition. Such design properties were confirmed during this test.

(4) During the Margin Test, the GTG was operated without failures or troubles. During both two margin tests, the maximum voltage variation was approximately 25.40% and the GTG recovered to nominal voltage in 4 seconds. The maximum frequency variation was approximately 3.35% and recovered to nominal speed (frequency) in 3 seconds.
On the other hand, according to Section C 1.4 in Regulatory guide 1.9, the voltage shall not decrease to less than 75 percent of nominal. However as shown in Figure G.1.0-1, it is evaluated by the analysis that the voltage variation evaluates 21.6% when GTG operates with the maximum design load of US-APWR.

(5) GTGs rotate at 18000 RPM and the rotational inertia is large. Therefore, transient load changes have little impact on rotation speed. Recovering from the rotation speed variation is quick because the governor is controlling rotation speed and the torque available. At 100% load transient/rejection, the frequency variation was -3.72 %/ 3.63 % respectively. The recovery to the rated frequency was 3.79 seconds/ 4.25 seconds.

7.2 Hot/Cold Starting Discussion

Based on the manufacture's experiences and technical knowledge, the reliability and/or loading capability of the MHI's GTG are not significantly affected by either ambient temperature or the temperature of the GTG components.

(1) Evaluating from the GTG's structure, design, operational principle, there are no significant differences between hot and cold conditions in GTG due to ambient or component temperature at the time of starting. For details, please see Attachment E.
(2) Therefore, there is no requirement to conduct a minimum number of starts at prescribed conditions. Performing the start & load acceptance tests at conditions close to the normal operation conditions is sufficient to prove the starting reliability.
(3) As recommended by the Manufacturer starting should not be attempted when lube Oil is greater than 70°C. Although this condition does not impact starting reliability; it does impact life and places undue stress on the unit.
Although there is no difference between the hot/cold conditions in GTG, there are definitions for hot/cold conditions given by the Manufacture. In this document, the cold condition refers to the condition in which 10 hours have passed and the temperature of the GTG structure has dropped as low as the ambient temperature since the engine stopped and turning began. The hot condition refers to the condition which is not a cold condition defined as above, such as just after the engine has stopped.
(4) The test results show there is no difference between the hot/cold conditions. Moreover, the required starting time of 100 seconds was met with a wide margin for all the 150 starts in both hot/cold conditions, although the average starting time for hot condition was a little longer than the cold condition as shown in Table 6.3-1. It can be concluded that the starting reliability of GTG is independent of temperature from the test.

7.3 Reliability Discussion

The summary of the reliability discussion of the GTG are as follows. For details, please see Attachment F:

(1) According to a domestic GTG's field data, the GTG failure rate is statistically evaluated as 3.5×10^{-4}/demand, which proves high reliability of the GTG.
(2) However, the PRA analysis of US-APWR uses 4.53×10^{-3}/demand for GTG failure rate which is the same value as US Class 1E EDG reliability data to be more conservative.
(3) In addition, to satisfy the starting reliability of 0.975 with 95% confidence as required by the R.G1.155, 150 times of start tests shall be performed with no failure.
(4) The test result of the start & load acceptance test shows 0 failure and has proved that the GTG satisfies the reliability requirement of 0.975 with 95% confidence.

8.0 SEISMIC TEST

8.1 Qualification Methodology

The US-APWR safety-related seismic category I mechanical and electrical equipment (including instrumentation and controls), and where applicable, their supports are designed to safely withstand the effects of postulated earthquakes and the effects of normal and accident conditions (i.e., seismic category I requirements) without loss of their intended safety-related functions. This includes equipment in the reactor protection system, engineered safety feature, Class 1E electrical equipment, the emergency power system, and auxiliary safety-related systems and supports.

The seismic qualification and documentation procedures used for safety-related mechanical and electrical equipment and their supports are in accordance with the IEEE Std 344 endorsed by R.G. 1.100.

The US-APWR mechanical and electrical equipment seismic qualification meets IEEE Std 344 endorsed by R.G. 1.100 for qualification by either analysis, testing or by a combination of both.

The qualification of the design of safety-related, seismic category I mechanical equipment to assure the structural integrity of the pressure boundary components follows the guidance provided in the ASME Boiler and Pressure Vessel Code, Section III (ASME Section III).

The major components and piping assemblies of the GTG system, and its qualification methods are summarized in Table 8.1-1.

Table 8.1-1 The qualification methods for the major components and piping assemblies of GTG system

Component	Qualification Method	Notes
Gas Turbine Engine and Gearbox Assembly	Test	Complete (1)
Generator Bearing Lubrication Oil System	Test	Complete (1)
Lube Oil Cooler Fan Assembly	Test	Complete (1)
Engine Control Panel	Test	(2)
Generator	Analysis	(3)
Air Receiver Assembly	Analysis	(3)
Fuel Oil Day Tank Assembly and Stand	Analysis	(3)
Air Start Manifold	Analysis	(3)

Notes
After the new RRS is issued,
(1) will be re-evaluated,
(2) will be redesigned and test
(3) will be redesigned and reanalyzed

This document reports the result of the seismic qualification of the following components. The seismic tests were performed based on the seismic requirements in US-APWR DCD revision 3.
Seismic Qualification by Test
- Gas Turbine Engine and Gearbox Assembly
- Generator Bearing Lubrication Oil System
- Lube Oil Cooler Fan Assembly #1 and #2

The response spectra used for the seismic tests is larger than that defined in US-APWR DCD Revision 3. This is because it was known at the time of the seismic tests that the response spectra will be revised. After the DCD Revision 3 submittal, the technical report, “MUAP-10001 Seismic Design Bases of the US-APWR Standard Plant” has been revised, and in near future the technical report “MUAP-10006 Soil-structure Interaction Analysis and Results for US-APWR Standard Plant” will be accordingly revised. Based on the revisions to those technical reports, the seismic test results will be re-evaluated.

As the other components, including Generator and Air Receiver Assembly, etc. that were not included in the seismic tests, will be qualified by analysis, and manufactured in accordance with the seismic requirements in DCD Revision 2. However, due to the above expected revision to the seismic requirements, the analysis of those components is not included in this technical report; but will be included in the future revision.

8.2 Seismic Qualification by Test

Seismic qualification tests of the following components were performed in accordance with IEEE Std 344, as discussed above.
- Gas Turbine Generator and Gearbox Assembly
- Generator Bearing Lubrication Oil System
- Lube Oil Cooler Fan Assembly

8.2.1 Equipment Specification

The specification of the Gas Turbine Engine & Gearbox is shown in Table 5.3-1and Table 5.3-2. A drawing of the Gas Turbine Engine & Gearbox is shown in Figure B.1.0-4

The specification of the Generator Bearing Lubrication Oil System and the Lube Oil Cooler Fan Assembly is shown in Table 5.3-5.

The drawings of the Generator Bearing Lubrication Oil System and Lube Oil Cooler Fan Assembly are shown in Figure B.1.0-4 and Figure B.1.0-9.

8.2.2 Seismic Qualification Methodology

8.2.2.1 Outline of Seismic Tests

In accordance with IEEE Std 344, the Gas Turbine Engine and Gearbox Assembly, the Generator Bearing Lubrication Oil System and the Lube Oil Cooler Fan Assembly are tested using multi-frequency random motion. Due to its large size, the Gas Turbine Engine and Gearbox Assembly are tested on a bi-axial simulation table using a horizontal input motion and vertical input motion simultaneously. The Generator Bearing Lubrication Oil System, and Lube Oil Cooler Fan Assembly are tested on tri-axial tables using two horizontal input motions and a vertical input motion simultaneously.

In accordance with IEEE Std 344, the equipment is demonstrated to withstand the equivalent effect of five operating-basis earthquake (OBE) excitations followed by one safe-shutdown earthquake (SSE) without loss of structural integrity and functionality, in accordance with IEEE Std 344-2004. In accordance with Appendix S to 10 CFR 50, the OBE for the US-APWR standard plant is set at 1/3 or less of the SSE and therefore eliminates the OBE from the design of structures, systems, and components (SSCs), as discussed in Section 3.7 of US-APWR DCD. With the elimination of the OBE from design considerations, the equipment is qualified with five 1/2 SSE events followed by one full SSE event (with ten maximum stress cycles per event).

The Required Response Spectra (RRS) used in the SSE tests are shown in Figure 8.2-1 thru Figure 8.2-9. The RRS for the OBE tests are half of the RRS for the SSE. Each RRS has a minimum 10% margin for In-Structure Response Spectra (ISRS) of the Power Source Building (PS/B), where GTG systems are located.

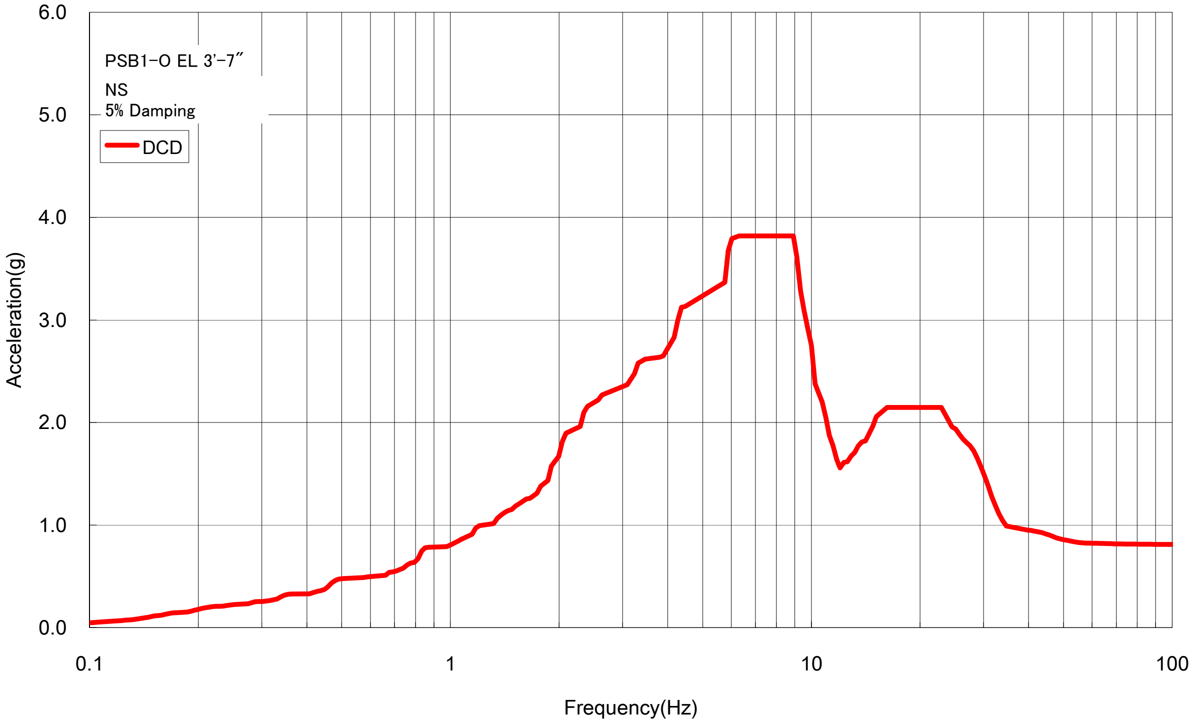


Figure 8.2-1 North-South RRS for Gas Turbine Engine and Gearbox Assembly

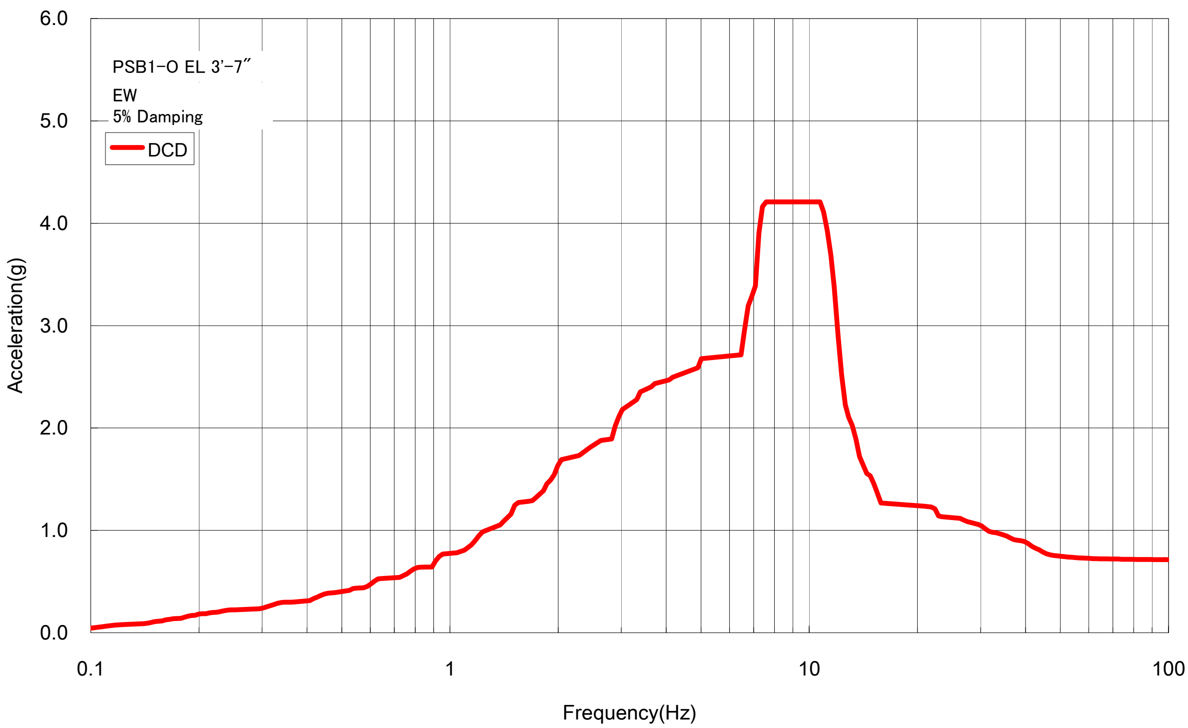


Figure 8.2-2 East-West RRS for Gas Turbine Engine and Gearbox Assembly

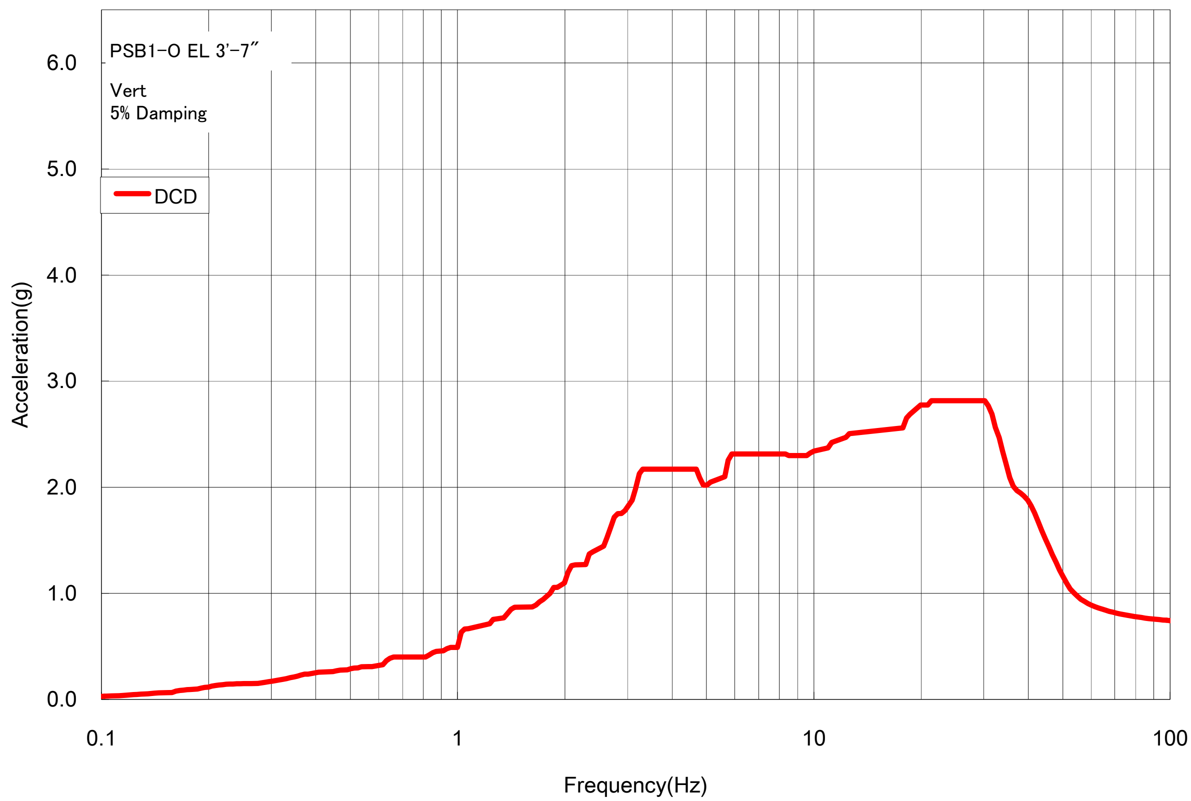


Figure 8.2-3 Vertical RRS for Gas Turbine Engine and Gearbox Assembly

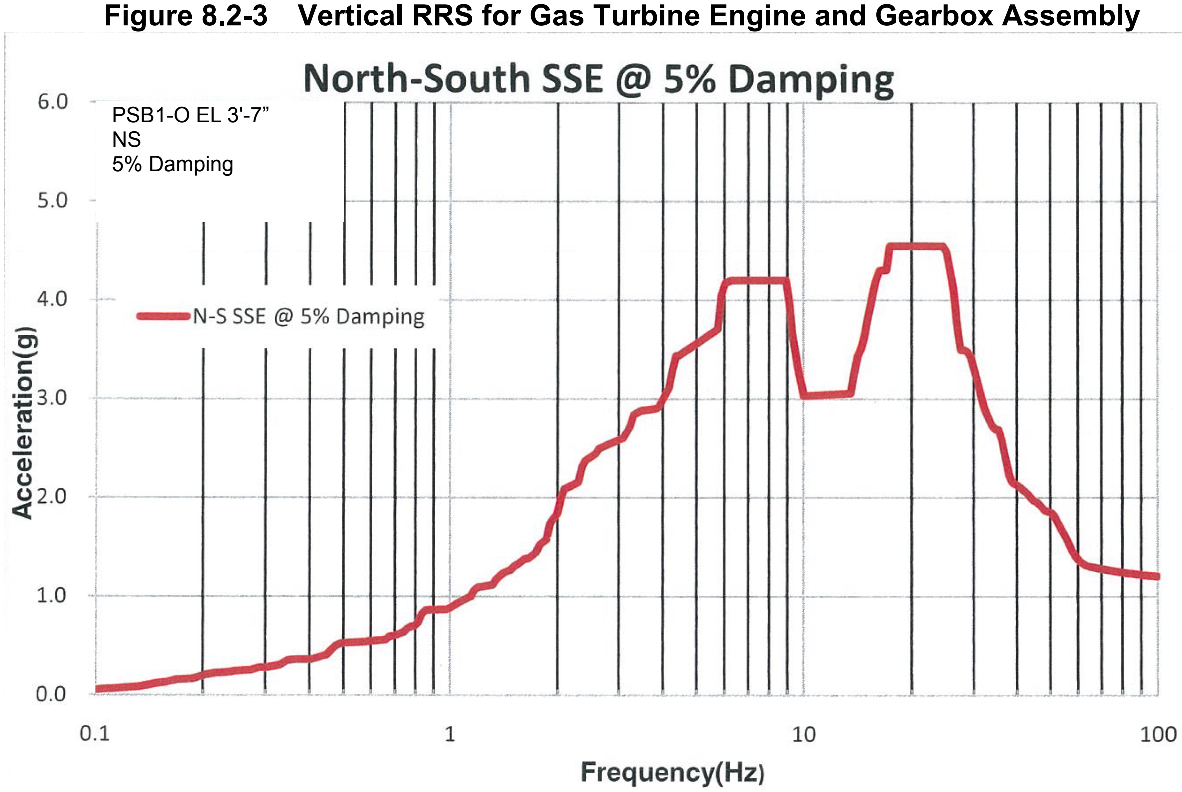


Figure 8.2-4 North-South RRS for Generator Bearing Lubrication Oil System

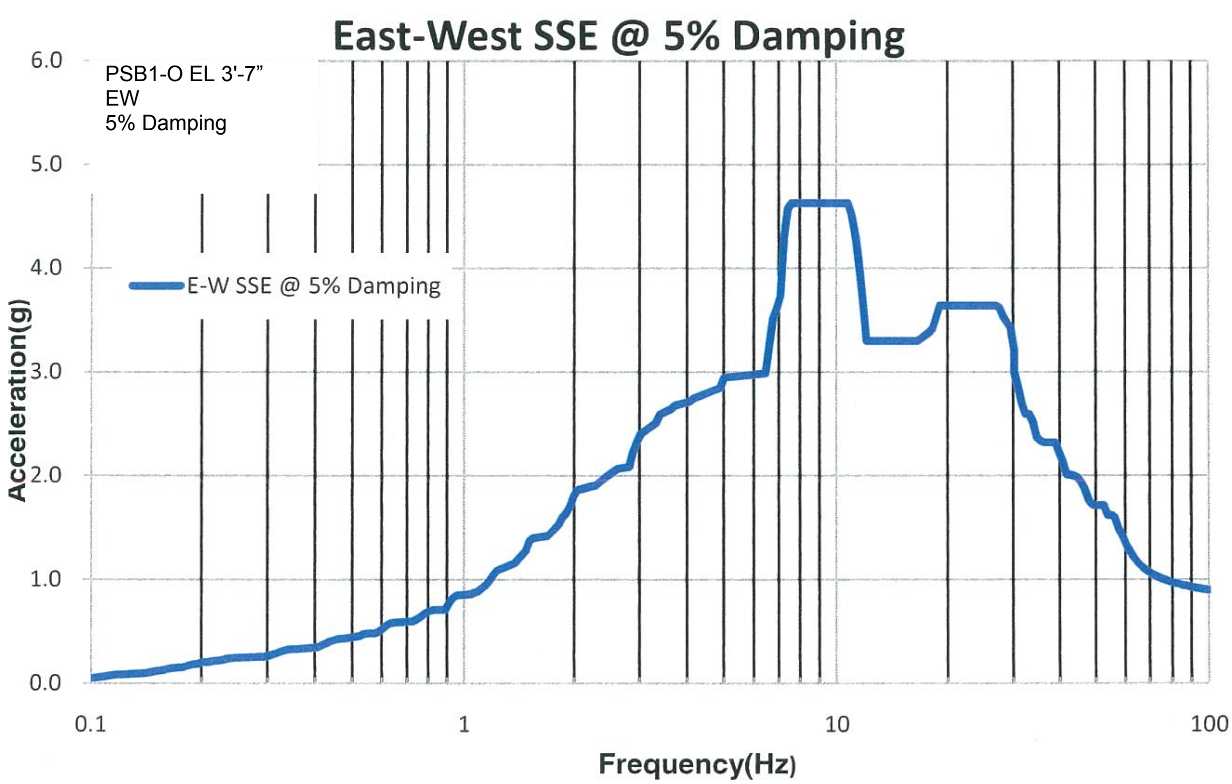


Figure 8.2-5 East-West RRS for Generator Bearing Lubrication Oil System

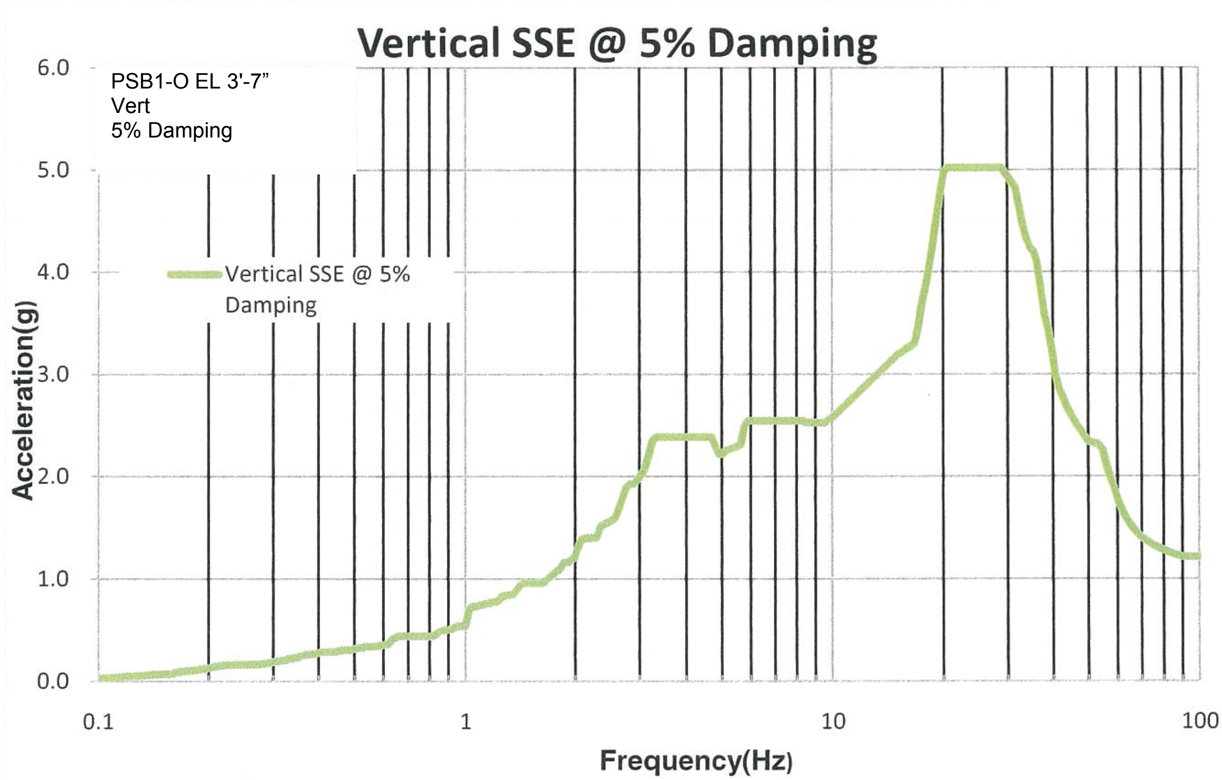


Figure 8.2-6 Vertical RRS for Generator Bearing Lubrication Oil System

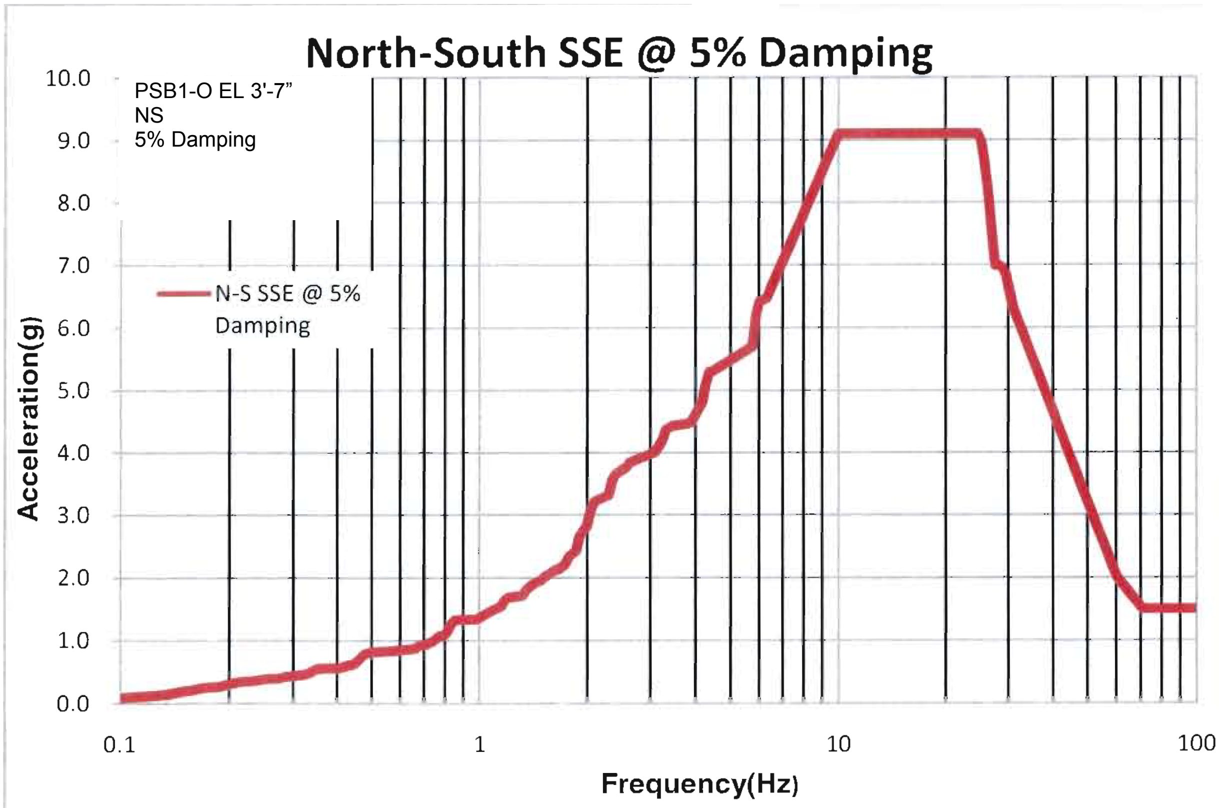


Figure 8.2-7 North-South RRS for Lube Oil Cooler Fan Assembly

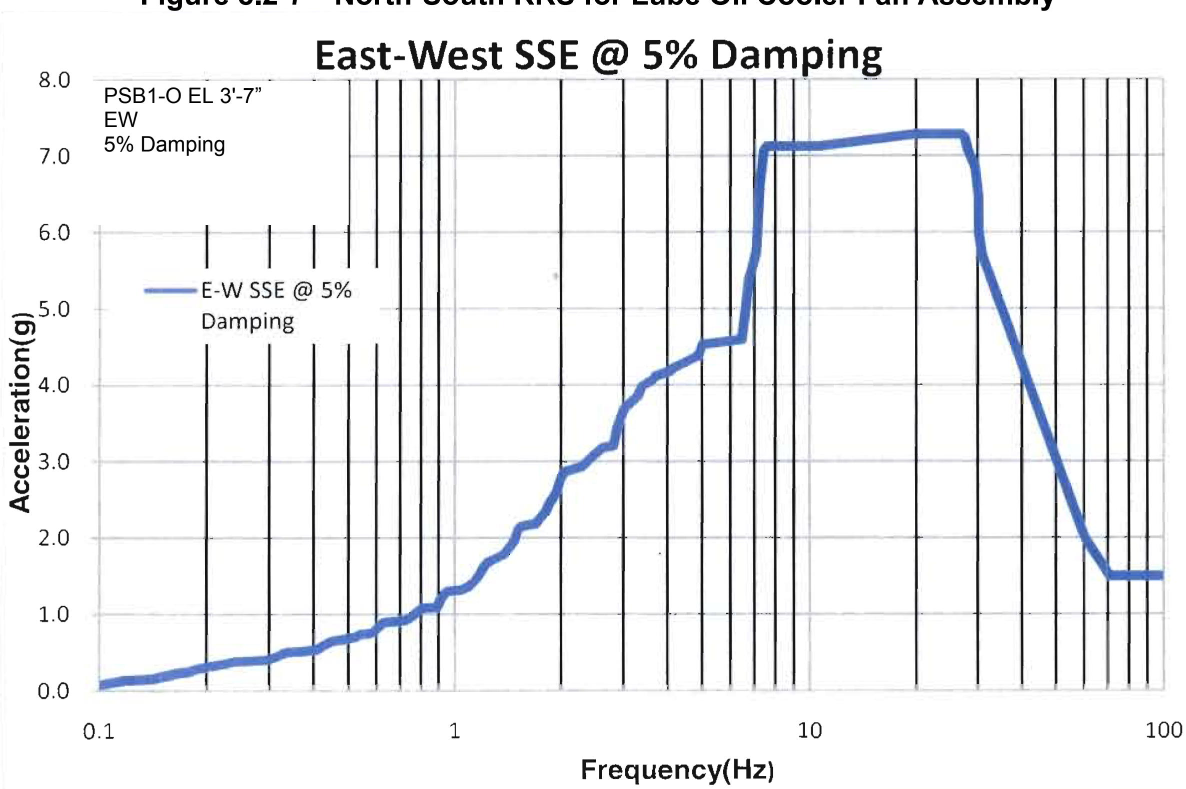


Figure 8.2-8 East-West RRS for Lube Oil Cooler Fan Assembly

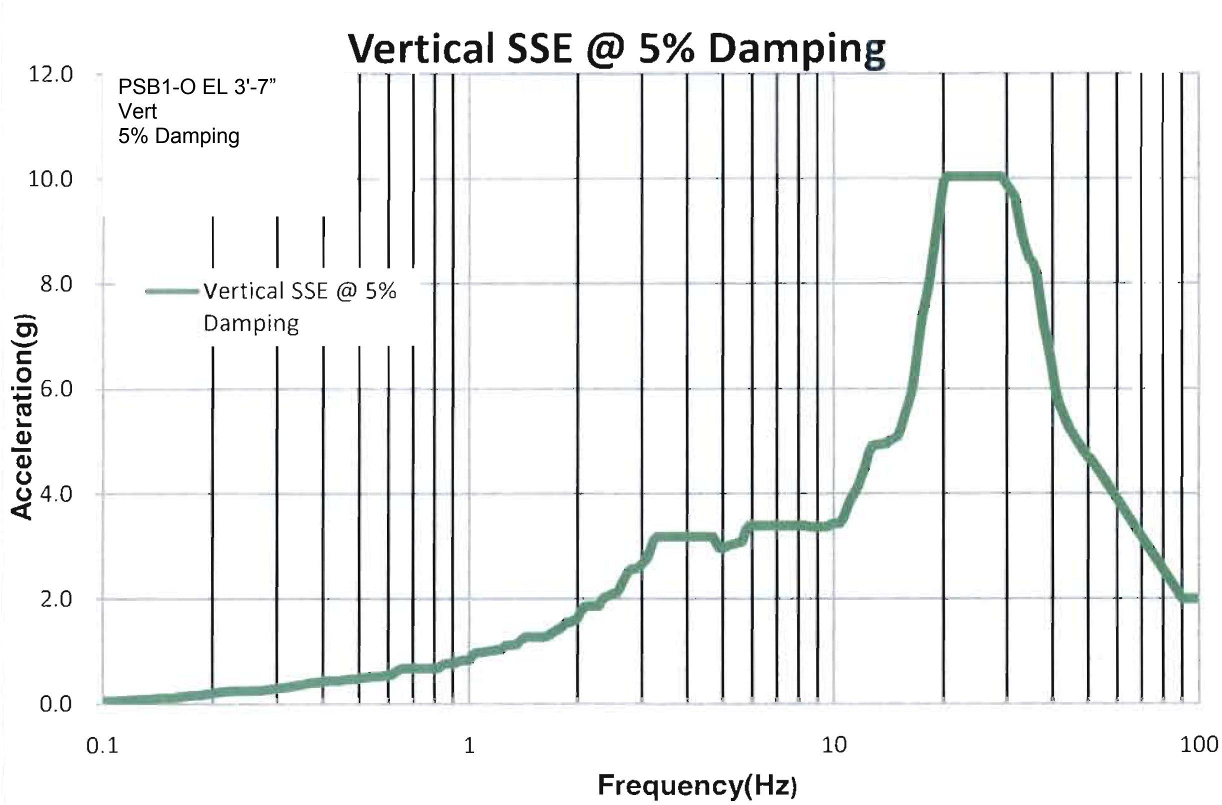


Figure 8.2-9 Vertical RRS for Lube Oil Cooler Fan Assembly

Figures 8.2-1, 8.2-2 and 8.2- 3, represent the RRS for two horizontal direction and vertical direction respectively, which are applied to the Gas Turbine Engine and Gearbox Assembly tests. Figures 8.2-4, 8.2-5 and 8.2-6, represent the RRS for two horizontal direction and vertical direction respectively, which are applied to the Generator Bearing Lubrication Oil System tests. Figures 8.2-7, 9.2-8 and 8.2-9, represent the RRS for two horizontal directions and one vertical direction respectively, which are applied to the Lube Oil Cooler Fan Assembly tests.

RRS used for each test are different from each other for the following reasons:
Each component test was performed independently. The first tests for the Generator Bearing Lubrication Oil System were performed in April 2011, The tests for the Gas Turbine Engine and Gearbox Assembly and the Lube Oil Cooler Fan Assembly were independently performed in April 2011 as well. Accordingly each test condition, (i.e. RRS), were planned at different times. The first tests were planned with the ISRS of DCD Revision 2 which was available at that time. However, later tests were planned with the ISRS of DCD Revision 3, which are different from the ISRS of DCD Revision 2. Consequently, the RRS for the first tests were different from those for the other tests. In addition, the RRS for the latter tests also differed depending on the size of the shaking table. The shaking table for the Lube Oil Cooler Fan Assembly is smaller and has a higher shaking capacity than the bi-axial shaking table for the Gas Turbine Engine and Gearbox Assembly, so the RRS for the former was set close to the shaking table capacity and therefore the RRS has a relatively high margin.

Note that MUAP-10006 “Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant” will be revised in October 2011, that is, results of PS/B Soil-Structure

Interaction Analyses including ISRS will be changed, and therefore RRS will be changed. It is to be confirmed after new ISRS are available whether Test Response Spectra (TRS), which were used in each test, can envelop new RRS.

For the Gas Turbine Generator and Gearbox Assembly, resonance search tests, i.e., sine-sweep tests, are performed. For the other components, resonance search test is not performed, because these type components are generally rigid (i.e., frequency > 50 Hz).

8.2.2.2 Acceptance Criteria

Gas Turbine Engine and Gearbox Assembly

Integrity and function of the Gas Turbine Engine and Gearbox Assembly are confirmed by checking the following parameters before, during and after the seismic test;
- Gas Turbine start up time
- Exhaust Gas temperature
- Lubrication Oil temperature

If there is any failure inside the Gas Turbine, it can lead to an abnormal start up time or exhaust gas temperature because of abnormal combustion conditions. Also, a Gas Turbine failure can lead to an abnormal lubrication oil temperature. Start up time is measured and checked if it starts within start up time on specification: 40 second. Exhaust gas temperature and Lubrication Oil Temperature are compared with those during initial type test. If there is no significant increase or decrease of those parameters, it shows that the Gas Turbine kept its Integrity and function.

Also, the following items are checked.
- Noise and vibration
- Turbine blade (by using fiberscope inspection inside Gas Turbine)

Abnormal noise and vibration are checked during every at start up, operation and shutdown. If there is any failure, such as failure of bearing, casing, or shaft lubrication oil system, it causes abnormal noise or vibration because Gas Turbine engine rotated at very high speed: about 1800 rpm. The turbine blades are inspected using a fiberscope before and after the seismic test to check turbine blade if there is no crack or lack of turbine blade.
If no abnormal noise, vibration and crack/lack of turbine blade are found, it shows that the Gas Turbine maintains its Integrity and function.
It is noted that fiberscope inspection can survey only turbine blade near combustor. Though overhaul is required to check the turbine blade completely, integrity of Gas Turbine can be confirmed with combination of series of parameter check and inspections above.

Generator Bearing Lubrication Oil System

Integrity and function of the Generator Bearing Lubrication Oil System are confirmed by checking following points after the seismic test;

- Loss of structural integrity of unit
- Lubricating oil pump outlet pressure recovers
- Hydraulic jacking oil pump outlet pressure recovers

Lube Oil Cooler Fan Assembly

Integrity and function of Lube Oil Cooler Fan Assembly are confirmed by checking following points after the seismic test;

- Loss of structural integrity of unit
- Fan Remains Operational
- Applied Voltage

8.2.2.3 Test Procedure

Gas Turbine Generator and Gearbox Assembly

a. Resonance Search Tests
A low-level (approximately 0.1 g) single-axis sine sweep is performed in each of the three orthogonal axes to determine major resonances of the equipment under test (EUT). The sweep is performed from 1 to 50 Hz at a sweep rate of one octave per minute.

b. Biaxial Seismic Simulation Tests
The EUT is subjected to a 30-second duration biaxial multi-frequency random motion, which is amplitude-controlled in one-sixth octave bandwidths spaced one-sixth octave apart over the frequency range of 1 to 100 Hz. Two simultaneous, but independent random signals are used as the excitation to produce phase-incoherent motions in the vertical and one horizontal axis. The amplitude of each one-sixth octave bandwidth is independently adjusted in each of the two axes until the TRS envelops the Required Response Spectra (RRS). The resulting table motion is analyzed by a response spectrum analyzer at 5% damping and plotted at one-sixth octave intervals over the frequency range of 1 to 100 Hz.
The EUT is subjected to five OBE Tests and two SSE Seismic Tests in each horizontal axis orientation. Three (3) OBE and one (1) SSE Tests are performed while the engine is in Operating Mode. One (1) OBE Test is performed while the engine is starting. The remaining OBE and SSE Tests are performed while the engine is in Standby Mode. During operation, the engine is unloaded. First, 5 OBE tests and following one SSE test were performed in accordance with IEEE Std 344, and then another SSE test was performed additionally.
The former SSE test was tested in Operating Mode as a most sever load condition, while the latter SSE test, although not required in IEEE Std 344 and the other regulation, was conservatively tested in Standby Mode as a representative of different Operating Mode. The OBE and SSE RRS Curves are shown in Figures 8.2-1 and 8.2-2 and 8.2-3 for two horizontal directions and vertical direction respectively.

c. Test Procedure
The details of the test procedure are as follows:
1. The EUT shall be bolted to a base frame test fixture using twelve 1-1/4"-7 grade 8 bolts and twenty-four hardened flat washers. The mounting hardware shall be torqued to 860 +/-5 ft-lbs. The mounting bolts torque shall be checked.
2. The test fixture shall be welded to the test table so that the horizontal axes of the EUT are collinear with the horizontal axes of the test table.
3. The EUT shall be supplied with #2 diesel fuel from a fuel tank.
4. The exhaust air shall be evacuated using a plenum box for each turbine outlet and channeling the exhaust outside the test area.

5. The critical parts of the functionality of the EUT shall be monitored and recorded using a strip chart recorder during each of the seismic test runs.
6. The EUT Functional and Standby Circuits shall be monitored and recorded during the EUT pre-test checkout, during the testing and at the conclusion of each axis tested.
7. The instrumentation listed in Table 8.2-2 on the following page shall be provided for the tests.
8. The EUT shall be subjected to the Resonance Search Tests and the Biaxial Seismic Simulation Tests
9. The EUT shall be rotated 90 degrees and the OBE and SSE Tests shall be repeated for another horizontal direction.
10. In case a minor correctable anomaly occurs during the seismic test, the anomaly shall be recorded, corrected and the test repeated.
11. The EUT shall be visually inspected at the completion of each horizontal axis test.
12. The EUT shall be subjected to functional testing at the completion of the seismic testing as applicable.

Table 8.2-1 The list of instrumentation

Item	Identification	Function Monitored	Test Data
Accelerometers	NS HCA VCA Or EW HCA VCA	Test table accelerations in each of the two orthogonal axes	Time History and Test Response Spectrum Plots for the control accelerometers for the Seismic Test
	1NS or 1EW 2V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	Transmissibility Plots from the Resonance Search Tests Test Response Spectrum Plots and Time History Plots from the Seismic Test
	3NS or 3EW 4V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	5NS or 5EW 6V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	7NS or 7EW 8V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	9NS or 9EW 10V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	11NS or 11EW 12V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	13NS or 13EW 14V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	15NS or 15EW 16V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
	17NS or 17EW 18V	EUT response accelerations as defined by Engine Systems in each of the two orthogonal axes	
Electrical Monitoring	1 up to 18	Engine Systems Schematic Drawing in Appendix B of 8001517-PS-GT-SEISMIC, Revision 2	Strip Chart with Control Accelerometer Reference Channel

Notes: NS North South
EW East West
HCA Horizontal Control Accelerometer
VCA Vertical Control Accelerometer
V Vertical

Generator Bearing Lubrication Oil System

The EUT shall be subjected to seismic testing consisting of random input motion, amplitude controlled in 1/6 octave bandwidths from 1 to 100 Hz for a minimum test duration of 30 seconds. The testing shall consist of five (5) OBE and one (1) SSE test runs using the RRS shown in Figures 8.2-4, 8.2-5 and 8.2-6 for two horizontal directions and vertical direction respectively. The OBE shall be 1/2 the SSE. The TRS shall envelop the RRS. The EUT shall be monitored to verify that structural integrity is maintained and that the pump outlet pressure recovers to its original value (slight pressure variations during the seismic testing are acceptable). Test response spectra shall be plotted for the three directions of each test run. The OBE and SSE time histories for the three directions shall also be plotted.

Lube Oil Cooler Fan Assembly

The EUT shall be subjected to seismic testing consisting of random input motion, amplitude controlled in 1/6 octave bandwidths from 1 to 100 Hz for a minimum test duration of 30 seconds. The testing shall consist of five (5) OBE and one (1) SSE test runs using the RRS shown in Figures 8.2-7, 8.2-8 and 8.2-9 for two horizontal directions and vertical direction respectively. The OBE shall be 1/2 the SSE. The TRS shall envelop the RRS. The specimen shall be monitored to verify that structural integrity is maintained and that the fan remains operational throughout the test. Test response spectra shall be plotted for the three directions of each test run. The OBE and SSE time histories for the three directions shall also be plotted.

8.2.3 Seismic Qualification Test Results

8.2.3.1 Gas Turbine Generator and Gearbox Assembly

The seismic qualification tests were performed following the methodology described in Subsection 8.2.2.1 through 8.2.2.3 above.
The test results conclude that the Gas Turbine Engine and Gearbox Assembly operated and performed as required in accordance with the acceptance criteria in Subsection 8.2.2.2. The details of each test case are summarized in Table 8.2-3.

The EUT successfully completed the Resonance Search Tests and the OBE and SSE Random Multi-frequency Tests. The details of the test results including the following data are provided in Appendix H.

Table 8.2-2 Test run description

Type Test	Axes	Test Run	Frequency (Hz)	Level	Notes
Resonance Search	Vertical	1	1 to 50	0.1 g	1
	Front-to-Back	2	1 to 50	0.1 g	---
Random Multifrequency Tests	Biaxial	3	1 to 100	OBE	2
	Biaxial	4	1 to 100	OBE	3
	Biaxial	5	1 to 100	OBE	4
	Biaxial	6	1 to 100	OBE	5
	Biaxial	7	1 to 100	OBE	5
	Biaxial	8	1 to 100	OBE	5
	Biaxial	9	1 to 100	<SSE	5, 6
	Biaxial	10	1 to 100	SSE	5
	Biaxial	11	1 to 100	SSE	3
Resonance Search	Side-to-Side	12	1 to 50	0.1g	1
Random Multifrequency Tests	Biaxial	13	1 to 100	OBE	3
	Biaxial	14	1 to 100	OBE	4
	Biaxial	15	1 to 100	OBE	5
	Biaxial	16	1 to 100	OBE	5
	Biaxial	17	1 to 100	OBE	5
	Biaxial	18	1 to 100	SSE	5
	Biaxial	19	1 to 100	SSE	3

Notes:

1. The EUT Mounting Hardware was torqued to 860 +/- 5 ft/lbs prior to the test run.
2. The EUT was not in Standby Mode, and the OBE test run was repeated.
3. The EUT was placed in standby mode prior to the test run.
4. The EUT was started during the test run.
5. The EUT was operating during the test run.
6. The test level was less than the required level, and the SSE test run was repeated.

The fundamental frequencies of GTG obtained from the Resonance Search Test are approximately greater than 30Hz in any directions.

The zero period acceleration of TRS in SSE tests are approximately 2.2 G for two horizontal directions and 3.1G for vertical direction.

8.2.3.2 Generator Bearing Lubrication Oil System

The seismic qualification tests were performed following the methodology described in Subsection 8.2.2.1 through 8.2.2.3. The test results conclude that the Lube Oil Cooler Fan Assembly operates and performs as required in accordance with the acceptance criteria in Subsection 8.2.2.2. The EUT successfully completed the OBE and SSE Random Multi-frequency Tests. The details of the test results are provided in Appendix I.

The zero period acceleration of TRS in SSE tests are approximately 2.0 G for X (East- West) direction, 2.6G for Y (North-South) direction and 2.8G for Z (vertical) direction.

8.2.3.3 Lube Oil Cooler Fan Assembly

The seismic qualification tests were performed following the methodology described in Subsection 8.2.2.1 through 8.2.2.3 above. The test results conclude that the Lube Oil Cooler Fan Assembly operates and performs as required in accordance with the acceptance criteria in Subsection 8.2.2.2. The EUT successfully completed the OBE and SSE Random Multi-frequency Tests. The details of the test results are provided in Appendix J.

The zero period acceleration of TRS in SSE tests are approximately 4.2 G for X (East- West) direction, 4.8G for Y (North-South) direction and 4.3G for Z (vertical) direction.

9.0 CONCLUSIONS

9.1 Conclusion of Initial Type Test Result

Based on the results provided in this Technical Report, it is concluded that the US-APWR GTG unit is successful in the initial type test and meets the requirements for Class 1E emergency power sources described in IEEE Std 387 endorsed by R.G1.9.

Considering the consistent trouble free performance of the GTG during the type testing and the transient testing, of particular note is the GTG's frequency stabilizing capability, one of the significant advantages of GTG. The GTG is well qualified for nuclear power plant Class 1E emergency power sources which require the loading of large loads in sequence. It can be concluded that the Class 1E test proves this GTG's capability and was meaningful.

9.2 Conclusion of Seismic Test Result

The results provided in this Technical Report demonstrated that the gas turbine engine and gearbox assembly , generator bearing lubrication oil system and lube oil cooler fan assembly were successful in the seismic test and complies with IEEE Std 344.

The gas turbine generator of the tested model is a commercial product. It passed all seismic tests without any seismic related improvements. During and after the tests in the severe seismic conditions the Gas Turbine engine and gearbox remained operable without detectable degradation in performance.

As the other components, including Generator and Air Receiver Assembly, etc. that were not included in the seismic test, will be qualified by analysis, and manufactured in accordance with the seismic requirement. However, due to the above expected revision to the seismic requirements, the analysis of those components is not included in this technical report; but will be included in the future revision.

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. The requirements of MNES, Quality Assurance Administrative and System Requirements (Nuclear)
2. The requirements of MNES, Quality Assurance Administrative and System Requirements for Safety Related Electrical Equipment
3. MUAP-07024, Qualification and Test Plan of Class 1E Gas Turbine Generator System
4. MUAP-10006, Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant
5. Design Control Document for the US-APWR Chapter 3, Design of Structures, Systems, Components and Equipment, MUAP-DC003, Revision 3, Mitsubishi Heavy Industries, Ltd., March 2011.
6. Design Control Document for the US-APWR Chapter 3, Design of Structures, Systems, Components and Equipment, MUAP-DC003, Revision 2, Mitsubishi Heavy Industries, Ltd., October 2009.

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 Figure. 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	2	0	907	907	448
		MOV Operated by SP Signal					
		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 MOV Operated by SP Signal	2	0	907	907	448
		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				

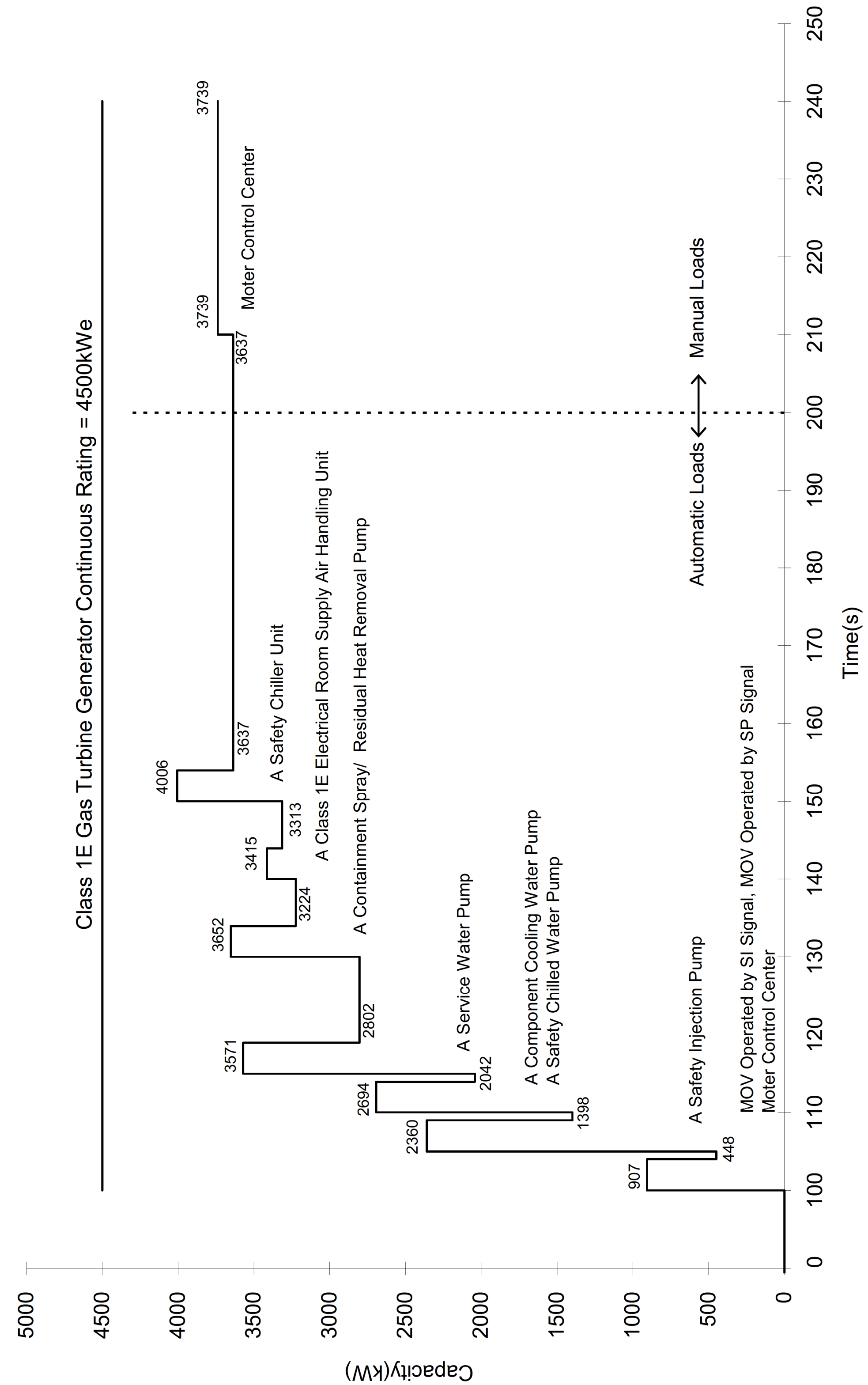


Figure A.1.0-1 LOCA Condition Class 1E GTG Load Profile (Train A)

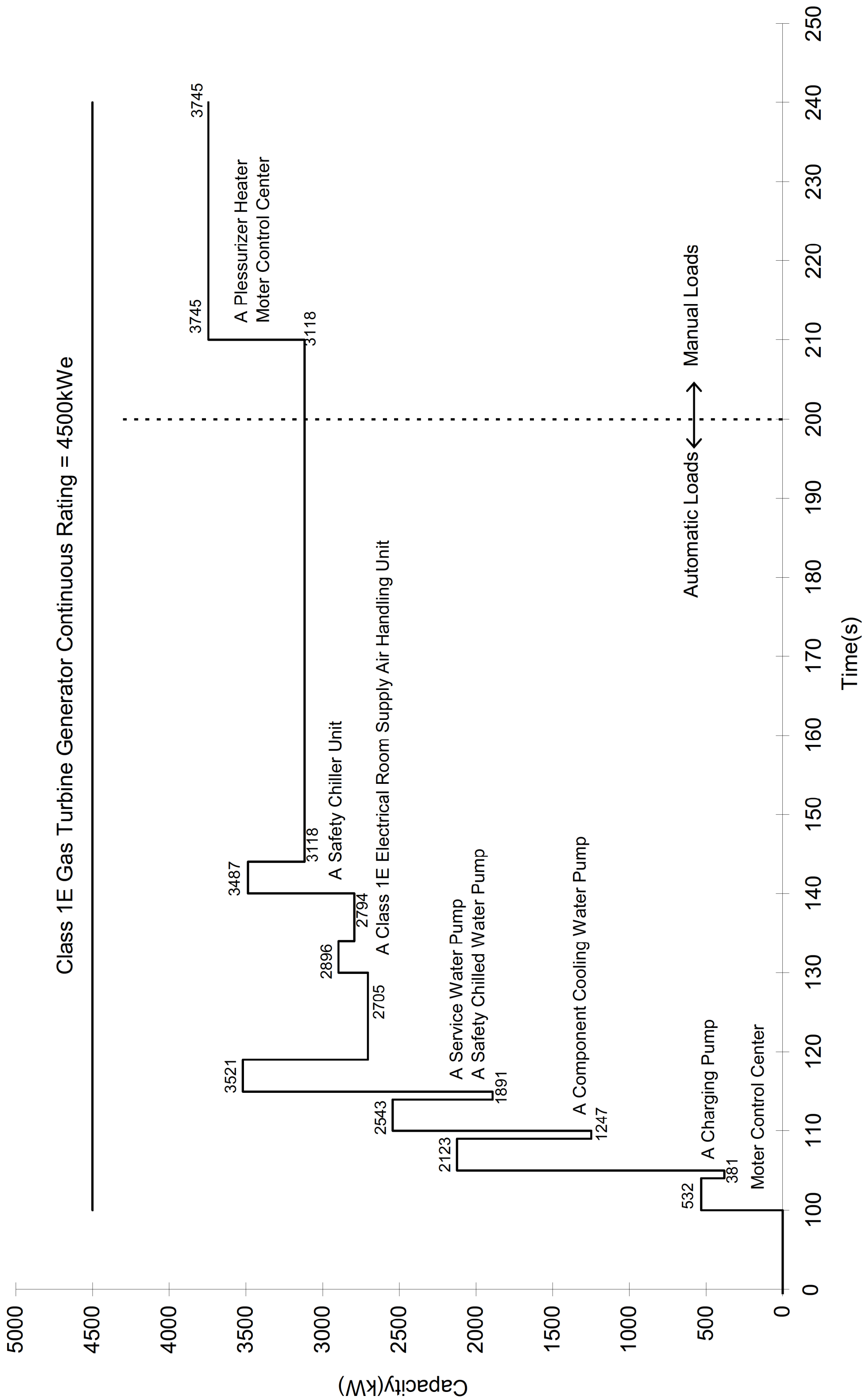


Figure A.1.0-2 LOOP Condition Class 1E GTG Load Profile (Train A)

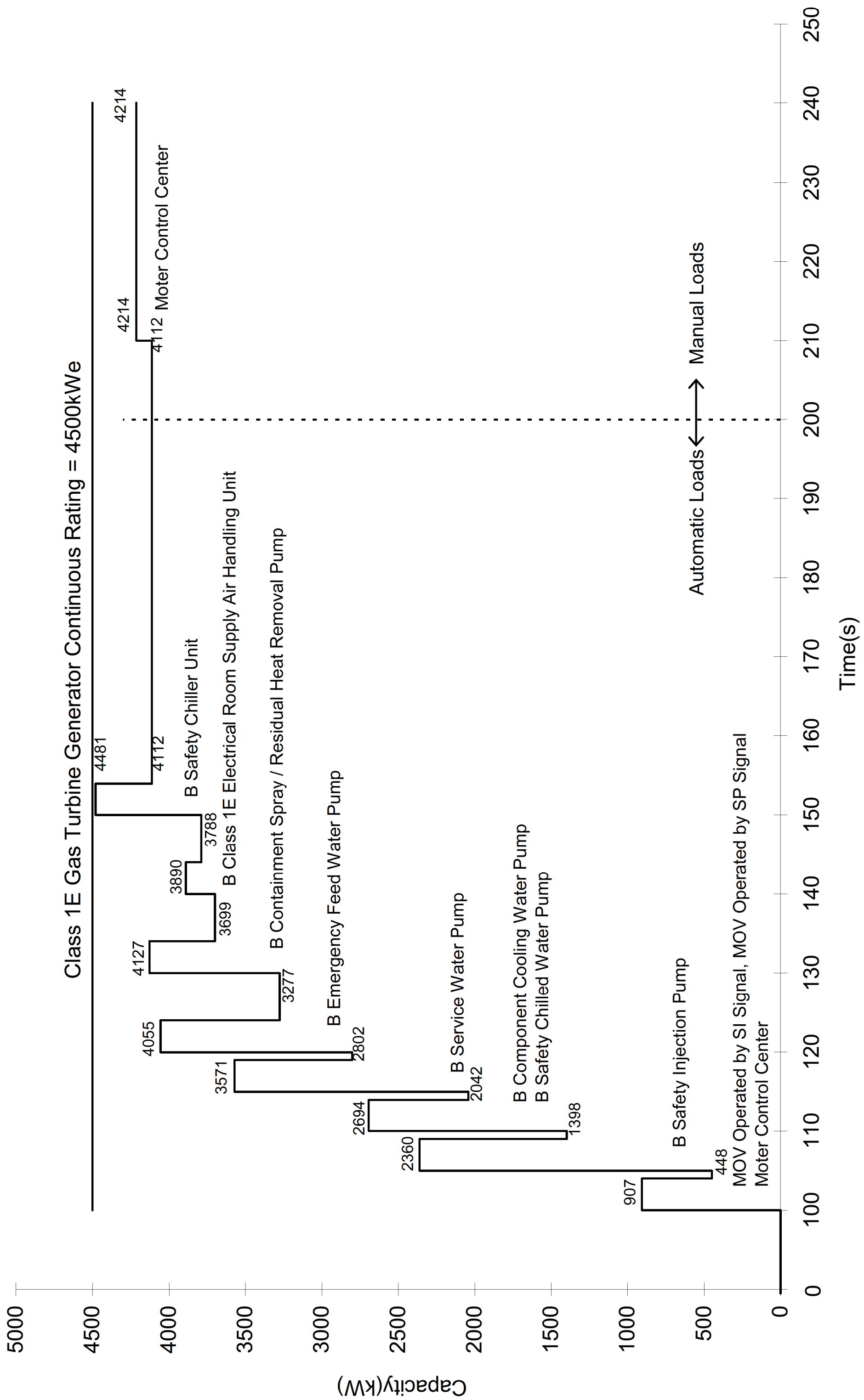


Figure A.1.0-3 LOCA Condition Class 1E GTG Load Profile (Train B)

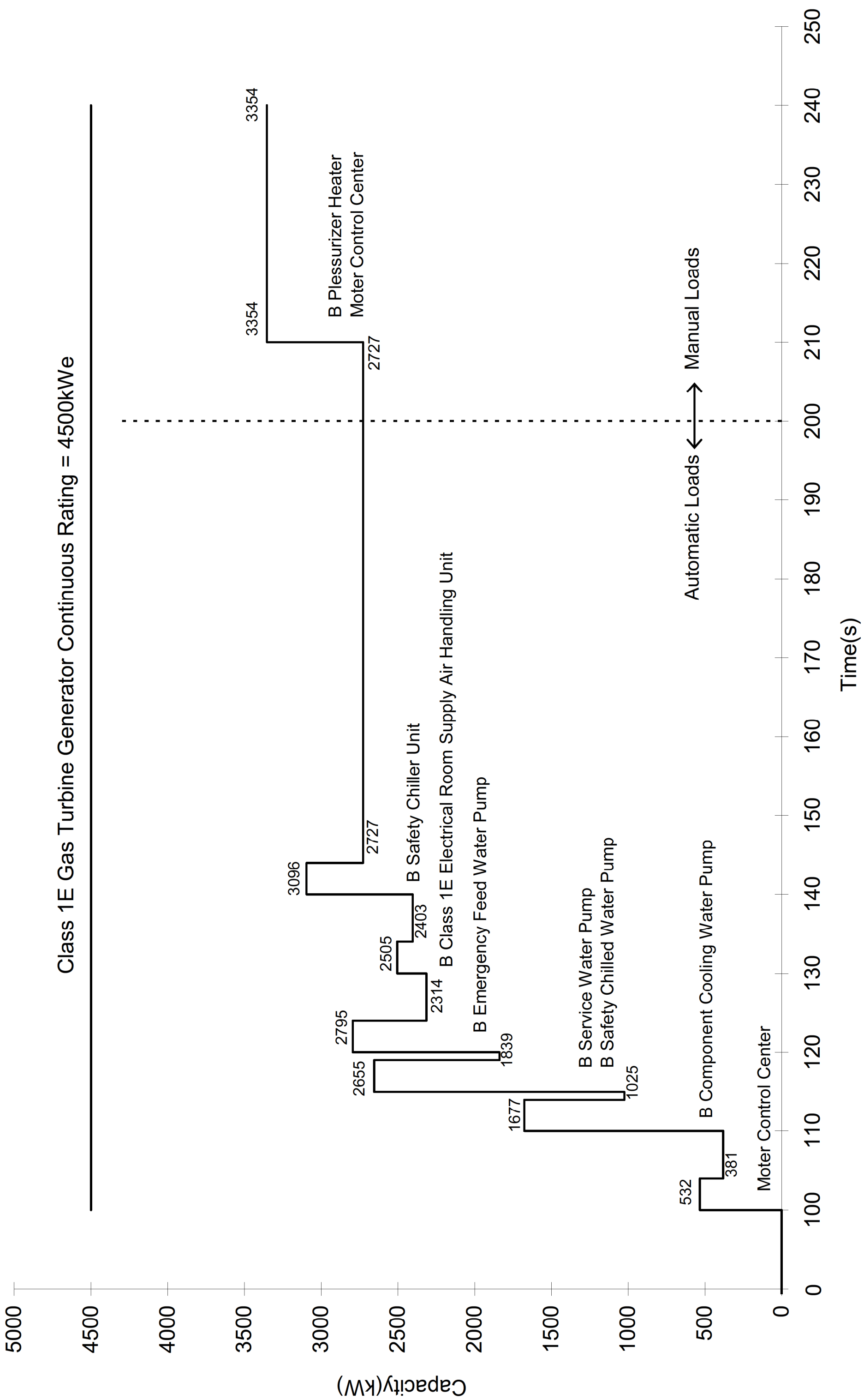


Figure A.1.0-4 LOOP Condition Class 1E GTG Load Profile (Train B)

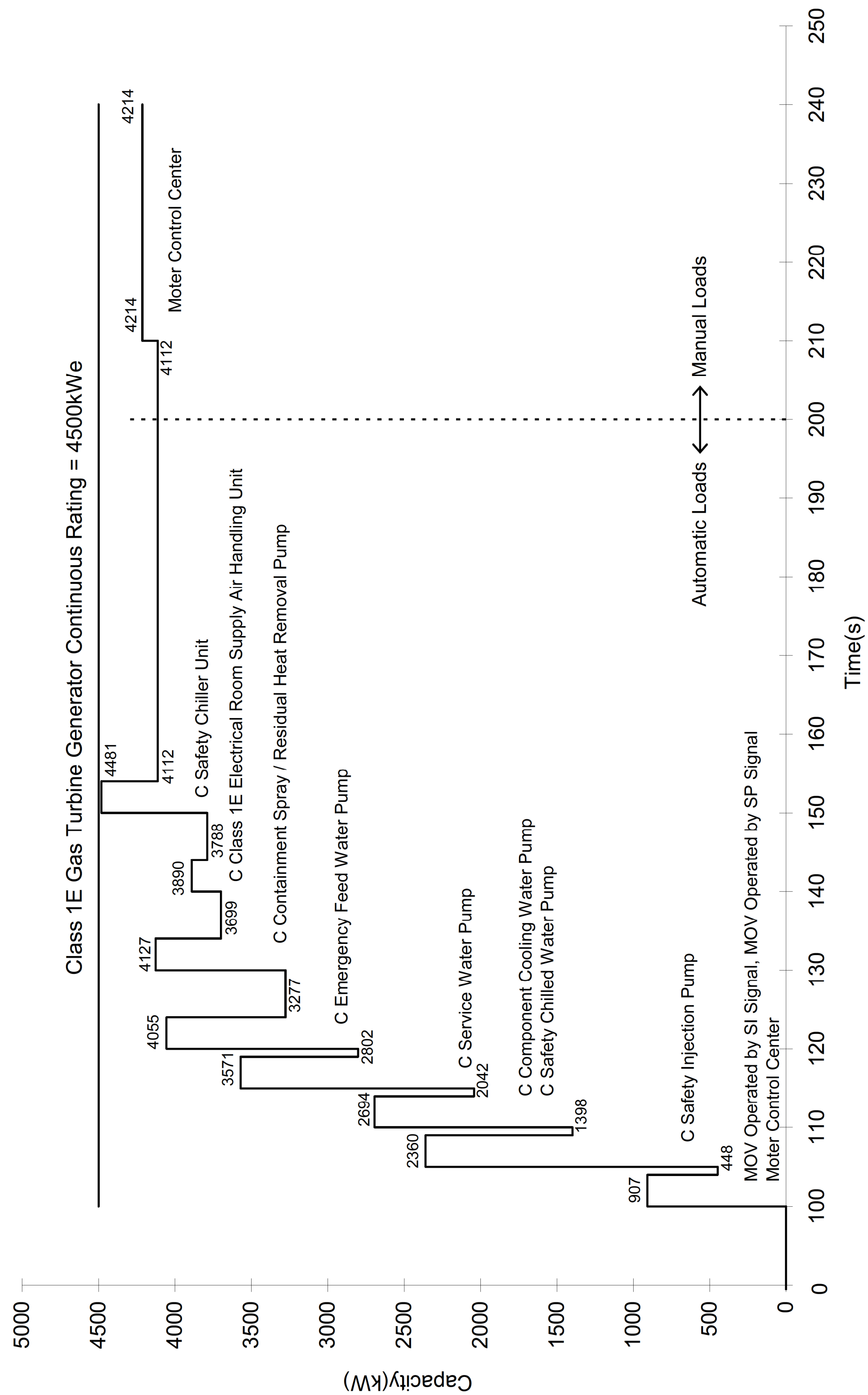


Figure A.1.0-5 LOCA Condition Class 1E GTG Load Profile (Train C)

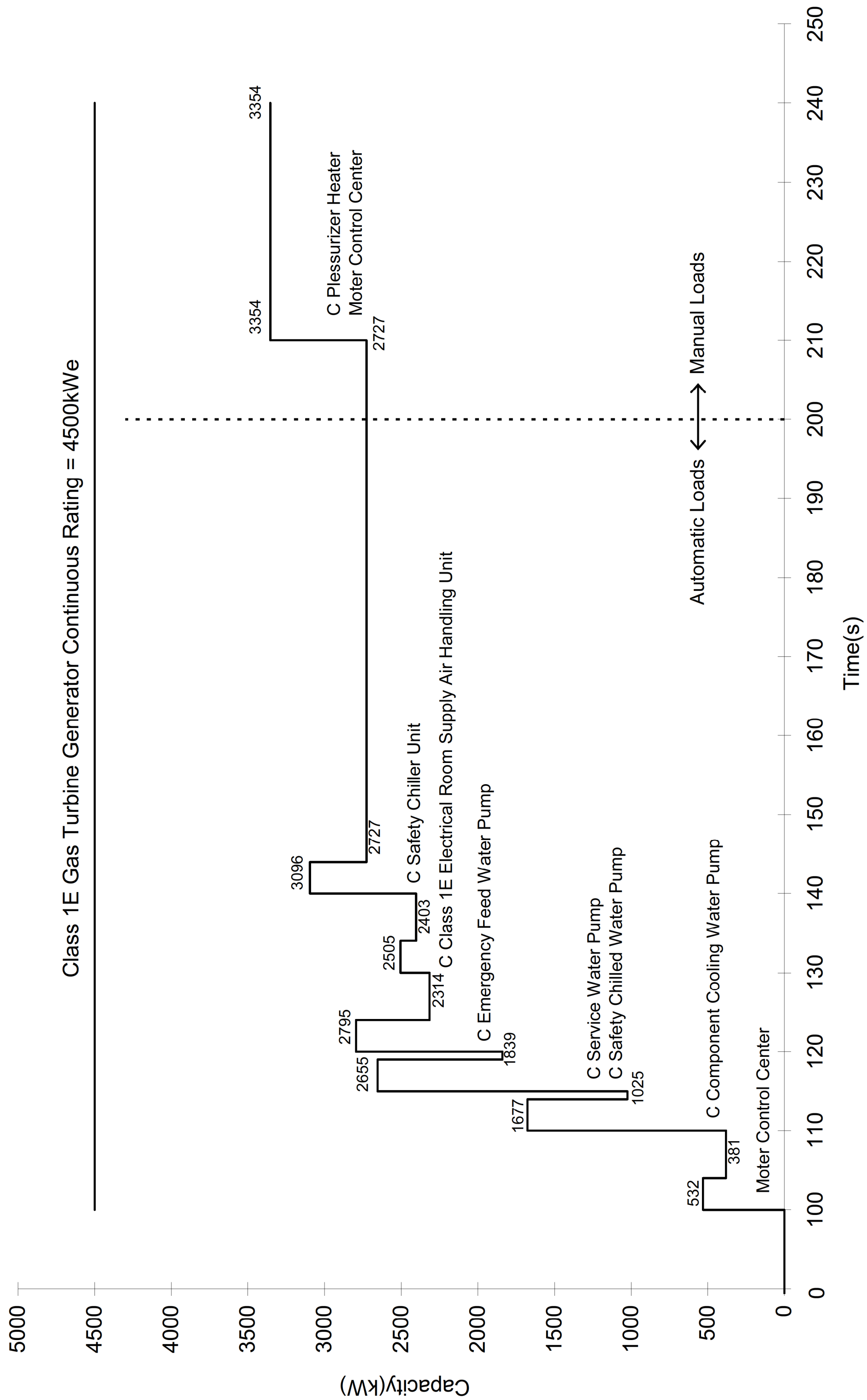


Figure A.1.0-6 LOOP Condition Class 1E GTG Load Profile (Train C)

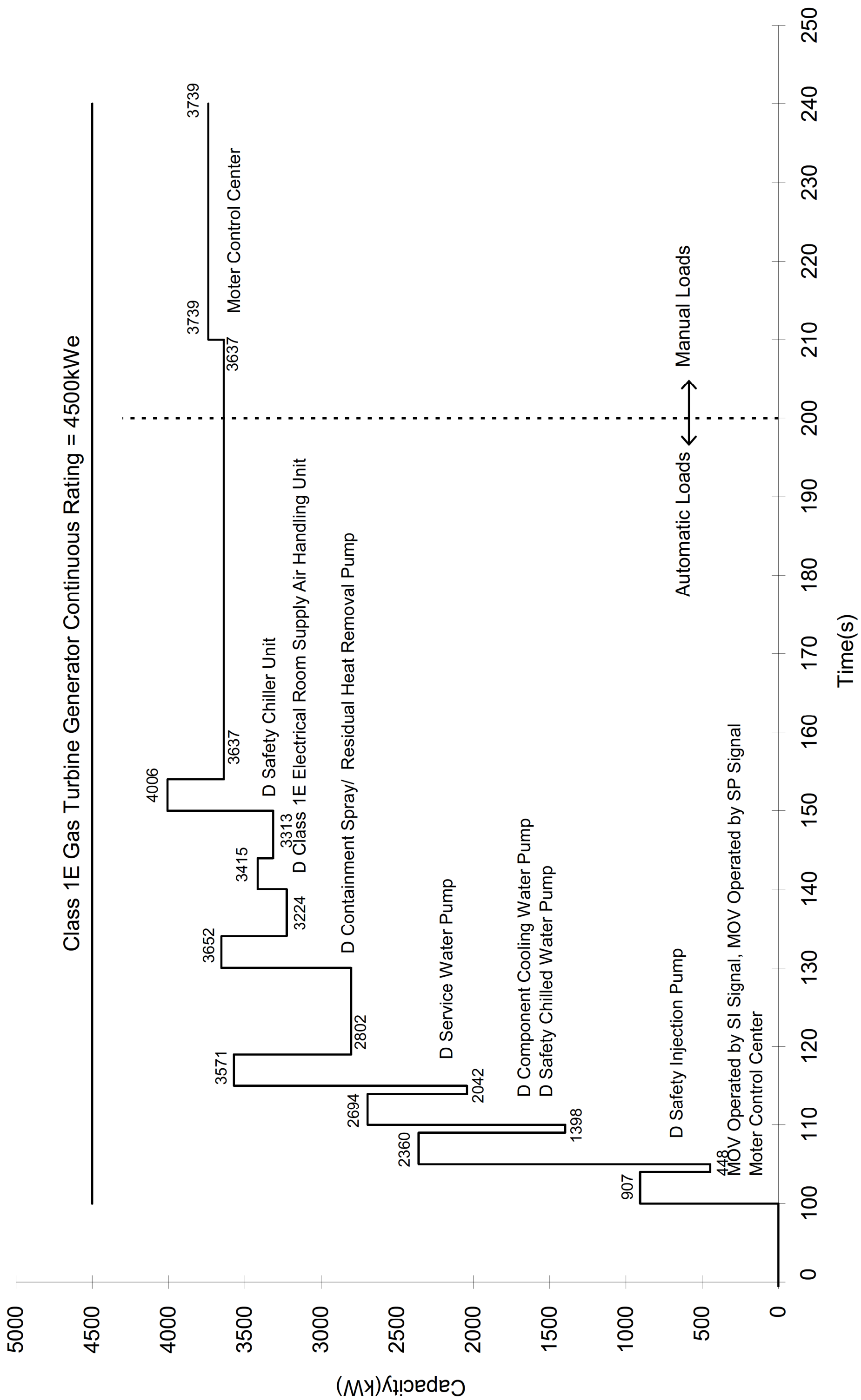


Figure A.1.0-7 LOCA Condition Class 1E GTG Load Profile (Train D)

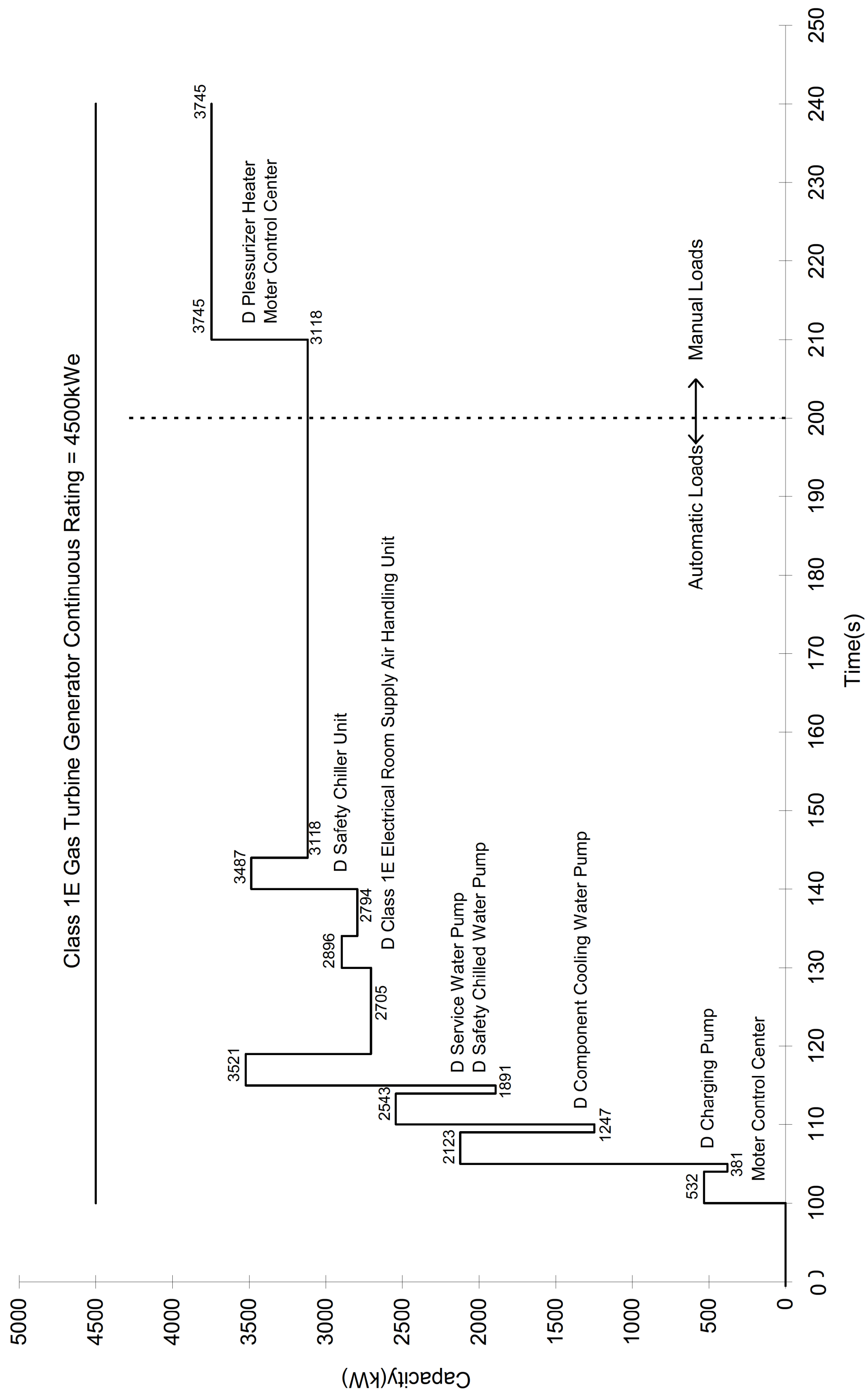


Figure A.1.0-8 LOOP Condition Class 1E GTG Load Profile (Train D)

Appendix B GTG Technical specification

Table B.1.0-1 Main Parts of Fuel, Oil, and Air System

Table B.1.0-2 Main Parts of Electric System

Table B.1.0-3 Engine Operation Limit and Protective Device Set Value

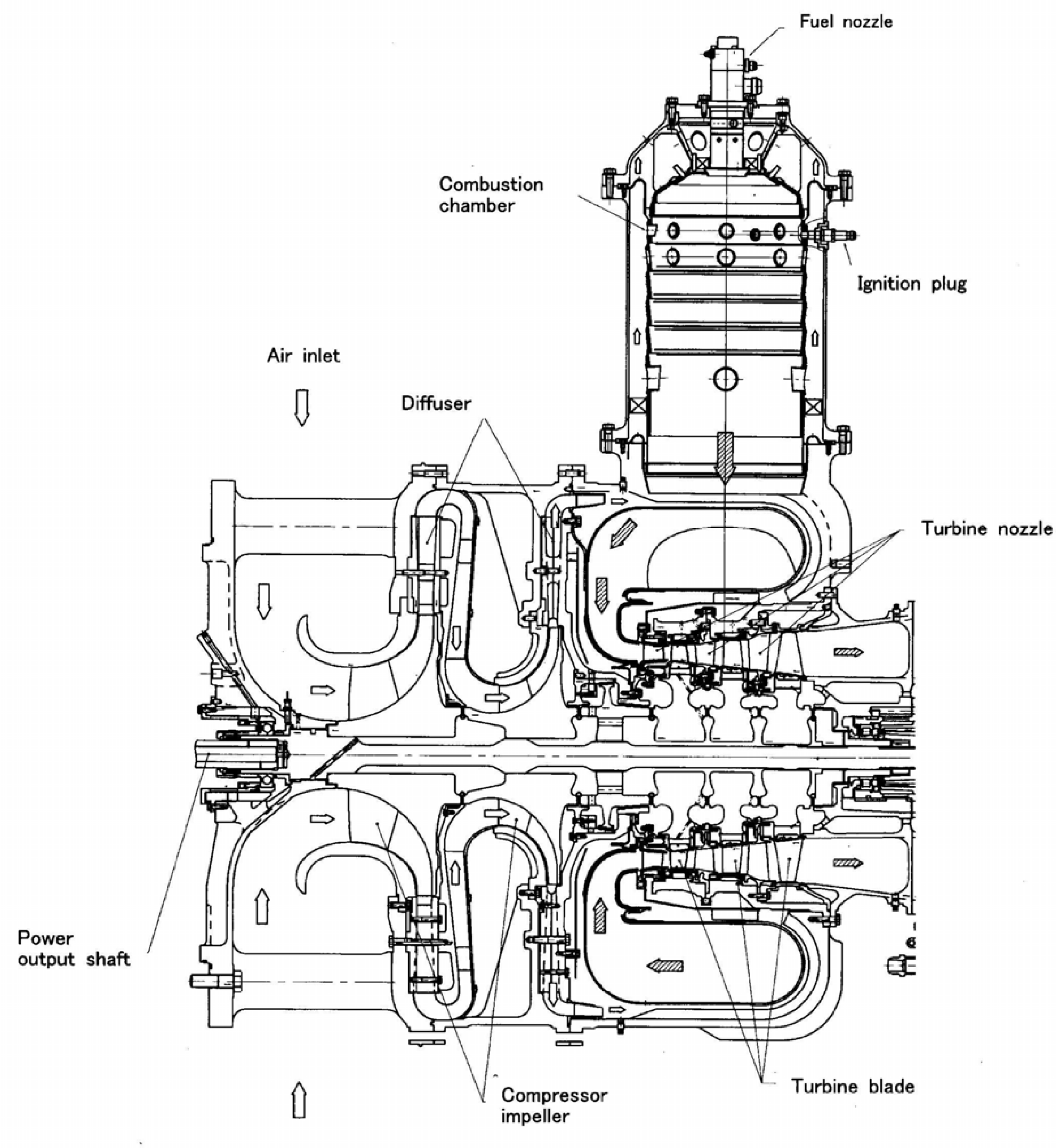
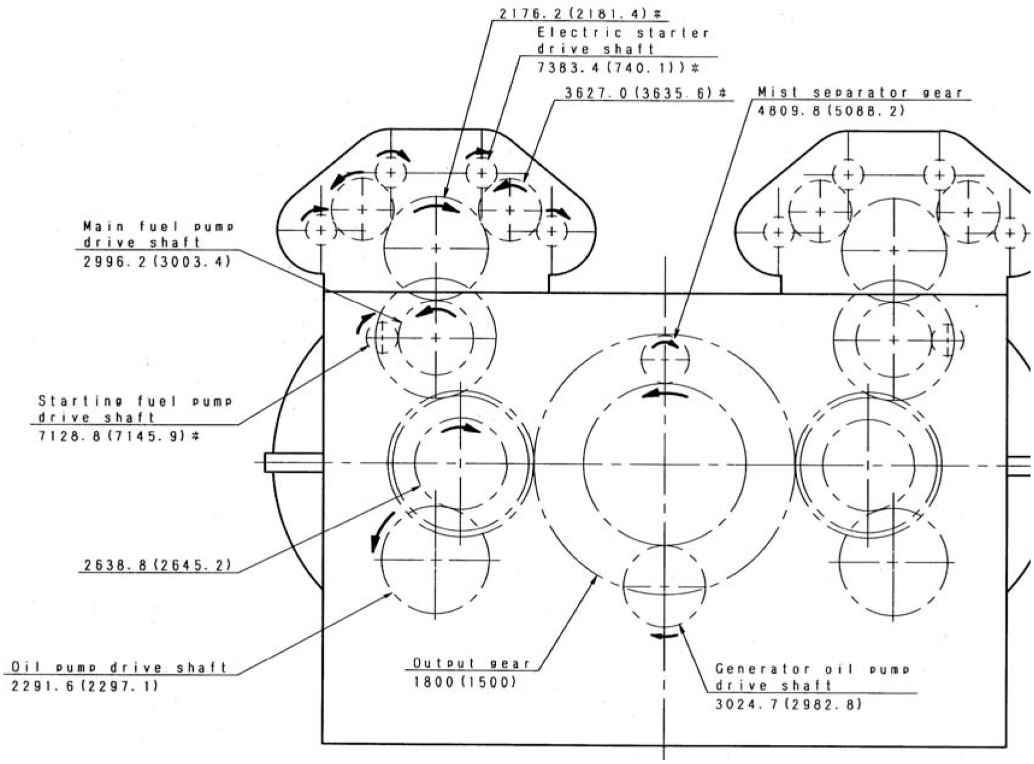


Figure B.1.0-1 Cross Sectional View of Power Section



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.1.0-2 Gear Train of Reduction Gear Box

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 1 of 6)

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 2 of 6)

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 3 of 6)

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 4 of 6)

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 5 of 6)

Figure B.1.0-3 Installation Drawing of Gas Turbine Assembly (Sheet 6 of 6)

Figure B.1.0-4 Drawing of Generator and Oil Supply Unit (Sheet 1 of 4)

Figure B.1.0-4 Drawing of Generator and Oil Supply Unit (Sheet 2 of 4)

Figure B.1.0-4 Drawing of Generator and Oil Supply Unit (Sheet 3 of 4)

Figure B.1.0-4 Drawing of Generator and Oil Supply Unit (Sheet 4 of 4)

Figure B.1.0-5 Drawing of Fuel Day Tank (Sheet 1 of 2)

Figure B.1.0-5 Drawing of Fuel Day Tank (Sheet 2 of 2)

Figure B.1.0-6 Drawing of Air Receiver (Sheet 1 of 4)

Figure B.1.0-6 Drawing of Air Receiver (Sheet 2 of 4)

Figure B.1.0-6 Drawing of Air Receiver (Sheet 3 of 4)

Figure B.1.0-6 Drawing of Air Receiver (Sheet 4 of 4)

Figure B.1.0-7 Drawing of Enclosure and Skid (Sheet 1 of 3)

Figure B.1.0-7 Drawing of Enclosure and Skid (Sheet 2 of 3)

Figure B.1.0-7 Drawing of Enclosure and Skid (Sheet 3 of 3)

Figure B.1.0-8 Configuration of Lubricant Oil System (Sheet 1 of 2)

Figure B.1.0-8 Configuration of Lubricant Oil System (Sheet 2 of 2)

Figure B.1.0-9 Configuration of Fuel Oil System

Figure B.1.0-10 Drawing of Starting Air System (Sheet 1 of 4)

Figure B.1.0-10 Drawing of Starting Air System (Sheet 2 of 4)

Figure B.1.0-10 Drawing of Starting Air System (Sheet 3 of 4)

Figure B.1.0-10 Drawing of Starting Air System (Sheet 4 of 4)

Figure B.1.0-11 Drawing of Intake / Exhaust Air System

Figure B.1.0-12 Drawing of Alarm Panel (Sheet 1 of 4)

Figure B.1.0-12 Drawing of Alarm Panel (Sheet 2 of 4)

Figure B.1.0-12 Drawing of Alarm Panel (Sheet 3 of 4)

Figure B.1.0-12 Drawing of Alarm Panel (Sheet 4 of 4)

Appendix C Parameter Chart

The parameter chart shown on next page indicates following record.

1. Start Signal
2. Voltage
3. Frequency
4. Ready to load
5. Load (kW)
6. The speed of rotation

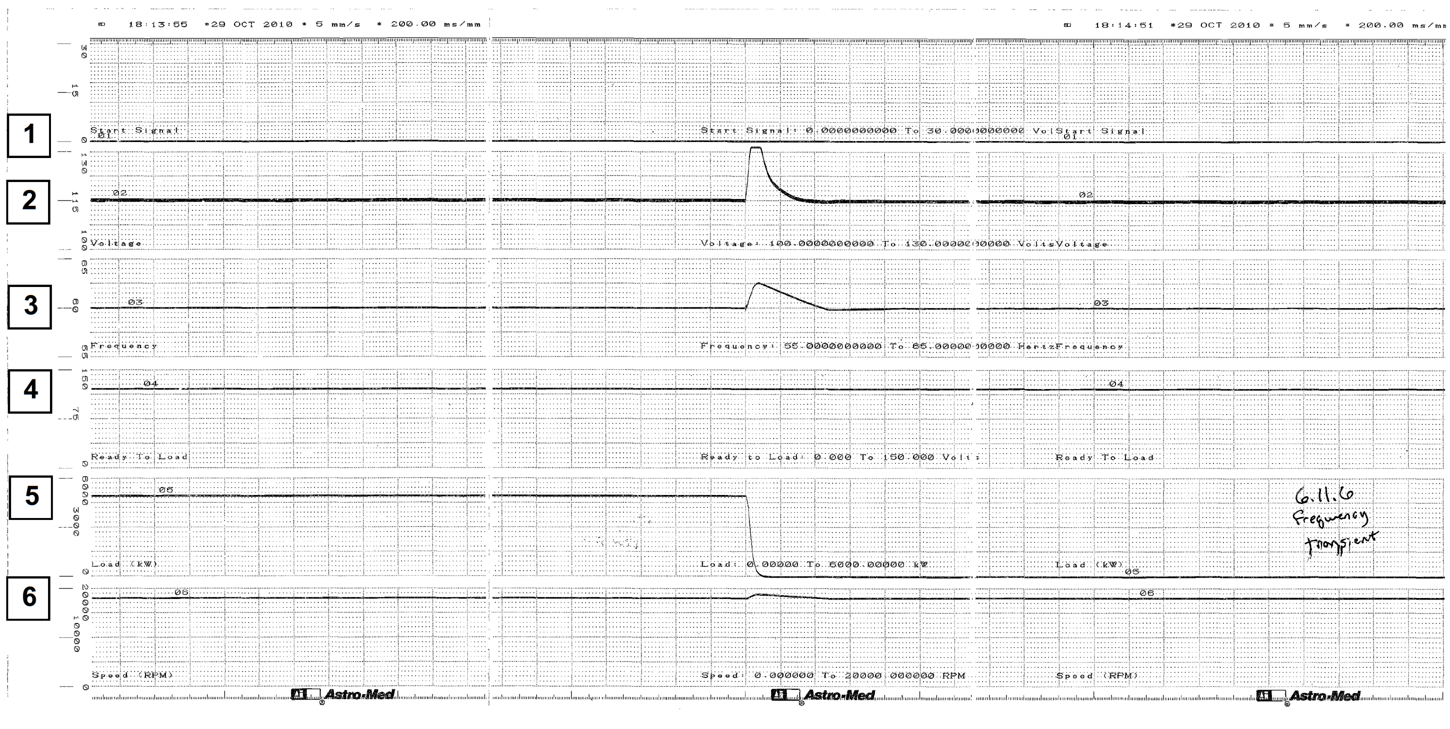


Figure C.1.0-1 Parameter Chart of Load Capability Test

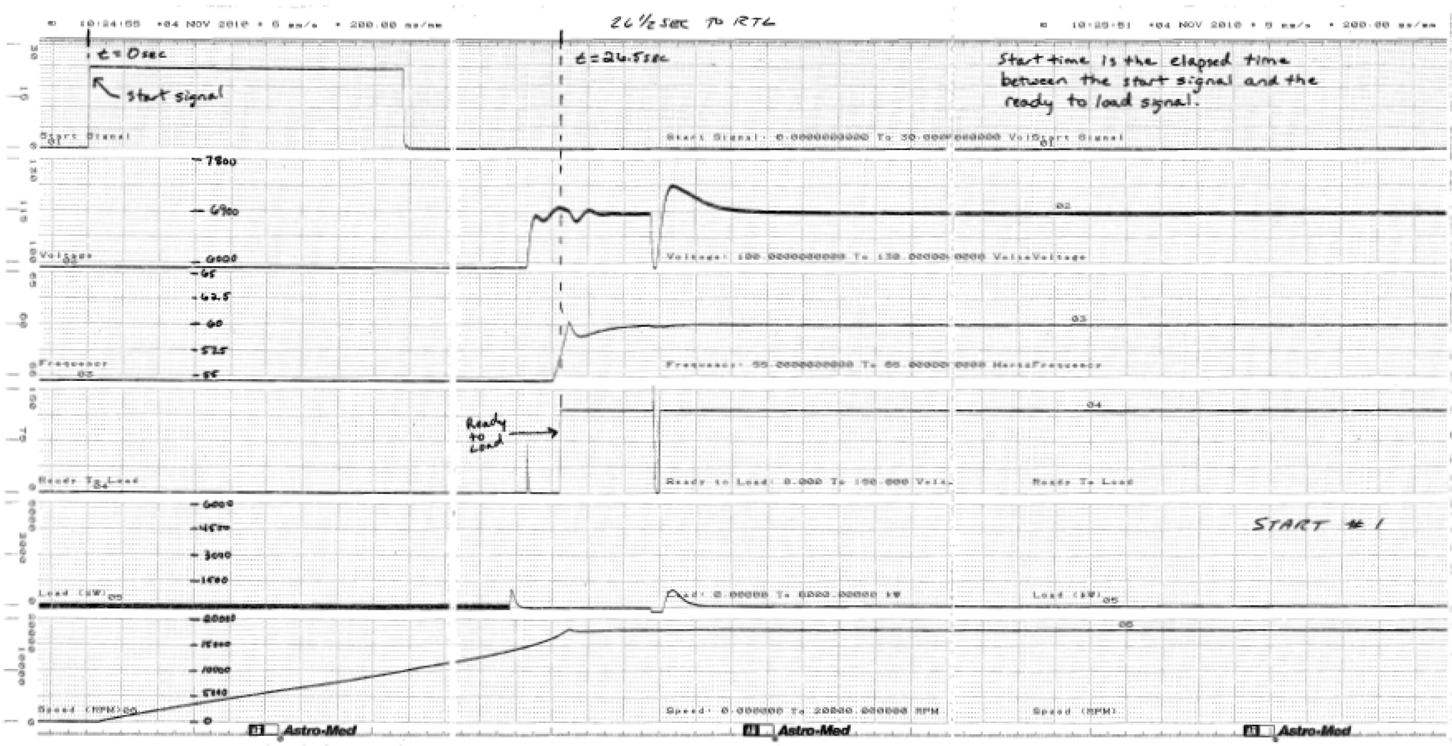


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Figure C.1.0-2 Parameter Chart of Start and Load Acceptance Test, No.1, Cold

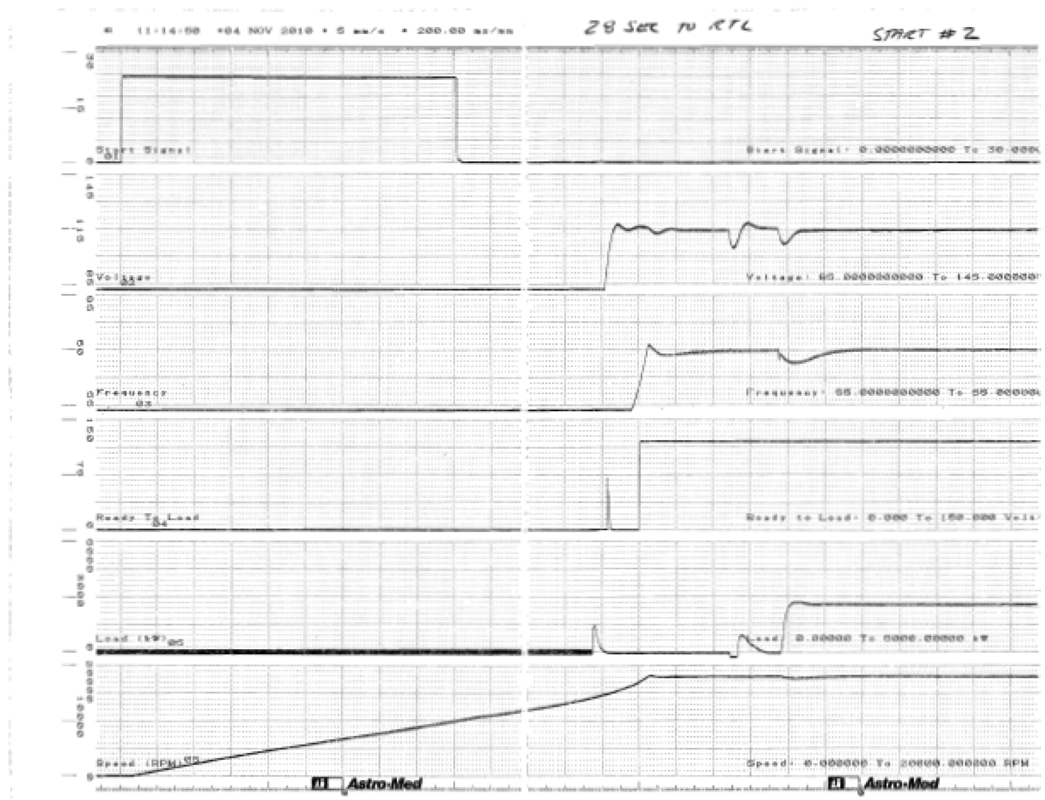

Figure C.1.0-3 Parameter Chart of Start and Load Acceptance Test, No.2, Hot

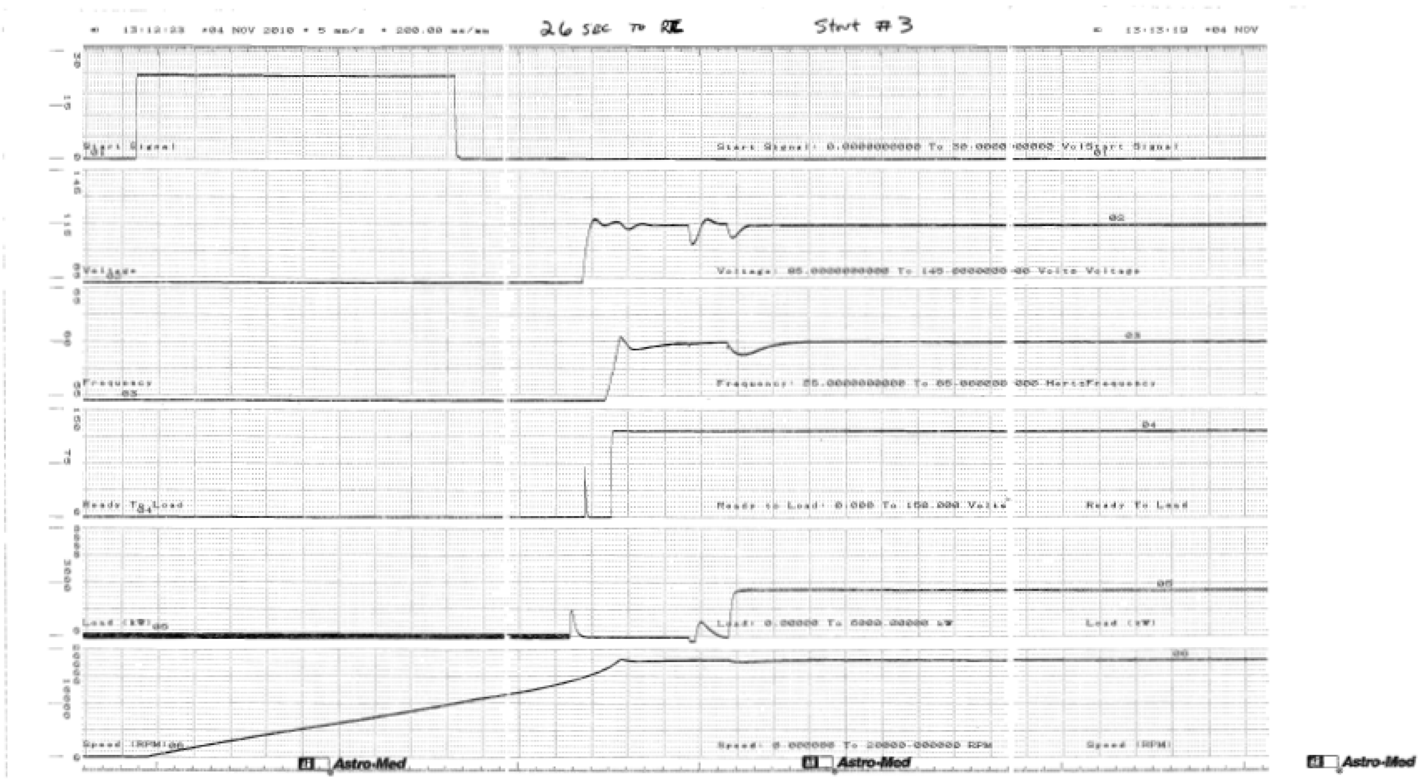

Figure C.1.0-4 Parameter Chart of Start and Load Acceptance Test, No.3, Hot

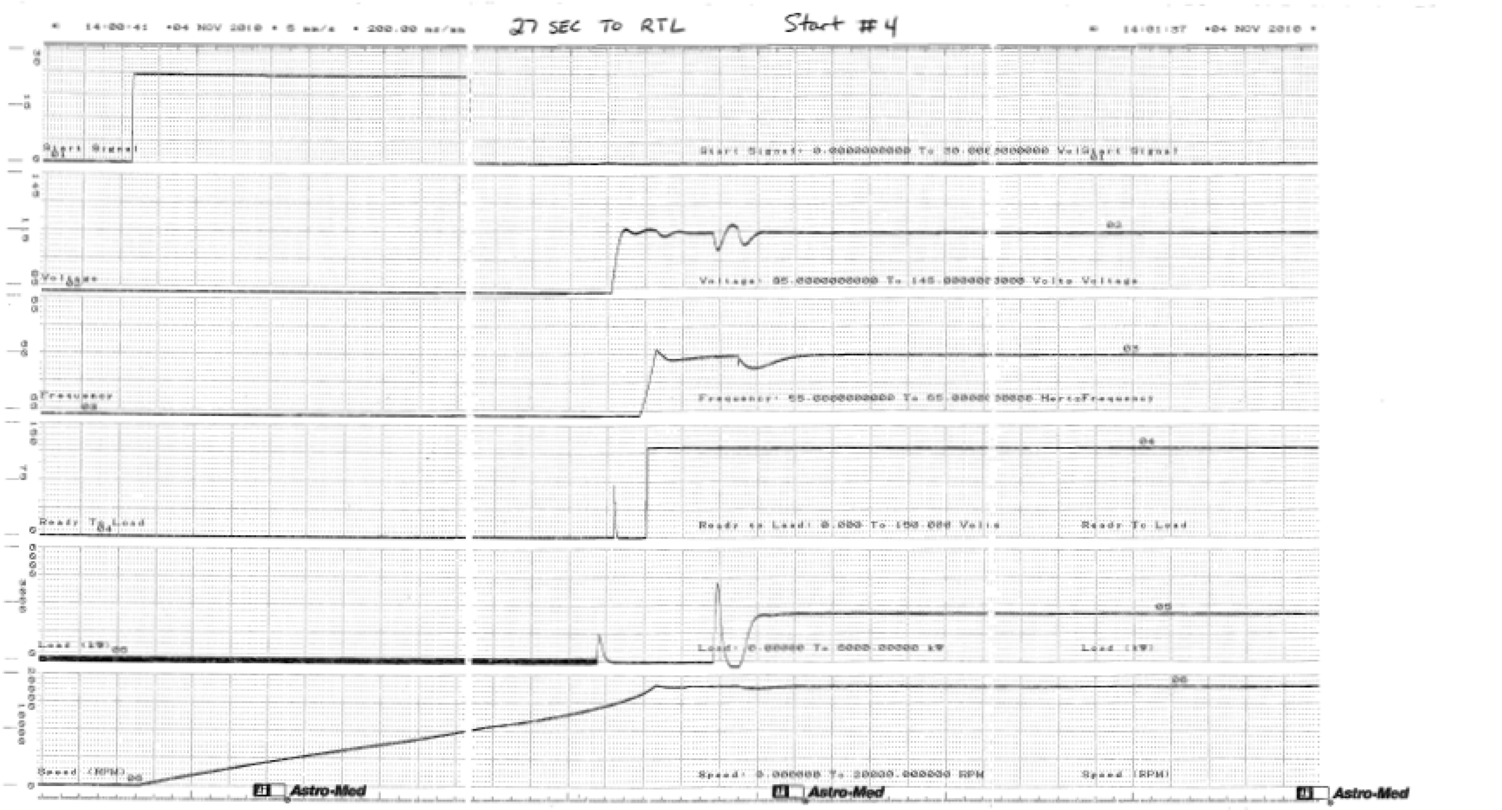

Figure C.1.0-5 Parameter Chart of Start and Load Acceptance Test, No.4, Hot

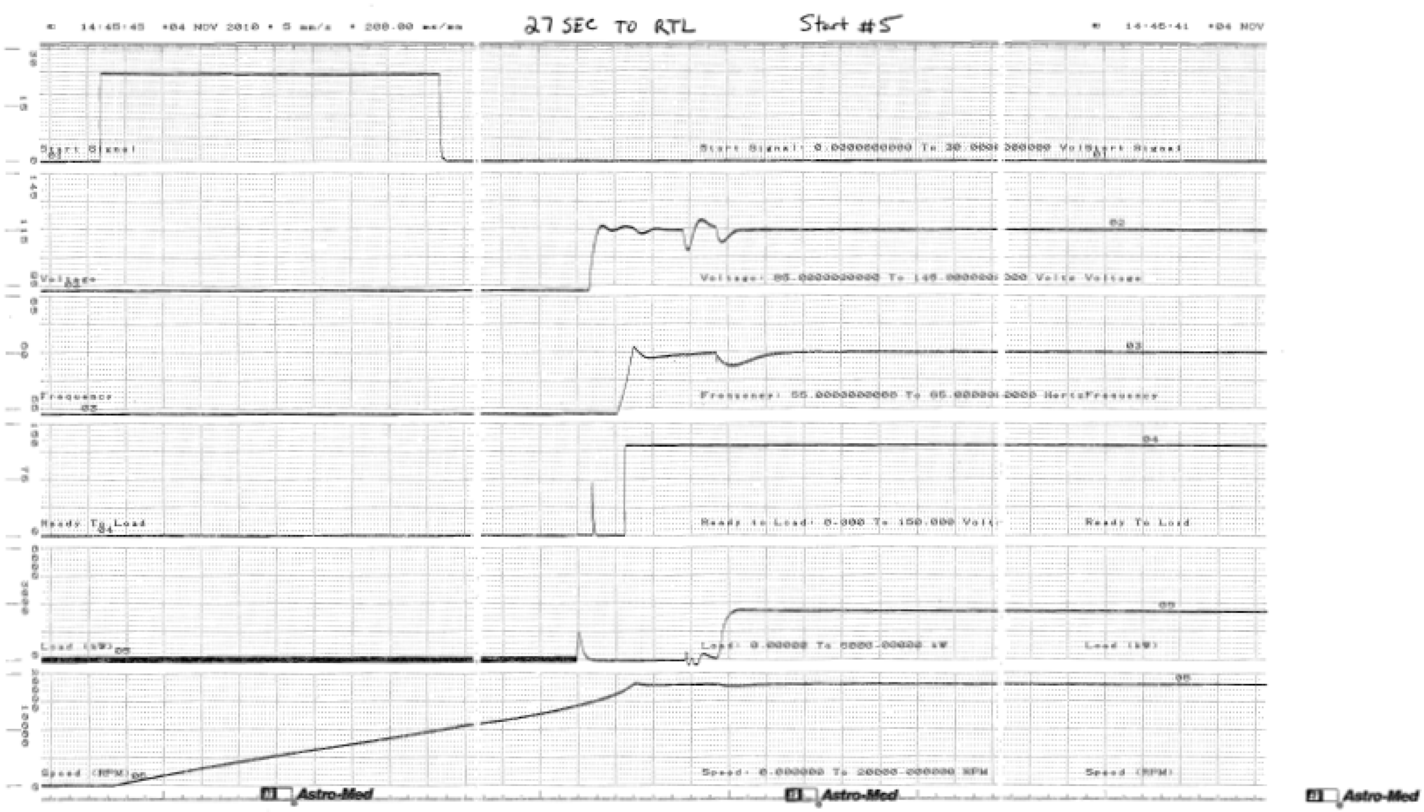

Figure C.1.0-6 Parameter Chart of Start and Load Acceptance Test, No.5, Hot

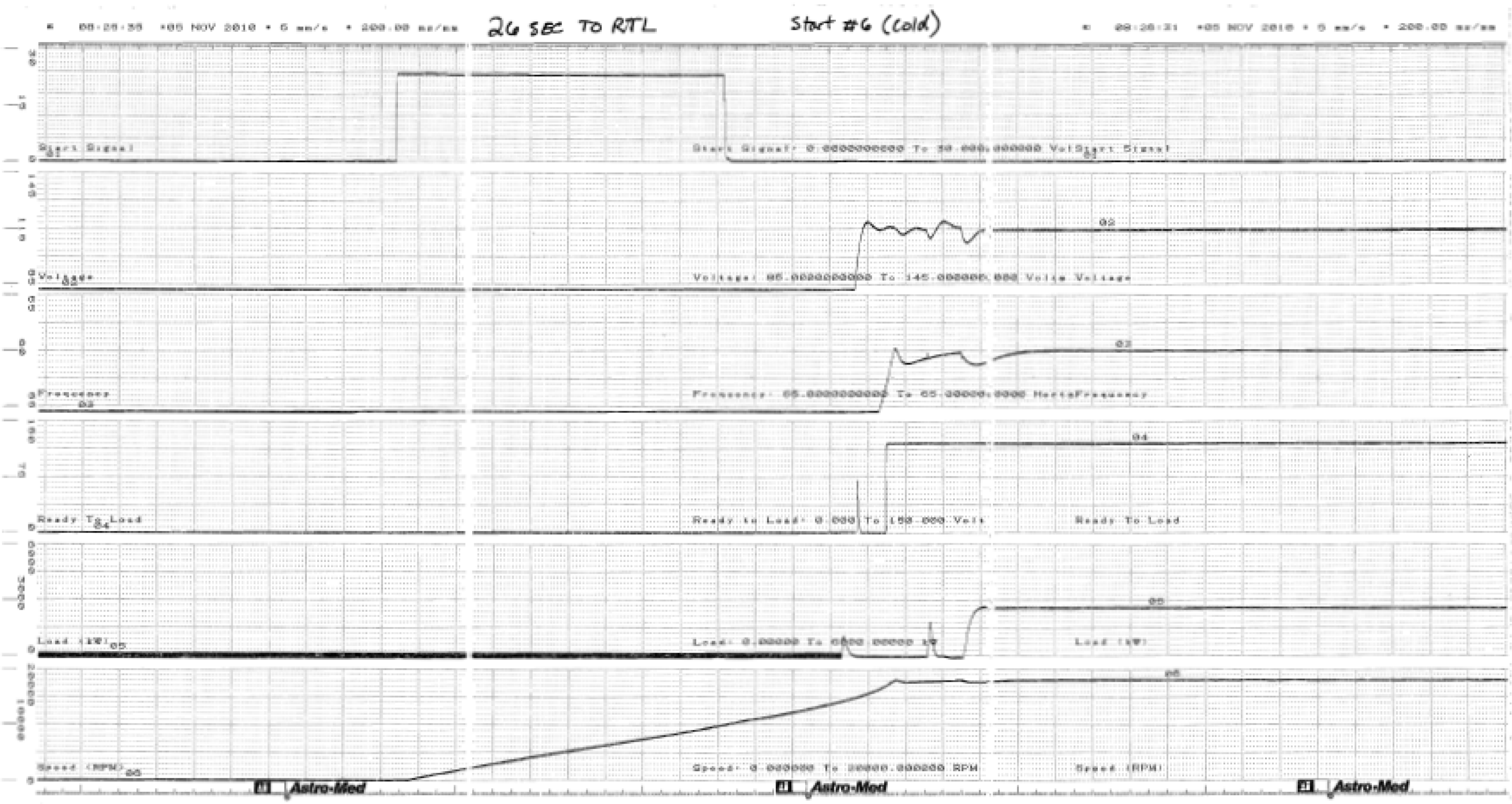

Figure C.1.0-7 Parameter Chart of Start and Load Acceptance Test, No.6, Cold

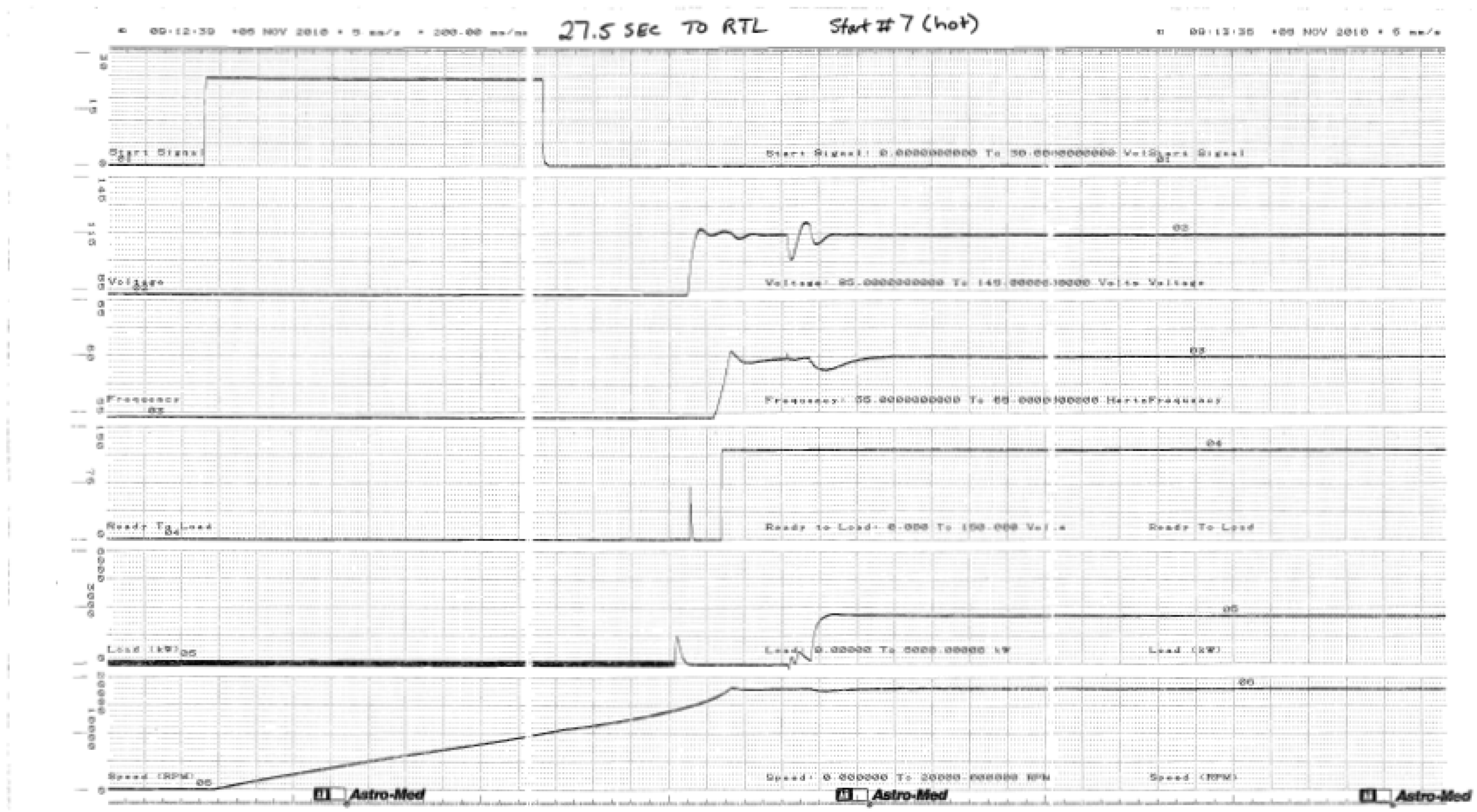

Figure C.1.0-8 Parameter Chart of Start and Load Acceptance Test, No.7, Hot

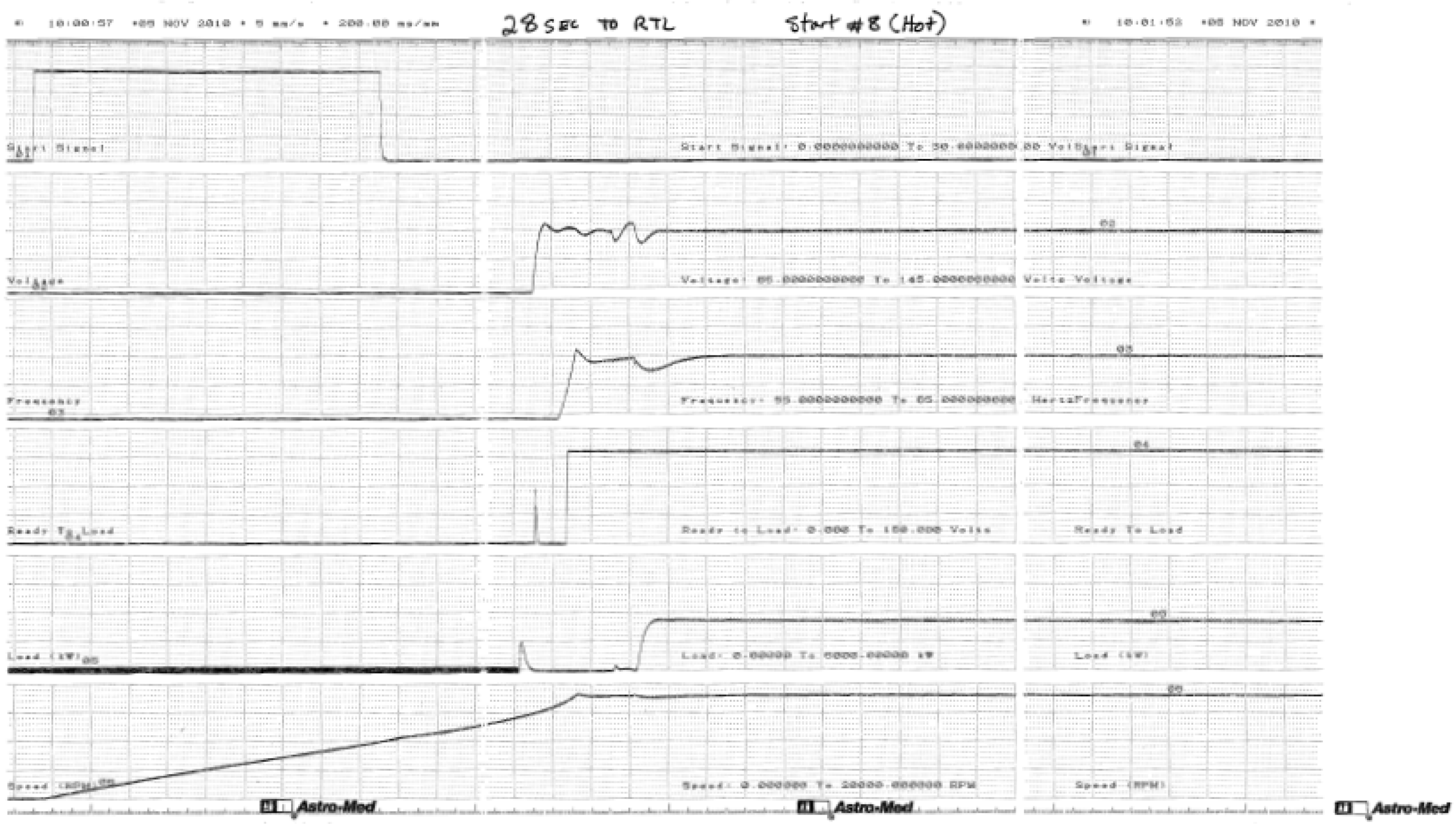

Figure C.1.0-9 Parameter Chart of Start and Load Acceptance Test, No.8, Hot

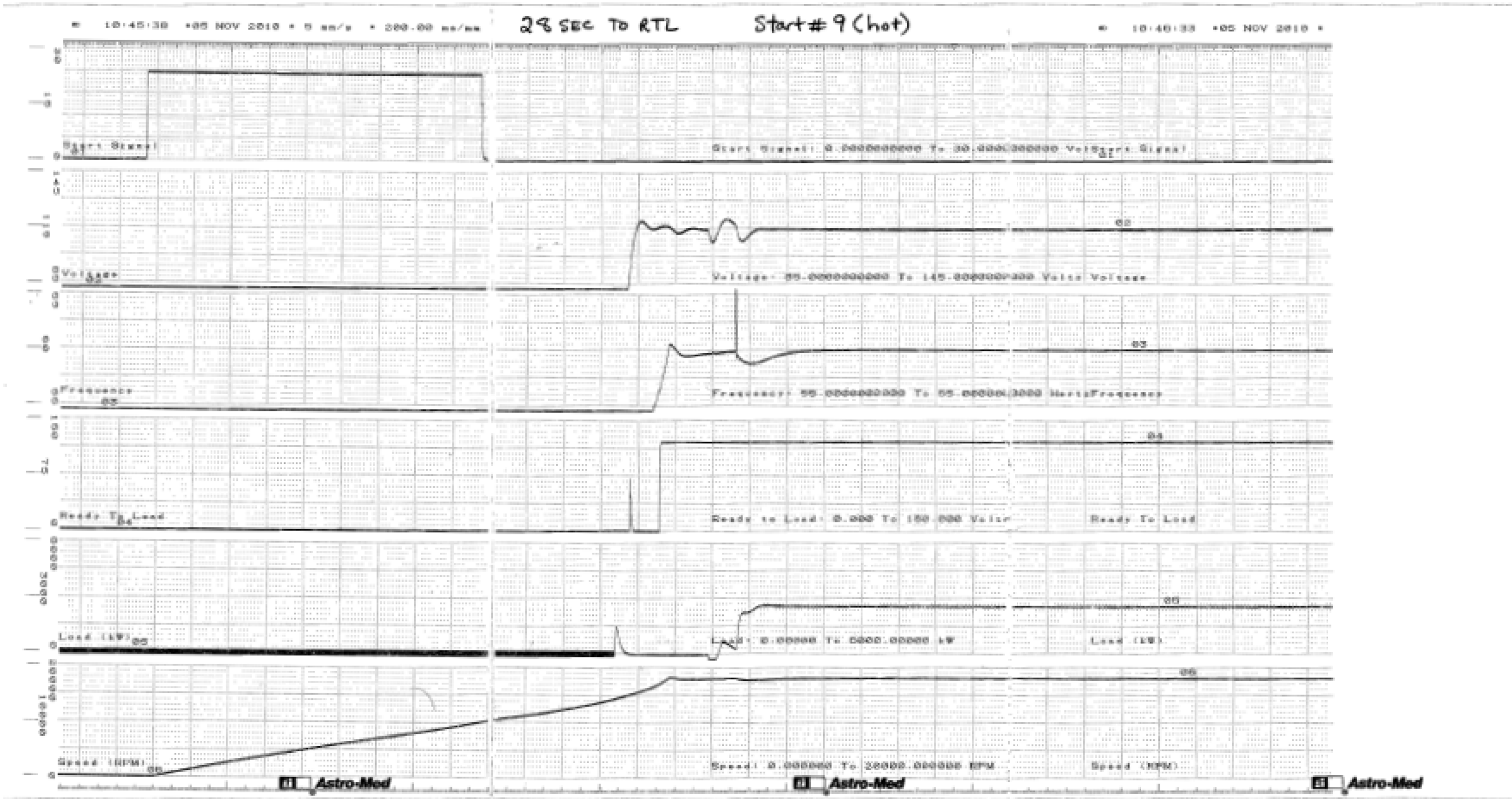

Figure C.1.0-10 Parameter Chart of Start and Load Acceptance Test, No.9, Hot

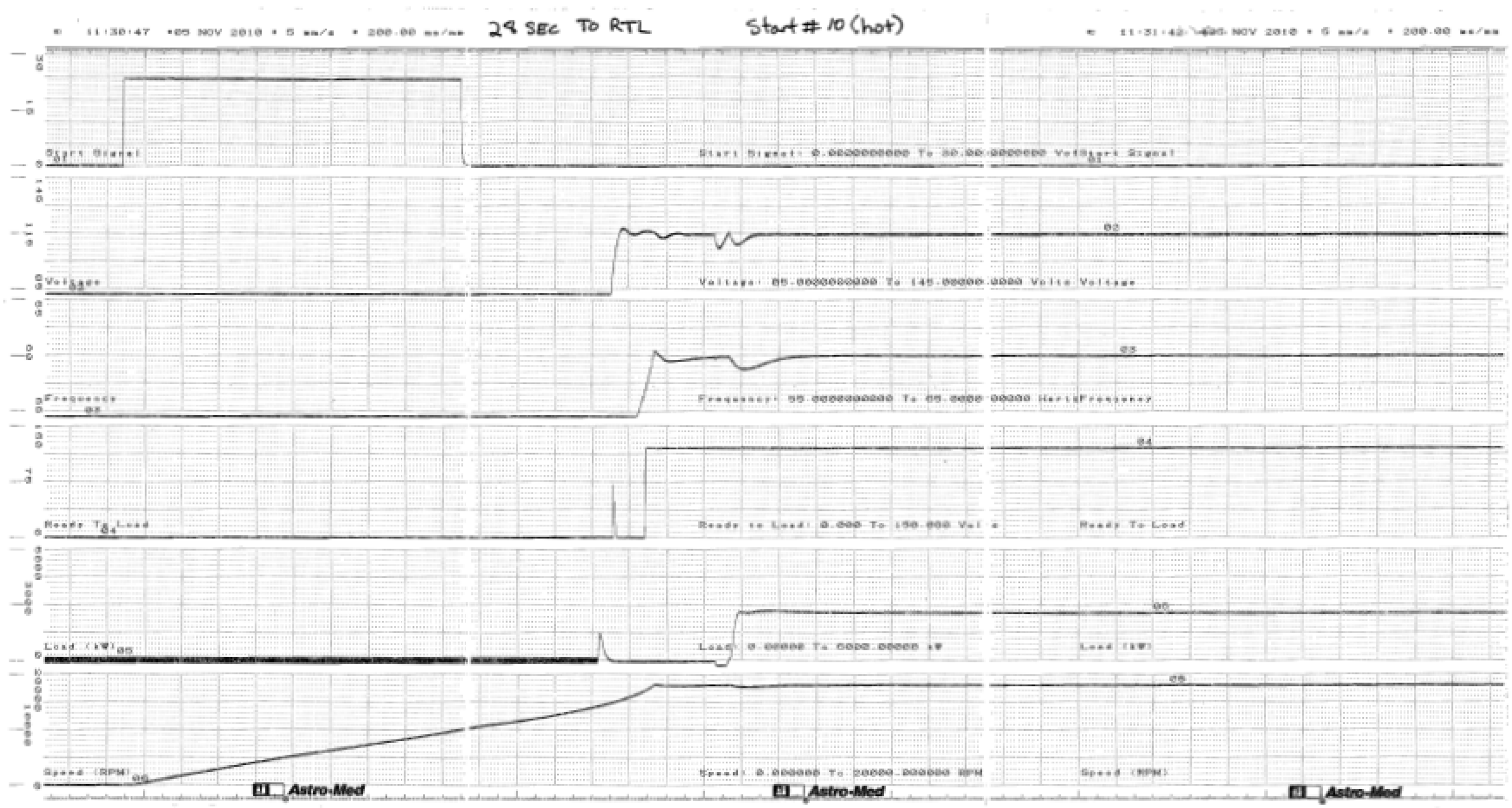

Figure C.1.0-11   Parameter Chart of Start and Load Acceptance Test, No.10, Hot

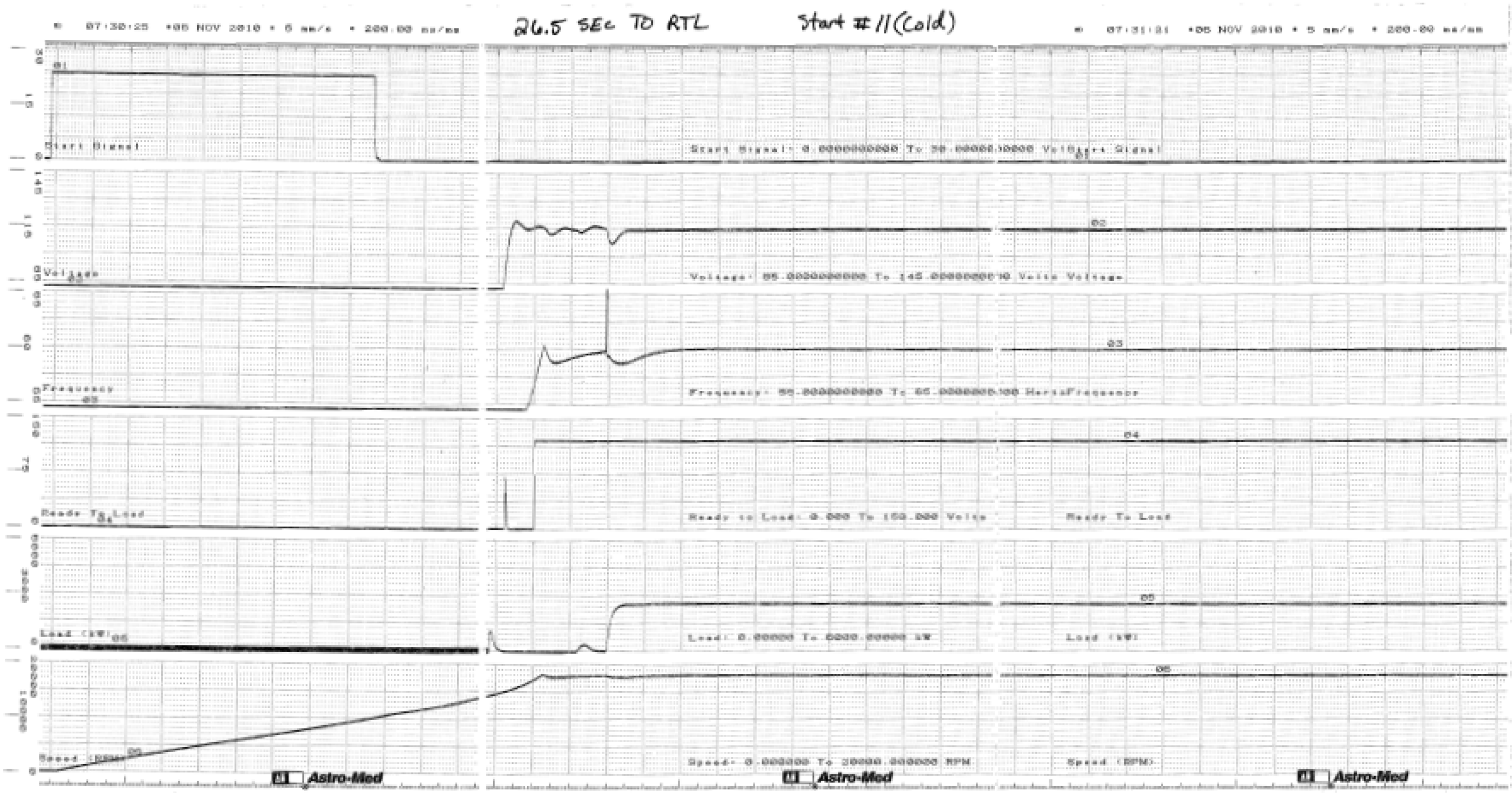

Figure C.1.0-12 Parameter Chart of Start and Load Acceptance Test, No.11, Cold

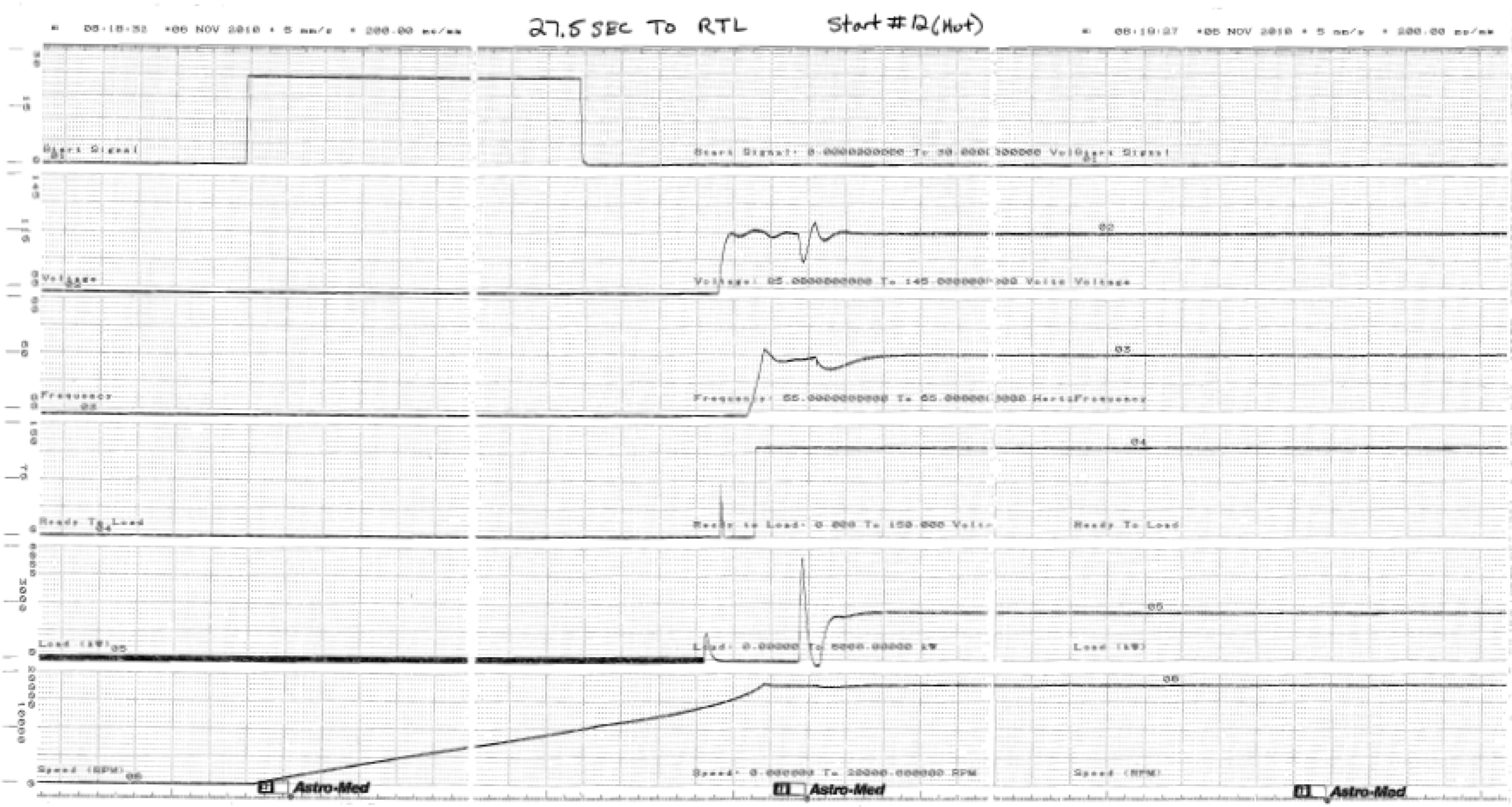

Figure C.1.0-13 Parameter Chart of Start and Load Acceptance Test, No.12, Hot

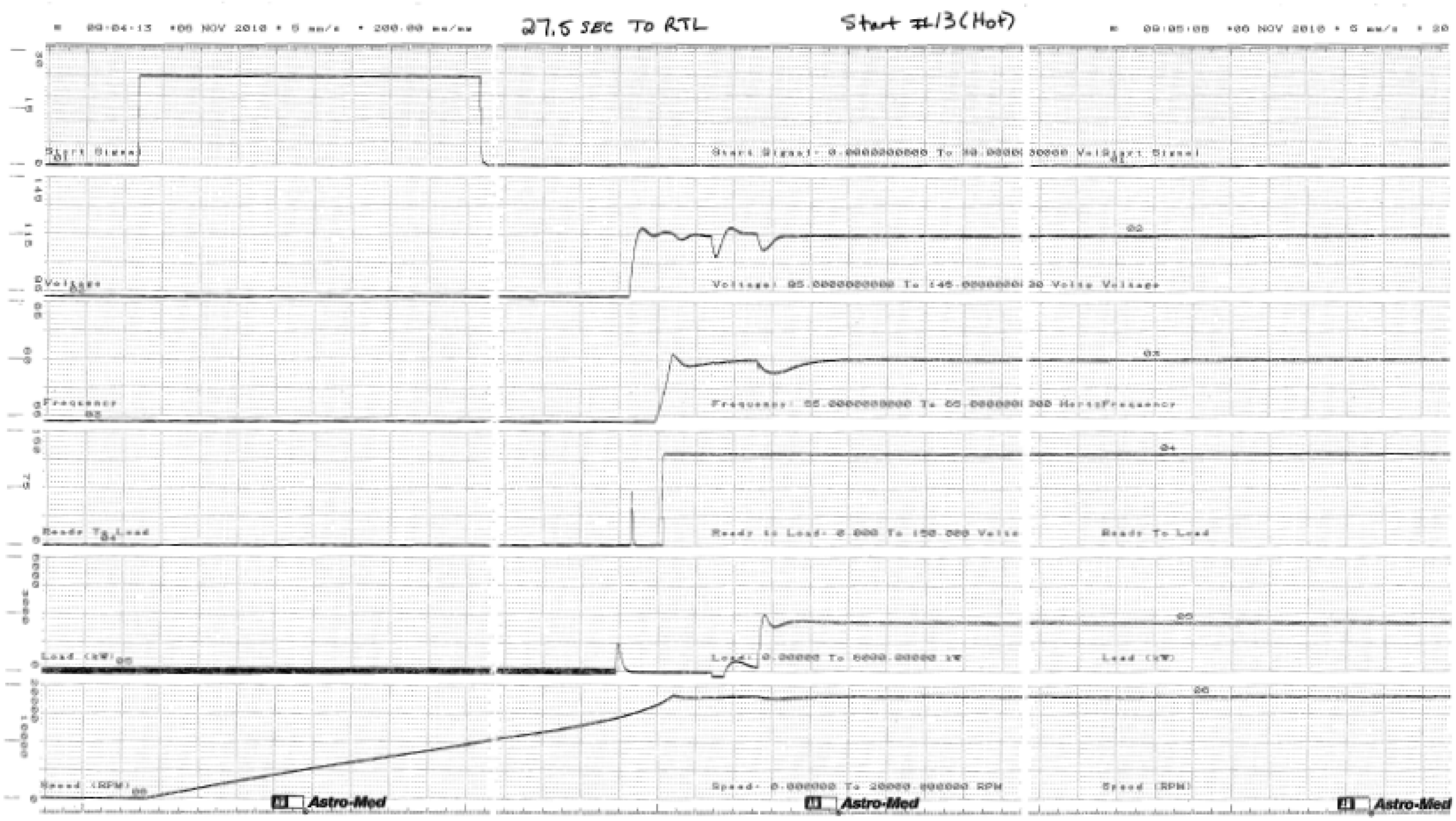

Figure C.1.0-14 Parameter Chart of Start and Load Acceptance Test, No.13, Hot

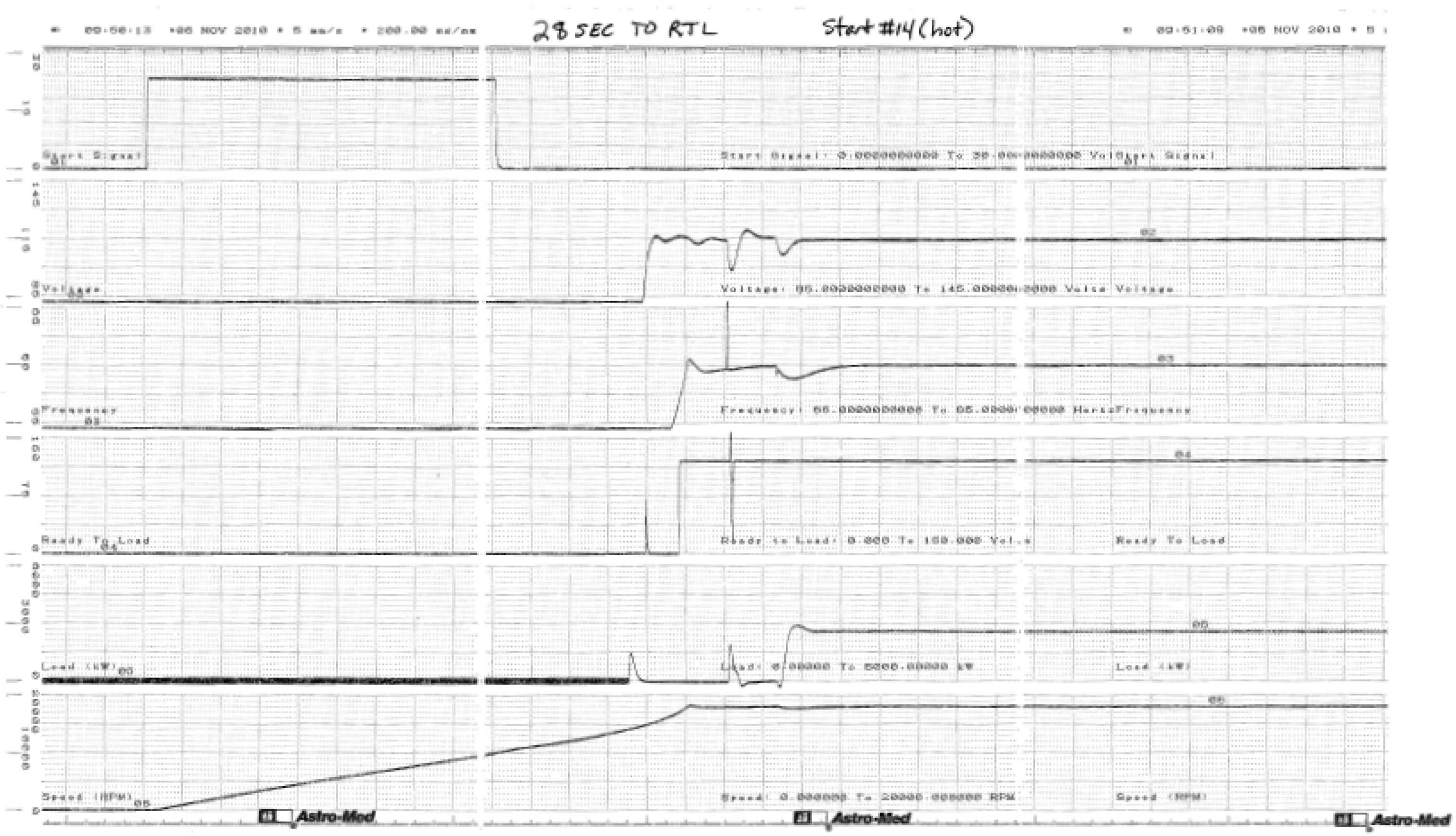

Figure C.1.0-15 Parameter Chart of Start and Load Acceptance Test, No.14, Hot

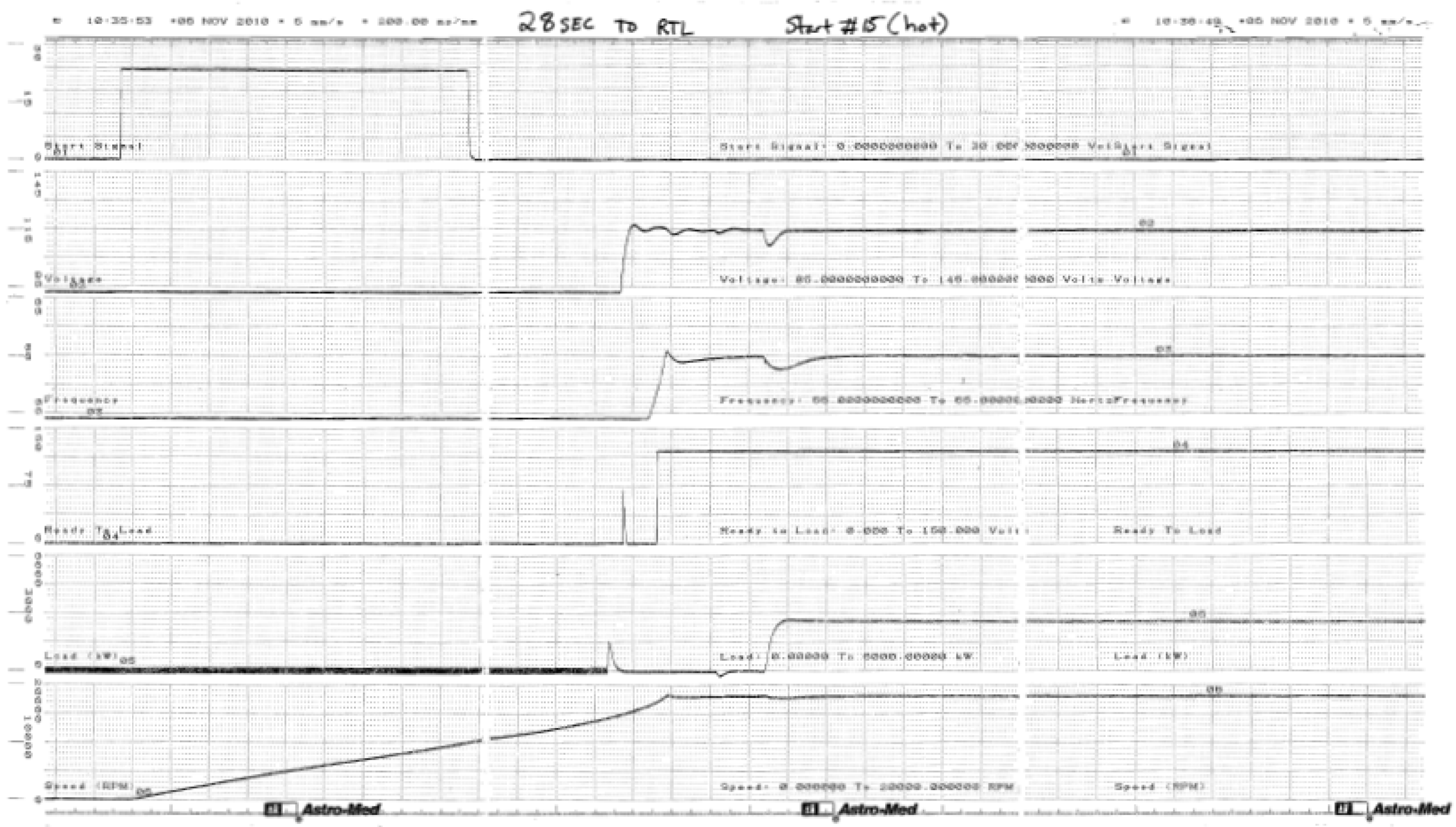

Figure C.1.0-16 Parameter Chart of Start and Load Acceptance Test, No.15, Hot

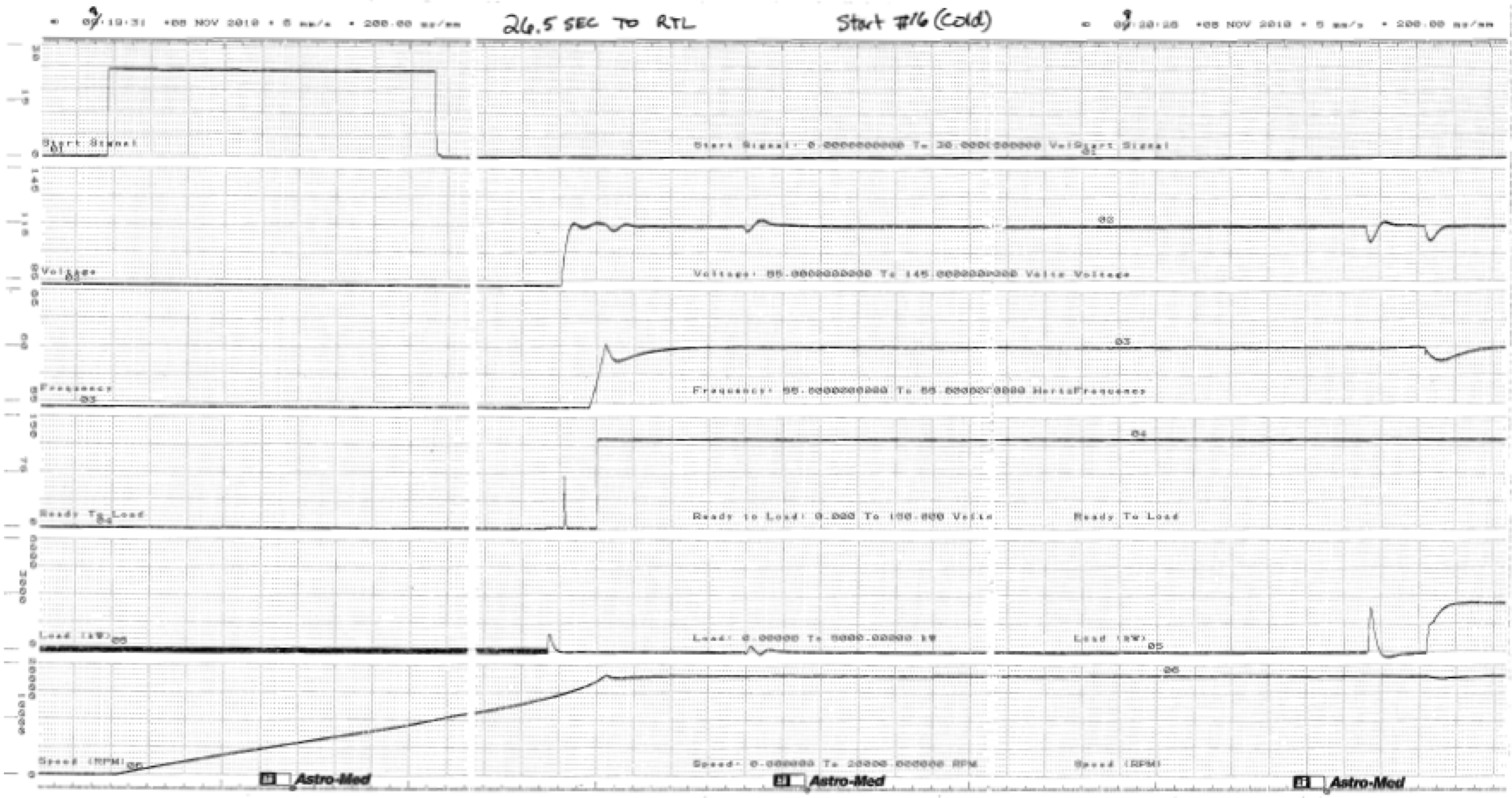

Figure C.1.0-17 Parameter Chart of Start and Load Acceptance Test, No.16, Cold

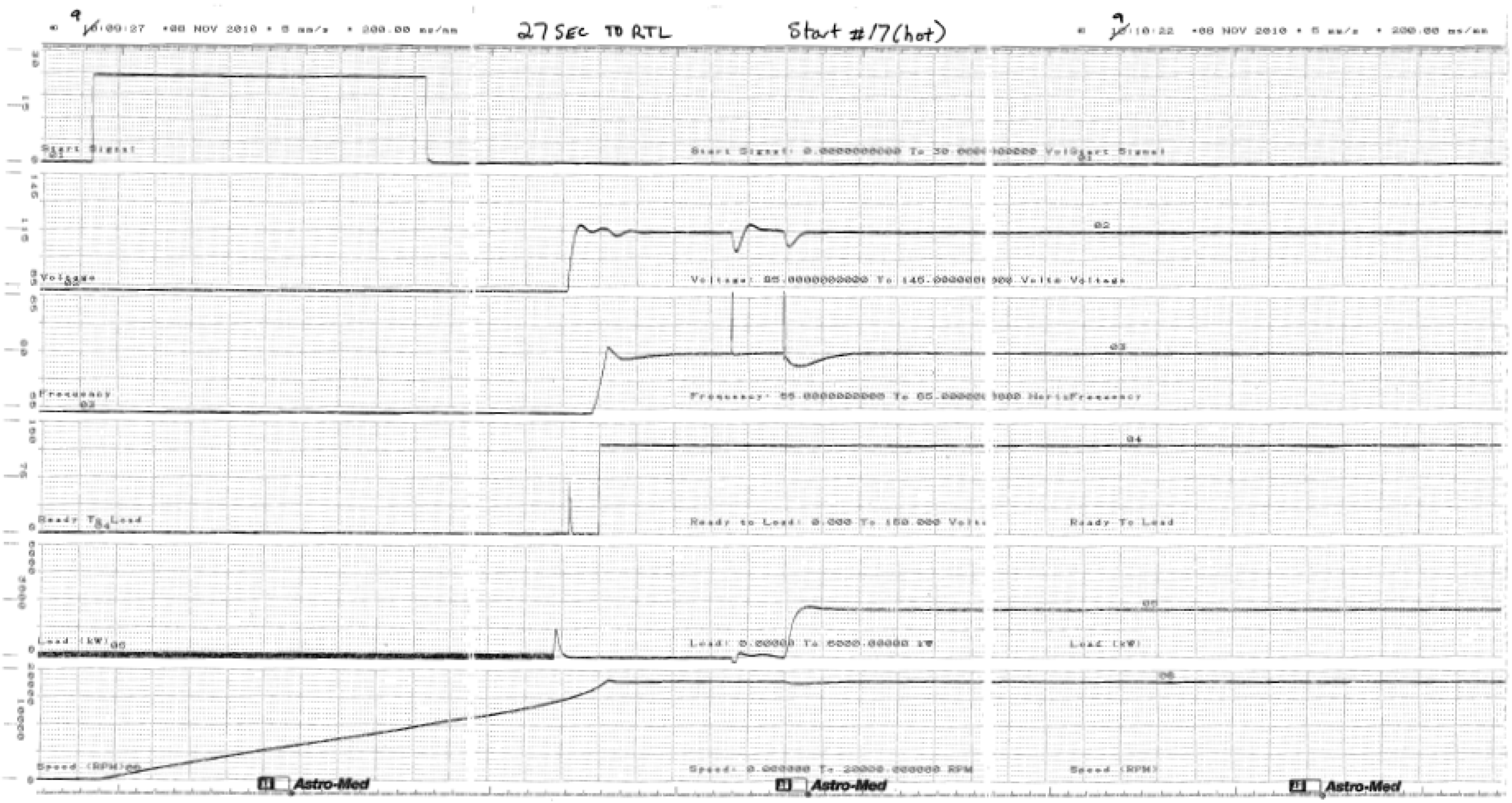

Figure C.1.0-18 Parameter Chart of Start and Load Acceptance Test, No.17, Hot

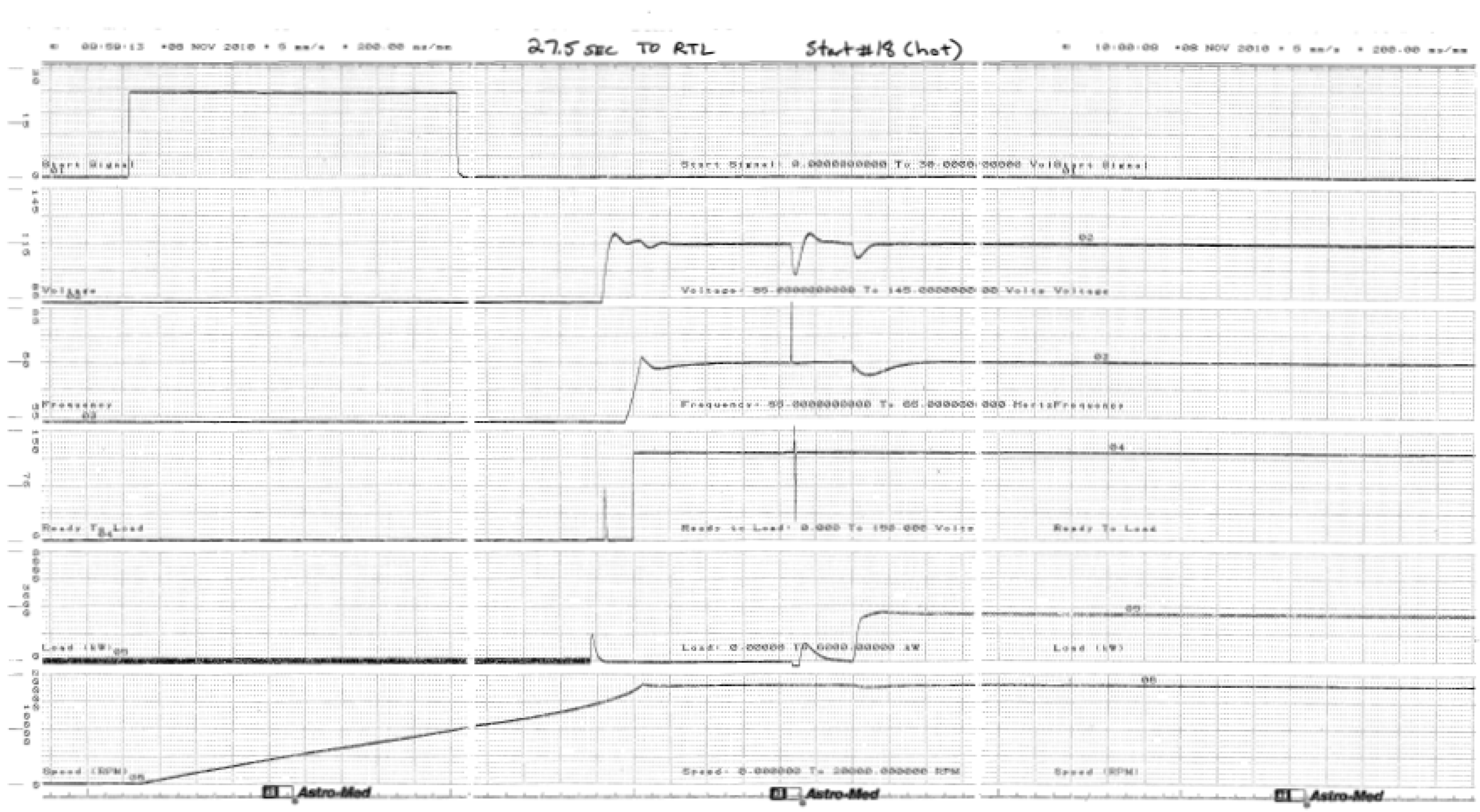

Figure C.1.0-19 Parameter Chart of Start and Load Acceptance Test, No.18, Hot