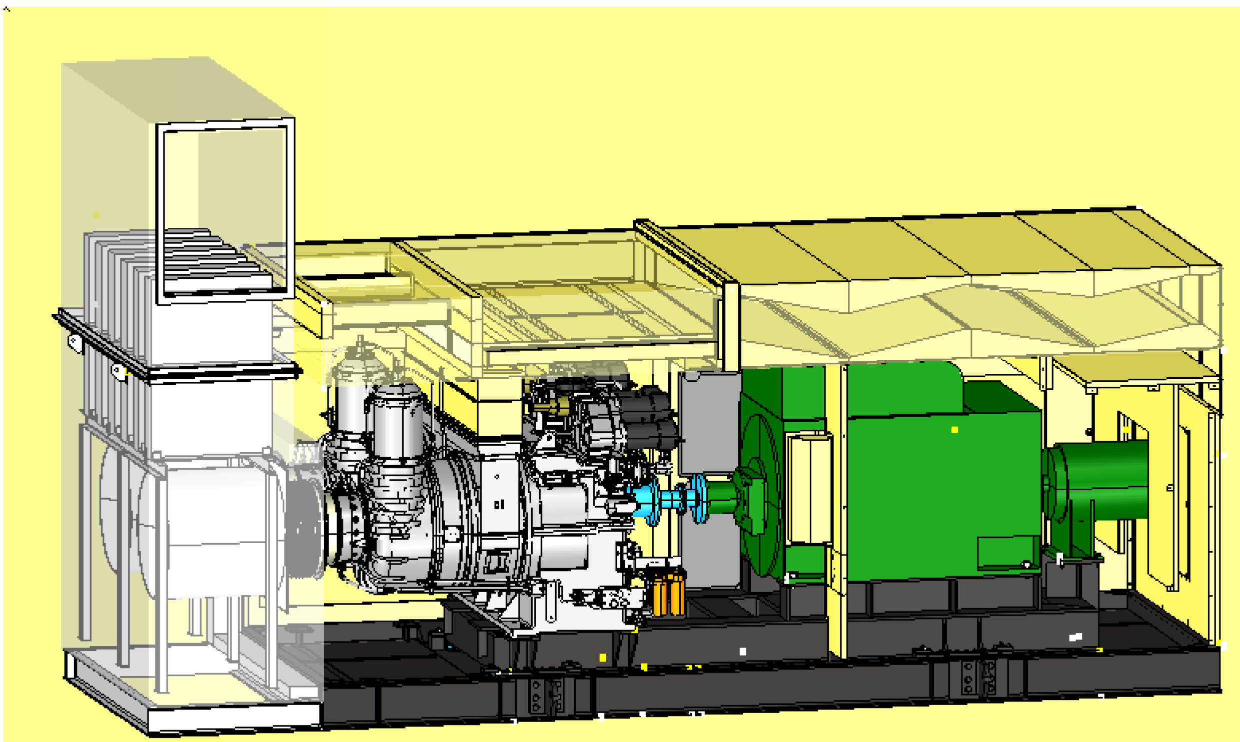
Initial Type Test Result of Class 1E Gas Turbine Generator System



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
	4-2	Changed number of Table 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
	6-2	Added description of Section 6.2.4 for clarification
	6-3	Revised parameter of Table 6.2-3
	6-3	Revised Section 6.3.2

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	6-4	Revised Section 6.3.4
	6-5	Added description of Section 6.4.2, Section 6.4.3 and Section 6.44
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	Appendix B-19 – B-22	Changed Figures B.1.0-6 (Sheet1 – 4)
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	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

Revision	Page	Description
2	Appendix C-160 – C-161	Added Figure C.1.0-158
	Appendix C-162	Changed number from Figure C.1.0-7 to C.1.0-159
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	Appendix E-2	Minor editorial clarification
	Appendix E-5	Revised Table E.2.0-1
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	Appendix F-7	Added Table F.3.0-4 and Table F.3.0-5
	Appendix K-1	Added Appendix K
	Appendix L-1	Added Appendix L
5	6-3	Minor editorial clarification
	6-6 – 6-7	Minor editorial clarification
	Appendix L-3	Added Section L.3.0
6	All	Typographical corrections and grammatical changes to ensure consistency and improve readability throughout the document.
	8-1 – 8-40	Added the results of seismic testing and analysis for the GTG components.
	Appendix M-1	Added Appendix M
	Appendix N-1	Added Appendix N
	Appendix O-1	Added Appendix O
7	All	Typographical corrections and grammatical changes to ensure consistency and improve readability throughout the document and addition of reference documents.
	8-1 – 8-79	Added the results of seismic testing and analysis for the GTG components.
	Appendix O-1	Appendix O was revised to update references
	Appendix P-1	Added Appendix P

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Abstract

This technical report describes the summary of results of initial type test and seismic test of US-APWR Class 1E Gas Turbine Generator (GTG) units.

MHI has performed an initial type test, as required by IEEE Std 387-1995, as part of Class 1E qualification program for US-APWR Class 1E GTG units.

This report documents and concludes that the GTG that was tested 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 part of the GTG components, as defined in IEEE Std 344, as part of the Class 1E qualification program for US-APWR Class 1E GTG units.

This report documents that specific GTG components were successfully qualified by the seismic test or analysis.

This technical report describes the following:

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

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List of Acronyms

ac	Alternate Current
AISC	American Institute of Steel Construction
ASME	American Society of Mechanical Engineers
CAD	Computer-Aided Design
CDP	Compressor Discharge Pressure
CFR	Code of Federal Regulations
CPS	Control Protection and Surveillance systems
CPU	Central Processing Unit
CT	Current Transformer
dc	Direct Current
DCD	Design Control Document
DG	Diesel Generator
ECCS	Emergency Core Cooling System
EGT	Exhaust Gas Temperature
ELV	Electric Liquid Fuel Valve
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
IEEE	Institute of Electrical and Electronics Engineers
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
MOP	Motor Operated Potentiometers
MTBF	Mean Time Between Failure
OBE	Operating–Basis Earthquake
PMG	Permanent Magnet Generator
PS/B	Power Source Building
QA	Quality Assurance
RRS	Required Response Spectra
RTD	Resistance Temperature Detector
R/B	Reactor Building
SAM	Seismic Anchor Movement
SRSS	Square Root of the Sum of the Squares
SSC	Structures, Systems and Components
SSE	Safe-Shutdown Earthquake
SLS	Safety Logic System
TRS	Test Response Spectra
UV	Under Voltage

VDU	Visual Display System
VRR	Voltage Raise Relay
VT	Voltage Transformer
ZPA	Zero Period Acceleration

1.0 INTRODUCTION/OVERVIEW

The US-APWR design applies Gas Turbine Generators (GTG), as Emergency Power Sources, in lieu of Diesel Generators (DGs).

Since GTGs have not been applied for Class 1E Emergency Power Sources (EPSs) for US nuclear power plants, there is no regulatory requirement for Class 1E GTGs. MHI decided to perform the Class 1E qualification in accordance with IEEE Std 387 (Reference 10-1), endorsed by RG 1.9 (Reference 10-2). MHI performed an Initial Type Test of the US-APWR GTG system, as required in IEEE Std 387 (Reference 10-1). The NRC has issued Interim Staff Guidance, ISG-21 (Reference 10-3), which is a design and qualification requirement of Class 1E GTGs. MHI also reflects the requirement of ISG-21 (Reference 10-3) in Class 1E GTG qualification testing. This report describes and provides a conclusion for the results of the Class 1E GTG initial type test.

The Initial type test consists of three kinds of tests: “Load capability test”, “Start and load acceptance test” and “margin test”. MHI performed all three tests and this report summarizes those test results. Also, MHI performed the seismic qualification Test, in accordance with IEEE Std 344 (Reference 10-4), endorsed by RG 1.100 (Reference 10-5).

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 the 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 (Design and Construction)
(4) Regulatory Guide 1.29 Rev. 4, Seismic Design Classification
(5) Regulatory Guide 1.32 Rev. 3, Criteria for Power Systems for Nuclear Power Plants
(6) 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)
(7) Regulatory Guide 1.61 Rev. 1, Damping Values for Seismic Design of Nuclear Power Plants
(8) Regulatory Guide 1.75 Rev. 3, Criteria for Independence of Electrical Safety Systems
(9) Regulatory Guide 1.92, Rev. 3, Combining Modal Responses and Spatial Components in Seismic Response Analysis
(10) Regulatory Guide 1.93 Rev. 0, Availability of Electric Power Sources
(11) Regulatory Guide 1.118 Rev. 3, Periodic Testing of Electric Power and Protection Systems
(12) Regulatory Guide 1.137 Rev. 1, Fuel-Oil Systems for Standby Diesel Generators
(13) Regulatory Guide, 1.100, Rev. 3, Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants
(14) Regulatory Guide, 1.155, Rev. 0, Station Blackout
(15) NUREG/CR-6928, Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants, February 2007
(16) NRC Information Notice 2006-22: New Ultra-low-sulfur Diesel Fuel Oil Could Adversely Impact Diesel Engine Performance
(17) 10 CFR 50, Appendix S - Earthquake Engineering Criteria for Nuclear Power Plants, Domestic Licensing of Production and Utilization Facilities, Energy
(18) 40 CFR 50 - NATIONAL PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS
(19) 40 CFR 52 - APPROVAL AND PROMULGATION OF IMPLEMENTATION PLANS
(20) 40 CFR 60 - STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES
(21) 40 CFR 61 - NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS
(22) 40 CFR 63 - NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS FOR SOURCE CATEGORIES
(23) 40 CFR 68 - CHEMICAL ACCIDENT PREVENTION PROVISIONS
(24) 40 CFR 70 - STATE OPERATING PERMIT PROGRAMS
(25) 40 CFR 71 - FEDERAL OPERATING PERMIT PROGRAMS
(26) 40 CFR 81 - DESIGNATION OF AREAS FOR AIR QUALITY PLANNING PURPOSES

(27) DC/COL-ISG-021, Final Interim Staff Guidance: 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, IEEE Recommended Practice - General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation
(2) IEEE 43-2000, IEEE 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, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
(6) IEEE 275-1992, IEEE 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 323-1974, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
(9) IEEE Std 323-2003, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
(10) IEEE 336-2005, IEEE Guide for Installation, Inspection, and Testing for Class 1E Power, Instrumentation, and Control Equipment at Nuclear Facilities
(11) IEEE 338-2006, IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems
(12) IEEE-344-2004, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
(13) IEEE-379-2000, IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems
(14) IEEE Std 384-2008, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits
(15) IEEE Std 387-1995, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations
(16) IEEE-415-1986, IEEE Guide for Planning of Preoperational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations
(17) IEEE-421.3-1997, IEEE Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines
(18) IEEE-421.4-2004, IEEE Guide for the Preparation of Excitation System Specifications
(19) IEEE 429-1994, IEEE 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
(20) IEEE-493-2007, IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power 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 for Design Qualification of Safety Systems 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) ASME NQA-1-1994, Quality Assurance Program Requirements for Nuclear Facility Applications
(4) ANSI B31.1-2007, Power Piping
(5) ANSI B37.20, Switchgear Assemblies including Metal Enclosed Bus
(6) ANSI/IEEE C37-90.1-2002, IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
(7) ANSI/IEEE C37-101-2006, IEEE Guide for Generator Ground Protection
(8) ANSI/IEEE C37.102-2006, IEEE Guide for AC Generator Protection
(9) ANSI/IEEE 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/IEEE C57.13-1993, IEEE Standard Requirements for Instrument Transformers (if needed)
(12) ANSI/IEEE C62.92.2-1989, IEEE Guide for the Application Guide for Neutral Grounding in Electrical Utility Systems, Part II - Grounding of Synchronous Generator Systems
(13) ANSI/ASME B16.11-2009, Forged Fittings, Socket-Welding and Threaded
(14) ANSI/ASME B16.25-2007, Buttwelding Ends
(15) ASME Boiler & Pressure Vessel Code, Section III, 2001 Edition through the 2003 Addenda, Rules for Construction of Nuclear Facility Components
(16) ANSI/ANS-59.51-1997, Fuel Oil Systems for Safety-Related Emergency Diesel Generators
(17) ASTM D396, Standard Specification for Fuel Oils
(18) ASTM D975-1981, Standard Specification for Diesel Fuel Oils
(19) ANSI/NFPA 37-2006, Combustion Engines and Gas Turbines, Stationary
(20) ASME Boiler & Pressure Vessel Code, Section XI, the latest version, Rules for Inservice Inspection of Nuclear Power Plant Components
(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
(29) ISO 3977-3, 2004, Gas turbines - Procurement - Part 3: Design requirements
(30) Steel Construction Manual, American Institute of Steel Construction, Fourteenth Edition, February 2012

(31) American Institute of Steel Construction, Inc. Document No. ANSI/AISC N690-1994(R2004), Supplement No. 2 to the Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, October 2004

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, which are only scheduled for maintenance during outages.

3.3 Design Basis Events:

Postulated events used in the design to establish the performance requirements of the structures, components, 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 twin diesel-fueled internal combustion engines coupled to an electrical generator 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 temperature is within ± 5.5°C (10°F) of the engine normal operating temperature 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 item of equipment or a system that duplicates the essential function of another item of equipment or a 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 environmental 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 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 (Reference 10-6).

IEEE Std 387 (Reference 10-1) defines the boundaries of systems and equipment included in its scope. Although there is no regulatory requirement for a Class 1E GTG system, MHI decided the scope of systems and equipment to be tested in Class 1E GTG qualification should be the same as those identified in IEEE Std 387 (Reference 10-1), and as shown in Figure 4.0-1. MHI manufactured a prototype system based on Figure 4.0-1 and tested the prototype system.

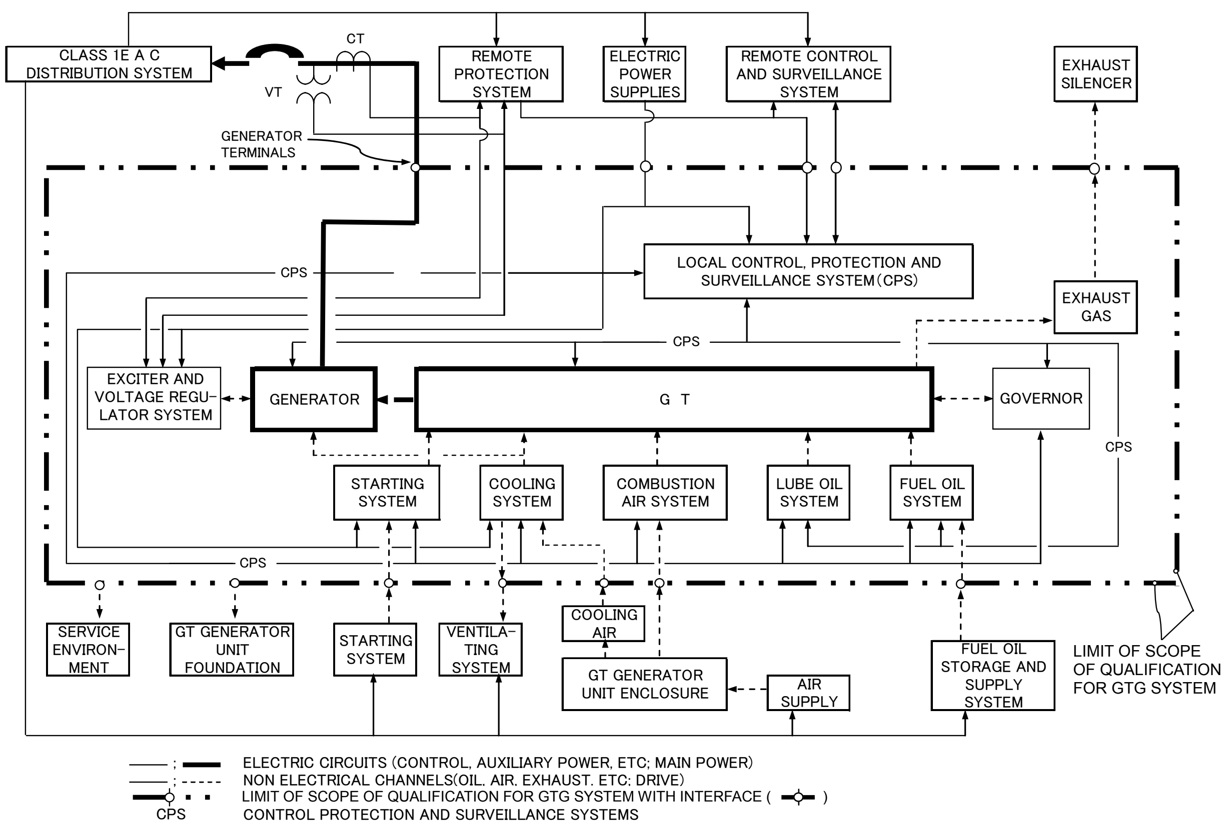

Figure 4.0-1 Scope Diagram

4.2 Prototype System Tested

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

Systems or components of the prototype GTG system contained inside the dashed line, shown in Figure 4.0-1, have the same specification as actual US-APWR GTG system. The other systems or components outside the dashed line are temporary and commercial and are only supplied for these tests.

Table 4.0-1 Design Condition of Prototype GTG System

Component	Condition
Gas Turbine Engine With gearbox	Same as actual US-APWR GTG system design
Generator	Same as actual US-APWR GTG system design
Generator Bearing Lubrication Oil Unit	Same as actual US-APWR GTG system design
Lube Oil Cooler Fan Assembly	Same as actual US-APWR GTG system design
Acoustic enclosure	Same as actual US-APWR GTG system design
Engine skid	Same as actual US-APWR GTG system design
Fuel day tank	Same as actual US-APWR GTG system design
Air start receiver	Same as actual US-APWR GTG system design
Air start valve unit	Same as actual US-APWR GTG system design
Air intake/ exhaust air duct	Temporary equipment for test
Local control cabinet	Same as actual US-APWR GTG system 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 (Reference 10-6). Also the GTG system is designed in accordance with IEEE Std 387 (Reference 10-1).

5.2 System Specification

5.2.1 Starting Time

(1) The US-APWR safety design and analysis requires that the GTG start within 100 seconds. Within 100 seconds, after the start signal is initiated, the GTG achieves the required voltage and frequency, and the GTG breaker is closed.
(2) US-APWR GTG specification requires that the required voltage and frequency be achieved within 40 seconds.

5.2.2 Rating

The US–APWR GTG is rated as follows:
- ✓ 4500 kW Continuous Rating @ 1,000 hrs Engine Overhaul Interval, 115°F Air Intake Temperature
- ✓ 4950 kW Short Time Rating @ 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 (Reference 10-7).
(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 (4500 kW) rating (1250 gallon rated) is provided. Tank is constructed in accordance with ASME Section III, Class 3 (Reference 10-8).

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

5.2.4 Lubrication Oil System

The Lubrication Oil System consists of two systems, described below:

(1) One complete lube oil system is furnished to supply oil under pressure to the GTG engine bearings and reducing gear bearings, and the other system is furnished to supply lubricating oil to the 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 start receivers in the prototype system tested. In the plant design, the total design capacity of air start receivers in each train is sufficient to provide the required air pressure for three starts. The receivers are constructed in accordance with ASME Section III, Class 3 (Reference 10-8).

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 (the secondary air pressure) to the specified pressure. The secondary air pressure depends on the air starter's maximum limit pressure at the air starter inlet.

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

The system configuration of the 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 the tested system is shown in Figure B.1.0-11. Those will be designed in accordance with the site specific condition during system installation at a plant.

5.2.7 Acoustic Enclosure/Engine Skid

The engine and generator systems are mounted on the skid type base plate, which is constructed of rolled steel sections welded together to form a rigid base. The baseplate is designed for bolting to a reinforced concrete foundation.

The enclosure assembly is mounted on the baseplate and houses the engine and generator systems. The enclosure assembly serves to route the ventilation air through the enclosure as well as reduce the overall sound level in the equipment space.

5.2.8 Control system

One free standing local control panel, having the 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 a signal received from the GTG safety logic system, which is a digital control cabinet that is not within the qualification scope.

5.2.9 Load Profiles

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

5.3 Component Specifications

5.3.1 Gas Turbine Engine and Gearbox

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

Table 5.3-1 Specification for Gas Turbine Engine and Gearbox

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 for 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 Acoustic Enclosure

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

5.3.4 Engine Skid

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

5.3.5 Fuel Day Tank

Specification for fuel day tank is shown in Table 5.3-3.

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 Start Receiver

Specification for air start receiver is shown in Table 5.3-4.

Table 5.3-4 Specification for Air Start Receiver

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

5.3.7 Lubrication Oil System

Specification for lubrication oil system is shown in Table 5.3-5.

Table 5.3-5 Specification for Lubrication Oil System

<table>
<tr><th colspan="2">Item</th><th>Specification</th></tr>
<tr><td rowspan="2">Lubrication Oil System for the engine bearings and reducing gear bearings</td><td>Total flow</td><td>112 USGPM [424 L/min]</td></tr>
<tr><td>Lube Oil Supply Pressure</td><td>0.34±0.05 MPa [G] at Manifold</td></tr>
<tr><td rowspan="3">Generator Bearing Lubrication Oil System</td><td>Total flow</td><td>2 USGPM [7.6 L/min]</td></tr>
<tr><td>Lube Oil Supply Pressure</td><td>14 PSI[1 bar Max] at the bearing</td></tr>
<tr><td>Voltage</td><td>480 VAC (lubricating oil),
125 VDC (hydraulic jacking)</td></tr>
<tr><td rowspan="2">Lube Oil Cooler Fan Assembly</td><td>Ambient temperature (maximum)</td><td>50°C (122°F)</td></tr>
<tr><td>Voltage</td><td>460 VAC</td></tr>
</table>

5.3.8 ELV (Electric Liquid fuel Valve) Driver

ELV (Electric Liquid fuel Valve) control the fuel flow to GTG. This is an all-electric fuel valve, which discharges fuel from the 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. Specification for ELV driver is shown in Table 5.3-6.

Table 5.3-6 Specification for ELV Driver

Output Range	Fuel control output	0 - 100%
	DC	4 - 20mA

6.0 INITIAL TYPE TEST

6.1 General

The testing was performed in accordance with the initial type test portion of IEEE Std 387-1995 (Section 6.2) (Reference 10-1) and ISG-021 (Reference 10-3), for application to gas turbine generator sets. The Initial Type Test basic requirements are provided in MUAP-07024-P (Reference 10-9). The objectives, basic requirements and acceptance criteria presented in MUAP-07024-P (Reference 10-9) 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 required, and to successfully reject load. One successful completion of the test sequence shall satisfy this requirement.

6.2.2 Basic Continuous Load Requirements

a) Load equal to the continuous rating shall be applied for the time required to reach engine temperature equilibrium.
b) Immediately following step 6.2.2.a), the short-time continuous 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 continuous 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 through 6.2-3. The GTG was operated in the stable condition without incident, failures or abnormal conditions.

Upon rejection of 110 % load, the engine did not trip on over speed. At the end of the full load operation, the load was increased to 110% of rated load and the load was immediately removed to verify that 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% 2 hour 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.

6.3.2 Basic Requirements

a) Engine cranking shall begin upon receipt of the start signal, and the GTG unit shall accelerate to the 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) (Reference 10-1) 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) (Reference 10-1). 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 (Reference 10-1), 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 in Section 6.3.3 were met, 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 Figure 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 Figure C.1.0-160.

The results of Margin Tests No. 1 and No. 2 met the requirements of Subsection 6.4.3 – Acceptance Criteria, Parts a) and b). When the test load was removed, the maximum frequency of Margin Tests No. 1 and No. 2 did not exceed 69 Hz, as required by Subsection 6.4.3 – Acceptance Criteria, Part c).

Therefore, it is concluded that the margin tests 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 (Reference 10-1) endorsed by RG 1.9 (Reference 10-2). MHI performed this test as an internal test in accordance with recommendation of the manufacturer. This test confirms capability of load transient and rejection.

6.5.2 Procedure, Test Condition

Three load transient tests were performed using conditions of 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 through 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 the transients and rejections. The voltage and frequency fluctuated during the load transients and rejections; however, the frequency recovered within a maximum of 4.25 seconds.

Test data demonstrated that sufficient engine torque was available to prevent engine stall and that the variation of voltage and frequency was within acceptable parameters.

Therefore, the test data demonstrated that the acceptance criteria were met, and that the load transient 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 ADDITIONAL DISCUSSIONS

7.1 Test Results

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

(1) The 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 the “Load Capability Test”, the GTG was operated without failure or abnormality. 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 the GTG 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 a consistent linear 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 failure or trouble. During each of the 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. According to Section C 1.4 of Regulatory Guide 1.9 (Reference 10-2), 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 analysis that the voltage variation is 21.6% when the GTG operates at the maximum US-APWR design load.
(5) The tested gas turbine engine rotated at 18000 RPM; therefore, 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 controls the rotation speed and the torque available. At 100% load transient/rejection, the frequency variation was -3.72 % and 3.63 % respectively. The recovery to the rated frequency was 3.79 seconds and 4.25 seconds, respectively.

7.2 Hot/Cold Starting

Based on the manufacturer's experience and technical knowledge, the reliability and/or loading capability of the US-APWR GTGs are not significantly affected by either ambient temperature or the temperature of the GTG components.

(1) Evaluating from the GTG's structure, design, and operational principle, there are no significant differences between hot and cold conditions in the GTG due to ambient or component temperature at the time of starting. For details, please see Appendix 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 operating conditions is sufficient to prove the starting reliability.
(3) As recommended by the Manufacturer starting should not be attempted when lube Oil temperature is greater than 70°C. Although this condition does not impact starting reliability; it does impact equipment life expectancy and places undue stress on the unit.
Although there is no difference between the hot/cold conditions in the GTG, there are definitions for hot/cold conditions given by the Manufacturer. 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 Gas Turbine Engine starting performance 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 the 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 the GTG is independent of GTG engine hot/cold temperature from the test.

7.3 Reliability

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

(1) According to a Japanese 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, to be more conservative, 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.
(3) In addition, to satisfy the starting reliability of 0.975 with 95% confidence as required by the RG 1.155 (Reference 10-10), 150 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 features, 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 (Reference 10-4) endorsed by RG 1.100 (Reference 10-5).

The US-APWR mechanical and electrical equipment seismic qualification meets IEEE Std 344 (Reference 10-4) endorsed by RG 1.100 (Reference 10-5) for qualification by either analysis, testing or by a combination of both.

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 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III (Reference 10-8).

The GTG System components, piping assemblies, and qualification methods that were used for each component, including the status of each test or analysis, are summarized in Table 8.1-1.

Note that the seismic tests for Gas Turbine Engine and Gearbox Assembly, Generator Bearing Lubrication Oil System, and Lube Oil Cooler Fan Assembly were completed as stated in Table 8.1-1, but the In-Structure Response Spectra (ISRS), i.e., Required Response Spectra (RRS), have been revised in DCD Rev.4 (Reference 10-11). The RRS applied in those tests were determined based on the ISRS developed in the technical report, MUAP-10006 Rev.1 “Soil-Structure Interaction Analyses and Results for US-APWR Standard Plant” (Reference 10-12) referenced in DCD Rev.3 (Reference 10-13). In DCD Rev.3 (Reference 10-13), the US-APWR Standard Plant Power Source Buildings (PS/Bs), where Class 1E GTG systems are located, were structurally independent from other structures. However, following the DCD Rev.3 (Reference 10-13) submittal, the PS/Bs were combined with the Reactor Building (R/B) and other structures on a common basemat. Therefore, the soil-structure interaction analyses for this new R/B complex, including PS/Bs, were performed and new ISRS were developed in MUAP-10006 Rev.3 (Reference 10-14). The RRS applied in the original seismic test and the RRS based on the new ISRS are hereafter referred to as the DCD Rev.3-based RRS and the DCD Rev.4-based RRS, respectively. As will be discussed in Subsection 8.2.1.2.1, the RRS applied in the original seismic test for the Generator Bearing Lubrication Oil System is referred to as the DCD Rev.2-based RRS.

Table 8.1-1 Qualification Methods for GTG System Components and Piping Assemblies

Component	Qualification Method	Status
Gas Turbine Engine and Gearbox Assembly	Test	Completed the test using the DCD Rev.3-based RRS and evaluated using the DCD Rev.4-based RRS
Generator Bearing Lubrication Oil System	Test	Completed the test using the DCD Rev.2-based RRS and evaluated using the DCD Rev.4-based RRS
Lube Oil Cooler Fan Assembly	Test	Completed the test using the DCD Rev.3-based RRS and retested using the DCD Rev.4-based RRS
Engine Control Panel including ELV Driver	Test	Completed the test using the DCD Rev.4-based RRS
Synchronous Generator	Analysis	Completed the analysis using the DCD Rev.4-based RRS
Air Start Receiver Assembly	Analysis	Completed the analysis using the DCD Rev.4-based RRS
Fuel Oil Day Tank Assembly and Stand	Analysis	Completed the analysis using the DCD Rev.4-based RRS
Air Start Manifold[1]	Analysis	Completed the analysis using the DCD Rev.4-based RRS

Note
[1] : Air Start Manifold includes:
- Air Start Manifold Skid
- Air Start Manifold Piping

Section 8.2 provides the results of the seismic qualification by testing using the DCD Rev.3-based RRS or DCD Rev.2-based RRS in Subsection 8.2.1. The comparison of these results to the DCD Rev.4-based RRS is provided in Subsection 8.2.1.4. These relevant seismic tests that were performed using the DCD Rev.3-based RRS and DCD Rev.2-based RRS were based on the seismic requirements in DCD Rev.3 (Reference 10-13) and DCD Rev.2 (Reference 10-15), respectively.

The component that was seismically tested using the DCD Rev.3-based RRS and then evaluated using the DCD Rev.4-based RRS is the Gas Turbine Engine and Gearbox Assembly. The component that was seismically tested using the DCD Rev.2-based RRS and then evaluated using the DCD Rev.4-based RRS is the Generator Bearing Lubrication Oil System.

This document also includes the seismic qualification test results for the Engine Control Panel (with some design modification) and for the Lube Oil Cooler Fan Assembly by using the DCD Rev.4-based RRS, in Subsection 8.2.2.

The results of the seismic qualification for the other components that were analyzed, not tested, are provided in Section 8.3, Seismic Qualification by Analysis.

8.2 Seismic Qualification Testing

8.2.1 Tests Using the DCD Rev.3-based RRS or DCD Rev.2-based RRS

Seismic qualification tests of the following components were performed in accordance with IEEE Std 344 (Reference 10-4), as discussed in Section 8.1, above.
- Gas Turbine Engine and Gearbox Assembly
- Generator Bearing Lubrication Oil System
- Lube Oil Cooler Fan Assembly

8.2.1.1 Equipment Specification

The specification of the Gas Turbine Engine & Gearbox is shown in Table 5.3-1 and the specification for the GTG is shown in Table 5.3-2.

A drawing of the Gas Turbine Engine & Gearbox is shown in Figure B.1.0-3.

The specification of the Generator Bearing Lubrication Oil System is shown in Table 5.3-5.

The drawings of the Generator Bearing Lubrication Oil System are shown in Figure B.1.0-4.

The specification of the Lube Oil Cooler Fan Assembly is shown in Table 5.3-5.

The Configuration of the Lube Oil Cooler Fan Assembly is shown in Figure B.1.0-8.

8.2.1.2 Seismic Qualification Methodology

8.2.1.2.1 Outline of Seismic Tests

In accordance with IEEE Std 344 (Reference 10-4), 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 input 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.

In accordance with IEEE Std 344 (Reference 10-4), 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 10 CFR 50, Appendix S (Reference 10-16), 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 (Reference 10-11). 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), as discussed in Section 3.10 of US-APWR DCD (Reference 10-11). Note that 1/2 SSE events are still referred to as OBE in this report despite the elimination of the OBE from design considerations.

The RRS used in the SSE tests are shown in Figures 8.2-1 through 8.2-9. The RRS for the OBE tests are half of the RRS for the SSE. Each DCD RRS has a minimum 10% margin for ISRS of the PS/B, where the GTG systems are located.

Figures 8.2-1, 8.2-2 and 8.2-3, represent the RRS for two horizontal directions and one 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 directions and one vertical direction respectively, which are applied to the Generator Bearing Lubrication Oil System tests. Figures 8.2-7, 8.2-8 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.

The RRS used for each test are different from each other for the following reasons:
Each component test was performed independently. Tests for the Generator Bearing Lubrication Oil System were performed in April 2011. Tests for the Gas Turbine Engine and Gearbox Assembly were performed in April 2011, and tests for the Lube Oil Cooler Fan Assembly were performed in June 2011. Each test condition, (i.e. RRS), was planned at different times. Due to the timing of DCD Revision 3 (Reference 10-13), which was submitted in March 2011, the Generator Bearing Lubrication Oil System tests were planned using the ISRS of DCD Revision 2 (Reference 10-15), which was the one available at the time the test was planned. On the other hand, the Gas Turbine Engine and Gearbox Assembly tests and the Lube Oil Cooler Fan Assembly tests were planned using the ISRS of DCD Revision 3 (Reference 10-13), which was the one available at the time the test was planned. The ISRS of DCD Revision 2 (Reference 10-15) and Revision 3 (Reference 10-13) were different. Consequently, the RRS for the Generator Bearing Lubrication Oil System tests were different from those for the Gas Turbine Engine and Gearbox Assembly tests and the Lube Oil Cooler Fan Assembly tests. The DCD Rev.2-based RRS envelop the DCD Rev.3-based RRS, and therefore the seismic test results of the Generator Bearing Lubrication Oil System are valid for the DCD Rev.3-based RRS. 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.

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

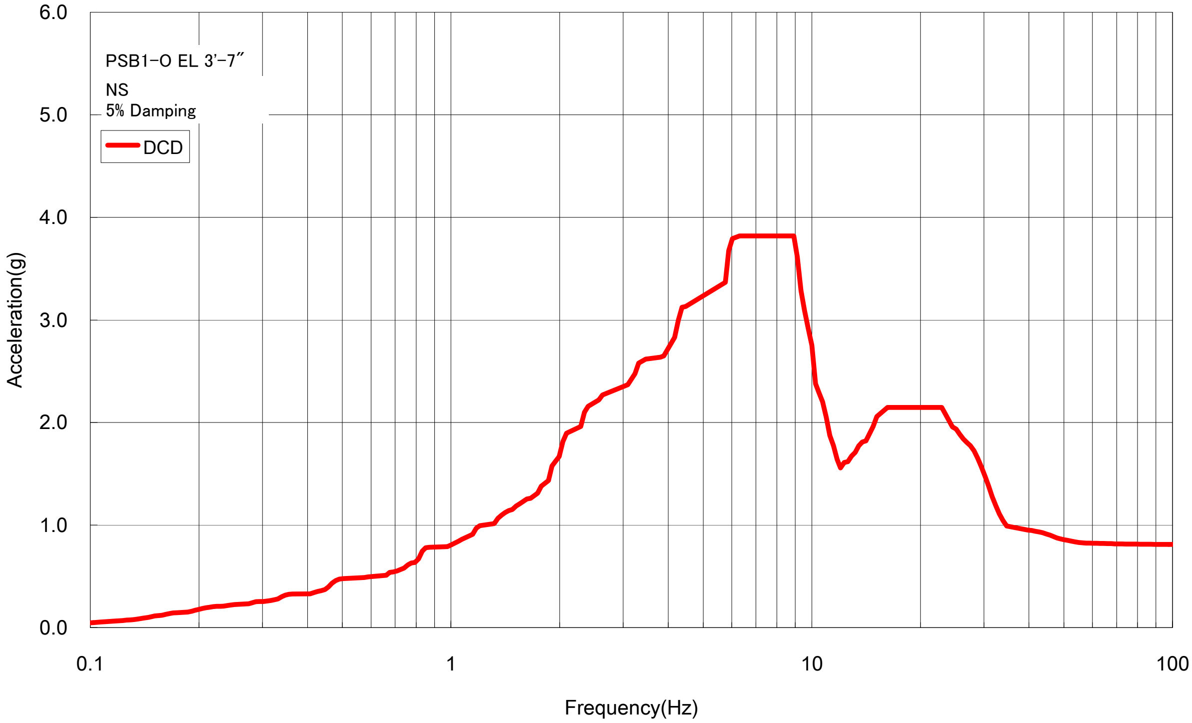

Figure 8.2-1 North-South DCD Rev.3-based RRS(with 10% margin) for Gas Turbine Engine and Gearbox Assembly

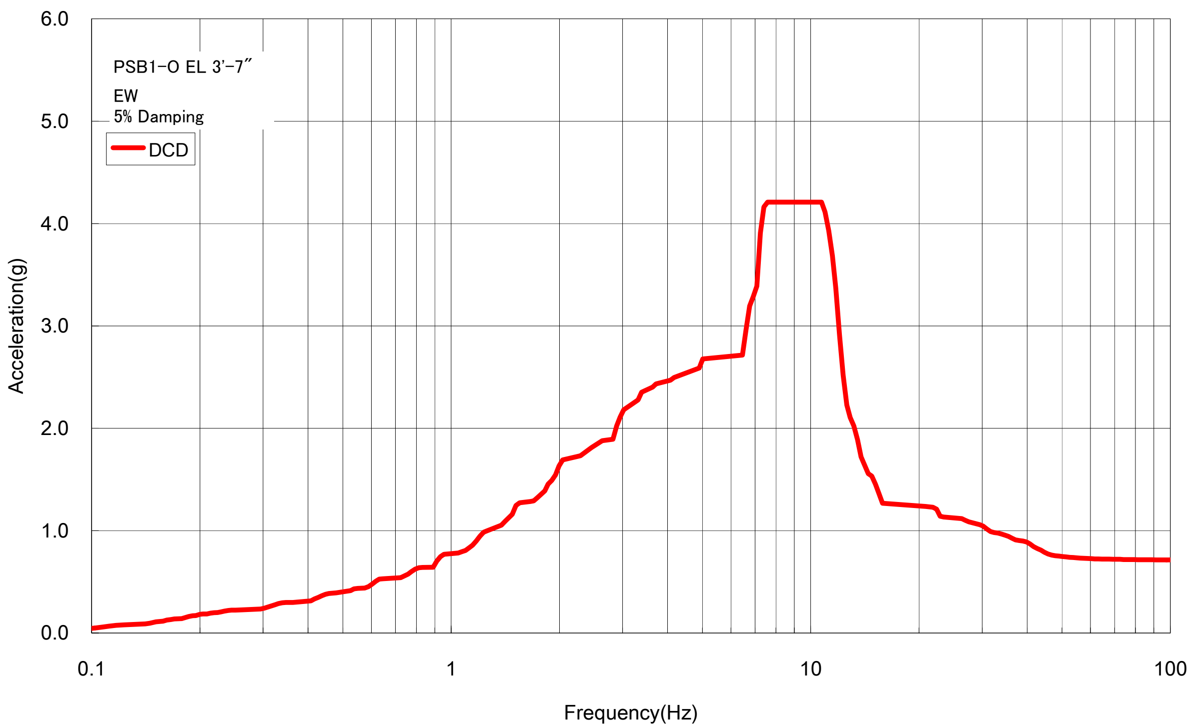

Figure 8.2-2 East-West DCD Rev.3-based RRS (with 10% margin) for Gas Turbine Engine and Gearbox Assembly

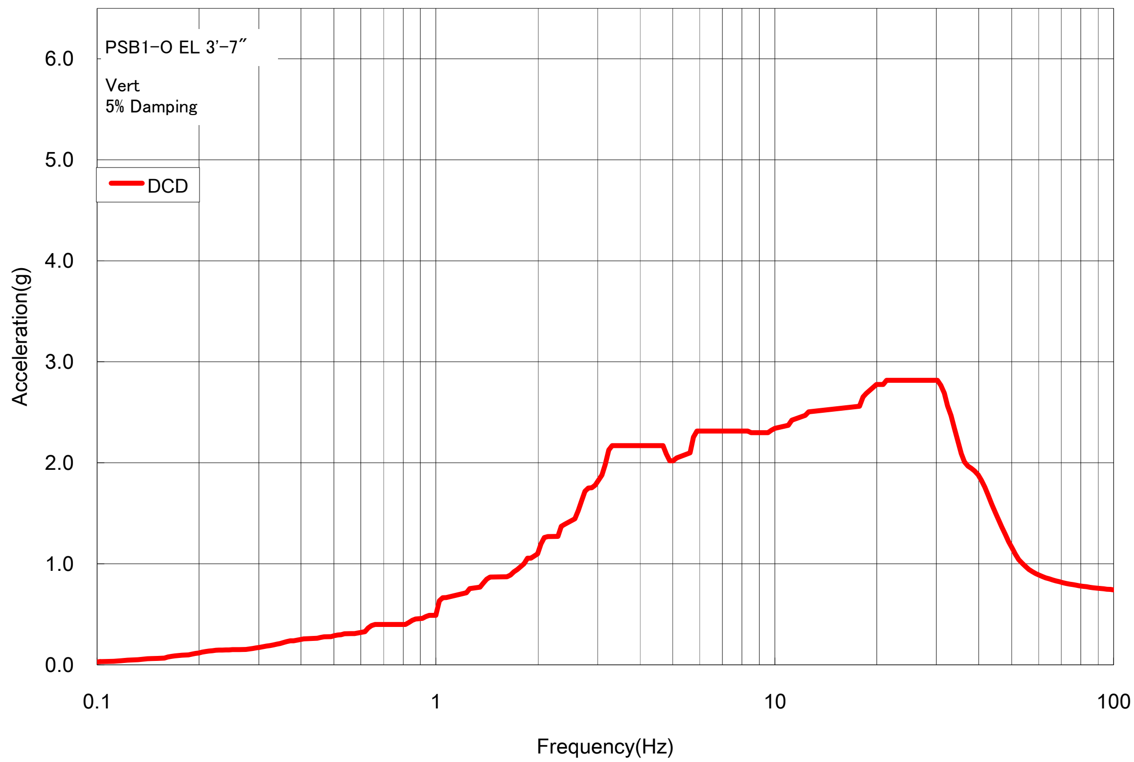

Figure 8.2-3 Vertical DCD Rev.3-based RRS(with 10% margin) for Gas Turbine Engine and Gearbox Assembly

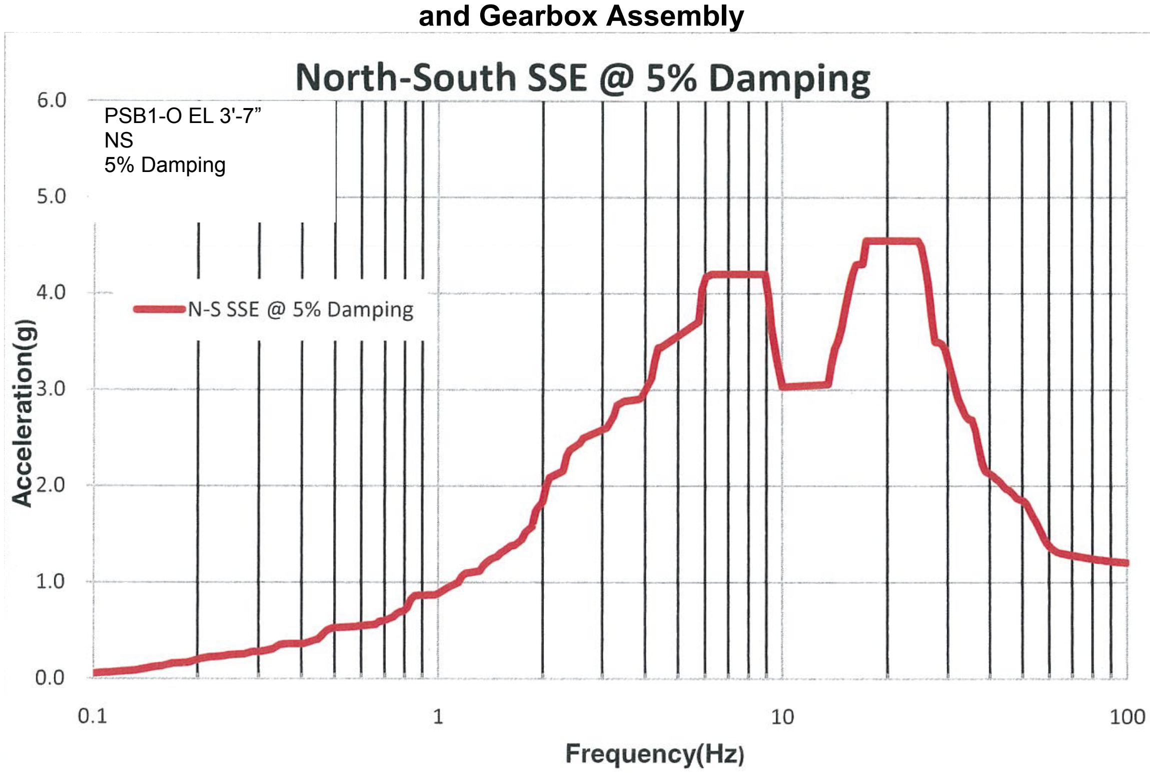

Figure 8.2-4 North-South DCD Rev.2-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System

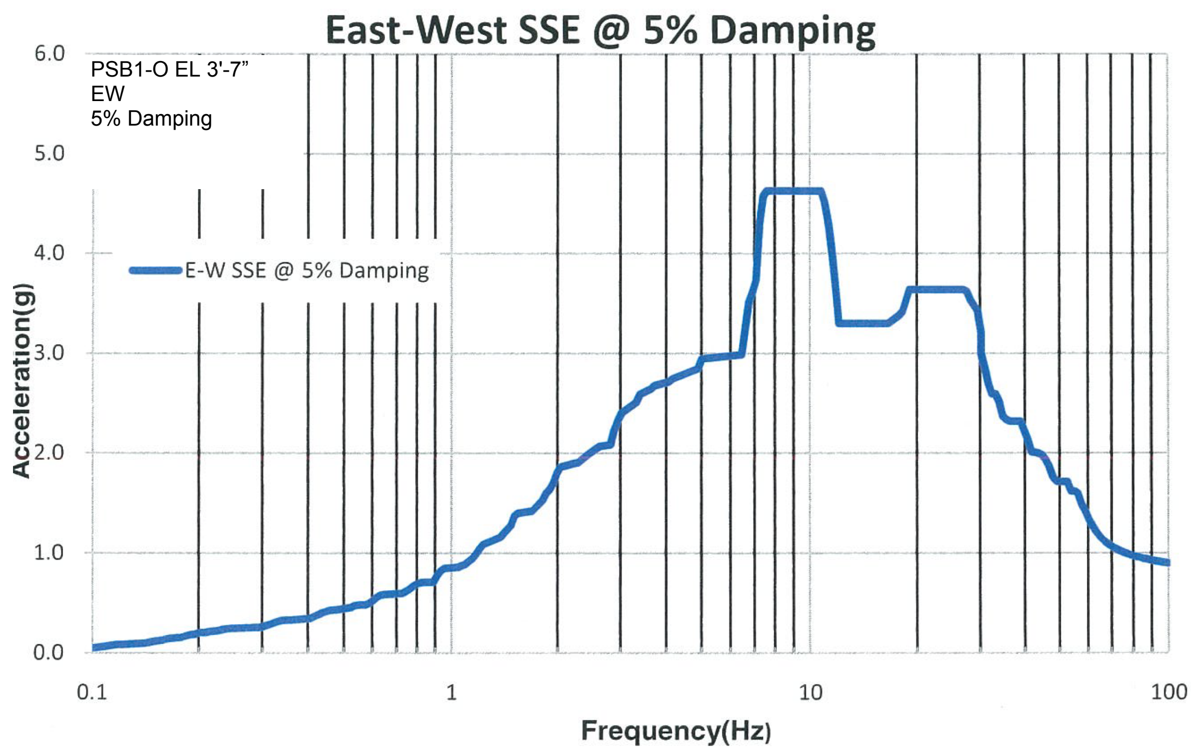

Figure 8.2-5 East-West DCD Rev.2-based RRS(with 10% margin) for Generator Bearing Lubrication Oil System

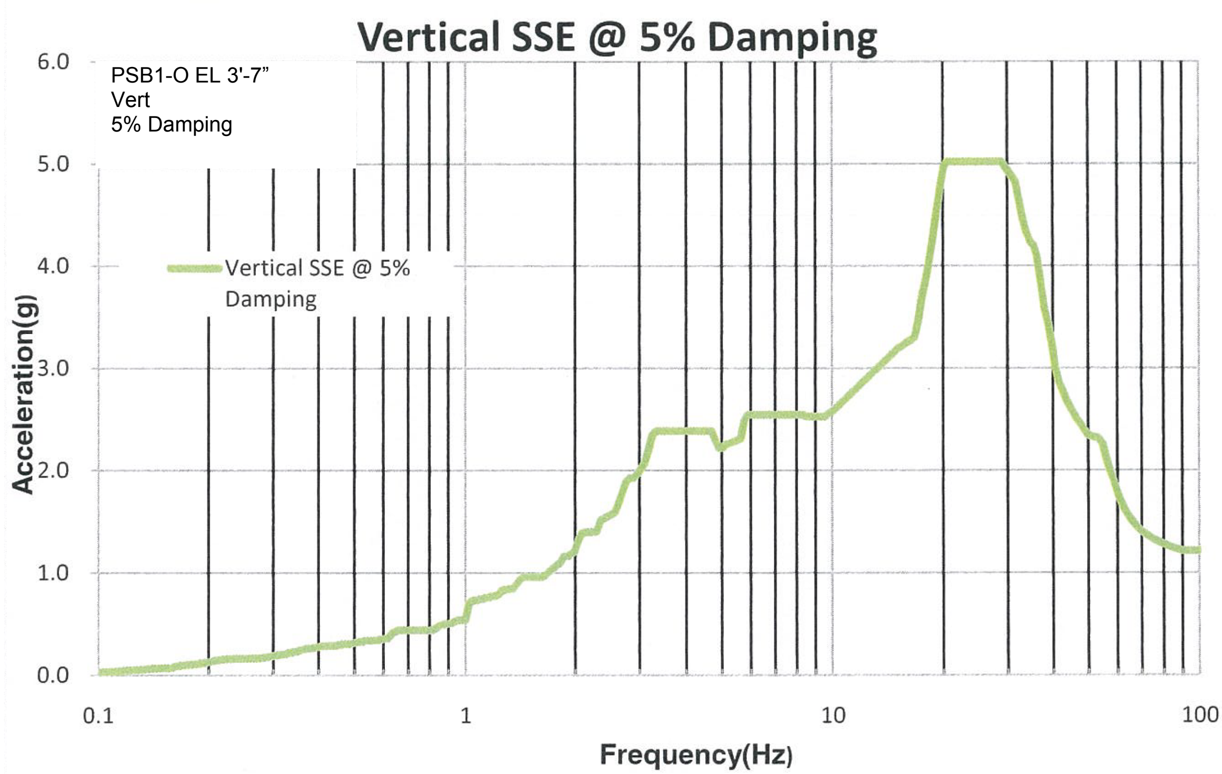

Figure 8.2-6 Vertical DCD Rev.2-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System

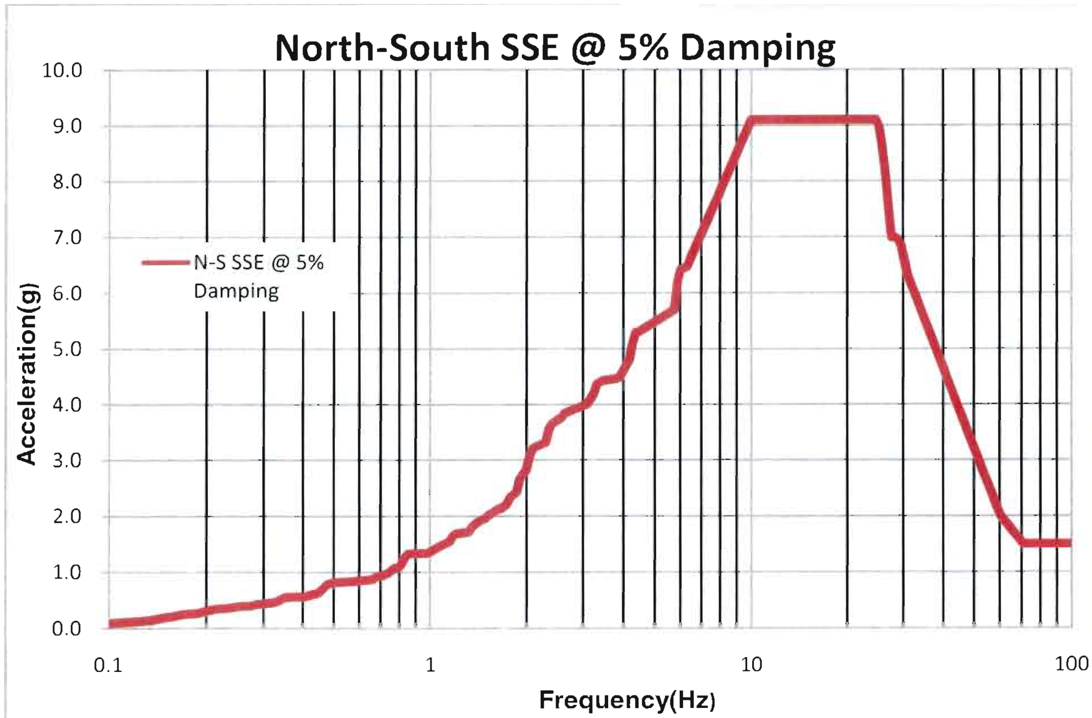

Figure 8.2-7 North-South DCD Rev.3-based RRS (with 10% margin) for Lube Oil Cooler Fan Assembly

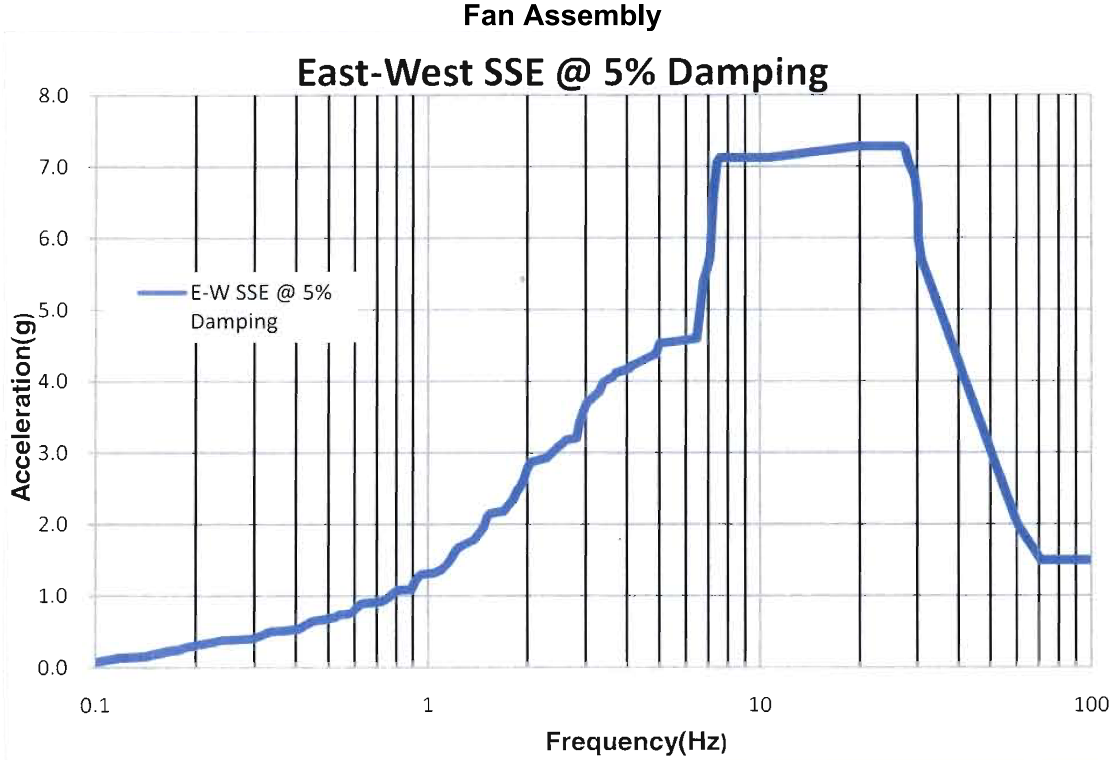

Figure 8.2-8 East-West DCD Rev.3-based RRS (with 10% margin) for Lube Oil Cooler Fan Assembly

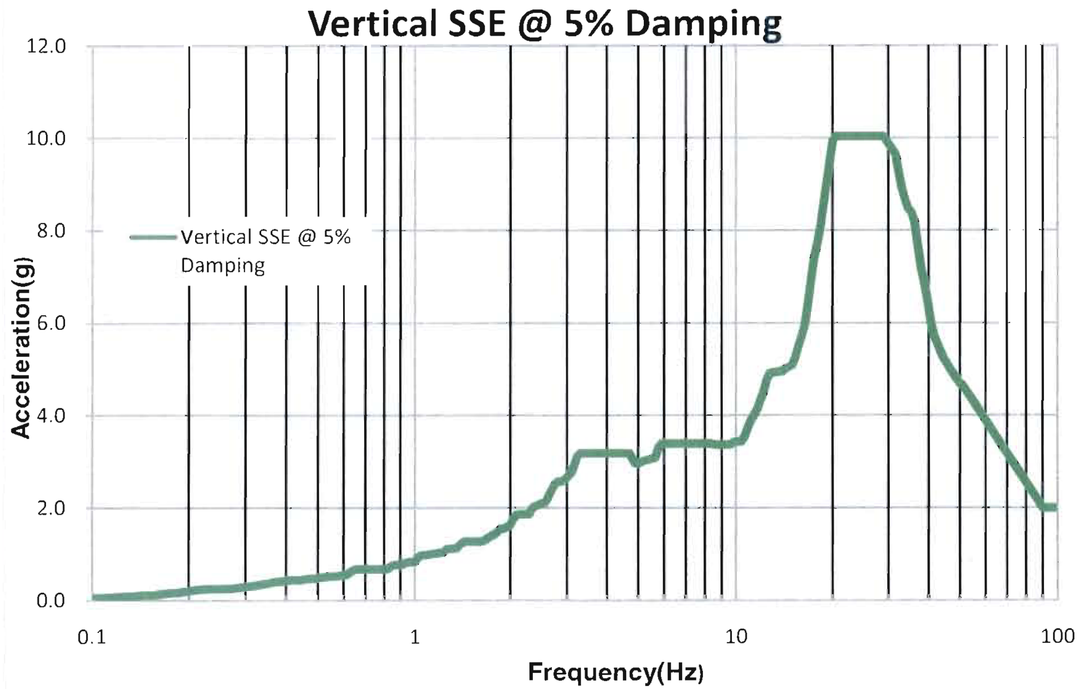

Figure 8.2-9 Vertical DCD Rev.3-based RRS (with 10% margin) for Lube Oil Cooler Fan Assembly

8.2.1.2.2 Acceptance Criteria

8.2.1.2.2.1 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 Engine start up time
- Gas Turbine Engine Exhaust Gas temperature
- Lubrication Oil temperature

If there is any failure inside the Gas Turbine Engine, it can lead to an abnormal start up time or exhaust gas temperature because of abnormal combustion conditions. Also, a Gas Turbine Engine failure can lead to an abnormal lubrication oil temperature. Start up time is measured and checked to determine if the Gas Turbine Engine starts within the start up time shown on the specification: 40 seconds. 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 confirms that the Gas Turbine Engine has maintained its integrity and functionality.

Also, the following items are checked.

- Abnormal noise and vibration
- Physical condition and presence of Turbine blades that are located near the combustor (by using fiberscope inspection inside Gas Turbine Engine)

Abnormal noise and vibration are checked during every start up, operation and shutdown. If there is any failure, such as a failure of bearing, the casing, or shaft lubrication oil system, it causes abnormal noise or vibration that may be noticed, because the Gas Turbine Engine rotates at a speed of about 1800 rpm. The turbine blades are inspected using a fiberscope before and after the seismic test to determine if a turbine blade is cracked or missing.

If no abnormal noise, vibration or a cracked or missing turbine blade is identified, it confirms that the Gas Turbine Engine has maintained its integrity and functionality.

It should be noted that a fiberscope inspection can survey only turbine blades that are near the combustor. Although overhaul is required to check the turbine blades completely, integrity of the Gas Turbine Engine can be confirmed with a combination of series of parameter checks and inspections, as explained above.

8.2.1.2.2.2 Generator Bearing Lubrication Oil System

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

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

8.2.1.2.2.3 Lube Oil Cooler Fan Assembly

Integrity and functionality 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

8.2.1.2.3 Test Procedure

8.2.1.2.3.1 Gas Turbine Engine 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 Gas Turbine Engine and Gearbox Assembly. The sweep is performed from 1 to 50 Hz at a sweep rate of one octave per minute.

b. Biaxial Seismic Simulation Tests

The Gas Turbine Engine and Gearbox Assembly 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 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 Gas Turbine Engine and Gearbox Assembly is subjected to five OBE Tests and two SSE Seismic Tests in each horizontal axis orientation. Three OBE and one SSE Tests are performed while the engine is in Operating Mode. One 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, five OBE tests followed by one SSE test were performed in accordance with IEEE Std 344 (Reference 10-4), and then an additional SSE test was performed.

The former SSE test was performed in Operating Mode as the most severe load condition, while the latter SSE test, although not required by IEEE Std 344 (Reference 10-4) and the other regulation, was conservatively tested in Standby Mode as a representation of a different Operating Mode. The OBE and SSE DCD Rev.3-based RRS Curves are shown in Figures 8.2-1, 8.2-2 and 8.2-3 for two horizontal directions and one vertical direction, respectively.

c. Test Procedure

The details of the test procedure are as follows:

1. The Gas Turbine Engine and Gearbox Assembly 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 Gas

Turbine Engine and Gearbox Assembly are collinear with the horizontal axes of the test table.

3. The Gas Turbine Engine and Gearbox Assembly 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 Gas Turbine Engine and Gearbox Assembly shall be monitored and recorded using a strip chart recorder during each of the seismic test runs.
6. The Gas Turbine Engine and Gearbox Assembly Functional and Standby Circuits shall be monitored and recorded during the Gas Turbine Engine and Gearbox Assembly pre-test checkout, during the testing and at the conclusion of each axis tested.
7. The instrumentation listed in Table 8.2-1 on the following page shall be provided for the tests.
8. The Gas Turbine Engine and Gearbox Assembly shall be subjected to the Resonance Search Tests and the Biaxial Seismic Simulation Tests.
9. The Gas Turbine Engine and Gearbox Assembly 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 Gas Turbine Engine and Gearbox Assembly shall be visually inspected at the completion of each horizontal axis test.
12. The Gas Turbine Engine and Gearbox Assembly 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	Response accelerations at the Lower Rear Engine Mount	Transmissibility Plots from the Resonance Search Tests Test Response Spectrum Plots and Time History Plots from the Seismic Test
	3NS or 3EW 4V	Response accelerations on top of the flange of the Right Side Combustor	
	5NS or 5EW 6V	Response accelerations on top of the flange of the Left Side Combustor	
	7NS or 7EW 8V	Response accelerations at the Top of the Gearbox	
	9NS or 9EW 10V	Response accelerations at the Rear Center of the Air Intake Plenum	
	11NS or 11EW 12V	Response accelerations at the Left Side Exciter Mounting Bracket	
	13NS or 13EW 14V	Response accelerations at the Top Center on Gearbox	
	15NS or 15EW 16V	Response accelerations at the ELV Mounting Bracket	
	17NS or 17EW 18V	Response accelerations at the Right Side Air Start Motor	
Electrical Monitoring	1 to 12	Turbine Speed, Exhaust Temperature Turbine #1/#2, Lube Oil Temperature Turbine #1/#2, K8 Relay, Start Fuel Pump, Turning Motor, Lube Oil Pressure Turbine #1/#2, Reference Accelerometer	*Strip Chart Recorder

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

* These channels were recorded on a strip chart recorder capable of detecting discontinuities of 2 milliseconds or longer.

8.2.1.2.3.2 Generator Bearing Lubrication Oil System

The Generator Bearing Lubrication Oil System shall be subjected to seismic testing consisting of random input motion, amplitude controlled in one-sixth octave bandwidths from 1 to 100 Hz for a minimum test duration of 30 seconds. The testing shall consist of five OBE and one SSE test runs using the RRS shown in Figures 8.2-4, 8.2-5 and 8.2-6 for two horizontal directions and one vertical direction, respectively. The OBE RRS shall be half of the SSE RRS. The TRS shall envelop the RRS. The Generator Bearing Lubrication Oil System 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.

8.2.1.2.3.3 Lube Oil Cooler Fan Assembly

The Lube Oil Cooler Fan Assembly 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.

8.2.1.3 Seismic Qualification Test Results

8.2.1.3.1 Gas Turbine Engine and Gearbox Assembly

The seismic qualification tests were performed following the methodology described in Subsection 8.2.1.2.1 through 8.2.1.2.3 above.

The test results demonstrate that the Gas Turbine Engine and Gearbox Assembly operated and performed as required in accordance with the acceptance criteria in Subsection 8.2.1.2.2. The details of each test case are summarized in Table 8.2-2.

The Gas Turbine Engine and Gearbox Assembly successfully completed the Resonance Search Tests and the OBE and SSE random multi-frequency tests. The details of the test results including the data in Table 8.2-2 are provided in Appendix H.

The fundamental frequencies of the Gas Turbine Engine obtained from the Resonance Search Test are greater than 30 Hz in any direction.

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

Table 8.2-2 Summary of Test Runs

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 Gas Turbine Engine and Gearbox Assembly Mounting Hardware was torqued to 860 +/- 5 ft/lbs prior to the test run.
2. The Gas Turbine Engine and Gearbox Assembly was not in Standby Mode, and the OBE test run was repeated.
3. The Gas Turbine Engine and Gearbox Assembly was placed in Standby Mode prior to the test run.
4. The Gas Turbine Engine and Gearbox Assembly was started during the test run.
5. The Gas Turbine Engine and Gearbox Assembly was operating during the test run.
6. The test level was less than the required level, and the SSE test run was repeated.
7. “Front-to-Back” and “Side-to-Side” is horizontal direction.

8.2.1.3.2 Generator Bearing Lubrication Oil System

The seismic qualification tests were performed following the methodology described in Subsection 8.2.1.2.1 through 8.2.1.2.3 above. The test results demonstrate that the Generator Bearing Lubrication Oil System operates and performs as required in accordance with the acceptance criteria in Subsection 8.2.1.2.2. The Generator Bearing Lubrication Oil System 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, 2.6 G for Y (North-South) direction and 2.8 G for Z (vertical) direction.

8.2.1.3.3 Lube Oil Cooler Fan Assembly

The seismic qualification tests were performed following the methodology described in Subsection 8.2.1.2.1 through 8.2.1.2.3 above. The test results demonstrate that the Lube Oil Cooler Fan Assembly operates and performs as required in accordance with the acceptance criteria in Subsection 8.2.1.2.2. The Lube Oil Cooler Fan Assembly 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, 4.8 G for Y (North-South) direction and 4.3 G for Z (vertical) direction.

8.2.1.4 Evaluation based on DCD Rev.4-based RRS

As discussed in Section 8.1, the seismic tests for the Gas Turbine Engine and Gearbox Assembly, for the Generator Bearing Lubrication Oil System, and for the Lube Oil Cooler Fan Assembly were performed using the DCD Rev.3-based RRS or DCD Rev.2-based RRS. The ISRS at the location where the Class 1E GTG systems are located have been revised in DCD Rev.4 (Reference 10-11) and consequently the RRS has been revised. Therefore, the TRS for the Gas Turbine Engine and Gearbox Assembly, for the Generator Bearing Lubrication Oil System, and for the Lube Oil Cooler Fan Assembly are compared to the DCD Rev.4-based RRS to determine if the previous testing remains valid.

For the Gas Turbine Engine and Gearbox Assembly, Figures 8.2-10 and 8.2-11 show the comparison of SSE TRS for all test runs to the DCD Rev.4-based SSE RRS with 10% margin. Figures 8.2-12 and 8.2-13 show the comparison of OBE TRS for all test runs to the DCD Rev.4-based OBE RRS with 10% margin.

For the Generator Bearing Lubrication Oil System, Figures 8.2-14 and 8.2-15 show the comparison of SSE TRS to the DCD Rev.4-based SSE RRS with 10% margin. Figures 8.2-16 and 8.2-17 show the comparison of OBE TRS for all test runs to the DCD Rev.4-based OBE RRS with 10% margin.

For all frequencies greater than 1 Hz, the TRS for each component exceeds the DCD Rev.4-RRS for both OBE and SSE cases. For frequency range less than 1 Hz, the TRS fall below the DCD Rev.4-RRS, but it is acceptable based upon IEEE 344-2004 paragraph 8.6.3.1, item (I) (Reference 10-4). Therefore, the seismic test results for the Gas Turbine Engine and Gearbox Assembly and for the Generator Bearing Lubrication Oil System remain valid.

On the other hand, the comparison of the TRS for the Lube Oil Cooler Fan Assembly to the DCD Rev.4-based RRS indicates that the previous testing is not valid (i.e. retest is needed).

For the Lube Oil Cooler Fan Assembly, Figures 8.2-18 and 8.2-19 show the comparison of SSE TRS to the DCD Rev.4-based SSE RRS with 10% margin. Figures 8.2-20 and 8.2-21 show the comparison of OBE TRS for all test runs to the DCD Rev.4-based OBE RRS with 10% margin. The retest results are provided in Subsection 8.2.2.

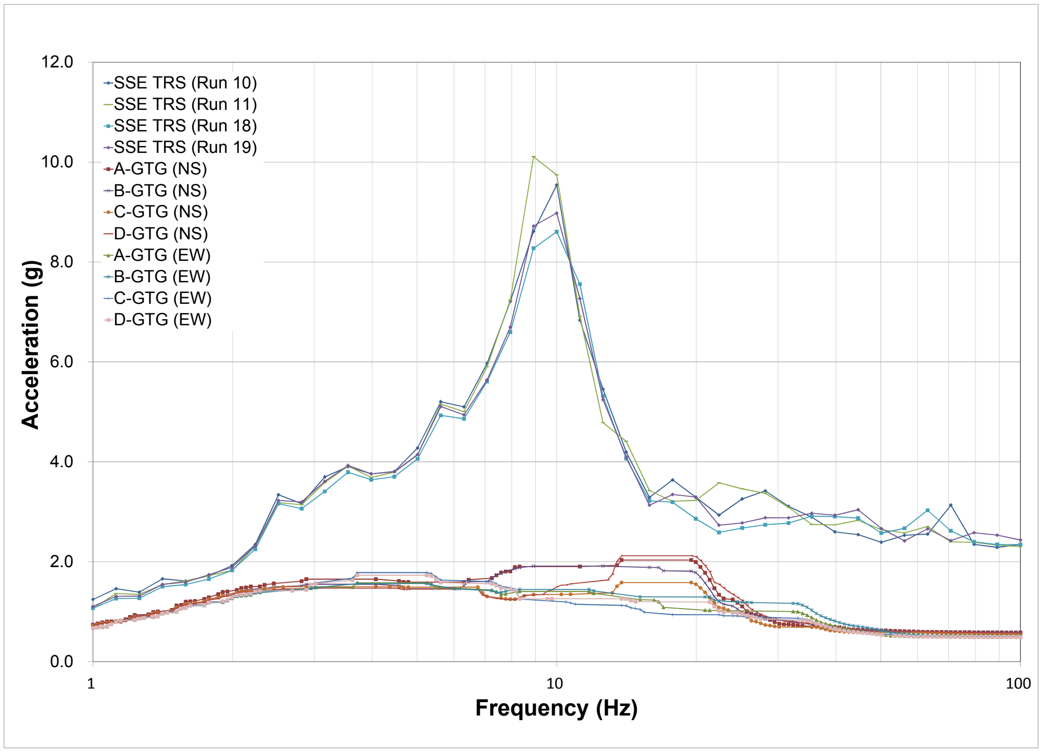

Figure 8.2-10 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Gas Turbine Engine and Gearbox Assembly, SSE, Horizontal Direction

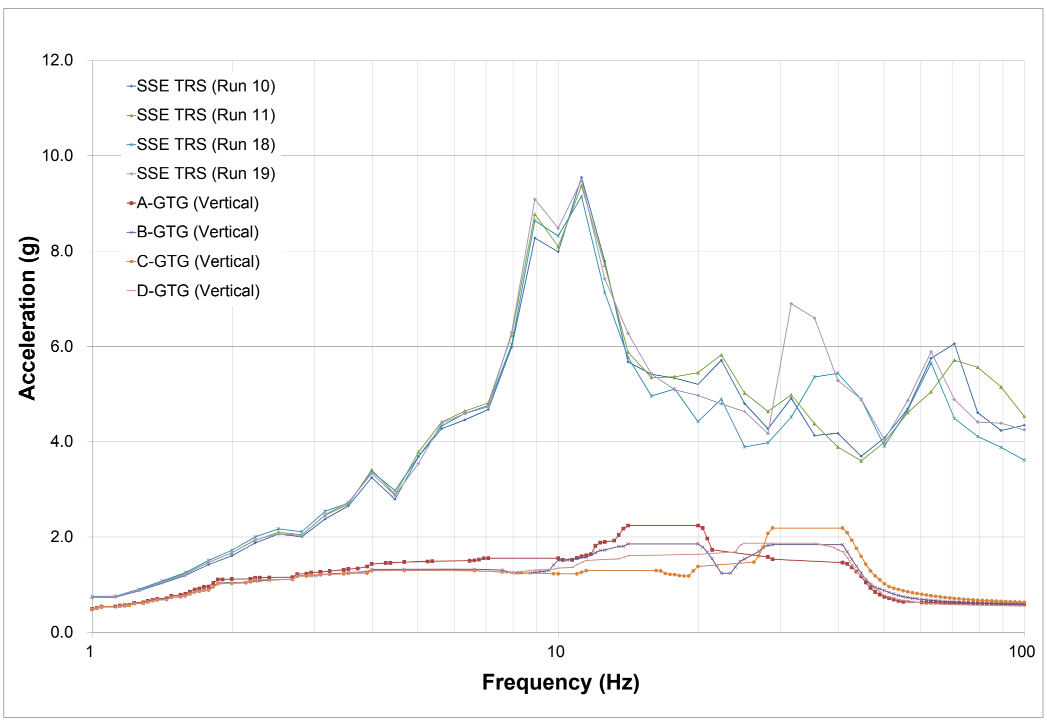

Figure 8.2-11 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Gas Turbine Engine and Gearbox Assembly, SSE, Vertical Direction

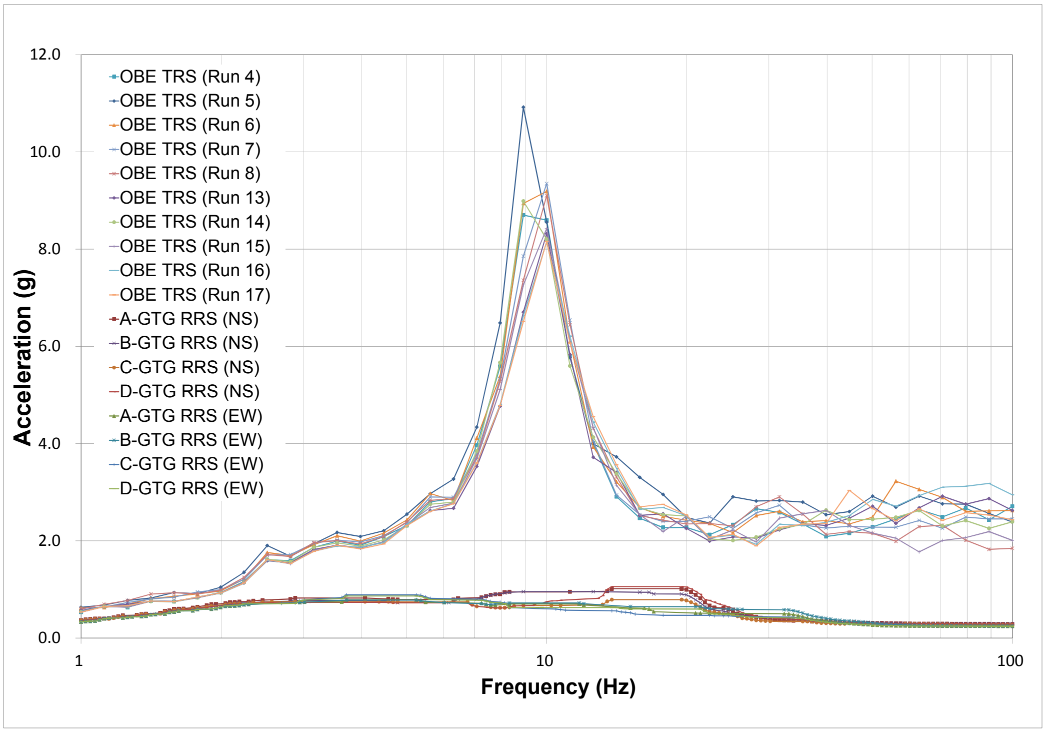

Figure 8.2-12 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Gas Turbine Engine and Gearbox Assembly, OBE, Horizontal Direction

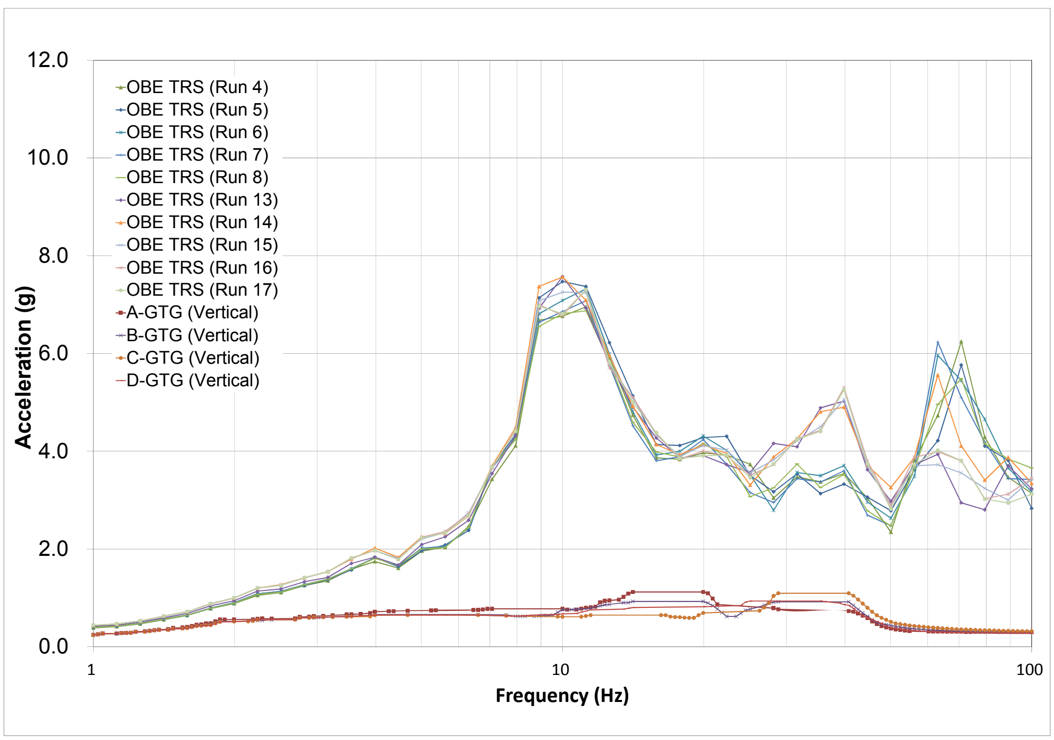

Figure 8.2-13 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Gas Turbine Engine and Gearbox Assembly, OBE, Vertical Direction

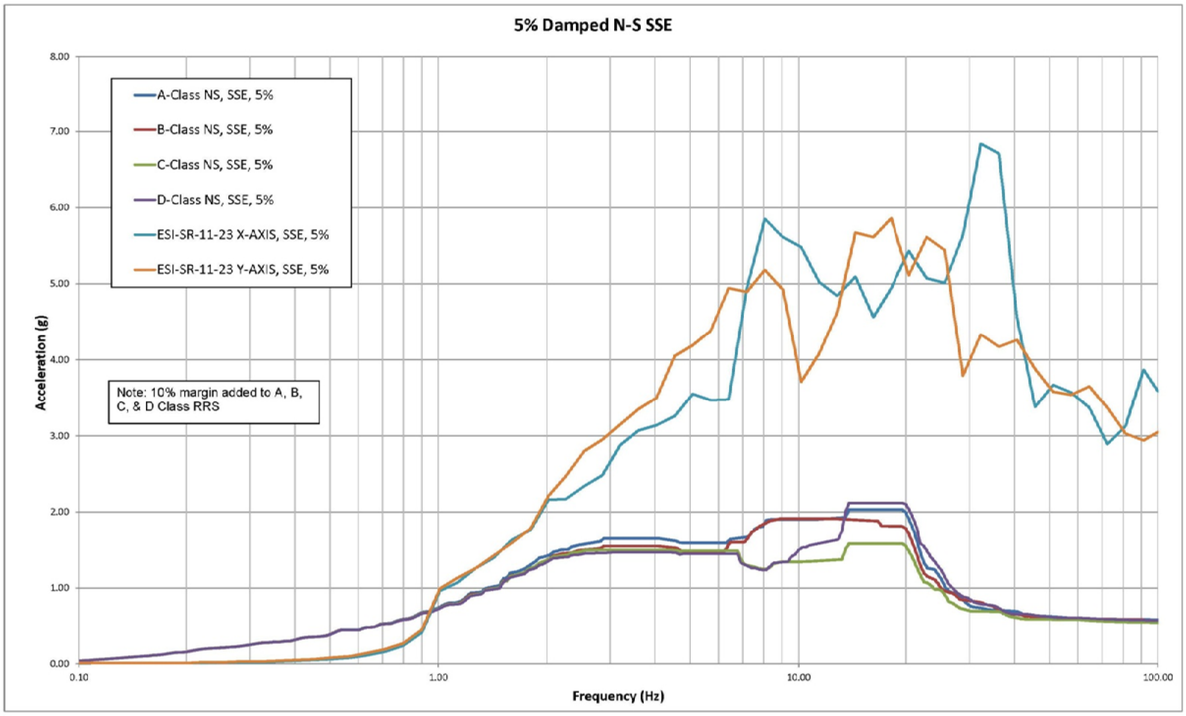

Figure 8.2-14 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, SSE, Horizontal Direction (Sheet 1 of 2)

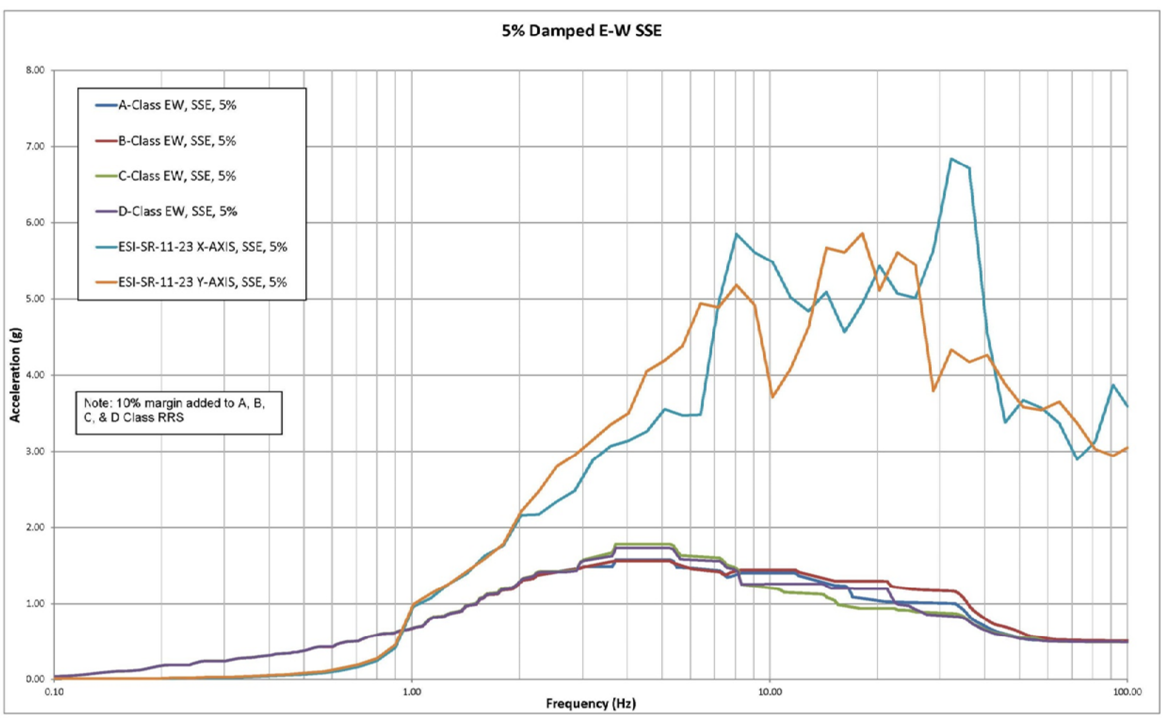

Figure 8.2-14 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, SSE, Horizontal Direction (Sheet 2 of 2)

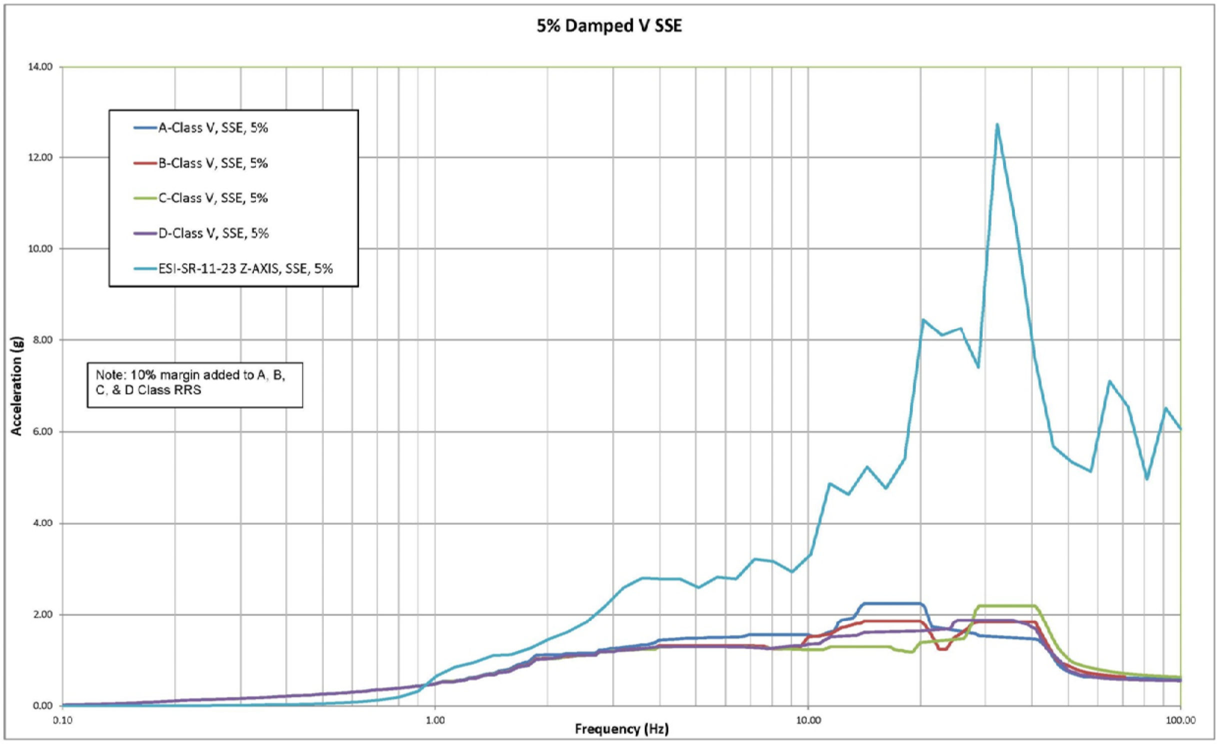

Figure 8.2-15 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, SSE, Vertical Direction

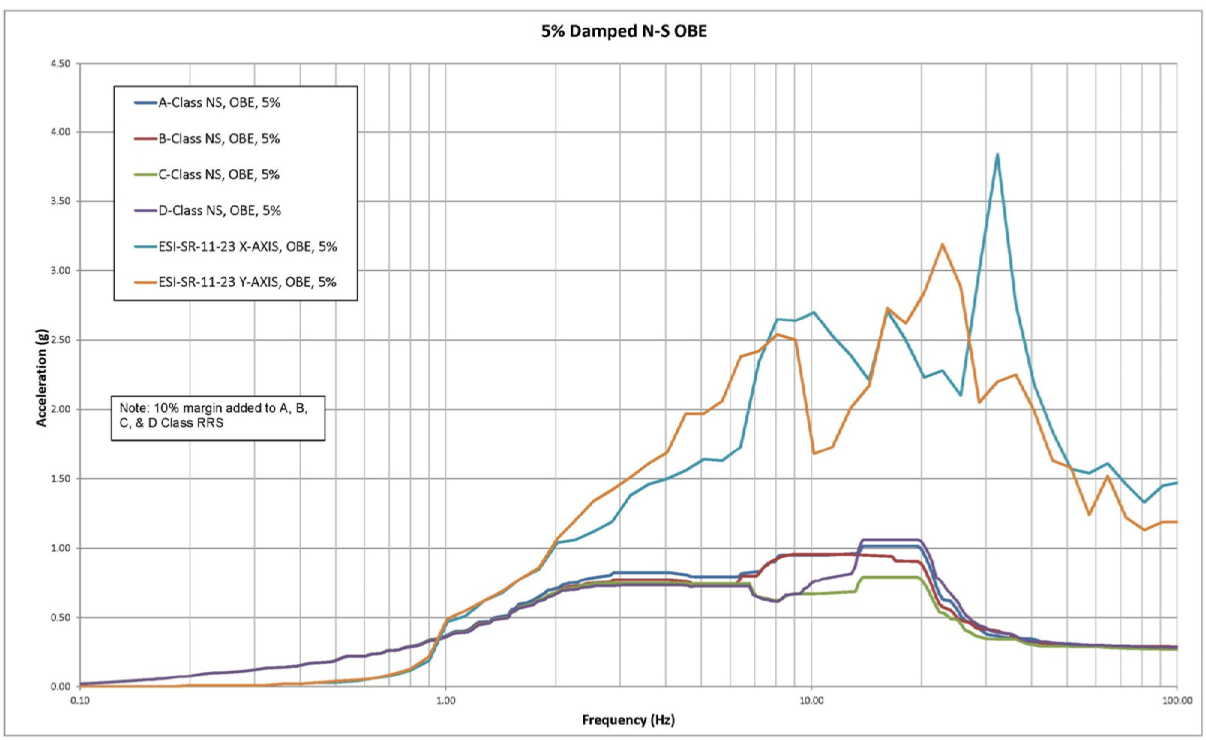

Figure 8.2-16 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, OBE, Horizontal Direction (Sheet 1 of 2)

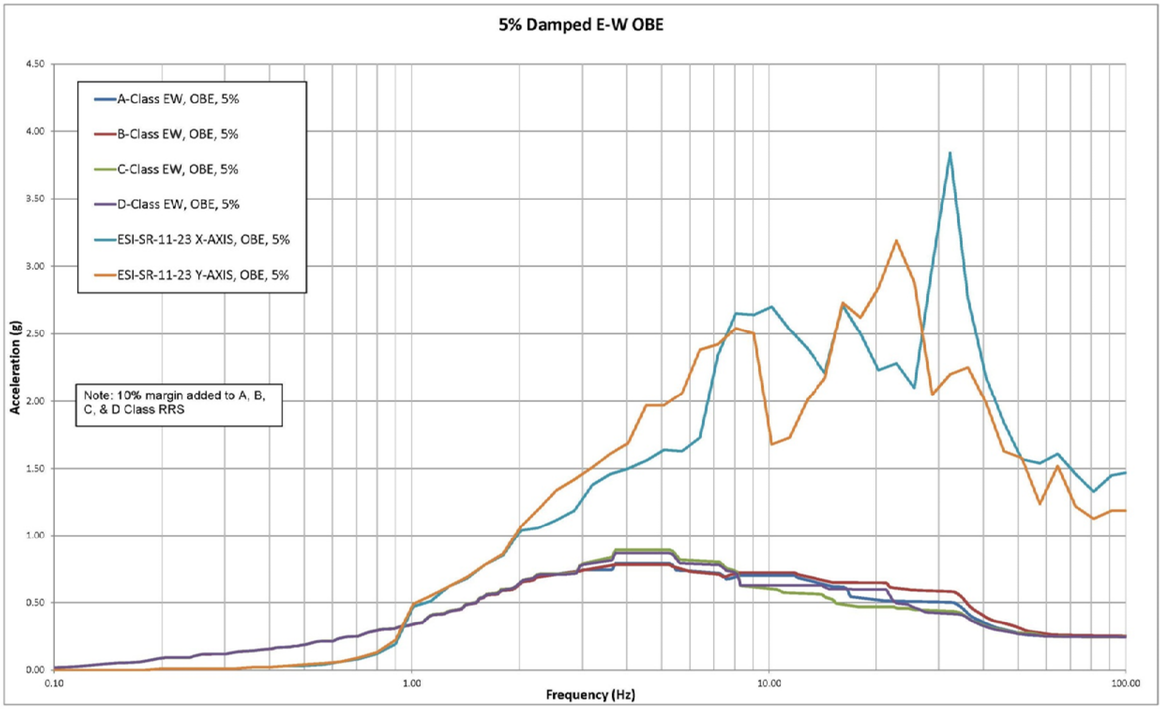

Figure 8.2-16 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, OBE, Horizontal Direction (Sheet 2 of 2)

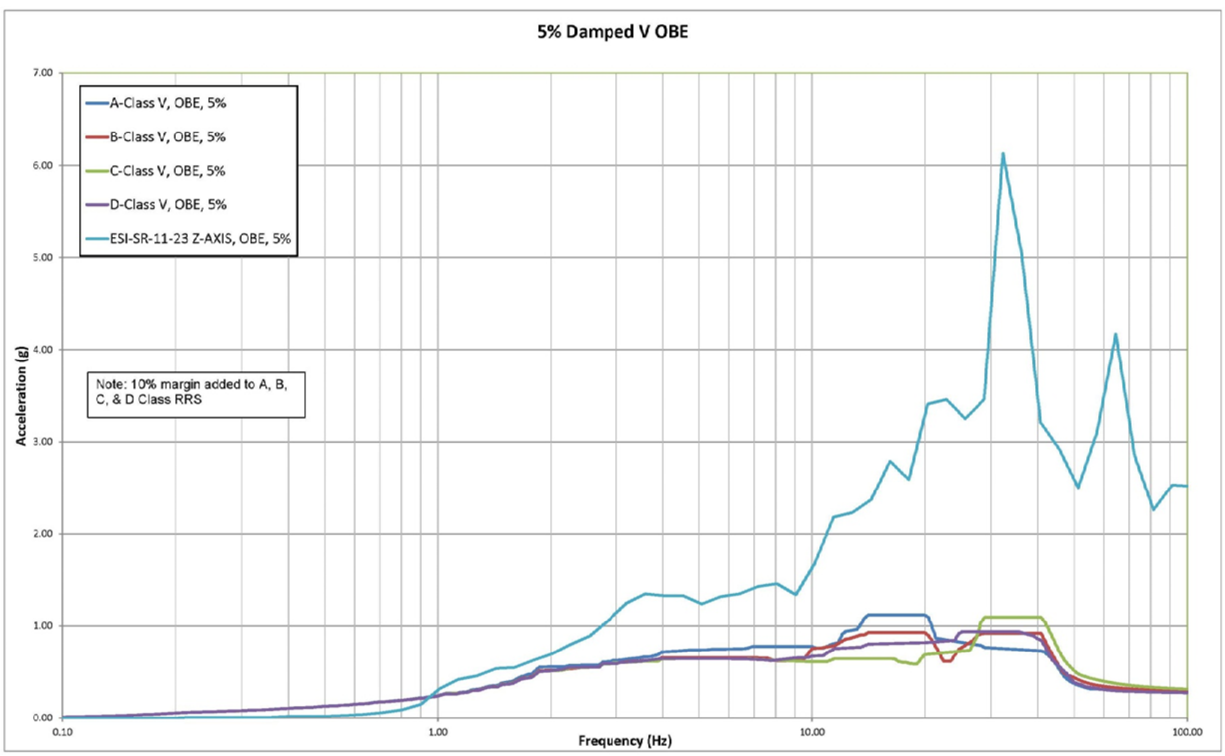

Figure 8.2-17 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for Generator Bearing Lubrication Oil System, OBE, Vertical Direction

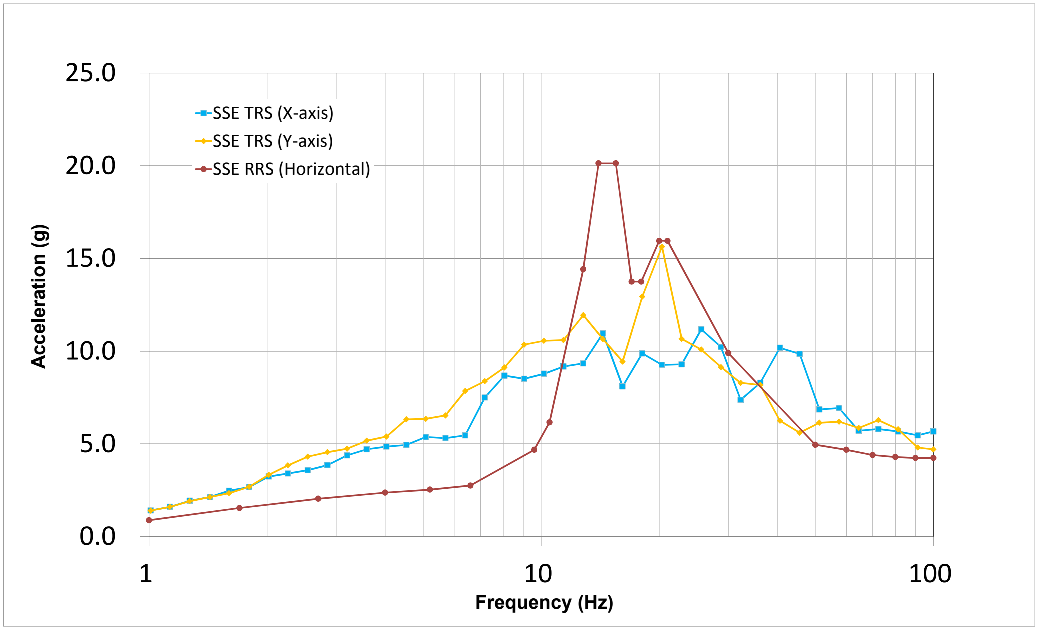

Figure 8.2-18 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly, SSE, Horizontal Direction

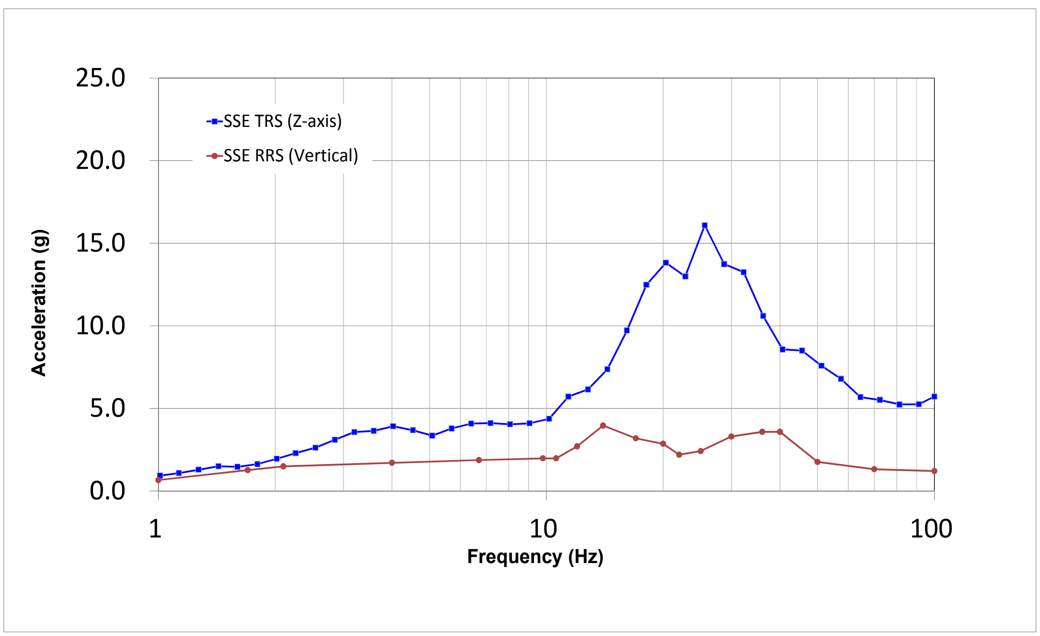

Figure 8.2-19 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly, SSE, Vertical Direction

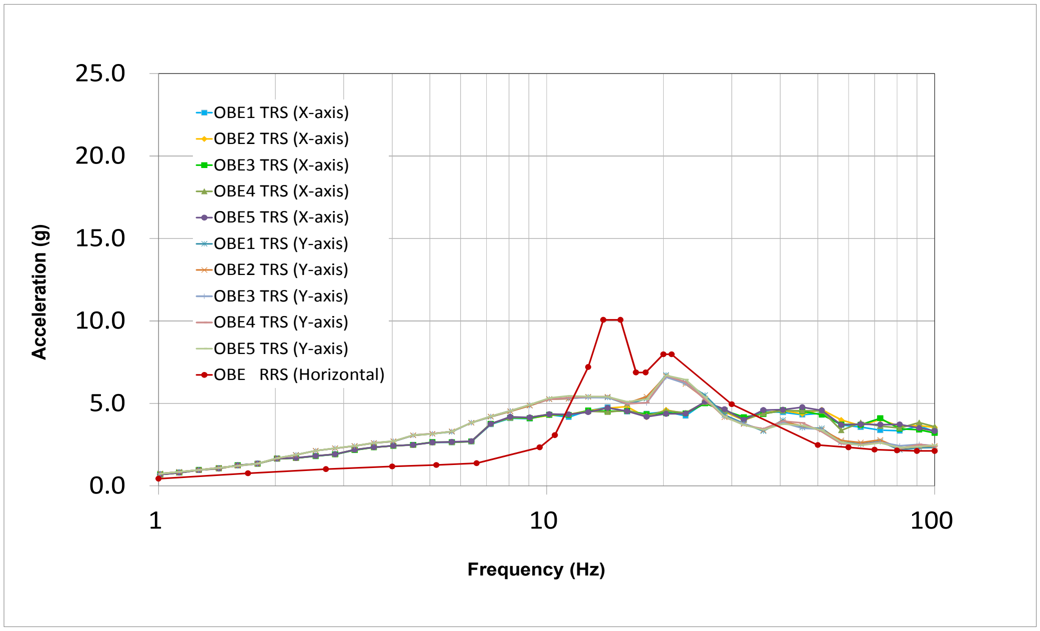

Figure 8.2-20 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly, OBE, Horizontal Direction

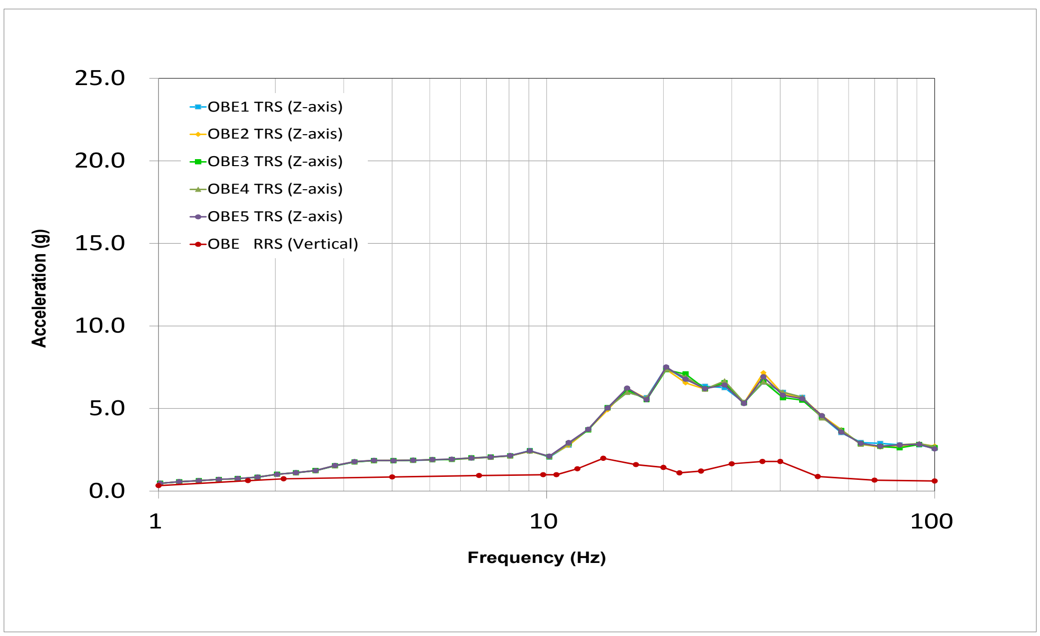

Figure 8.2-21 Comparison of TRS and DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly, OBE, Vertical Direction

8.2.2 Tests using the DCD Rev.4-based RRS

Seismic qualification test of the Engine Control Panel, the ELV Driver, which is a component of the Engine Control Panel, and the Lube Oil Cooler Fan Assembly were performed in accordance with IEEE Std 344 (Reference 10-4).

The summary of seismic qualification methodology and results, including equipment specification, for the Engine Control Panel and the ELV Driver is provided in Subsections 8.2.2.1 through 8.2.2.3. The details of the tests of the components are provided in Appendices M and N. Appendix M sometimes refers to the Engine Control Panel as the “Control Panel for a Gas Turbine Engine” or the “Gas Turbine Engine Control Panel”. Also, Appendix N refers to the ELV Driver as the “Woodward Governor ELV Driver”. No difference is intended.

Note that the Lube Oil Cooler Fan Assembly was previously tested using a DCD Rev.3-based RRS. That test is documented in Appendix J. However, as discussed previously, a retest was needed since the TRS was not bounding. The seismic testing for the Lube Oil Cooler Fan Assembly summarized in Subsections 8.2.2.2 and 8.2.2.3, with detailed results shown in Appendix P, completely supersedes the previous testing described in Appendix J.

8.2.2.1 Equipment Specification

A new engine control panel, which is of a more robust design than was used for the original control panel in the Initial Type Test, was used for this test. A drawing of the Engine Control Panel including ELV Driver is shown in Appendix M. The specification for ELV Driver is shown in the Table 5.3-6.

8.2.2.2 Seismic Qualification Methodology

8.2.2.2.1 Outline of Seismic Tests

In accordance with IEEE Std 344 (Reference 10-4), each test was conducted in basically the same manner as described in Subsection 8.2.1.2. The Engine Control Panel, the ELV Driver, and the Lube Oil Cooler Fan Assembly are tested on tri-axial tables using two horizontal input motions and one vertical input motion, which are multi-frequency random motion, simultaneously. Five OBE and one SSE test runs were performed in accordance with IEEE Std 344 (Reference 10-4).

The DCD Rev.4-based RRS used in the SSE tests of the Engine Control Panel are shown in Figures 8.2-22 and 8.2-23. The DCD Rev.4-based RRS were developed by enveloping the ISRS for the GTG system locations.

The DCD Rev.4-based RRS used in the SSE test of the ELV Driver are shown in Figures 8.2-24 and 8.2-25. The ELV Driver is attached to the subpanel within the Engine Control Panel. Therefore, the DCD Rev.4-based RRS were developed using the subpanel response accelerometer data recorded in the Engine Control Panel seismic test. An amplification factor for the subpanel was developed by comparing the panel response to the table response in the SSE test of the Engine Control Panel. The amplification factor spectra are shown in Figures 8.2-24 and 8.2-25. This amplification factor was applied to the RRS for the Engine Control Panel. The resulting RRS used for the ELV Driver are shown in Figures 8.2-24 and 8.2-25. The details of the development of the DCD Rev.4-based RRS are provided in Appendix N.

The DCD Rev.4-based RRS used in the SSE tests of the Lube Oil Cooler Fan Assembly are shown in Figures 8.2-26 and 8.2-27. The Lube Oil Cooler Fan Assembly is installed inside the acoustic enclosure. Therefore, the RRS was developed by a time history analysis of the engine skid/acoustic enclosure finite element model for the Lube Oil Cooler Fan Assembly location.

Each RRS has a 10% margin for DCD Rev.4-based ISRS of the PS/B, where the GTG systems are located. The RRS for each OBE test are half of the RRS for the SSE.

For the Engine Control Panel, resonance search tests are performed. For the other components, a resonance search test was not performed, because components of these type are generally rigid (i.e., frequency > 50 Hz).

8.2.2.2.2 Acceptance Criteria

8.2.2.2.2.1 Engine Control Panel

The Engine Control Panel shall be operational during the seismic test and shall be monitored to verify that structural integrity is maintained. Operability during the test will be verified by monitoring critical outputs of the Engine Control Panel. Additionally, contact chatter in critical circuits of the Engine Control Panel shall be monitored and any chatter greater than 2 milliseconds shall be identified.

8.2.2.2.2.2 ELV Driver

The ELV Driver shall be operational during the seismic test and shall be monitored to verify that structural integrity is maintained. Additionally, for all tests, the output of the ELV position indicator shall be monitored to confirm no variation from the steady-state position. This indicator shall be videotaped during all tests.

8.2.2.2.2.3 Lube Oil Cooler Fan Assembly

The Lube Oil Cooler Fan Assembly shall be operational during the seismic test and shall be monitored to verify that structural integrity is maintained and the Lube Oil Cooler Fan Assembly remains operational throughout the operational test runs.

8.2.2.2.3 Test Procedure

8.2.2.2.3.1 Engine Control Panel

a. Resonance Search Tests

A low-level (0.1 g) single-axis sine sweep shall be performed in each of the three orthogonal axes to determine major resonances of the Engine Control Panel. The sweep is performed from 1 to 100 Hz at a sweep rate of one octave per minute.

Note: The IEEE 344 Section 8.1.4.1 (Reference 10-4) states that a 0.2 g peak input is the conventional input level but it may be adjusted lower to avoid equipment damage, or higher to take nonlinearities into consideration.

b. Triaxial Seismic Simulation Tests

The Engine Control Panel shall be subjected to 30-second duration triaxial multiple-frequency random motion which shall be amplitude-controlled in one-sixth octave bandwidths spaced one-sixth octave apart over the frequency range of 1 to 100 Hz. Three simultaneous, but independent, random signals shall be used as input motion to produce phase-incoherent motions in one vertical and two horizontal axes. The amplitude of each one-sixth octave bandwidth shall be independently adjusted in each of the three axes until the TRS envelop the RRS. The resulting table motion shall be 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 Engine Control Panel shall be subjected to five OBE Tests and two SSE Seismic Tests in the tri-axial configuration. Four OBE Tests and one SSE Test shall be performed while the Engine Control Panel is in the operating mode. The remaining one OBE and one SSE Test shall be performed while the Engine Control Panel is in the standby mode. The RRS for the OBE and SSE Test are shown in Figures 8.2-22 and 8.2-23, which includes 10% margin, for horizontal direction and vertical direction, respectively.

c. Test Procedure

1. The Engine Control Panel shall be subjected to functional testing prior to the seismic testing.
2. The Engine Control Panel shall be visually inspected upon receipt for any shipping damage.
3. The Engine Control Panel shall be identified and tagged with part number, serial number.
4. The Engine Control Panel shall be bolted to a fabricated base frame test fixture using twelve 5/8"-11 grade 8 bolts. The mounting hardware shall be torqued to 115 +/-5 ft-lbs. The torque shall be documented and verified with a data sheet.
5. The test fixture shall be welded to the test table so that the horizontal axes of the Engine Control Panel are collinear with the horizontal axes of the test table. The weld pattern for the mounting fixture shall be a one quarter inch weld bead approximately 2 inches long and every sixteen inches around the outside of the base frame.
6. The Engine Control Panel Functional and Standby Circuits shall be monitored and recorded during the Engine Control Panel pre-test checkout, during the testing and at the conclusion of each axis tested. All instrumentation for the Engine Control Panel monitoring channels and seismic response data shall be checked and verified prior to the each seismic test run.

8.2.2.2.3.2 ELV Driver

The ELV Driver shall be subjected to random input motion, amplitude controlled in one-sixth octave bandwidths from 1 to 100 Hz for a minimum test duration of 30 seconds. The testing shall consist of five OBE and two SSE test runs using the RRS shown in Figures 8.2-24 and 8.2-25 for horizontal direction and vertical direction, respectively. The RRS for the OBE shall be half of the RRS for the SSE.

Four OBE and one SSE test runs shall be performed while the ELV Driver is in the operating mode. The remaining one OBE and one SSE test runs shall be performed while the ELV Driver is in standby mode.

TRS and time histories shall be plotted for the three directions of each test run.

The ELV Driver shall be visually examined after testing to determine the after-tested physical condition and the results.

After completion of seismic testing, the ELV Driver shall be functionally tested to verify operability.

For the ELV Driver, the resonance search test is not performed, because an electrical device of this type is generally rigid (i.e., frequency > 50 Hz).

8.2.2.2.3.3 Lube Oil Cooler Fan Assembly

The Lube Oil Cooler Fan Assembly shall be subjected to random input motion, amplitude controlled in one-sixth octave bandwidths from 1 to 100 Hz for a minimum test duration of 30 seconds. The testing shall consist of five OBE and one SSE test runs using the RRS shown in Figures 8.2-26 and 8.2-27, which includes 10% margin, for horizontal direction and vertical direction, respectively. The RRS for the OBE shall be half of the RRS for the SSE. The RRS was developed by a time history analysis of the engine skid/acoustic enclosure finite element model for the Lube Oil Cooler Fan Assembly location. The TRS shall envelop the RRS. Three OBE test runs shall be performed while the Lube Oil Cooler Fan Assembly is in the standby mode (not operating). The remaining two OBE and one SSE test runs shall be performed while the Lube Oil Cooler Fan Assembly is in operating mode. The Lube Oil Cooler Fan Assembly shall be monitored to verify that structural integrity is maintained and that the fan remains operational throughout the operational test runs. TRS 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.

For the Lube Oil Cooler Fan Assembly, the resonance search test is not performed, because a component of this type is generally rigid (i.e., frequency > 50 Hz).

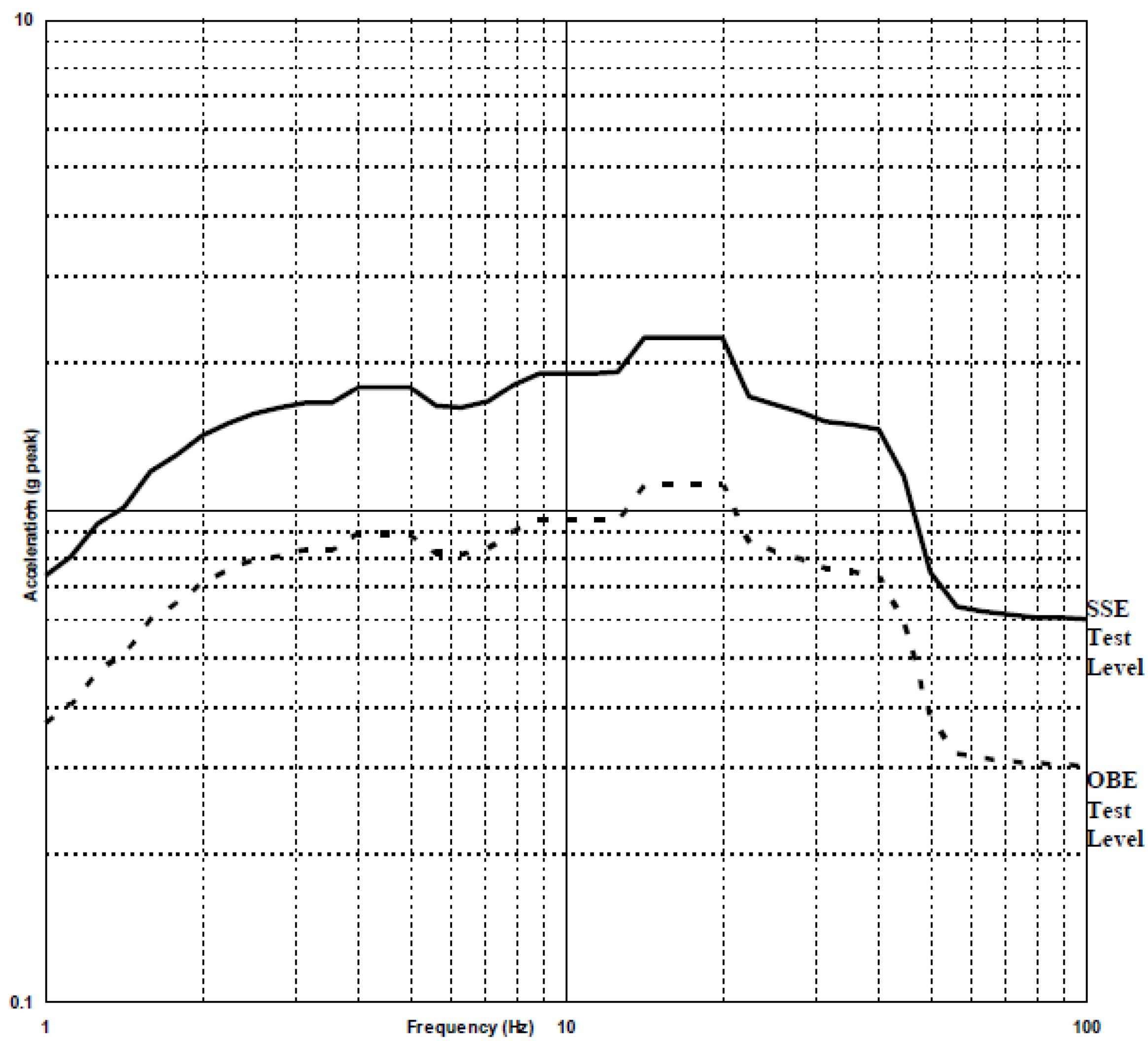

Figure 8.2-22 Enveloped Horizontal DCD Rev.4-based RRS (with 10% margin) of the Engine Control Panel

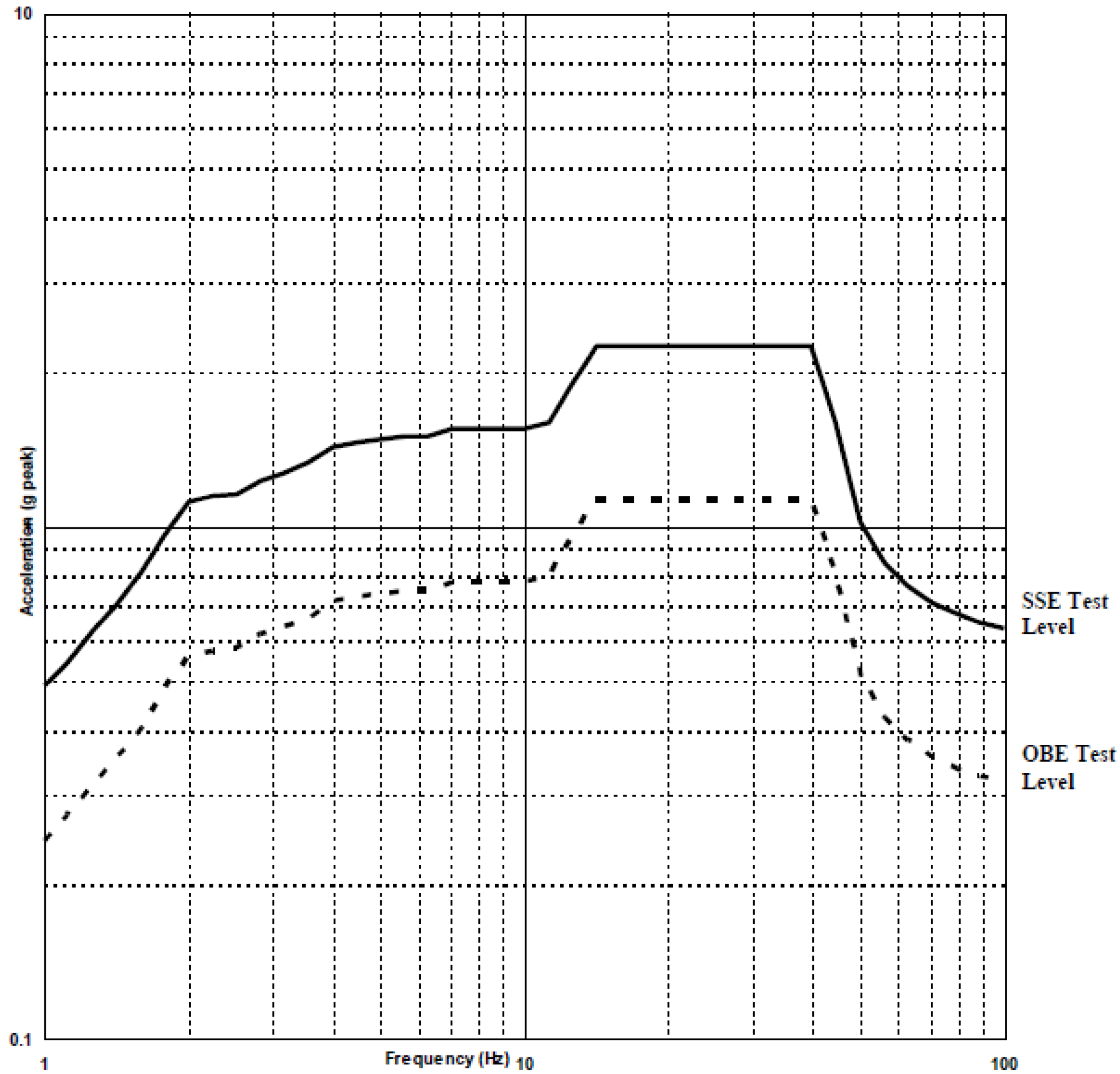

Figure 8.2-23 Vertical DCD Rev.4-based RRS (with 10% margin) for the Engine Control Panel

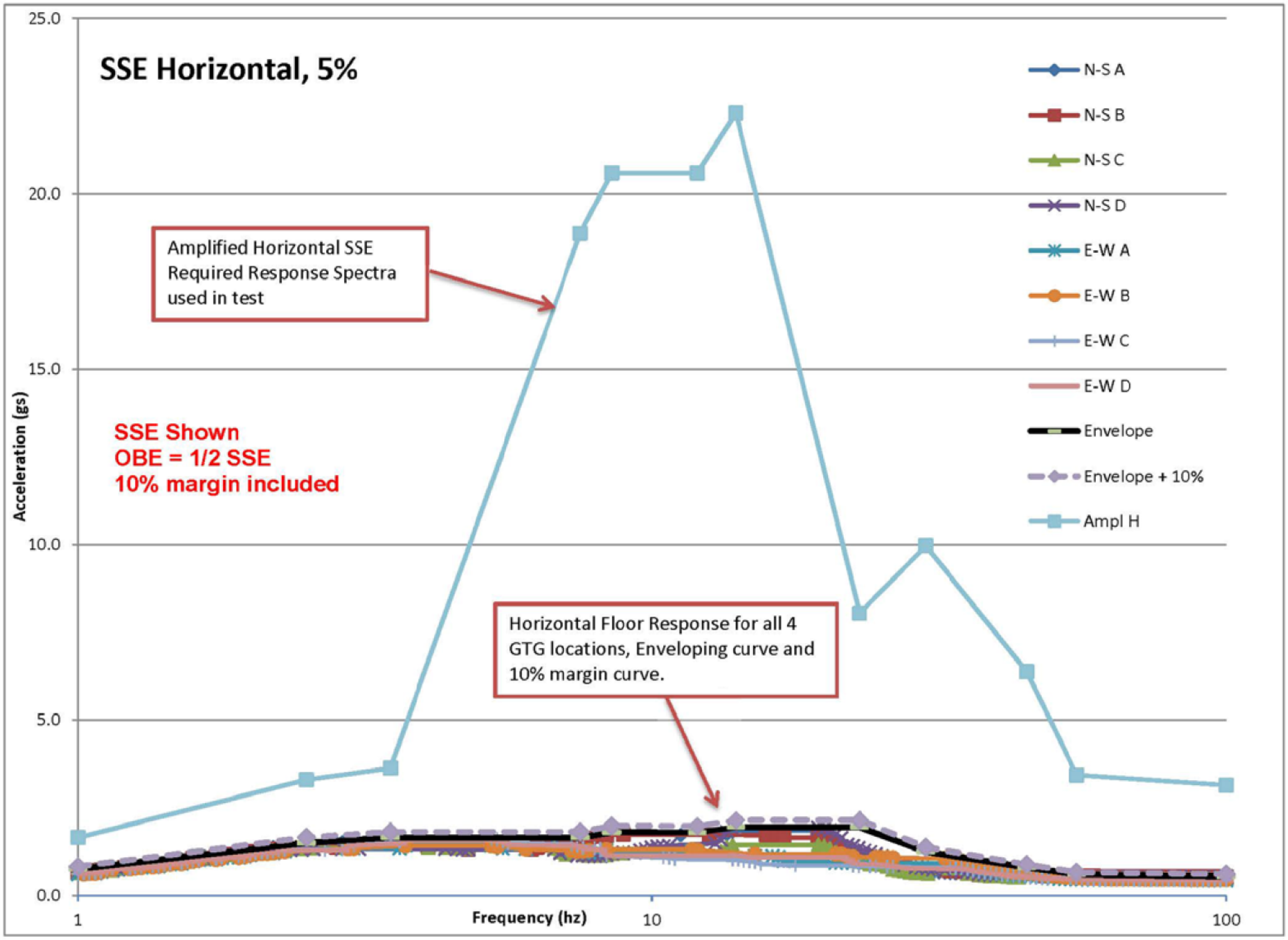

Figure 8.2-24 Enveloped Horizontal DCD Rev.4-based RRS (with 10% margin) for the ELV Driver

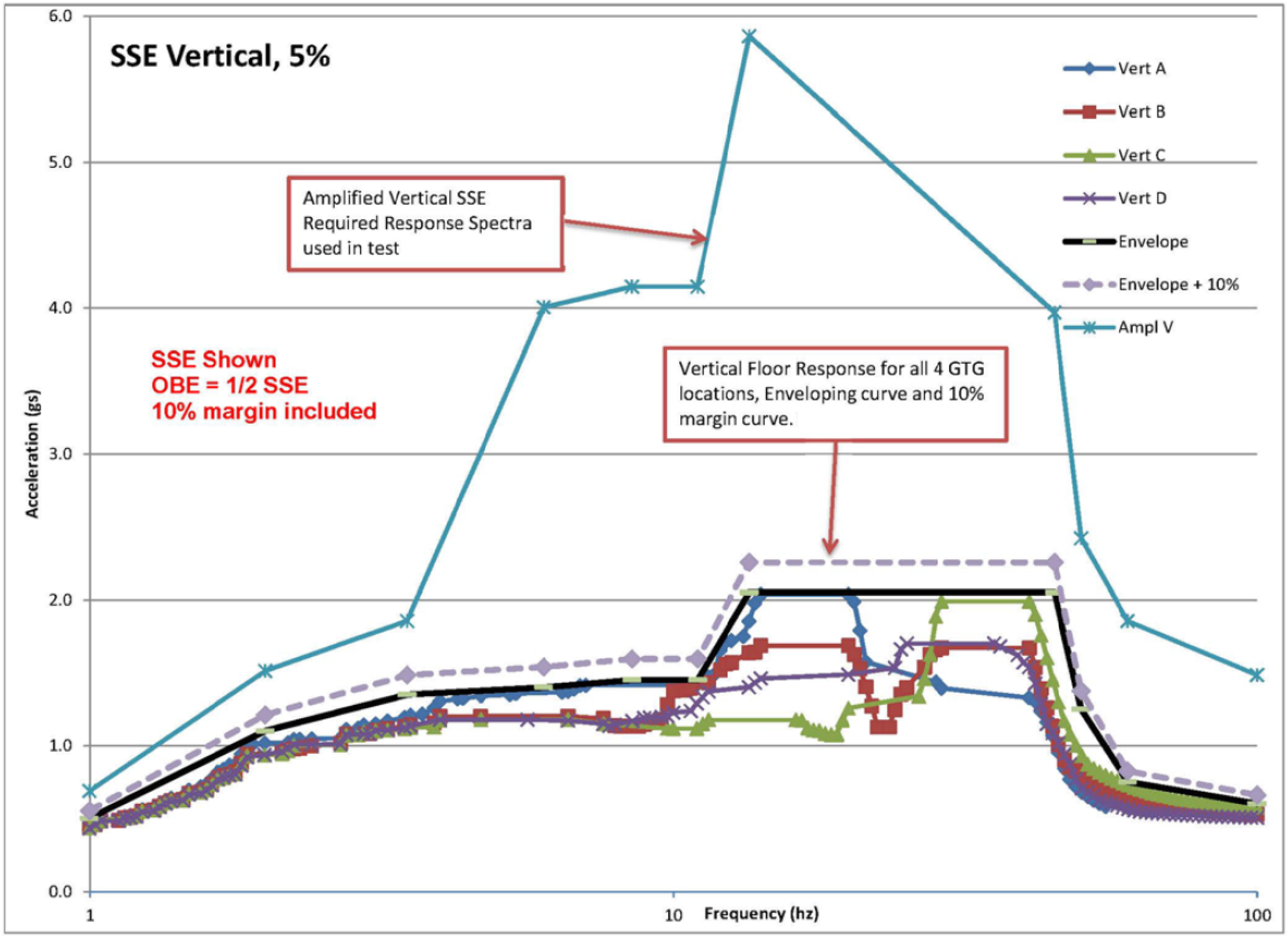

Figure 8.2-25 Vertical DCD Rev.4-based RRS (with 10% margin) for the ELV Driver

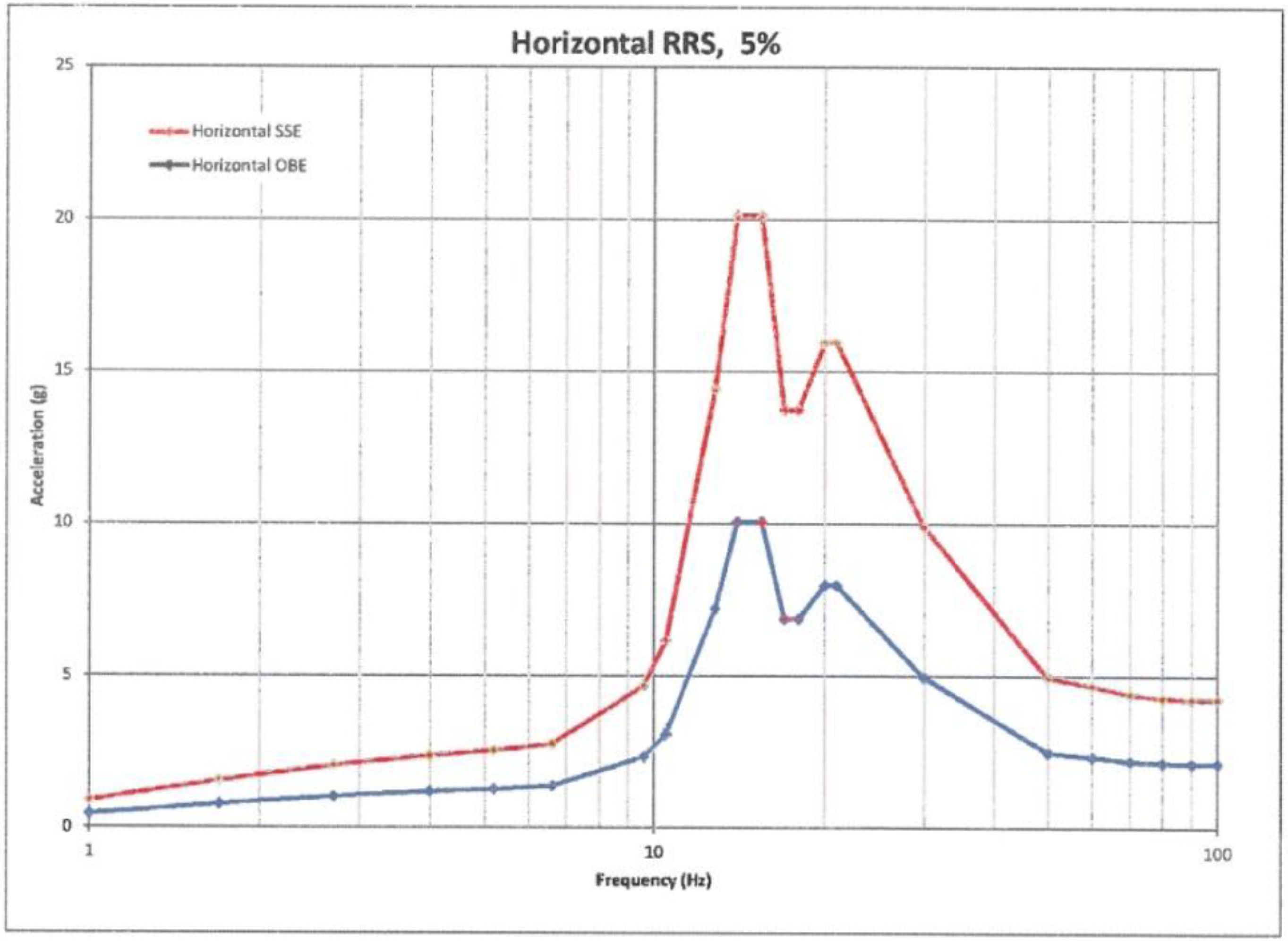

Figure 8.2-26 Enveloped Horizontal DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly

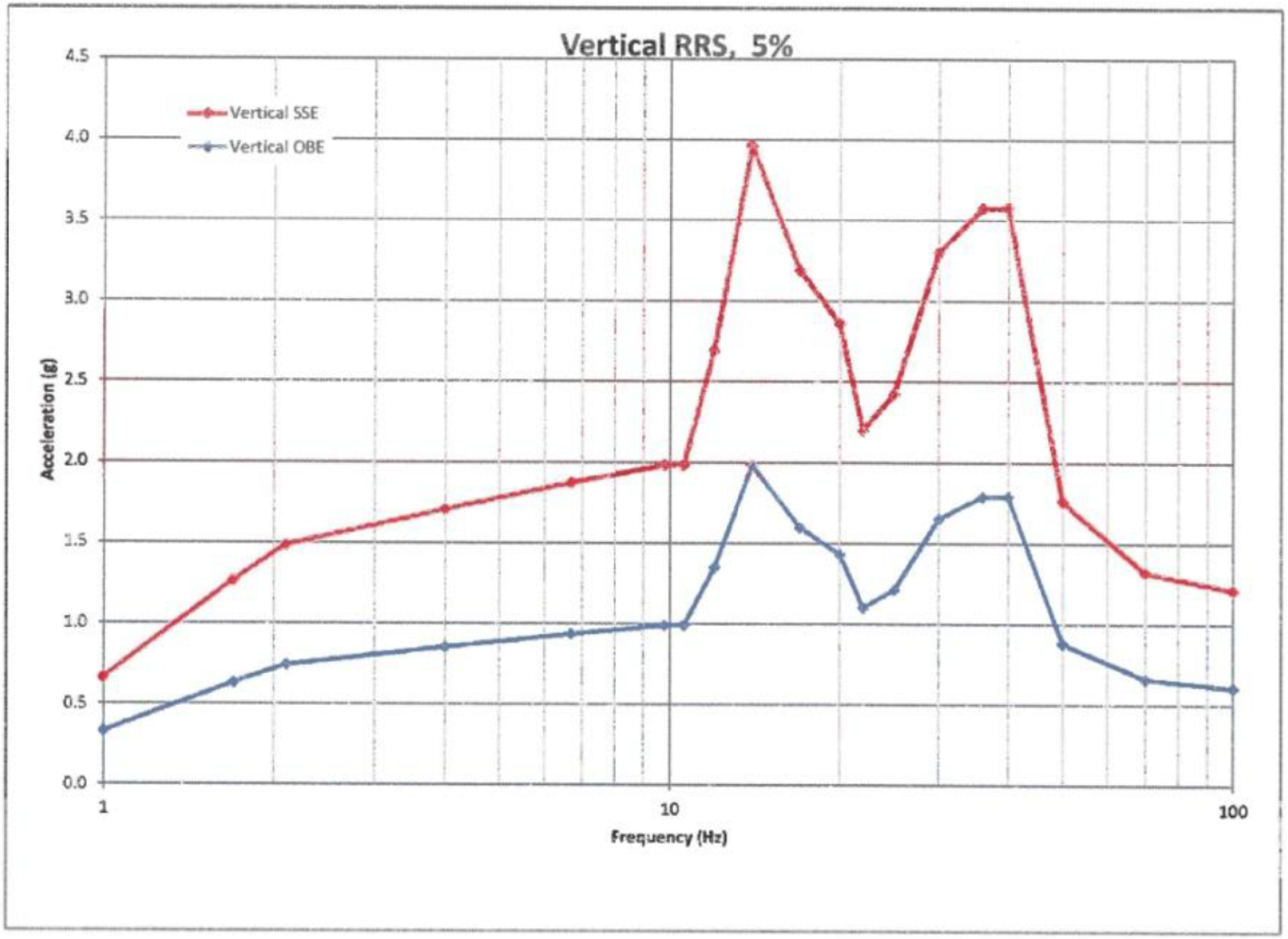

Figure 8.2-27 Vertical DCD Rev.4-based RRS (with 10% margin) for the Lube Oil Cooler Fan Assembly

8.2.2.3 Seismic Qualification Test Results

8.2.2.3.1 Engine Control Panel

The seismic qualification tests were performed following the methodology described in Subsections 8.2.2.2.1 through 8.2.2.2.3 above. The test results demonstrate that the Engine Control Panel operated and performed as required in accordance with the acceptance criteria in Subsection 8.2.2.2.2. The details of each test case are summarized in Table 8.2-3.

The Engine Control Panel successfully completed the OBE and SSE random multi-frequency tests with exception of contact chatter that was recorded during the SSE test runs. The assessment of this issue is described in Subsection 8.2.2.4 below. The details of the test results are provided in Appendix M.

The zero period acceleration of the TRS in the SSE tests are approximately 1.3 G for Front-to-Back (East-West) direction, 1.9 G for Side-to-Side (North-South) direction and 3.9 G for V (vertical) direction.

The fundamental frequencies of the engine control panel obtained from the resonance search test are approximately 14 Hz and more for Front-to-Back (East-West) direction, 17 Hz and more for Side-to-Side (North-South) direction and greater than 30 Hz for V (vertical) direction.

8.2.2.3.2 ELV Driver

The seismic qualification tests were performed following the methodology described in Subsections 8.2.2.2.1 through 8.2.2.2.3 above. The test results demonstrate that the ELV Driver operated and performed as required in accordance with the acceptance criteria in Subsection 8.2.2.2.2.

The ELV Driver successfully completed the OBE and SSE random multi-frequency tests. The details of the test results are provided in Appendix N.

The zero period acceleration of the TRS in the SSE tests are approximately 11.1 G for X (East-West) direction, 8.6 G for Y (North-South) direction and 6.1 G for Z (vertical) direction.

8.2.2.3.3 Lube Oil Cooler Fan Assembly

The seismic qualification tests were performed following the methodology described in Subsections 8.2.2.2.1 through 8.2.2.2.3 above. The test results demonstrate that the Lube Oil Cooler Fan Assembly operated and performed as required in accordance with the acceptance criteria in Subsection 8.2.2.2.2.

The Lube Oil Cooler Fan Assembly successfully completed the OBE and SSE random multi-frequency tests. The details of the test results are provided in Appendix P.

The zero period acceleration of TRS in SSE tests are approximately 5.9 G for X (East-West) direction, 5.6 G for Y (North-South) direction and 5.0 G for Z (vertical) direction.

Table 8.2-3 Test Run Description for Engine Control Panel

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

Notes:

1. The Engine Control Panel Mounting Hardware was torqued to 115 +/- 5 ft/lbs prior to the test run.
2. The Engine Control Panel was in Standby Mode.
3. The Engine Control Panel was in Operating Mode during the test run.
4. Chatter was detected during test run.
5. The test run was repeated because the Test Response Spectra was lower than the Required Response Spectra.
6. The test run was performed by the request of Engine Systems for information only.

8.2.2.4 Assessment of Contact Chatter

During the SSE tests in the operational and non-operational test runs, contact chatter was detected. Proper operation during the test was verified by monitoring critical outputs of the control panel as defined in Appendix M. The details of the evaluation of the contact chatter are summarized in Table 8.2-4 and Table 8.2-5.

Some relay contact chatter can be detected, however the logic for operability of the GTG is not affected if indication is not provided or if an alarm is triggered by relay contact chatter. Even if relay contact chatter affects GTG operability logic, momentary contact chatter has no adverse effects on the function of starting and operating the GTG. It is concluded that all contact chatter which was detected during the SSE tests has no adverse effects on the operability of the GTG.

Table 8.2-4 Evaluation of Contact Chatter during SSE Testing Performed in the Starting/Operating Mode

<table>
<tr><th>Contact Chatter</th><th>Evaluation</th></tr>
<tr><td>Three digital readouts lost power during the test (Lube Oil Temp #1, Exhaust Temp #1, and Exhaust Temp #2).</td><td>The digital readouts on the door of the engine control panel are used for indication only, and therefore the momentary loss of function of these devices has no adverse effects on the function of starting and operating of the GTG.</td></tr>
<tr><td>GTG Not in Auto Alarm sounded on annunciator.</td><td>The GTG Not in Auto Alarm is used for indication only and therefore this alarm has no adverse effects on the function of starting and operating of the GTG.</td></tr>
<tr><td>ESR (Emergency Shutdown Relay) chattered for approximately 3.3 ms.</td><td rowspan="2">The following circuits are potentially impacted by the contact chatter of ESR.
• Start Air Solenoid Valves
• Generator permanent magnet generator (PMG)
• Gas Turbine Exciter # 1 and #2
• Gas Turbine Fuel Solenoid Valve (Main, Balance & Primary)
Regarding start air solenoid valves and PMG, the short duration of contact chatter of the ESR (up to maximum 6.5 ms) will not have adverse effects on operability of the GTG.
Regarding the gas turbine exciters and fuel solenoid valves, loss of function of these devices for less than 10 ms and therefore the shorter duration of the contact chatter would have no adverse effects on the function of starting and operating of the GTG.</td></tr>
<tr><td>ESR chatter caused a loss of voltage for the GT Exciters, PSV1 (Primary Fuel Solenoid Valve #1), MSV1 (Main Fuel Solenoid Valve #1), & SV71 (Air Start Solenoid Valve #1).</td></tr>
<tr><td>VRR (Voltage Raise Relay) chattered for approximately 3.1 ms.</td><td>The VRR is an input to the MOP (Motor Operated Potentiometers) which affect the input reference to the automatic voltage regulator(s). If the VRR relay chatters, it is possible that a small increase in the input reference would occur; however, in emergency operation, normally closed emergency start relay (R3) contacts open and disable the VRR input to the MOPs. Therefore, chatter of the VRR relay would have no adverse effects on the function of starting and operating of the GTG.</td></tr>
</table>

Table 8.2-5 Evaluation of Contact Chatter during SSE Testing Performed in the Standby Mode

Contact Chatter	Evaluation
Four digital readouts lost power during the test (Lube Oil Temp #1, Exhaust Temp #1, Exhaust Temp #2, and Engine Speed).	The digital readouts on the door of the engine control panel are used for indication only, and therefore the momentary loss of function of these devices has no adverse effects on the function of starting and operating of the GTG.
TM1 (GTG Turing Motor #1) and TM2 (GTG Turing Motor #2) lost power for approximately 44 ms.	TM1 and TM2 are the GTG turning motors, used to slowly roll the turbine engine for 10 hours after operation. Momentary loss of the turning motors for 44 milliseconds would have no adverse effects on the function of starting and operating of the GTG.
K3 (Primary Solenoid Voltage On Relay) chattered for approximately 5.5 ms.	When the PLC output for the primary fuel solenoid valve is true, the K3 relay is energized. Contacts of K3 are used in the generator space heater circuit, the generator bearing circulating oil pump control, and to energize the primary fuel solenoids. A momentary change of state of the generator space heater and bearing oil pump circuit is inconsequential, and a momentary interruption of the primary fuel solenoid valve circuits would not affect the starting or continued operation of the GT engine. Therefore, K3 relay chatter has no adverse effects on the function of starting and operating of the GTG.
R3 (Emergency Start Relay) chattered for approximately 7 ms.	A momentary interruption of these circuits would not affect the starting or continued operation of the turbine engine. Therefore, R3 relay chatter has no adverse effects on the function of starting and operating of the GTG.

8.3 Seismic Qualification by Analysis

Seismic qualification by analysis is performed for the following components:

- Synchronous Generator
- Air Start Receiver Assembly
- Fuel Oil Day Tank Assembly and Stand
- Air Start Manifold Skid
- Air Start Manifold Piping

8.3.1 Equipment Specification

The specification for Generator is shown in the Table 5.3-2.
A drawing of Generator is shown in Figure B.1.0-4.

The specification for Air Start Receiver is shown in the Table 5.3-4
A drawing of Air Start Receiver Assembly is shown in Figure B.1.0-6.

The specification for Fuel Oil Day Tank Assembly and Stand is shown in Table 5.3-3.
A drawing of Fuel Oil Day Tank Assembly and Stand is shown in Figure B.1.0-5.

A drawing of Air Start Manifold Skid is shown in Figure B.1.0-10.

8.3.2 Seismic Qualification Methodology

8.3.2.1 Outline of Seismic Qualification by Analysis

Seismic response analyses and stress analyses, including operational condition, are performed in accordance with IEEE 344 Std (Reference 10-4) and applicable codes and standards, such as ASME Code Section III (Reference 10-8).

Load combination and acceptance criteria in stress analyses are also in accordance with applicable codes and standards, such as ASME Code Section III (Reference 10-8).

Seismic input motion, i.e., RRS, in analyses for components which are installed on floor directly or with rigid basemat or skid, are developed using the DCD Rev.4 based ISRS of four locations in PS/B, where the four Class 1E GTG units are located, respectively. These four ISRS are enveloped for each direction, i.e., N-S direction, E-W direction and vertical direction. (See Figures 8.3-3 and 8.3-4 and description in Subsection 8.3.2.3.1.)

The summary of the load combination and acceptance criteria, response and stress evaluation procedure, and seismic qualification results are described in Subsection 8.3.2.2, Subsection 8.3.2.3 and Subsection 8.3.3, respectively. The detailed analyses and results for the Synchronous Generator are provided in Appendix O. Note that the component names used in the appendix may vary slightly from the names used in this report. No difference is intended.

8.3.2.2 Load Combination and Acceptance Criteria

8.3.2.2.1 Synchronous Generator

Operating conditions (deadweight) stresses and seismic acceleration induced stresses are

taken into account in the seismic analysis of the Synchronous Generator. The stress effects due to the short circuit torque load are also evaluated only for qualifying the bolt reaction stresses at the generator frame mounting and RENK bearing frame mounting locations.

The allowable stresses for operating or deadweight conditions are in accordance with the American Institute of Steel Construction (AISC) Steel Construction Manual (Reference 10-17).

The stress limit coefficients for operating-plus-seismic conditions are obtained from the AISC N690 code (Reference 10-18).

For the bolts that secure the Synchronous Generator to the engine skid and the RENK bearing to the synchronous generator rotor shaft, the allowable shear stress and tensile stress for the combination of operating-plus-seismic-plus-short circuit torque load are in accordance with the AISC Steel Construction Manual (Reference 10-17), Tables 7-1 (Page 7-22) and 7-2 (Page 7-23), respectively.

From the viewpoint of mechanical interferences, air gap criteria are also considered as follows: The blades behind both the RENK bearings should not contact the shroud (0.25” air gap) during the input seismic response spectra loading. The main field air gap is 0.295” and there should be no mechanical interference that will occur in the main field region. Similarly, the Exciter air gap is 0.040” and the PMG air gap is 0.035”.

8.3.2.2.2 Air Start Receiver Assembly

The loads to be evaluated for the load combinations are defined in Table 8.3-1. The stress limits for each load combination are defined in Table 8.3-2 through Table 8.3-4 for each of the components evaluated.

The allowable stress for bolted joints is in accordance with Subparagraph NF-3324.6 of the ASME Code, Section III (Reference 10-8).

Requirements for buckling of plate-and-shell-type supports are provided in Table NF-3552(b)-1 of the ASME Code, Section III (Reference 10-8).

For the mounting plate attachment fillet welds, the stress acceptance criteria are given in Subsection ND-3356 of the ASME Code, Section III (Reference 10-8). For the support skirt gusset welds, the stress acceptance criteria are given in Subsection NF-3266 of the ASME Code, Section III (Reference 10-8). The criteria in Table NF-3324.5(a)-1 of the ASME Code, Section III (Reference 10-8) are applicable to the welds, where the allowable shear stress in the welds is 0.30Su. For the fillet welds and groove welds, such as the nozzle attachment welds, the stress acceptance criteria are given in Subsection ND-3359 of the ASME Code, Section III (Reference 10-8).

8.3.2.2.3 Fuel Oil Day Tank Assembly and Stand

The loads to be evaluated for the load combinations are defined in Table 8.3-5. The stress limits for each load combination are defined in Table 8.3-6 through Table 8.3-8 for each of the components evaluated.

No nozzle loads are defined for application on the nozzles. Therefore, unit loads are applied to the nozzles to determine a stress state for a unit condition. The stresses are scaled up to the

maximum allowable value and the unit loads are multiplied by that scale factor to determine the maximum nozzle capacity loads for each nozzle.

The allowable stress for bolted joints is provided in Subparagraph NF-3324.6 of the ASME Code, Section III (Reference 10-8).

Based on Euler's equation for column buckling for a simple beam/plate with fixed ends boundary constraints and the applicable dimensions and material properties, the critical buckling stresses for the frame support box beams and the saddle plates are much greater than the yield strength of the box beam material and the saddle plate material respectively. Therefore, it is appropriate and conservative to use the yield strength of the box beam and the saddle plates as the critical buckling stress. Per Table of the ASME Code, Section III (Reference 10-8), the buckling acceptance limit for linear-type structures is compressive stress not exceeding 2/3Sy. Per Table NF-3552(b)-1 of the ASME Code, Section III (Reference 10-8), the buckling acceptance limit for plate-type structures is compressive stress not exceeding 1/2Sy.

For the fillet welds and groove welds, such as the nozzle attachment welds, the stress acceptance criteria are given in Subsection ND-3359 of the ASME Code, Section III (Reference 10-8).

For the saddle support wrapper plate-to-tank shell fillet welds, the stress acceptance criteria are given in Subsection ND-3356 of the ASME Code, Section III (Reference 10-8). For the frame support welds, the stress acceptance criteria are given in Subsection NF-3324 of the ASME Code, Section III (Reference 10-8). For the saddle support plate welds, the stress acceptance criteria are given in Subsection NF-3266 of the ASME Code, Section III (Reference 10-8). The criteria in Table NF-3324.5(a)-1 of the ASME Code, Section III (Reference 10-8) are applicable to the welds for these two components.

8.3.2.2.4 Air Start Manifold Skid

The loads to be evaluated for the load combinations are defined in Table 8.3-9. The stress limits for each load combination are defined in Table 8.3-10.

The allowable stress for bolted joints is provided in Subparagraph NF-3324.6 of the ASME Code, Section III (Reference 10-8).

Based on Euler's equation for column buckling for a simple beam/plate with fixed ends boundary constraints and the applicable dimensions and material properties, the critical buckling stress for the Air Start Manifold Skid components is much greater than the yield strength of the skid material. Therefore, it is appropriate and conservative to use the yield strength of the skid as the critical buckling stress. Per Table NF-3523(b)-1 of the ASME Code, Section III (Reference 10-8), the buckling acceptance limit for linear-type structures is compressive stress not exceeding 2/3Sy.

8.3.2.2.5 Air Start Manifold Piping

The ASME Code rules require that the effects of dead load, pressure, thermal expansion, thermal anchor movements, seismic inertia, and seismic anchor movements be evaluated for the affected piping. The analysis for these loadings was performed using the program PIPESTRESS, Version 3.7.0 (Reference 10-19).

The air start manifold piping is analyzed and evaluated according to the rules in Subsection ND of the ASME Code, Section III (Reference 10-8). Since the air start manifold piping is classified as ASME Class 3, it is evaluated under the rules stated in ND-3650 of the ASME Code, Section III (Reference 10-8).

Table 8.3-1 Service Levels and Load Combinations for the Air Start Receiver Assembly

Service Levels	Loads
Design and Normal Operating (Service Level A)	Pressure + Deadweight + Nozzle Loads
Service Level B (Treated as Upset and Faulted)	Pressure + Deadweight + Nozzle Loads + SSE

Table 8.3-2 Service Conditions and Stress Limits for Vessel of the Air Start Receiver Assembly

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	σ_m < 1.0 S	$(\sigma_m$ or $\sigma_L)+\sigma_b$ < 1.5 S
Level B	σ_m < 1.1 S	$(\sigma_m$ or $\sigma_L)+\sigma_b$ < 1.65 S

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-3 Service Conditions and Stress Limits for Component Support Structures of the Air Start Receiver Assembly

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	$\sigma_m < 1.0$ S	$(\sigma_m$ or $\sigma_L) + \sigma_b < 1.5$ S
Level B	$\sigma_m < 1.0$ S * 1.33	$(\sigma_m$ or $\sigma_L) + \sigma_b < 1.5$ S * 1.33
Level A/B	N/A	$\sigma_L < 1/2\ S_y$ for buckling limit (plate)

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-4 Service Conditions and Stress Limits for Piping of the Air Start Receiver Assembly

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	$\sigma_m < 1.5\ S_h$	$\sigma_L + \sigma_b < 1.5\ S_h$
Level B	$\sigma_m < 1.8\ S_h$	$\sigma_L + \sigma_b < 1.8\ S_h$

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-5 Service Levels and Load Combinations for the Fuel Oil Day Tank Assembly and Stand

Service Levels	Loads
Design and Normal Operating (Service Level A)	Pressure + Nozzle Loads + Deadweight
Service Level B (Treated as Upset and Faulted)	Pressure + Nozzle Loads + Deadweight + SSE

Table 8.3-6 Service Conditions and Stress Limits for Tank of the Fuel Oil Day Tank Assembly and Stand

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	$\sigma_m < 1.0$ S	$(\sigma_m$ or $\sigma_L)+\sigma_b < 1.5$ S
Level B	$\sigma_m < 1.1$ S	$(\sigma_m$ or $\sigma_L)+\sigma_b < 1.65$ S

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-7 Service Conditions and Stress Limits for Component Support Structures of the Fuel Oil Day Tank Assembly and Stand

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	σ_m < 1.0 S	(σ_m or σ_L)+ σ_b < 1.5 S
Level B	σ_m < 1.0 S * 1.33	(σ_m or σ_L)+ σ_b < 1.5 S * 1.33
Level A/B	N/A	σ_L < 2/3 S_y for buckling limit (linear) σ_L < 1/2 S_y for buckling limit (plate)

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-8 Service Conditions and Stress Limits for Piping of the Fuel Oil Day Tank Assembly and Stand

Service Level	Stress Limit (Membrane)	Stress Limit (Membrane plus Bending)
Level A	σ_m < 1.5 S_h	σ_L+σ_b < 1.5 S_h
Level B	σ_m < 1.8 S_h	σ_L+σ_b < 1.8 S_h

Note:

Stress definitions given as:

σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.

S = allowable stress as defined in the applicable ASME Code of Construction.

Table 8.3-9 Service Levels and Load Combinations for the Air Start Manifold Skid

Service Levels	Loads
Design and Normal Operating (Service Level A)	Deadweight
Service Level B (Treated as Upset and Faulted)	Deadweight + SSE

Table 8.3-10 Service Conditions and Stress Limits for the Air Start Manifold Skid

Service Level	Stress Limit Membrane (σ_m)	Stress Limit Membrane+ Bending (σ_m+σ_b)	Reference
Level A	σ_m < 1.0 S	(σ_m or σ_L)+ σ_b < 1.5 S	[1, Table NF-3523(b)-1]
Level B	σ_m < 1.0 S * 1.33	(σ_m or σ_L)+ σ_b < 1.5 S * 1.33	[1, Table NF-3623(b)-1]
Level A & Level B	σ_L < 2/3 S_y for buckling limit (linear)		[1, Table NF-3523(b)-1]

Service Level	Fillet Weld Stress Limit Tensile (σ_m)	Fillet Weld Stress Limit Shear (τ_m)	Reference
Level A	σ_m < 0.3 S_u	τ_m < 0.4 S_y	[1, Table NF-3324.5(a)-1] [1, Table NF-3623(b)-1]
Level B	σ_m < 0.3 S_u * 1.33	τ_m < 0.4 S_y * 1.33	

Notes:

1. The indicated stress limits for welds are based on fillet welds and all welds are evaluated as such.
2. Stress definitions given as:
   - σ_m = general primary membrane stress. This stress is equal to the average normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.
   - σ_L = local primary membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.
   - σ_b = primary bending stress. This stress is equal to the linear varying portion of the normal stress across the solid section under consideration. This stress excludes discontinuities and concentrations and is produced only by mechanical loads.
   - S = allowable stress as defined in the applicable ASME Code of Construction.

8.3.2.3 Response and Stress Evaluation Procedure

8.3.2.3.1 Synchronous Generator

The seismic qualification analysis is performed in two steps. First, a three-dimensional (3-D) finite element model of the generator is developed and a modal analysis is performed to determine all mode shapes within the frequency range from 0.1 Hz to 100 Hz in order to capture modes within the zero period acceleration (ZPA) frequency. An acceleration of 1g is applied in the vertical direction to simulate gravity and this load case along with its respective results are used in combination with the single point response spectrum seismic analysis results and the operational stresses to seismically qualify the Synchronous Generator.

The finite element model is developed and the modal analysis is performed using the ANSYS finite element analysis software package (References 10-20 and 10-21). The CAD geometry for the synchronous generator is imported into the model of ANSYS for analysis. Figures 8.3-1 and 8.3-2 show the developed finite element model.

The second step is to perform a finite element analysis using the generator finite element model by applying a single point response spectrum representing the RRS for the SSE and combining the results of this analysis with the gravity (deadweight) analysis results discussed above. The results of these two analyses are algebraically added and compared to the stress allowable values in Subsection 8.3.2.2.1 above.

The RRS used are shown in Figures 8.3-3 and 8.3-4. The RRS are developed using the DCD Rev.4 based ISRS of four locations in PS/B, where four units of Class 1E GTG systems are located respectively. These four ISRS are enveloped for each direction, i.e., N-S direction, E-W direction and vertical direction. In addition, each bounding ISRS for N-S direction and E-W direction are enveloped again. Finally, the bounding ISRS for the horizontal direction and vertical direction are adjusted and smoothed. The resulting ISRS are used as the RRS for each direction. The horizontal RRS is used for both horizontal directions. The RRS is applied separately in both the Global X and Global Z directions in the finite element analysis. The RRS in the vertical direction is applied in the Global Y direction in the finite element analysis. These RRS are also applied to the analyses for the Air Start Receiver Assembly, the Fuel Oil Day Tank Assembly and Stand, and the Air Start Manifold as described in each related subsection below. (See Figures 8.3-3 and 8.3-4.)

8.3.2.3.2 Air Start Receiver Assembly

Finite element analyses are performed to evaluate the Air Start Receiver Assembly under design and normal operating condition loads (i.e., pressure, deadweight and nozzle loads) and SSE loads.

The evaluation is performed for the three parts. The Level A evaluation includes the deadweight and the maximum pressure. The Level B loads include the Level A loads plus the horizontal and vertical RRS, which are discussed in Subsection 8.3.2.3.1 above. Finally unit load evaluations are considered to determine the capacity loads for the nozzles. The finite element model used for the evaluations is shown in Figure 8.3-5. All the finite element analyses are modeled and analyzed using the ANSYS general purpose finite element computer program (Reference 10-20).

After the loads are evaluated, the stress results are evaluated to the allowable stresses. For

simplicity, if principal stress plots demonstrate that the stress in the entire structure is below the allowable stress, then no further post-processing of stresses is performed. If the stresses exceed the allowable, then detailed post-processing of stresses is performed to extract linearized stresses and compare to the allowable stresses.

The nozzle capacity loads are determined from the unit load evaluations that are performed. The stresses from the unit loads are scaled until the allowable stress is reached. This determines the scale factor to apply to the unit loads applied on the model and thus the nozzle capacity loads.

8.3.2.3.3 Fuel Oil Day Tank Assembly and Stand

Finite element analyses are performed to evaluate the Fuel Oil Day Tank Assembly and Stand under design and normal operating condition loads (i.e., pressure, deadweight and nozzle loads) and SSE loads.

For the evaluation, the tank is assumed to be full of fuel. The evaluation is performed for the three parts. The Level A evaluation includes the deadweight, hydrostatic pressure due to the fuel, and the maximum pressure. The Level B loads include the Level A loads plus the horizontal and vertical RRS, which are discussed in Subsection 8.3.2.3.1 above. Finally unit load evaluations are considered to determine the capacity loads for the nozzles. The finite element model used for the evaluations is shown in Figure 8.3-6. All the finite element analyses are modeled and analyzed using the ANSYS general purpose finite element computer program (Reference 10-20).

After the loads are evaluated, the stress results are compared to the allowable stresses. For simplicity, if principal stress plots demonstrated that the stress in the entire structure is below the allowable stress, then no further post-processing of stresses is performed. If the stresses exceed the allowable, then detailed post-processing of stresses is performed to extract linearized stresses and compare to the allowable stresses.

The nozzle capacity loads are determined from the unit load evaluations that are performed. The stresses from the unit loads are scaled until the allowable stress is reached. This determines the scale factor to apply to the unit loads applied on the model and thus the nozzle capacity loads.

8.3.2.3.4 Air Start Manifold Skid

Finite element analyses are performed to evaluate the Air Start Manifold Skid under design and normal operating condition loads (deadweight) and SSE loads.

The evaluation is performed for the two Service Levels evaluated. The Level A evaluation includes the deadweight of the structure. The Level B loads include the Level A loads plus the horizontal and vertical RRS, which are discussed in Subsection 8.3.2.3.1 above. The finite element model used for the evaluations is shown in Figure 8.3-7. All the finite element analyses are modeled and analyzed using the ANSYS general purpose finite element computer program (Reference 10-20).

After the loads are evaluated, the stress results are compared to the allowable stresses. For simplicity, stress plots are evaluated for the entire structure and compared to the allowable stress. If the entire structure is below the allowable stress, then the structure is qualified. For

evaluation of the bolted connections, either ANSYS beam elements are used, or the model is constrained to simulate the connection. These stresses are then extracted and compared to the allowable stress.

8.3.2.3.5 Air Start Manifold Piping

The seismic inertia analysis is performed using the program PIPESTRESS, Version 3.7.0 (Reference 10-19) by the 3-D response spectrum modal superposition method. The geometric model for the Air Start Manifold Piping, showing the node point locations and pipe supports, is shown in Figure 8.3-8. Directional responses are generated for each orthogonal direction, and the modal responses are then combined by SRSS. The modal coupling is the 10% grouping method based on the NRC Reg. Guide 1.92 (Reference 10-22).

The RRS are developed from separate calculations that provide a seismic analysis of the Air Start Manifold Skid frame in which response spectra are generated that account for the amplification of the floor motion by the structure. That analysis is based on 3% damping RRS. The horizontal RRS applied in this analysis are specified for the X and Z directions; Y is vertical.

A seismic anchor movement (SAM) analysis is run for the SSE case using the displacements at the attachment points of the supports to the air start manifold frame. Anchor displacements are coded at each relevant pipe support location based on the attachment elevation. The SAMs for parallel sets of pipe support locations on the air start manifold frame are bounded and the maximum SAM values are used.

The SAM analysis is run as three separate cases in the global coordinate directions, which are then combined in the same method as the seismic inertia cases (3-D SRSS). SAM stresses are treated as secondary, and generally combined with the thermal expansion stresses. However, as the piping is self-contained on the Air Start Manifold Skid and there are no interfaces with equipment that is external to the Air Start Manifold Skid, there are no thermal anchor movements to be incorporated into the analysis.

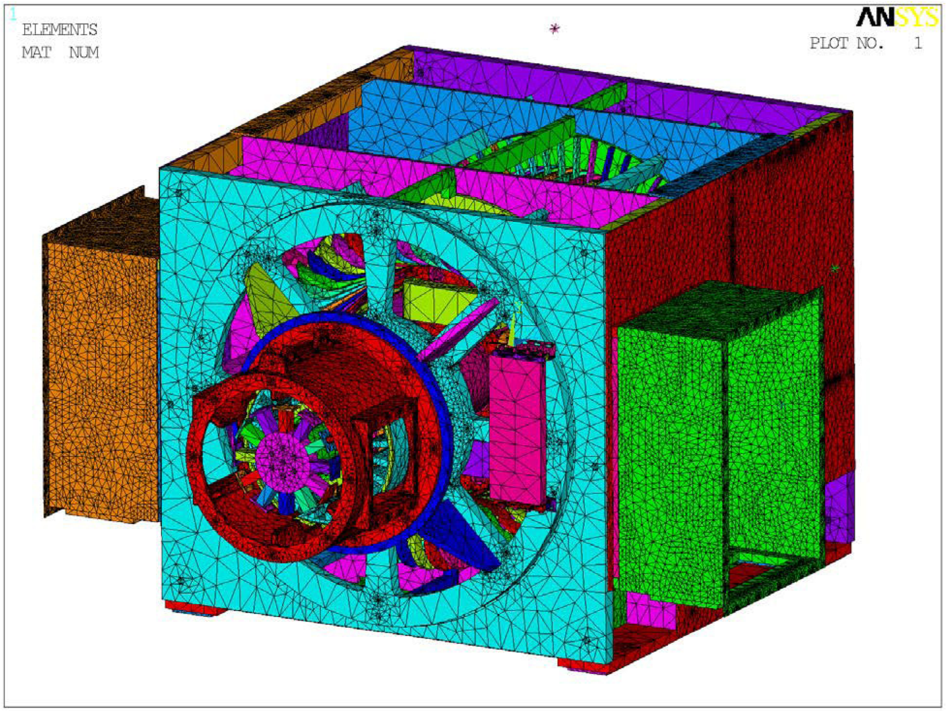

Figure 8.3-1 Finite Element Model of Synchronous Generator – PMG/Exciter End Isometric View

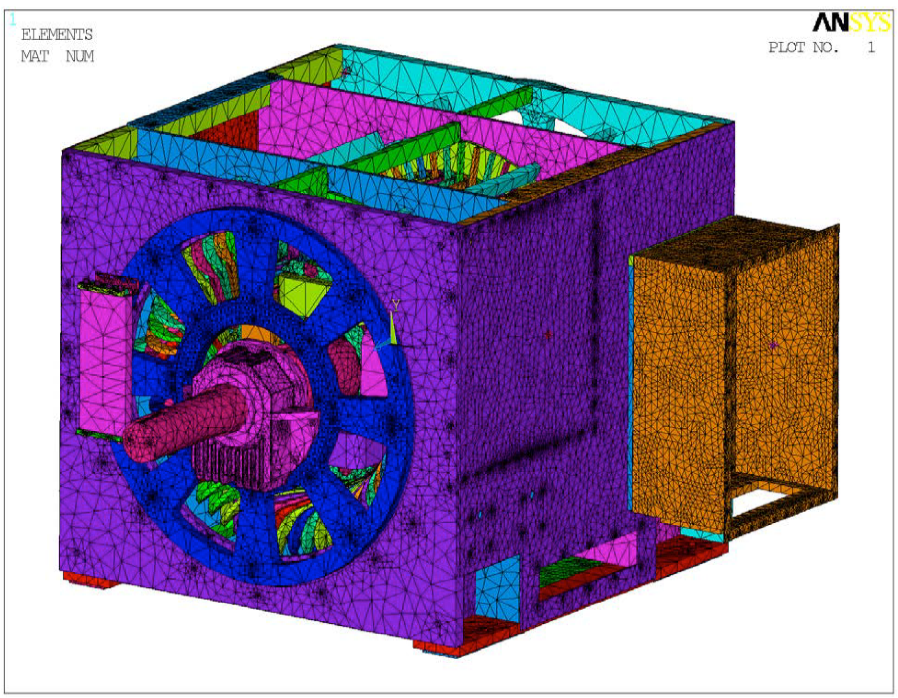

Figure 8.3-2 Finite Element Model of Synchronous Generator - Gas Turbine/Prime Mover End Isometric View

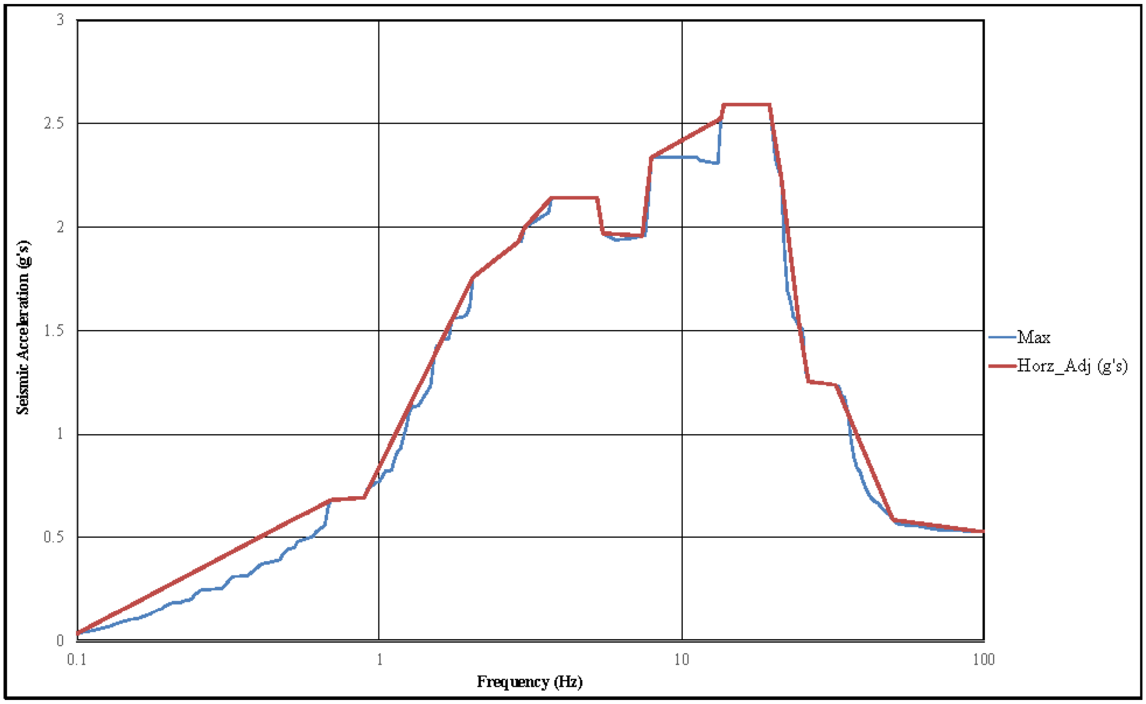

Figure 8.3-3 Bounding and Adjusted RRS for Horizontal Direction, 3% Damping Curve

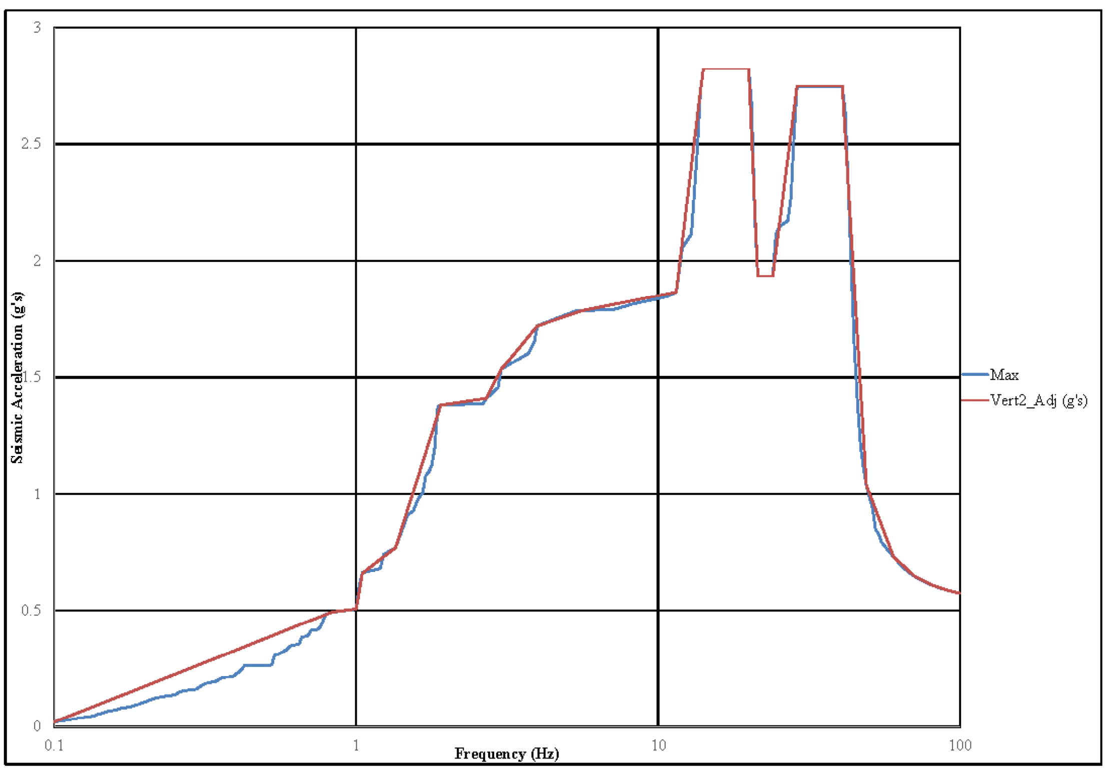

Figure 8.3-4 Bounding and Adjusted RRS for Vertical Direction, 3% Damping Curve

Figure 8.3-5 Finite Element Model of Air Start Receiver Assembly

Figure 8.3-6 Finite Element Model of Fuel Oil Day Tank Assembly and Stand

Figure 8.3-7 Finite Element Model of Air Start Manifold Skid

Figure 8.3-8 Air Start Manifold Piping Geometric Model

8.3.3 Seismic Qualification Results

8.3.3.1 Synchronous Generator

The stress states in each load direction were combined by taking the SRSS in order to generate a total stress state for seismic conditions. The resulting stresses were used as input for total stress evaluation shown in Table 8.3-11. Table 8.3-12 shows the comparison of operating load stresses against allowable stresses for both the normal and maximum shear directions. The stress results for the operating loads and the seismic loads were combined by algebraic addition. Table 8.3-13 shows the comparison of operating load stresses combined with seismic stresses against the operating-plus-seismic allowable stresses.

Table 8.3-14 shows the qualification of all bolts in the synchronous generator for operating-plus-seismic-plus-short circuit torque loads.

The SRSS of the maximum displacement in all three orthogonal directions was computed for the three input response spectrum analyses. For the Generator fan, the vector sum of the total maximum displacement in all three orthogonal directions was conservatively taken as the same as the Generator salient poles/main field. The vector sum of the total maximum displacement in all three orthogonal directions due to the short circuit torque load was algebraically summed with the input response spectrum run displacements. The results were compared with acceptable mechanical interference and air gap criteria and are as shown in Table 8.3-15.

In conclusion, the maximum operating, as well as the maximum operating-plus-input response spectrum seismic normal and shear stresses for the synchronous generator meet the stress allowables. Hence, it can be concluded that the synchronous generator of the Gas Turbine Generator system meets the specified acceptance criteria for nuclear applications. The blades behind both the RENK bearings do not contact the shroud during the RRS loading provided. There is no mechanical interference that will occur in the main field region, exciter air gap and the PMG air gap. All bolts in the synchronous generator (generator frame and RENK bearing frame) satisfy the operating-plus-seismic-plus-short circuit torque load criteria.

8.3.3.2 Air Start Receiver Assembly

The comparison of the stresses for Level A is shown in Table 8.3-16. The comparison of the stresses for Level B (SSE) is shown in Table 8.3-17. As shown in the tables, all the stresses meet the allowable values. Table 8.3-18 and Table 8.3-19 give the nozzle capacity loads. The minimum thickness requirements and nozzle reinforcement requirements are all satisfied. Table 8.3-20 and Table 8.3-21 show the bolt stress. All requirements for the bolts are met.

For buckling of plate-and-shell-type supports, the nominal stresses in the support skirt away from discontinuities (which include peak stresses at or near the vessel welds) are less than approximately 3 ksi, which is below the allowable buckling stress of ½*Sy = 12.5 ksi. Therefore, the support skirt meets the buckling criteria.

8.3.3.3 Fuel Oil Day Tank Assembly and Stand

The comparison of the stresses for Level A is shown in Table 8.3-22. Similarly, Table 8.3-23 contains the comparison of the Level B (SSE) stresses. Table 8.3-24 and Table 8.3-26 contain the results for the bolts for Service Level A without and with the nozzle capacity loads, respectively. Table 8.3-25 and Table 8.3-27 contain the results for the bolts for Service Level B

without and with the nozzle capacity loads, respectively. As shown in the tables, all the bolts meet the criteria. Table 8.3-28 and Table 8.3-29 give the nozzle capacity loads. The minimum thickness requirements and nozzle reinforcement requirements are all satisfied. For the load combinations, the Fuel Oil Day Tank Assembly and Stand meets the ASME requirements.

8.3.3.4 Air Start Manifold Skid

The comparison of the stresses for Level A is shown in Table 8.3-30 and Table 8.3-31. The comparison of the stresses for Level B (SSE) is shown in Table 8.3-32 and Table 8.3-33. For the buckling evaluation, the 3x3 box beams are the primary vertical supports. For Service Level A loading, the maximum membrane-plus-bending stress intensity is 1.227 ksi which is below the buckling limit 23.4 ksi. For Service Level B loading, the maximum membrane-plus-bending principle stress is 8.909 ksi which is below the buckling limit of 23.4 ksi. Therefore, the buckling criterion is met.

For the load combinations, the Air Start Manifold Skid meets the ASME requirements.

8.3.3.5 Air Start Manifold Piping

For the air start manifold piping, stress results for the applicable ASME Code equation described in Subsection 8.3.2.2.5 are shown in Table 8.3-34. Pipe support reaction results for these same piping sets are also shown in Table 8.3-35.

All the ASME Code allowable stresses are met for Equations 8 and 11 of ND-3650 (Reference 10-8).

Table 8.3-11 Resultant Input Response Spectrum Seismic Stress Results for the Synchronous Generator

Component	Calculated Input Response Spectrum Seismic Stress Components						Resultant Input Response Spectrum Seismic Stresses			
	X	X	Y	Y	Z	Z				
	Normal Stress (psi)	Shear Stress (psi)	Normal Stress (psi)	Shear Stress (psi)	Normal Stress (psi)	Shear Stress (psi)	SRSS Normal (psi)	Average or Peak	SRSS Shear (psi)	Average or Peak
GTG (Excluding Exciter Frame and RENK Bearing Frame)	2261.00	707.73	3142.00	373.25	5112.00	1679.00	6412.24	Peak	1859.9	Peak
Exciter Frame and RENK Bearing Frame (Grey Cast Iron ASTM A48)	635.20	107.68	534.36	169.67	1665.00	602.16	1860.44	Peak	634.8	Peak

Table 8.3-12 Operating Stress Evaluation and Comparison with AISC Stress Criteria for the Synchronous Generator

Component	Operating Stress Evaluation				Allowable Operating Stress		Margin Normal (%) [1-(Calculated / Allowable)]*100%	Margin Shear (%) [1-(Calculated / Allowable)]*100%	Stress Check
	Normal Stress (psi)	Average or Peak	Shear Stress (psi)	Average or Peak	Normal Allowable (psi)	Shear Allowable (psi)			Pass (Y/N)
GTG (Excluding Exciter Frame and RENK Bearing Frame)[1]	5472.20	Peak	652.41	Peak	24000	16000	77.20	95.92	Y
Exciter Frame and RENK Bearing Frame (Grey Cast Iron ASTM A48)[1]	942.15	Peak	302.89	Peak	3000	1732	68.60	82.51	Y

Note:

1. The GTG (excluding Exciter Frame and RENK Bearing Frame) and Exciter Frame and RENK Bearing Frame (Grey Cast Iron ASTM A48) ultimate tensile strength and yield strength are obtained as described in Appendix O. The operating allowable stress criteria in tension and shear are derived in Appendix O.

Table 8.3-13 Combined Operating and Input Response Spectrum Seismic Stress Evaluation and Comparison with AISC Stress Criteria for the Synchronous Generator

Component	Combined Operating and Seismic Stress Evaluation						
	Combined Operating and Seismic Stresses		Operating and Seismic Stress Allowable		Margin Normal (%) [1-(Calculated / Allowable)]*100%	Margin Shear (%) [1-(Calculated / Allowable)]*100%	Stress Check
	Combined Normal Stress	Combined Shear Stress	Normal	Shear			Pass (Y/N)
	(psi)	(psi)	(psi)	(psi)			
GTG (Excluding Exciter Frame and RENK Bearing Frame)[1]	11884.44	2512.31	38400	22400	69.05	88.78	Y
Exciter Frame and RENK Bearing Frame (Grey Cast Iron ASTM A48)[1]	2802.59	937.69	4800	2425	41.61	61.33	Y

Note:

1. The Gas Turbine Generator (Excluding Exciter Frame and RENK Bearing Frame) and Exciter Frame and RENK Bearing Frame (Grey Cast Iron ASTM A48) ultimate tensile strength and yield strength are obtained as described in Appendix O. The allowable operating-plus-seismic stress criteria in tension and shear are derived after taking guidance from Appendix O.

Table 8.3-14 Bolt Stress Qualification for the Synchronous Generator – Operating, Short Circuit Torque and Seismic Loads

Component[1]	Reaction Force SRSS (lbf)			SRSS Shear	SRSS Tension	SRSS Shear per Bolt	SRSS Tension per Bolt	Computed Shear Stress	Computed Tensile Stress	Margin Shear Service Level B %	Margin Tensile Service Level B %	Stress Check
	Fx	Fy	Fz	(lbf)	(lbf)	(lbf)	(lbf)	(psi)	(psi)	[1-(Calculated / Allowable)]*100%	[1-(Calculated / Allowable)]*100%	Pass (Y/N)
Deadweight												
Generator Mounting Bolts	12.10	32431.00	187.80	188.19	32431.00	47.05	8107.75	38.34	6606.79	N/A	N/A	N/A
Spectrum Acceleration Loads												
Generator Mounting Bolts	17723.22	19044.38	8070.94	19474.41	19044.38	4868.60	4761.10	3967.29	3879.69	N/A	N/A	N/A
Short Circuit Torque Load												
Generator Mounting Bolts	1090.10	13620.00	1027.20	1497.82	13620.00	1497.82	13620.00	1220.53	11098.57	N/A	N/A	N/A
Deadweight + Spectrum Acceleration + Short Circuit Torque Loads												
Generator Mounting Bolts	N/A	N/A	N/A	N/A	N/A	6413.47	26488.85	5226.16	21585.05	80.64	52.03	**Y**
Deadweight												
RENK Bearing Mounting Bolts	10.85	8912.50	4440.50	8912.51	4440.50	1782.50	888.10	5810.05	2894.76	N/A	N/A	N/A
Spectrum Acceleration Loads												
RENK Bearing Mounting Bolts	5089.90	5326.62	3846.61	7367.49	3846.61	1473.50	769.32	4802.86	2507.60	N/A	N/A	N/A
Short Circuit Torque Load												
RENK Bearing Mounting Bolts	16271.96	16271.96	20313.86	23012.03	20313.86	4602.41	4062.77	15001.51	13242.58	N/A	N/A	N/A
Deadweight + Spectrum Acceleration + Short Circuit Torque Loads												
RENK Bearing Mounting Bolts	N/A	N/A	N/A	N/A	N/A	7858.41	5720.19	25614.42	18644.93	5.13	58.57	**Y**

Note:

1. Per Appendix O, the minimum allowable strengths in tension and shear for all bolts are conservatively set at 45,000 psi and 27,000 psi, respectively.

Table 8.3-15 Mechanical Interferences and Air Gap Criteria Comparison for the Synchronous Generator

Component	Allowable Air Gap (inches)	Total Displacement FEA (inches)[1]	Acceptance Criteria
Generator Main Field	0.295	0.094	PASS
Generator Exciter	0.040	0.026	PASS
Generator PMG	0.035	0.026	PASS
Generator Fans[2]	0.250	0.015	PASS

Notes:

1. The SRSS of the maximum displacement in all three orthogonal directions is computed for the three input response spectrum analyses.
2. The Generator fan displacements are obtained from the analysis performed in Appendix O.

Table 8.3-16 ASME Code, Stress Results of the Air Start Receiver Assembly for Service Level A

Location	Stress Category	Criteria	Allowable Stress (ksi)	Stress (ksi)	Pass/Fail
Top Vent Nozzle, Path 1	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	22.43	Pass
Top Vent Nozzle, Path 2	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	22.66	Pass
Top Vent Nozzle, Path 3	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	17.30	Pass
Drain Nozzle, Path 4	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	23.48	Pass
Drain Nozzle, Path 5	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	24.21	Pass
Drain Nozzle, Path 6	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	18.49	Pass
Vessel Shell, Path 33	σ_m	1.0S	16.70	14.42	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	16.76	Pass
Vessel Shell, Path 34	σ_m	1.0S	16.70	7.54	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	17.21	Pass
Vessel Shell, Path 35	σ_m	1.0S	16.70	15.20	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	15.87	Pass
Through Vessel/Skirt Weld, Path 36	σ_m	1.0S	16.70	7.13	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	19.05	Pass
Through Vessel/Skirt Weld, Path 37	σ_m	1.0S	16.70	7.88	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	17.28	Pass
Vessel Shell, Path 38	σ_m	1.0S	16.70	8.98	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	16.20	Pass
Vessel Shell, Path 39	σ_m	1.0S	16.70	15.53	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	17.69	Pass
Manway Plate (center), Path 40	σ_m	1.0S	16.70	0.11	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	11.39	Pass
Drain Pipe, Path 41	σ_m	1.5S	25.05	9.65	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	11.92	Pass
Top Vent Pipe, Path 42	σ_m	1.5S	25.05	2.28	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	2.50	Pass
N2/N3 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.29	Pass
	Shear, σ_L	0.60 x 1.5S	15.03	3.14	Pass
N2/N3 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.21	Pass
	Tension, σ_L	0.74 x 1.5S	18.54	11.24	Pass
N2/N3 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	0.49 x 1.5S	12.27	9.77	Pass
N1 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.13	Pass
	Shear, σ_L	0.60 x 1.5S	15.03	0.84	Pass
N1 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.05	Pass
	Tension, σ_L	0.74 x 1.5S	18.54	10.53	Pass
N1 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	0.49 x 1.5S	12.27	10.01	Pass
N5/N6 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.15	Pass
	Shear, σ_L	0.60 x 1.5S	15.03	0.40	Pass
N5/N6 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.07	Pass
	Tension, σ_L	0.74 x 1.5S	18.54	14.88	Pass
N5/N6 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	0.49 x 1.5S	12.27	8.32	Pass
N7 Manway Outside Fillet Weld	Shear, σ_L	0.49 x 1.5S	12.27	9.47	Pass
N7 Manway Inside Fillet Weld	Shear, σ_L	0.49 x 1.5S	12.27	0.78	Pass
Vessel Mounting Plate (side 1)	Shear	0.55 x S	9.19	5.23	Pass
Vessel Mounting Plate (side 2)	Shear	0.55 x S	9.19	5.80	Pass
Skirt Mounting Plate (side 1)	Shear	0.55 x S	9.19	1.92	Pass
Skirt Mounting Plate (side 2)	Shear	0.55 x S	9.19	1.92	Pass
Manway Bolts	Tension	Su/2	62.50	10.34	Pass
	Shear	0.62 x Su/3	25.83	10.34	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.188	Pass
	Bearing	L/2d	<= 1.5	0.542	Pass
Anchor Bolts	Tension	Su/2	62.50	0.698	Pass
	Shear	0.62 x Su/3	25.83	0.002	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.00	Pass
	Bearing	L/2d	<= 1.5	0.571	Pass
Drain Valve U-Bolt	Tension	Su/2	62.50	0.127	Pass
Support Skirt, Foot, Gussets	σ_m	1.0S	16.70	14.73	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	25.05	14.73	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1/2Sy	12.5	3	Pass
Support skirt welds	Shear	0.30Su	18.4	14.73	Pass

Table 8.3-17 ASME Code, Stress Results of the Air Start Receiver Assembly for Service Level B

Location	Stress Category	Criteria	Allowable Stress (ksi)	Stress (ksi)	Pass/Fail
Top Vent Nozzle, Path 1	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	23.13	Pass
Top Vent Nozzle, Path 2	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	24.32	Pass
Top Vent Nozzle, Path 3	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	18.97	Pass
Drain Nozzle, Path 4	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	23.49	Pass
Drain Nozzle, Path 5	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	24.23	Pass
Drain Nozzle, Path 6	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	18.50	Pass
Vessel Shell, Path 33	σ_m	1.1S	18.37	14.45	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	16.76	Pass
Vessel Shell, Path 34	σ_m	1.1S	18.37	7.55	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	17.22	Pass
Vessel Shell, Path 35	σ_m	1.1S	18.37	15.20	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	15.87	Pass
Through Vessel/Skirt Weld, Path 36	σ_m	1.1S	18.37	7.20	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	19.05	Pass
Through Vessel/Skirt Weld, Path 37	σ_m	1.1S	18.37	7.88	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	17.28	Pass
Vessel Shell, Path 38	σ_m	1.1S	18.37	8.99	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	16.20	Pass
Vessel Shell, Path 39	σ_m	1.1S	18.37	15.53	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	17.70	Pass
Manway Plate (center), Path 40	σ_m	1.1S	18.37	0.11	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	27.56	11.39	Pass
Drain Pipe, Path 41	σ_m	1.8Sh	30.06	9.66	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.8Sh	30.06	11.92	Pass
Top Vent Pipe, Path 42	σ_m	1.8Sh	30.06	6.82	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.8Sh	30.06	9.11	Pass
N2/N3 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.29	Pass
	Shear, σ_L	1.1 x 0.60 x 1.5S	16.53	3.19	Pass
N2/N3 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.21	Pass
	Tension, σ_L	1.1 x 0.74 x 1.5S	20.39	11.29	Pass
N2/N3 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	1.1 x 0.49 x 1.5S	13.50	9.82	Pass
N1 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.13	Pass
	Shear, σ_L	1.1 x 0.60 x 1.5S	16.53	0.89	Pass
N1 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.05	Pass
	Tension, σ_L	1.1 x 0.74 x 1.5S	20.39	10.58	Pass
N1 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	1.1 x 0.49 x 1.5S	13.50	10.06	Pass
N5/N6 nozzle Outside Bevel/Groove Weld	Shear, σ_m	0.60 x 1.0S	10.02	0.15	Pass
	Shear, σ_L	1.1 x 0.60 x 1.5S	16.53	0.46	Pass
N5/N6 nozzle Outside Bevel/Groove Weld	Tension, σ_m	0.74 x 1.0S	12.36	8.07	Pass
	Tension, σ_L	1.1 x 0.74 x 1.5S	20.39	14.96	Pass
N5/N6 nozzle Inside Fillet Weld	Shear, σ_m	0.49 x 1.0S	8.18	7.92	Pass
	Shear, σ_L	1.1 x 0.49 x 1.5S	13.50	8.39	Pass
N7 Manway Outside Fillet Weld	Shear, σ_L	1.1 x 0.49 x 1.5S	13.50	9.50	Pass
N7 Manway Inside Fillet Weld	Shear, σ_L	1.1 x 0.49 x 1.5S	13.50	0.83	Pass
Vessel Mounting Plate (side 1)	Shear	1.1 x 0.55 x S	10.10	5.32	Pass
Vessel Mounting Plate (side 2)	Shear	1.1 x 0.55 x S	10.10	5.89	Pass
Skirt Mounting Plate (side 1)	Shear	1.1 x 0.55 x S	10.10	2.15	Pass
Skirt Mounting Plate (side 2)	Shear	1.1 x 0.55 x S	10.10	2.13	Pass
Manway Bolts	Tension	1.15 x Su/2	71.88	10.45	Pass
	Shear	1.15 x 0.62 x Su/3	29.71	10.45	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.145	Pass
	Bearing	L/2d	<= 1.5	0.542	Pass
Anchor Bolts	Tension	1.15 x Su/2	71.88	2.404	Pass
	Shear	1.15 x 0.62 x Su/3	29.71	1.023	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.002	Pass
	Bearing	L/2d	<= 1.5	0.571	Pass
Drain Valve U-Bolt	Tension	1.15 x Su/2	71.88	0.079	Pass
Support Skirt, Foot, Gussets	σ_m	1.33 x 1.0S	22.21	14.96	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.33 x 1.5S	33.32	14.96	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1/2Sy	12.5	3	Pass
Support skirt welds	Shear	0.30Su	18.4	14.96	Pass

Table 8.3-18 Nozzle Capacity Loads of the Air Start Receiver Assembly for Service Level A

Allowable nozzle loads (Service Level A)						
Nozzle	**F1, Axial (lbs)**	**F2, shear (lbs)**	**F3, shear (lbs)**	**M1, bending (in-lbs)**	**M2, bending (in-lbs)**	**M3, torsion (in-lbs)**
Top Vent Nozzle	270.1	67.5	67.5	2329.2	2329.2	2329.2
Top Vent Pipe	1489.6	372.4	372.4	12848.1	12848.1	12848.1
Drain Nozzle	219.3	54.8	54.8	690.9	690.9	690.9
N2/N3 nozzle	415.5	103.9	103.9	3583.5	3583.5	3583.5
N1 nozzle	87.8	21.9	21.9	346.3	346.3	346.3
N5/N6 nozzle	79.9	20.0	20.0	315.2	315.2	315.2

Table 8.3-19 Nozzle Capacity Loads of the Air Start Receiver Assembly for Service Level B

Allowable nozzle loads (Service Level B)						
Nozzle	**F1, Axial (lbs)**	**F2, shear (lbs)**	**F3, shear (lbs)**	**M1, bending (in-lbs)**	**M2, bending (in-lbs)**	**M3, torsion (in-lbs)**
Top Vent Nozzle	365.5	91.4	91.4	3152.8	3152.8	3152.8
Top Vent Pipe	1384.1	346.0	346.0	11937.7	11937.7	11937.7
Drain Nozzle	868.1	217.0	217.0	2734.7	2734.7	2734.7
N2/N3 nozzle	609.2	152.3	152.3	5254.6	5254.6	5254.6
N1 nozzle	133.0	33.2	33.2	524.7	524.7	524.7
N5/N6 nozzle	111.7	27.9	27.9	440.5	440.5	440.5

Table 8.3-20 Bolts Results of the Air Start Receiver Assembly, Including Nozzle Capacity Loads, for Service Level A

Location	Stress Category	Criteria	Allowable Stress (ksi)	Stress (ksi)	Pass/Fail
Manway Bolts	Tension	Su/2	62.50	11.48	Pass
	Shear	0.62 x Su/3	25.83	11.48	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.231	Pass
	Bearing	L/2d	<= 1.5	0.542	Pass
Anchor Bolts	Tension	Su/2	62.50	2.903	Pass
	Shear	0.62 x Su/3	25.83	1.511	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.006	Pass
	Bearing	L/2d	<= 1.5	0.571	Pass

Table 8.3-21 Bolts Results of the Air Start Receiver Assembly, Including Nozzle Capacity Loads, for Service Level B

Location	Stress Category	Criteria	Allowable Stress (ksi)	Stress (ksi)	Pass/Fail
Manway Bolts	Tension	1.15 x Su/2	71.88	11.58	Pass
	Shear	1.15 x 0.62 x Su/3	29.71	11.58	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.178	Pass
	Bearing	L/2d	<= 1.5	0.542	Pass
Anchor Bolts	Tension	1.15 x Su/2	71.88	6.314	Pass
	Shear	1.15 x 0.62 x Su/3	29.71	3.554	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.022	Pass
	Bearing	L/2d	<= 1.5	0.571	Pass

Table 8.3-22 ASME Code, Stress Results of Tank of the Fuel Oil Day Tank Assembly and Stand for Service Level A

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/ Fail
Tank Shell	σ_m	1.0S	20.00	9.47	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	30.00	9.47	Pass
Saddle Support	σ_m	1.0S	20.00	13.89	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	30.00	13.89	Pass
	σ_L	1/2*Sy	19.00	13.89	Pass
Saddle Support Plate Welds	Shear	0.30Su	21.00	13.89	Pass
Frame Support	σ_m	1.0S	16.60	4.33	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.5S	24.90	4.33	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	2/3*Sy	24.00	4.33	Pass
Frame Support Welds	Shear	0.30Su	17.40	4.33	Pass
Frame Support Gussets	$\sigma_L+\sigma_b$	1.0S	20.00	1.95	Pass
Engine Supply Assembly Piping	σ_m	1.5Sh	25.65	2.28	Pass
	$\sigma_L+\sigma_b$	1.5Sh	25.65	2.28	Pass
Fuel Supply Assembly Piping	σ_m	1.5Sh	25.65	5.75	Pass
	$\sigma_L+\sigma_b$	1.5Sh	25.65	5.75	Pass
Storage Return + Tank Drain Assemblies Piping	σ_m	1.5Sh	25.65	8.78	Pass
	$\sigma_L+\sigma_b$	1.5Sh	25.65	8.78	Pass
Remaining Piping, Nozzles, and Outlets	σ_m	1.5Sh	25.65	3.12	Pass
	$\sigma_L+\sigma_b$	1.5Sh	25.65	3.12	Pass
U-Bolts	Tension	Su/2	62.50	0.30	Pass
Electrical Box Mounting Plate Bolt	Tension	Su/2	62.50	0.00	Pass
	Shear	0.62Su/3	25.83	0.01	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0000	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Front Wrapper Plate Fillet Weld	Shear	0.55S	11.00	0.98	Pass
Rear Wrapper Plate Fillet Weld	Shear	0.55S	11.00	0.98	Pass
Tank Drain Nozzle Full Penetration Welds	Shear & Tension	1.0S	20.00	3.10	Pass
Front Heater Nozzle Fillet Welds	Shear	0.49S	9.80	1.83	Pass
Engine Supply Nozzle Full Penetration Welds	Shear & Tension	1.0S	20.00	0.98	Pass
Rear Heater Nozzle Fillet Welds	Shear	0.49S	9.80	1.83	Pass
Storage Return Nozzle Full Penetration Welds	Shear & Tension	1.0S	20.00	0.92	Pass
Fuel Supply Nozzle Full Penetration Welds	Shear & Tension	1.0S	20.00	1.18	Pass
Temperature Switch #1 Nozzle Fillet Welds	Shear	0.49S	9.80	2.24	Pass
Temperature Switch #2 Nozzle Fillet Welds	Shear	0.49S	9.80	2.25	Pass
Plugged Half Coupling #1 Fillet Welds	Shear	0.49S	9.80	2.26	Pass
Plugged Half Coupling #2 Fillet Welds	Shear	0.49S	9.80	2.25	Pass
Level Sensor Nozzle Fillet Welds	Shear	0.49S	9.80	1.81	Pass
Float Switch #1 Nozzle Fillet Welds	Shear	0.49S	9.80	1.80	Pass
Float Switch #2 Nozzle Fillet Welds	Shear	0.49S	9.80	1.80	Pass
Plugged Top Nozzle #1 Fillet Welds	Shear	0.49S	9.80	2.03	Pass
Plugged Top Nozzle #2 Fillet Welds	Shear	0.49S	9.80	2.02	Pass
Top Studding Outlet Fillet Welds	Shear	0.49S	9.80	1.43	Pass
45° Studding Outlet Fillet Welds	Shear	0.49S	9.80	0.77	Pass

Table 8.3-23 ASME Code, Stress Results for Tank of the Fuel Oil Day Tank Assembly and Stand for Service Level B

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/ Fail
Tank Shell	σ_m	1.1S	22.00	8.84	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.65S	33.00	29.96	Pass
Saddle Support	σ_m	1.33*1.0S	26.60	12.34	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.33*1.5S	39.90	35.08	Pass
	σ_L	1/2*Sy	19.00	12.34	Pass
Saddle Support Plate Welds	Shear	0.30Su	21.00	12.34	Pass
Frame Support	σ_m	1.33*1.0S	22.08	10.31	Pass
	$(\sigma_m$ or $\sigma_L)+\sigma_b$	1.33*1.5S	33.12	17.55	Pass
	σ_L	2/3*Sy	24.00	10.31	Pass
Frame Support Welds	Shear	0.30Su	17.40	10.31	Pass
Frame Support Gussets	$\sigma_L+\sigma_b$	1.1S	22.00	11.68	Pass
Engine Supply Assembly Piping	σ_m	1.8Sh	30.78	11.07	Pass
	$\sigma_L+\sigma_b$	1.8Sh	30.78	11.07	Pass
Fuel Supply Assembly Piping	σ_m	1.8Sh	30.78	18.69	Pass
	$\sigma_L+\sigma_b$	1.8Sh	30.78	29.74	Pass
Storage Return + Tank Drain Assemblies Piping	σ_m	1.8Sh	30.78	19.54	Pass
	$\sigma_L+\sigma_b$	1.8Sh	30.78	30.32	Pass
Remaining Piping, Nozzles, and Outlets	σ_m	1.8Sh	30.78	4.46	Pass
	$\sigma_L+\sigma_b$	1.8Sh	30.78	4.46	Pass
U-Bolts	Tension	1.15*Su/2	71.88	2.25	Pass
Electrical Box Mounting Plate Bolt	Tension	1.15*Su/2	71.88	0.33	Pass
	Shear	1.15*0.62Su/3	29.71	1.03	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0012	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Front Wrapper Plate Fillet Weld	Shear	1.1*0.55S	12.10	3.53	Pass
Rear Wrapper Plate Fillet Weld	Shear	1.1*0.55S	12.10	3.53	Pass
Tank Drain Nozzle Full Penetration Welds	Shear & Tension	1.1S	22.00	10.85	Pass
Front Heater Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.63	Pass
Engine Supply Nozzle Full Penetration Welds	Shear & Tension	1.1S	22.00	3.18	Pass
Rear Heater Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.64	Pass
Storage Return Nozzle Full Penetration Welds	Shear & Tension	1.1S	22.00	3.20	Pass
Fuel Supply Nozzle Full Penetration Welds	Shear & Tension	1.1S	22.00	7.26	Pass
Temperature Switch #1 Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.53	Pass
Temperature Switch #2 Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.54	Pass
Plugged Half Coupling #1 Fillet Welds	Shear	1.1*0.49S	10.78	2.55	Pass
Plugged Half Coupling #2 Fillet Welds	Shear	1.1*0.49S	10.78	2.54	Pass
Level Sensor Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.27	Pass
Float Switch #1 Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.12	Pass
Float Switch #2 Nozzle Fillet Welds	Shear	1.1*0.49S	10.78	2.28	Pass
Plugged Top Nozzle #1 Fillet Welds	Shear	1.1*0.49S	10.78	2.93	Pass
Plugged Top Nozzle #2 Fillet Welds	Shear	1.1*0.49S	10.78	2.99	Pass
Top Studding Outlet Fillet Welds	Shear	1.1*0.49S	10.78	1.90	Pass
45° Studding Outlet Fillet Welds	Shear	1.1*0.49S	10.78	1.30	Pass

Table 8.3-24 ASME Code, Stress Results for Bolts of the Tank of Fuel Oil Day Tank Assembly and Stand, Excluding Nozzle Loads, for Service Level A

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/Fail
Frame Left Base Plate Anchor Bolt	Tension	Su/2	62.50	0.99	Pass
	Shear	0.62Su/3	25.83	0.04	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0003	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Frame Right Base Plate Anchor Bolt	Tension	Su/2	62.50	0.96	Pass
	Shear	0.62Su/3	25.83	0.04	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0002	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Front Saddle Leg Bolt	Tension	Su/2	62.50	2.15	Pass
	Shear	0.62Su/3	25.83	5.53	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0470	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Rear Saddle Leg Bolt	Tension	Su/2	62.50	2.11	Pass
	Shear	0.62Su/3	25.83	5.61	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0483	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass

Table 8.3-25 ASME Code, Stress Results for Bolts of the Tank of Fuel Oil Day Tank Assembly and Stand, Excluding Nozzle Loads, for Service Level B

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/Fail
Frame Left Base Plate Anchor Bolt	Tension	1.15*Su/2	71.88	4.35	Pass
	Shear	1.15*0.62Su/3	29.71	3.00	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0138	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Frame Right Base Plate Anchor Bolt	Tension	1.15*Su/2	71.88	4.10	Pass
	Shear	1.15*0.62Su/3	29.71	2.71	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0116	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Front Saddle Leg Bolt	Tension	1.15*Su/2	71.88	7.56	Pass
	Shear	1.15*0.62Su/3	29.71	16.60	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.3234	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Rear Saddle Leg Bolt	Tension	1.15*Su/2	71.88	7.61	Pass
	Shear	1.15*0.62Su/3	29.71	16.86	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.3331	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass

Table 8.3-26 ASME Code, Stress Results for Bolts of the Tank of Fuel Oil Day Tank Assembly and Stand, Including Nozzle Loads, for Service Level A

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/Fail
Frame Left Base Plate Anchor Bolt	Tension	Su/2	62.50	1.80	Pass
	Shear	0.62Su/3	25.83	0.85	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0019	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Frame Right Base Plate Anchor Bolt	Tension	Su/2	62.50	1.78	Pass
	Shear	0.62Su/3	25.83	0.85	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0019	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Front Saddle Leg Bolt	Tension	Su/2	62.50	7.24	Pass
	Shear	0.62Su/3	25.83	10.62	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.1824	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Rear Saddle Leg Bolt	Tension	Su/2	62.50	7.20	Pass
	Shear	0.62Su/3	25.83	10.71	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.1850	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass

Table 8.3-27 ASME Code, Stress Results for Bolts of the Tank of Fuel Oil Day Tank Assembly and Stand, Including Nozzle Loads, for Service Level B

Component	Stress Category	Criteria	Allowable Stress (ksi)	FEA Stress (ksi)	Pass/Fail
Frame Left Base Plate Anchor Bolt	Tension	Su/2	62.50	5.17	Pass
	Shear	0.62Su/3	25.83	3.81	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0286	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Frame Right Base Plate Anchor Bolt	Tension	Su/2	62.50	4.91	Pass
	Shear	0.62Su/3	25.83	3.52	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.0248	Pass
	Bearing	L/2d	<= 1.5	0.95	Pass
Front Saddle Leg Bolt	Tension	Su/2	62.50	12.65	Pass
	Shear	0.62Su/3	25.83	21.70	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.7463	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass
Rear Saddle Leg Bolt	Tension	Su/2	62.50	12.70	Pass
	Shear	0.62Su/3	25.83	21.95	Pass
	Combined	$f_t^2/F_{tb}^2+f_y^2/F_{yb}^2$	<= 1.0	0.7632	Pass
	Bearing	L/2d	<= 1.5	0.75	Pass

Table 8.3-28 Nozzle Capacity Loads of the Tank of Fuel Oil Day Tank Assembly and Stand for Service Level A

Piping Assembly	Pipe Diameter (in)	FZ Axial (lbs)	FX Lateral (lbs)	FY Vertical (lbs)	MZ Torsion (in-lbs)	MX In-Plane Bending (in-lbs)	MY Out-of-Plane Bending (in-lbs)
Engine Supply	1.900	448.3	112.1	112.1	-638.8	-638.8	638.8
Fuel Supply	1.900	-151.1	37.8	37.8	215.3	215.3	-215.3
Storage Return	2.375	-240.2	60.1	60.1	427.9	427.9	-427.9

Notes:
1. The forces and moments are applied in global Cartesian coordinates: Z = Axial, X = Lateral, Y = Vertical.
2. Negative FZ indicates tension direction is in the -Z direction for the subject component.

Table 8.3-29 Nozzle Capacity Loads of the Tank of Fuel Oil Day Tank Assembly and Stand for Service Level B

Piping Assembly	Pipe Diameter (in)	FZ Axial (lbs)	FX Lateral (lbs)	FY Vertical (lbs)	MZ Torsion (in-lbs)	MX In-Plane Bending (in-lbs)	MY Out-of-Plane Bending (in-lbs)
Engine Supply	1.900	443.6	110.9	110.9	-632.2	-632.2	632.2
Fuel Supply	1.900	-118.3	29.6	29.6	168.6	168.6	-168.6
Storage Return	2.375	-236.8	59.2	59.2	421.8	421.8	-421.8

Notes:
1. The forces and moments are applied in global Cartesian coordinates: Z = Axial, X = Lateral, Y = Vertical.
2. Negative FZ indicates tension direction is in the -Z direction for the subject component.

Table 8.3-30 ASME Code Evaluation for Support Structure of the Air Start Manifold Skid for Service Level A

Component	Membrane Stress Check			Membrane + Bending Stress Check		
	Maximum σ_m, ksi	Allowable Stress, ksi	Pass/ Fail	Maximum $\sigma_m+\sigma_b$, ksi	Allowable Stress, ksi	Pass/ Fail
3x3 Box Beams	0.461	16.6	Pass	0.553	24.9	Pass
2x2 Box Beams	0.111	16.6	Pass	0.240	24.9	Pass
Main I-Beam	0.252	16.6	Pass	1.003	24.9	Pass
CSA I-Beam - Vertical	0.343	16.6	Pass	0.530	24.9	Pass
CSA I-Beam - Horizontal	0.263	16.6	Pass	0.389	24.9	Pass
Gusset Plates	0.556	16.6	Pass	0.570	24.9	Pass
APSA	0.401	16.7	Pass	1.614	25.1	Pass
Fork Pocket	0.121	16.6	Pass	0.132	24.9	Pass
Small Bore Support Plates	0.063	16.6	Pass	0.401	24.9	Pass
Small Bore Welds	0.175	16.6	Pass	0.175	24.9	Pass

Component	Weld Tensile Stress Check			Weld Shear Stress Check		
	Maximum σ_m, ksi	Stress Limit ksi	Pass/ Fail	Maximum σ_m, ksi	Stress Limit ksi	Pass/ Fail
3x3 Box Beams	0.461	22.6	Pass	0.461	14.0	Pass
2x2 Box Beams	0.111	22.6	Pass	0.111	14.0	Pass
Main I-Beam	0.252	22.6	Pass	0.252	14.0	Pass
CSA I-Beam - Vertical	0.343	22.6	Pass	0.343	14.0	Pass
CSA I-Beam - Horizontal	0.263	22.6	Pass	0.263	14.0	Pass
Gusset Plates	0.556	22.6	Pass	0.556	14.0	Pass
APSA	0.401	27.7	Pass	0.401	9.6	Pass
Fork Pocket	0.121	22.6	Pass	0.121	14.0	Pass
Small Bore Support Plates	0.063	22.6	Pass	0.063	14.0	Pass
Small Bore Welds	0.175	22.6	Pass	0.175	14.0	Pass

Note:

The tensile stress and the shear stress used for comparison to the Stress Limit are conservatively based on the factored 1st Principal membrane stress.

Table 8.3-31 ASME Code Evaluation for Bolted Joints of the Air Start Manifold Skid for Service Level A

Bolt	Total Load (kips)		Bolt Information			Shear Stress Check			Tensile Stress Check		
	Shear	Tensile	#	Diameter, in	Area, in^2	Stress, ksi	Allowable, ksi	Pass/Fail	Stress, ksi	Allowable, ksi	Pass/Fail
Anchor Bolts - Left Base	0.148	1.646	6	0.75	0.442	0.056	25.833	Pass	0.621	62.500	Pass
Anchor Bolts - Right Base	0.000	1.606	6	0.75	0.442	0.000	25.833	Pass	0.606	62.500	Pass
APSA Bolts - Left Side	0.044	0.118	4	0.50	0.196	0.056	21.700	Pass	0.150	52.500	Pass
APSA Bolts - Right Side	0.044	0.118	4	0.50	0.196	0.056	21.700	Pass	0.150	52.500	Pass

Bolts	Combined Tensile and Shear Stress Check							Bearing Stress Check				
	Shear	Allowable	Tensile	Allowable	Total	Combined Allowable	Pass/ Fail	Bolt Diameter	Span Length	Check	Allowable	Pass/ Fail
	f_t, ksi	F_{tb}, ksi	f_v, ksi	F_{vb}, ksi				d, in	L, in	L/2d		
Anchor Bolts - Left Base	0.056	25.833	0.621	62.500	0.0001	1.0	Pass	0.75	0.82	0.308	1.5	Pass
Anchor Bolts - Right Base	0.000	25.833	0.606	62.500	0.0001	1.0	Pass	0.75	0.82	0.308	1.5	Pass
APSA Bolts - Left Side	0.056	21.700	0.150	52.500	0.0000	1.0	Pass	0.5	0.78	0.195	1.5	Pass
APSA Bolts - Right Side	0.056	21.700	0.150	52.500	0.0000	1.0	Pass	0.5	0.78	0.195	1.5	Pass

Table 8.3-32 ASME Code Evaluation for Support Structure of the Air Start Manifold Skid for Service Level B

Component	Membrane Stress Check			Membrane + Bending Stress Check		
	Maximum σ_m, ksi	Allowable Stress, ksi	Pass/ Fail	Maximum σ_m+σ_b, ksi	Allowable Stress, ksi	Pass/ Fail
3x3 Box Beams	2.439	22.078	Pass	4.281	33.117	Pass
2x2 Box Beams	1.710	22.078	Pass	3.401	33.117	Pass
Main I-Beam	1.713	22.078	Pass	13.331	33.117	Pass
CSA I-Beam - Vertical	7.523	22.078	Pass	20.958	33.117	Pass
CSA I-Beam - Horizontal	1.015	22.078	Pass	9.683	33.117	Pass
Gusset Plates	1.910	22.078	Pass	7.839	33.117	Pass
APSA	1.161	22.211	Pass	2.889	33.317	Pass
Fork Pocket	0.786	22.078	Pass	0.989	33.117	Pass
Small Bore Support Plates	0.120	22.078	Pass	0.675	33.117	Pass
Small Bore Welds	0.267	22.078	Pass	0.267	33.117	Pass

Component	Weld Tensile Stress Check			Weld Shear Stress Check		
	Maximum σ_m, ksi	Stress Limit ksi	Pass/ Fail	Maximum σ_m, ksi	Stress Limit ksi	Pass/ Fail
3x3 Box Beams	2.439	30.1	Pass	2.439	18.7	Pass
2x2 Box Beams	1.710	30.1	Pass	1.710	18.7	Pass
Main I-Beam	1.713	30.1	Pass	1.713	18.7	Pass
CSA I-Beam - Vertical	7.523	30.1	Pass	7.523	18.7	Pass
CSA I-Beam - Horizontal	1.015	30.1	Pass	1.015	18.7	Pass
Gusset Plates	1.910	30.1	Pass	1.910	18.7	Pass
APSA	1.161	36.8	Pass	1.161	12.8	Pass
Fork Pocket	0.786	30.1	Pass	0.786	18.7	Pass
Small Bore Support Plates	0.120	30.1	Pass	0.120	18.7	Pass
Small Bore Welds	0.267	30.1	Pass	0.267	18.7	Pass

Note:

The tensile stress and the shear stress used for comparison to the Stress Limit are conservatively based on the factored 1st Principal membrane stress.

Table 8.3-33 ASME Code Evaluation for Bolted Joints of the Air Start Manifold Skid for Service Level B

Bolt	Total Load (kips)		Bolt Information			Shear Stress Check			Tensile Stress Check		
	Shear	Tensile	#	Diameter, in	Area, in²	Stress, ksi	Allowable, ksi	Pass/Fail	Stress, ksi	Allowable, ksi	Pass/Fail
Anchor Bolts - Left Base	1.622	7.887	6	0.75	0.442	0.612	29.708	Pass	2.975	71.875	Pass
Anchor Bolts - Right Base	1.592	7.767	6	0.75	0.442	0.600	29.708	Pass	2.930	71.875	Pass
APSA Bolts - Left Side	0.294	0.514	4	0.50	0.196	0.374	24.955	Pass	0.654	60.375	Pass
APSA Bolts - Right Side	0.292	0.510	4	0.50	0.196	0.372	24.955	Pass	0.649	60.375	Pass

Bolts	Combined Tensile and Shear Stress Check							Bearing Stress Check				
	Shear	Allowable	Tensile	Allowable	Total	Combined Allowable	Pass/ Fail	Bolt Diameter	Span Length	Check	Allowable	Pass/ Fail
	f_t, ksi	F_{tb}, ksi	f_v, ksi	F_{vb}, ksi				d, in	L, in	L/2d		
Anchor Bolts - Left Base	0.612	29.708	2.975	71.875	0.002	1.0	Pass	0.75	0.82	0.308	1.5	Pass
Anchor Bolts - Right Base	0.600	29.708	2.930	71.875	0.002	1.0	Pass	0.75	0.82	0.308	1.5	Pass
APSA Bolts - Left Side	0.374	24.955	0.654	60.375	0.000	1.0	Pass	0.5	0.78	0.195	1.5	Pass
APSA Bolts - Right Side	0.372	24.955	0.649	60.375	0.000	1.0	Pass	0.5	0.78	0.195	1.5	Pass

Table 8.3-34 Code Equation Stress Results for the Air Start Manifold Piping

Case	Highest Stress, psi	Allowable Stress, psi	Node Point	Location
Design	3381	25,050	M10, B10	3 X 2 Reducer the 2 inch EZR Pressure Regulator Valve
Primary Upset	29,953	30,060	E02	Reducer at Connection of 3 X 3 X 1.25 Reducing Tee and ½ Inch Piping
Secondary (Thermal + SSE SAM) Eq. 11	14,054	41,750	W03	Tee on the 0.5 Inch line next to the Check Valves

Table 8.3-35 Pipe Support Reactions (Load Case 136) for the Air Start Manifold Piping

Node Point	F_x, lb.	F_y, lb.	F_z, lb.	M_x, ft.-lb.	M_y, ft.-lb.	M_z, ft.-lb.
Q18	198	577	894	1,146	16,402	1,083
F18	219	662	967	1,220	18,282	1,192
M01	140	179	-	-	-	-
M08	273	197	-	-	-	-
Q09	482	521	-	-	-	-
Q15	708	837	-	-	-	-
B01	149	188	-	-	-	-
B08	288	210	-	-	-	-
F09	534	454	-	-	-	-
F15	787	899	-	-	-	-
X24	13	36	-	-	-	-
X01	485	70	-	-	-	-
X13	277	404	-	-	-	-
X17	258	334	-	-	-	-
AA02	638	-	230	-	-	-

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 was successful in the initial type test and meets the requirements for Class 1E emergency power sources described in IEEE Std 387 (Reference 10-1) endorsed by RG 1.9 (Reference 10-2).

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 a GTG. The GTG is 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.

9.2 Conclusion of Seismic Qualification Result

The results provided in this Technical Report demonstrate that the gas turbine engine and relevant components were successfully qualified in the seismic tests or analyses and that they comply with the requirements of IEEE Std 344 (Reference 10-4).

10.0 REFERENCES

10-1 IEEE Std 387-1995, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations

10-2 Regulatory Guide 1.9 Rev. 4, Application and Testing of Safety-Related Diesel Generators in Nuclear Power Plants

10-3 DC/COL-ISG-021, Final Interim Staff Guidance: Review of Nuclear Power Plant Designs using a Gas Turbine Driven Standby Emergency Alternating Current Power System

10-4 IEEE-344-2004, IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

10-5 Regulatory Guide, 1.100, Rev. 3, Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants

10-6 IEEE Std 308-2001, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations

10-7 ASTM D396, Standard Specification for Fuel Oils

10-8 ASME Boiler & Pressure Vessel Code, Section III, 2001 Edition through the 2003 Addenda, Rules for Construction of Nuclear Facility Components

10-9 MUAP-07024-P, Qualification and Test Plan of Class 1E Gas Turbine Generator System

10-10 Regulatory Guide, 1.155, Rev. 0, Station Blackout

10-11 Design Control Document for the US-APWR Chapter 3, Design of Structures, Systems, Components and Equipment, MUAP-DC003, Revision 4, Mitsubishi Heavy Industries, Ltd., August 2013

10-12 Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant, MUAP-10006, Revision 1, January 2011.

10-13 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.

10-14 Soil-Structure Interaction Analyses and Results for the US-APWR Standard Plant, MUAP-10006, Revision 3, November, 2012.

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10-16 Earthquake Engineering Criteria for Nuclear Power Plants, NRC Regulations Title 10, Code of Federal Regulations, 10 CFR Part 50, Appendix S

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10-20 ANSYS Mechanical APDL and PrepPost, Release 12.1, ANSYS, Inc., September 2009.

10-21 ANSYS Workbench 2.0 Framework, Version: 12.1 x64, ANSYS, Inc., October 2009.

10-22 Regulatory Guide 1.92, Rev. 3, Combining Modal Responses and Spatial Components in Seismic Response Analysis

10-23 PQD-HD-19005, Revision 4, Quality Assurance Program(QAP) Description For Design Certification of the US-APWR