07/19/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 876-6210 REVISION 3**
SRP SECTION:	**08.03.01 - AC POWER SYSTEMS (ONSITE)**
APPLICATION SECTION:	**TIER 2, SECTION 08.03.-1**
DATE OF RAI ISSUE:	**12/15/2011**

QUESTION NO. : 08.03.01-43

In the response to RAI 818-5872, Question 08.03.01-42, the applicant provided the Qualification Testing Log for the Gas Turbine Generator (GTG) qualification. The log provided in the response indicated the performance of maintenance activities (Fuel Nozzle Cleaning) consisted of removing, cleaning and re-installing the fuel nozzle in each of the two combustion chambers. The applicant's response also stated the following: The maintenance activity is recommended by the gas turbine engine manufacturer as part of the routine maintenance. This maintenance interval is tied to the number of starts of the gas turbine and is recommended by the manufacturer that the fuel nozzles be cleaned every 50 starts. IEEE Standard 387-1995, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," as endorsed in Regulatory Guide 1.9, "Application and testing of Safety-Related Diesel generators in Nuclear Power Plants," states in its Section 6.2.2, "Start and load acceptance tests," Item e.2, the following:

> 2) Tests performed for verification of a scheduled maintenance procedure required during this series of tests. This maintenance procedure shall be defined prior to conducting the start and load acceptance tests and will then become a part of the normal maintenance schedule after installation.

IEEE Standard 387-1995, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," as endorsed in Regulatory Guide 1.9, "Application and testing of Safety-Related Diesel generators in Nuclear Power Plants," states in its Section 6.1, "General," the following:

> All qualification shall be performed in accordance with a written plan that defines analysis and tests to be performed, parameters to be monitored during tests, test instrumentation, and acceptance criteria for equipment.

a. Provide information to support that the scheduled maintenance activity conducted was part of the test procedures because this information was not provided in the submitted technical reports, MUAP-07024-P (R2), "Qualification and Test Plan of Class 1E Gas Turbine Generator System", MUAP-10023-P (R3), "Initial Type Test Result of Class 1E GTG System", and Technical Specifications.

b. Provide details related to the maintenance procedures defined prior to conducting the start and load acceptance tests, and document this maintenance activity in the US¬APWR DCD in all appropriate sections where GTG qualification is discussed, as well as in the Qualification Plan Technical Report, MUAP-07024-P (R2).

c. Add an ITAAC in the DCD, Tier 1, Table 2.6.4-1, “EPS Systems Inspections, Tests, Analyses, and Acceptance Criteria,” in order to verify the qualification of the GTGs.

d. Provide the detailed written plan that defines analysis and tests to be performed, parameters to be monitored during tests, test instrumentation, and acceptance criteria for equipment that was followed during the qualification testing of the GTGs.

ANSWER:

Part a.
Fuel nozzle cleaning was not discussed in the test plan report, MUAP-07024-P(R2) “Qualification and Test Plan of Class 1E Gas Turbine Generator System” however, the engine manufacturer’s procedures, which included fuel nozzle cleaning, existed prior to the test. An engine manufacturer’s representative was present to support the test and perform the manufacturer’s recommended maintenance and inspections. The fuel nozzle cleaning is discussed in MUAP-10023-P(R3) “Initial Type Test Result of Class 1E Gas Turbine Generator Systems,” Subsection 6.3.2 Item e. This maintenance activity is one of several recommended by the engine manufacturer. It was the only recommended maintenance item triggered during the series of tests. The intent is to prevent the buildup of gums and other insoluble materials, such as carbon within the fuel nozzle and the fuel nozzle tip; this buildup is commonly referred to as “fuel nozzle coking.” The general effect of severe coking is a reduction in ignition and operating performance over time.

Cleaning of the fuel nozzles installed on the gas turbine engine (Fig. 1) will be conducted in accordance with the engine manufacturer’s standard maintenance procedures which were reviewed and approved by MHI prior to cleaning. These procedures were not included in the test plan report, MUAP-07024-P(R2); however, the report will be revised to clarify the division of responsibility associated with the qualification testing. The responsibility for performing any manufacturer’s recommended maintenance is assigned to the engine manufacturer’s technical representative. Additionally, any required maintenance is to be performed in accordance with MHI approved procedures. The approved test procedure along with documentation that the maintenance was performed shall be included in a revision to the test results report, MUAP-10023-P(R4). A summary of the fuel nozzle cleaning procedure is provided below. This summary will also be included in the revision to the test plan report, MUAP-07024-P(R3).

(Interval)
Cleaning work shall be carried out after every 50 engine starts.
(The frequency of cleaning work may be determined and adjusted based upon the engine manufacturer’s recommendation.)

(Estimated time)
Work including preparation and clean up are estimated to take approximately two hours.

(Detail of Process)
1. Disconnect the two fuel lines and a cooling air flexible tube from the fuel nozzle. Remove the four bolts and the fuel nozzle from the engine.
2. Perform rough cleaning of any apparently dirty sections with waste cloth.
3. Soak fuel nozzle in a detergent solution for 0.5 ～1 hour.
4. Brush the end of the fuel nozzle with a soft brush.

5. Rinse the fuel nozzle with clean water, and wipe with soft waste cloth.
6. Reinstall the fuel nozzle on the engines with new gaskets and washers.
7. Reconnect the fuel lines and the air cooling tubes to the nozzles.
8. Start the engine and operate it for 2-3 minutes to check for fuel oil or lube oil leakage or abnormal noise.

MHI considered the need for a Technical Specification for fuel nozzle cleaning and has determined that such a specification is not appropriate because:

(i) Fuel nozzle cleaning, although performed during the GTG qualification testing, is not essential to the operability of the GTGs in the US-APWR application, as discussed in the response to Question 08.03.01-44.

(ii) Fuel nozzle cleaning is a preventative maintenance task. Preventive maintenance activities are not typically included in Technical Specification surveillances. As described in Section 2.3.2 and Table 2 of DC/COL-ISG-21, “Interim Staff Guidance on the Review of Nuclear Power Plant Designs Using a Gas Turbine Driven Standby Emergency Alternating Current Power System,” surveillance requirements for the GTG are not unique with respect to typical surveillances requirements performed for emergency diesel generators. The surveillance requirements recommended in ISG-21 are similar to those in the Standard Technical Specifications (STS) for emergency onsite power sources. Neither document includes preventive maintenance activities as specified surveillance requirements. Given that the fuel nozzle cleaning is not essential to GTG operability, there is no basis to alter the Technical Specification surveillance testing for GTGs from that described in these documents. The ongoing reliability of the Class 1E GTGs is assured through the performance of a set of preventive maintenance activities defined by the vendor including, but not limited to, fuel nozzle cleaning. Control of Input to the preventive maintenance program for the Class 1E GTGs is governed provided by the maintenance rule program, as specified in DC/COL-ISG-21 (e.g., Article 3, Modified SRP Section 8.3.1(I) - Section III, paragraphs 7 and 8), and in DCD Section 8.3.1.2 through commitments to Regulatory Guide 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.” This position is supported by NRC resolution to Generic Safety Issue B-56, “Diesel Generator Reliability,” where the NRC permitted licensees to remove reliability-related surveillance requirements (i.e., the accelerated testing requirements) from the emergency onsite power Technical Specifications and implement these tasks as part of the maintenance rule program (refer to NRC Generic Letter 94-01, “Removal of Accelerated Testing and Special Reporting Requirements for Emergency Diesel Generators” that implemented part of this resolution). The objective of the maintenance rule program is to require monitoring of the overall continuing effectiveness of licensee maintenance programs to ensure, in part, that safety-related SSCs are capable of performing their intended functions. The maintenance program will determine the appropriate frequency of preventive maintenance tasks including fuel nozzle cleaning, making adjustments as necessary (per RG 1.160) to ensure that target reliability values will be achieved. DCD Section 8.3.1.1.3.9 will be revised to address the Class 1E GTG preventive maintenance activities that will be established.

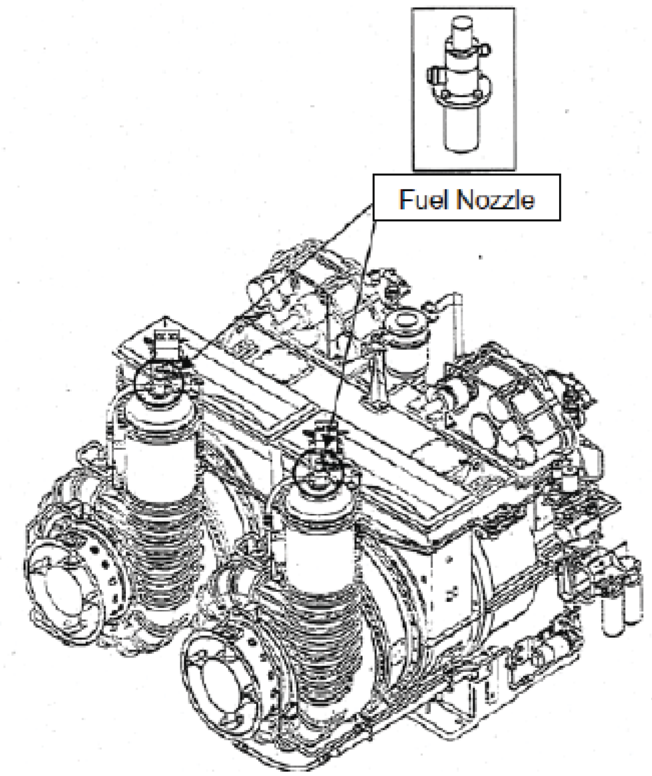

Fig.1 Appearance of fuel nozzle and its installation position

Part b.

The response to Part a. provides the detail of the maintenance procedure for fuel nozzle cleaning, which was defined prior to conducting the start and load acceptance test. A new Subsection 8.3.1.1.3.9 will be added to the DCD. This subsection will address the manufacturer's recommendations required to maintain Class 1E qualification and performance and specifically the requirement regarding fuel nozzle cleaning. Attachment 1 provides the changes to the DCD. A similar statement is included in MUAP-07024-P(R2). MUAP-10023(R3) Subsection 6.3.2 Item e discusses the fuel nozzle cleaning maintenance activity.

Part c.

Based upon information provided by the NRC staff subsequent to the 12/15/2011 meeting, an ITAAC is not required.

Part d.

The parameters to be monitored during testing, test instrumentation, and acceptance criteria for equipment are indicated in Tables 1 and 2. These also will be included in the revised MUAP-10023-P (R4) "Initial Type Test Result of Class 1E Gas Turbine Generator System."

Table 1 Parameters to be Monitored During Initial Type Test (1 of 2)

Table 1 Parameters to be Monitored During Initial Type Test (2 of 2)

Table 2 Parameters to be Monitored During Seismic Test

Impact on DCD

As described in Part b. of the response, DCD Subsection 8.3.1.1.3 will be revised as shown in Attachment 1.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on Technical / Topical Reports

As described in Part a. of the response, MUAP-07024-P (R2) Section 7.0 will be revised as shown in Attachment 2.

As described in Parts a. and d. of the response, MUAP-10023-P (R3) Appendices K and D, respectively, will be revised as shown in Attachment 3.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/19/2012

US-APWR Design Certification

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APPLICATION SECTION:	**TIER 2, SECTION 08.03.-1**
DATE OF RAI ISSUE:	**12/15/2011**

QUESTION NO. : 08.03.01-44

With regards to the maintenance activities outlined in the response to RAI 818-5872, Question 08.03.01-42, explain whether performing these activities was an essential factor for the GTG to successfully complete the qualification tests.

ANSWER:

Although the engine manufacturer recommended fuel nozzle cleaning after 50 engine starts based on their typical industrial experiences, this cleaning activity can not be defined as essential to the successful completion of the 150 start and load acceptance tests for the US-APWR application. This is because the quality of fuel for nuclear applications, such as the US-APWR, is better than the quality of other typical industrial applications which is the engine manufacturer's basis for their maintenance procedure. The impact of not cleaning the fuel nozzle, as with any turbine engine, is that gums and other insoluble materials, such as carbon may buildup and degrade performance over time. With high quality fuel, reduction in the performance rarely occurs before 150 starts, as the engine manufacturer stated. However, because it is the engine manufacturer's recommended maintenance item required during the series of tests, it was included in the planned test sequence. Documentation from the engine manufacturer is provided in Attachment 3, MUAP-1023-P(R4), Appendix K, Section K.3.0.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on Technical / Topical Reports

MUAP-10023-P (R3) Appendix K will be revised as shown in Attachment 3.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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QUESTION NO. : 08.03.01-45

In the response to RAI 818-5872, Question 08.03.01-42, the applicant provided the Qualification Testing Log for the Gas Turbine Generator (GTG) qualification. Such log displayed a failure of the reactive load bank due to a short circuit (Start Test No. 128). The applicant further discussed that the start test was repeated but that an unusual sound was heard by one of the technicians. Upon an inspection following the test, an inspection revealed distortion in the foreign object debris (FOD) screen. The KHI representative stated this was from the sudden application of load during the load bank failure, causing a pulse or pressure wave in the air intake. Upon removal of the right side adapter, it was determined that a portion of the acoustical enclosure roof had been ingested into the engine's air intake plenum, and had deformed an RTD in the air intake. Additionally, some of the perforated surface material of the piece had been bent. It was determined that three narrow portions of the acoustical enclosure roof which should have been welded in place during the fabrication of the enclosure, were not secured; therefore, this allowed the piece to be drawn into the engine plenum. One of the three items was too long to be ingested. The two smaller pieces were secured to prevent further possible displacement. Subsequently, a maintenance start (MS-4) was performed, and the Start and Load acceptance test continued with Start Test No. 129. IEEE Standard 387-1995, “IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations,” as endorsed in Regulatory Guide 1.9, “Application and testing of Safety-Related Diesel generators in Nuclear Power Plants,” states in its Section 6.2.2 d)5), “Start and load acceptance tests,” the following:
“If the cause for failure to start or accept load in accordance with the preceding sequence falls under any of the categories listed below, that particular test shall be disregarded, and the test sequence shall be resumed without penalty following identification and correction of the cause for the unsuccessful attempt…
5) Failure of any of the temporary service systems such as dc power source, output circuit breaker, load, interconnecting piping and wiring, and any other temporary setup that will not be a part of the permanent installation.

a. State whether the applicant identified the cause of the reactive load bank failure, and the subsequent discovery of the portion of the acoustical enclosure roof that had been

ingested into the engine's air intake plenum, and whether or not this failure could affect the GTG during operation.

b. State the corrective action taken in order to preclude this failure from repeating, and whether a design change was done to this effect.

c. Provide information to support the characterization of the load bank failure based on the definition of a failed and successful start and load acceptance tests.

ANSWER:

MHI has determined the cause of the load bank failure, a design change was determined not to be necessary and the load bank failure is not relevant to the determination of successful start/load acceptance testing.

Part a. Cause of Load Bank and Acoustical Enclosure Failures

Cause of Load Bank Failure

After the under-frequency shutdown of the GTG, the Qualification Vendor investigated the load bank facility. It was discovered that a major failure had occurred at one of the reactive load banks. The load bank facility includes individual cabinets each containing 375 KVAR inductive loads. The actual load available at the time of the GTG testing was 4729 KVAR. One of the load banks had significant burn marks, sheet metal burnout, and loss of 3 phase bus work. A large sheet metal cover was located 8 to 10 feet away from the unit, having been burned through and dislodged from its normal position.

Due to normal load bank maintenance, the Qualification Vendor replaced many of the control contactors that were originally supplied with the equipment. The original contactors included rigid copper connectors that provided physical support for the three phase control bus. However as the years progressed, the original style contactors became obsolete. The newer contactors were available only with flexible conductors which provide no support to the control bus work. This had the effect of leaving the bus work susceptible to movement during energization. The Qualification Vendor believes the lack of adequate support at the end of the copper bus work allowed two phases to contact each other creating an explosive phase to phase to ground fault.

Acoustical Enclosure Failure

The component that was dislodged from the acoustical enclosure roof (ceiling) consisted of an outer steel welded box, insulating material, and a perforated cover that was riveted to the box. The entire assembly was specified to be welded into the ceiling frame. The manufacturer failed to weld the assembly in place. During the load bank failure, it became dislodged from its location and fell through the Foreign Object Debris (FOD) screen and into the combustion air intake plenum.

The ingestion of the ceiling component could have affected the GT engine, although it was shown by inspection and further operation that no damage had occurred. A portion of the perforated cover was bent backwards, and some of the insulating material was missing. It is assumed this material passed harmlessly through the GT engine. No metallic components were ingested in the engine.

Part b. Corrective Action and Need for Design Change

The Vendor, performing the qualification testing, removed the damaged reactive load bank from service. Excess capacity allowed the reconfiguration of the load bank for the remainder of the tests. The ceiling component was reattached back in original position and temporary clamps were installed to ensure it would remain in place.

A design change was not required or made because this was a manufacturing defect, not a design deficiency. The lack of welds, which would have prevented the component from being dislodged, was the issue. The Vendor performing the qualification testing discussed this with the manufacturer to ensure it would not be repeated in future units.

A similar event could not realistically occur in an actual nuclear power plant. The initiating event was the load bank failure which essentially added a large totally reactive load to the machine. In a power plant application such large purely reactive loads do not exist. The majority of the loads are a fixed combination of inductive and resistive elements, induction motors. By design a load equal to 200 to 300 percent of the GTG rating would not be connected to a safety bus due the potential of overloading the machine. Therefore, a similar electrical event is not considered credible in a plant application.

A manufacturing defect (e.g., non-welded components) with the enclosure could potentially affect the GTG during operation by either coming into contact with high speed rotating parts or disruption of the combustion air flow. The intake air plenum is designed to preclude large components from entering and coming into contact with the rotating parts. Smaller components would be stopped by the foreign object debris screen. The other potential affect would be disruption of the air flow.   As indicated by the two successful runs while the ceiling component was inside the air plenum and post discovery inspections the GT engine performance was unchanged. It should also be noted that with fixed speed gas turbines the combustion air intake volume is constant and independent of load. The component that lodged itself in the air plenum is one of the largest acoustical ceiling panels that exist in the flow path. In the absence of a manufacturing defect similar events are not considered credible.

Part c. Relevance of load bank failure to test success/failure

Per the test procedure (MUAP-10023-P(R3) Appendix D Section 6.12), an acceptable start and load acceptance test is defined as:

1 GTG cranking shall begin upon receipt of the emergency start signal, and the unit shall accelerate to 60 Hz frequency and 6.9 kV voltage within 100 seconds.
2 Immediately following step 1, the GTG shall be loaded in a single step to 2250 kW (minimum).
3 After the load is applied, the EGTG shall continue to operate until lube oil and exhaust gas temperatures are within ±5.5 ºC (± 10 ºF) of normal engine operating temperatures for the corresponding load.

These are consistent with the Acceptance Criteria of IEEE Std 387 1995 section 6.2.2 items a), b), and c).

During Start and Load Acceptance test No. 128:

- Criterion 1 was met; The GTG started in approximately 28 seconds.

- Criterion 2 was met; The GTG accepted a load of greater the 2250 kW,

- Criterion 3 was <u>not</u> met; Due to the load bank failure, the GTG tripped on under frequency approximately 15 min after accepting the load. This was prior to the lube oil and exhaust gas temperatures stabilizing within ± 5.5 ºC (± 10 ºF) of their normal value.

Consequently, Test No 128 could not be classified as a success because the third criterion had not been achieved. Test No 128 was classified as "Disregarded" per IEEE Std 387-1995, paragraph 6.2.2.e Item 5.

IEEE Std 387-1995, paragraph 6.2.2.e states:

If the cause for failure to start or accept load in accordance with the preceding sequence falls under any of the categories listed below, that particular test shall be disregarded, and the test sequence shall be resumed without penalty following identification and correction of the cause for the unsuccessful attempt.

1) Unsuccessful start attempts that can definitely be attributed to operator error, including setting of alignment control switches, rheostats, or potentiometers, or other adjustments that may have been changed inadvertently prior to that particular start test.

2) Tests performed for verification of a scheduled maintenance procedure required during this series of tests. This maintenance procedure shall be defined prior to conducting the start and load acceptance tests and will then become a part of the normal maintenance schedule after installation.

3) Tests performed in the process of troubleshooting. Each start attempt performed in the troubleshooting process shall be defined as such before a start attempt is made.

4) Successful start attempts that were terminated intentionally without loading.

5) Failure of any of the temporary service systems such as dc power source, output circuit breaker, load, interconnecting piping and wiring, and any other temporary setup that will not be a part of the permanent installation.

The load bank failure clearly falls within Item 5 above, i.e., failure of the load which will not be part of the permanent installation.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on Technical / Topical Reports

MUAP-10023-P(R3) Appendix L will be revised as shown in Attachment 3.

i. Demonstrate that the fuel transfer pumps transfer fuel from each fuel storage tank to the day tank of each Class 1E GTG.

j. Demonstrate that, with the Class 1E GTG operating in a test mode and connected to its Class 1E bus, a simulated ECCS signal overrides the test mode by: (1) returning the GTG to standby operation, and (2) automatically energizing the emergency loads with offsite power.

k. Demonstrate that the specified automatic trip signals for the GTG are bypassed automatically as designed.

l. Demonstrate that by starting and running (unloaded) redundant units simultaneously, common failure modes that may be undetected with single GTG testing do not occur.

The test procedures will specifically state that the Class 1E GTG unit is to be reset at the conclusion of the test to allow an automatic start when required.

8.3.1.1.3.9 Maintenance

DCD_08.03.01-43

Maintenance should be performed in accordance with the requirements of GTG engine manufacturer. Of particular importance is cleaning of the fuel nozzle. The fuel nozzle should be cleaned in accordance with the manufacturer's recommendations. A GTG engine maintenance plan will be established.

8.3.1.1.3.10 Fuel Oil Storage and Transfer Systems

Each Class 1E GTG is provided with dedicated and independent fuel oil supply system, fuel oil day tank and storage tank. The fuel oil systems are not shared between the GTGs of redundant groups and these systems are designed to minimize common cause failure between the GTGs of redundant groups.

The day tank capacity is adequate for 1.5 hours of operation Class 1E GTG at maximum required loading.

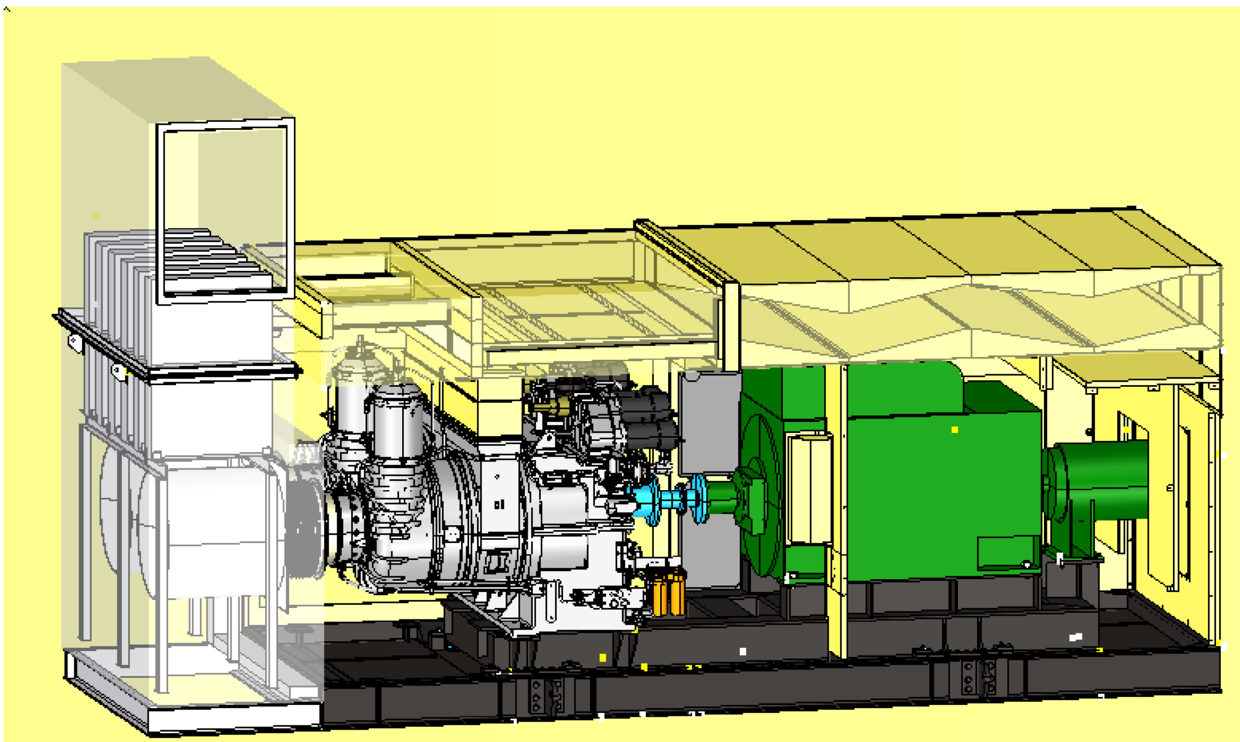
The maximum expected loading for Class 1E GTG occurs under LOOP+LOCA conditions. The electrical power and control circuit power supplies for the Class 1E fuel oil system are provided from the Class 1E power systems in the same train.

The day tank is located inside the associated Class 1E GTG room in the PS/B. The fuel level in the day tank is maintained automatically by the fuel transfer pumps pumping the fuel from the storage tanks on day tank low level. Each day tank is provided with two fuel transfer pumps.

The storage tank capacity is adequate to meet the maximum load demand on the associated Class 1E GTG for 7 days. One independent and dedicated storage tank is provided for each Class 1E GTG. The storage tanks are located outside of the PS/B.

The Class 1E GTG fuel oil system is described in Subsection 9.5.4.

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



Non-Proprietary Version

October 2010

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

Abstract

This technical report describes the design criteria, ~~the~~ design features, testing and qualification requirement for the Class 1E Gas Turbine Generator (GTG) units of the US-APWR.

MHI will perform the qualification program including tests with two partner companies. One has many years of experience ~~of~~ supplying commercial grade GTG's. The other has extensive experience~~s~~ ~~of~~ supplying Class 1E Diesel Generator (DG) units to US conventional nuclear power plants, as well as Commercial Grade Dedication per EPRI NP5652.

This report provides reasonable assurance that GTG's ~~is~~are highly reliable and dependable and very well suited to perform their safety functions as required by the US codes and Standards. These include:

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

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

This technical report describes the following~~s~~:

Design criteria
Design features, specifications
Seismic analysis
Reliability
Class 1E qualification plan

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

Table of Contents

7.0 INITIAL TYPE TEST

7.1 Division of Responsibility

The roles and responsibilities for this Initial type test are indicated in the following subsections.

7.1.1 MHI

A) Testing Program Management
B) Preparation of MUAP-07024-P “Qualification and Test Plan of Class 1E Gas Turbine Generator System”
C) Review and approval of procedures
D) Preparation of MUAP-10023-P ”Initial Type Test Result of Class 1E Gas Turbine Generator System”

7.1.2 Qualification Testing Vendo~~e~~r

A) Procure GTG support systems (excluding GTG engine, and Gear Box)
B) Assemble GTG and support system
C) Preparation of Testing Procedures (excluding GTG engine and Gear Box)
D) Operation of the GTG during testing
E) Conduct Initial Type Tests
F) Record and document Test results

7.1.3 Engine Manufacturer

A) Provide technical support associated with the GT engine and Gear Box
B) Perform daily inspections of Engine and Gear Box
C) Perform manufacturers recommended preventive maintenance impacted by the test series

7.2 Initial Type Test

The Initial Type Tests shall be conducted under the control of an approved written procedure. All data collected and recorded shall be turned over at the conclusion of the testing and summarized in the Initial Type Test Report.

7.2.1 Load Capability Testing

7.2.1.1 Objective

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

7.2.1.2 Basic Requirements

a) Load equal to the continuous rating shall be applied for the time required to reach engine temperature equilibrium.

b) Immediately following step 7.2.1.2.a), the short-time rated load shall be applied for a period of 2 h and the continuous rated load shall be applied of 22 h. The short-time rating load rejection test shall be performed.

7.2.1.3 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% if 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.

7.2.2 Start and Load Acceptance Test

7.2.2.1 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.

A total of 150 starts shall be performed.

7.2.2.2 Basic Requirements

a) Engine cranking shall begin upon receipt of the start-diesel signal, and the diesel generator unit shall accelerate to specified frequency and voltage within the required time interval.
b) Immediately following step a), the diesel-generator unit shall accept a single-step load of ~~a~~50% of the continuous kilowatt rating. Load may be a totally resistive load or a combination of resistive and inductive loads.
c) ~~20~~ Twenty starts shall be performed under the cold condition, and 130 starts shall be 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.
d) The engine manufacturer recommended maintenance at recommended intervals shall be performed during the testing sequence . Following the maintenance activity, the GTG shall be started to conduct post maintenance testing and verify proper maintenance activities. This run shall not be considered part of the 150 start tests. IEEE Std 387-1995 section 6.2.2. e) permits such scheduled maintenance to be performed during start and load acceptance test.

7.2.2.3 Acceptance Criteria

All starts shall be achieved within 100 seconds. 150 starts should be performed with no failures. The EGTG 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.

7.2.3 Margin Test

7.2.3.1 Objective

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.

7.2.3.2 Basic Requirements

At least two margin tests shall be performed using either the same or a 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.

7.2.3.3 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) GTG frequency does not exceed 69 Hz upon rejection of the margin test load.

7.2.4 Load Transient Tests

7.2.4.1 Objective

This test is not required by IEEE Std 387-1995 as endorsed by R.G . 1.9. This is an internal test in accordance with recommendations of the manufacturer. This test confirms capability for load transient and rejection.

7.2.4.2 Basic requirements

Three load transient tests shall be performed using a condition with 25% to 100% load. The detail test procedure shall be included and conducted as part of the overall testing procedure, with the results included in the Appendix D, Technical Report, MUAP-10023-P (R3), “Initial Type Test Result of Class 1E Gas Turbine Generator System ”.

7.2.4.3 Acceptance Criteria

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

7.3 Preventive Maintenance During the Test Sequence.

Recommended manufacturer's normal preventive maintenance shall be conducted if the maintenance interval will be exceeded during the test sequence. Recommended maintenance activity shall be conducted in accordance with manufacturer prepared and MHI approved procedures.

7.3.1 Maintenance procedures

Maintenance required during the testing sequence shall be conducted per written and approved procedures prior to initiation of the activity. The detailed maintenance procedure covering each maintenance activity shall be included along with documentation within the MUAP-10023-P (R3), "Initial Type Test Results of Class 1E Gas Turbine Generator System". The post maintenance testing runs shall be disregarded as permitted by section 6.2.2.e) 2) of IEEE Std 387-1995.

7.3.2 The impact on the qualification testing

The impact on the qualification testing shall be assessed prior to conducting any maintenance activity and documented in the initial type test results report. The impact assessment shall evaluate the effect of any maintenance activity on the validity of the initial type testing. Daily inspections and engine manufacture's recommended maintenance do not require an impact assessment.

7.3.3 Performance of any preventive maintenance

The performance of any preventive maintenance shall be accomplished by the manufacturer's technical representative and shall be noted in the daily inspection log.

7.4 Procedures

Certified copies of the completed procedures used during the test shall be included in Appendix D Technical Report, MUAP-10023-P (R3) "Initial Type Test Results of Class 1E Gas Turbine Generator System". A summary of the fuel nozzle cleaning procedure is also provided below.

(Interval)

Cleaning work shall be carried out after every 50 engine starts.

(The frequency of cleaning work may be determined and adjusted by the engine manufacturer.)

(Estimated time)

Work including preparation and clean up are estimated to take approximately two hours.

(Detail of Process)

1. Disconnect the two fuel lines and a cooling air flexible tube from the fuel nozzle. Remove the four bolts and the fuel nozzle from the engine.
2. Perform rough cleaning of any apparently dirty sections with waste cloth.
3. Soak fuel nozzle in a detergent solution for 0.5 ～1 hour.
4. Brush the end of the fuel nozzle with a soft brush.
5. Rinse the fuel nozzles with clean water, and wipe with soft waste cloth.
6. Reinstall the fuel nozzle on the engines with new gaskets and washers.
7. Reconnect the fuel lines and the air cooling tubes to the nozzles.
8. Start the engine and operate it for 2-3 minutes to check for fuel oil or lube oil leakage or abnormal noise.

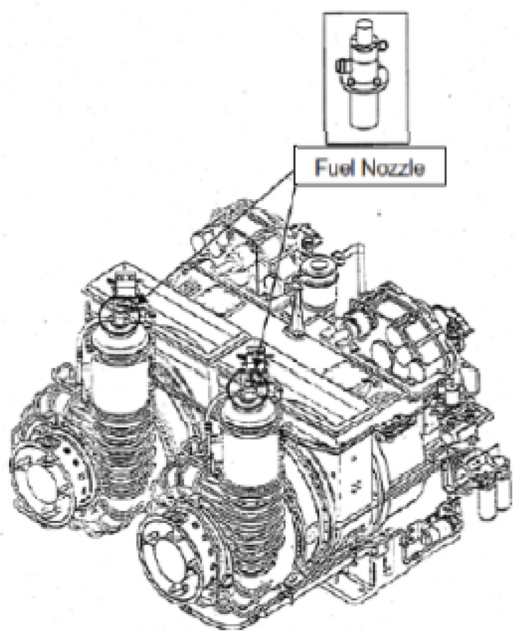


Fig.1 Appearance of fuel nozzle and its installation position

C.4.0 Acceptance Tests

C.4.1 Factory Test

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

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

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

(3) In addition to the manufacturer's standard tests, the following type tests shall be performed.

(a) Engine Performance TestsLoad Transient Tests.
The objective, basic requirements and acceptance criteria are indicated in section 7.2.4.

The following tests shall be performed.
50% Load for 1 hour
75% Load for 1 hour
100% Load for 2 hours
110% Load for 2 hours

(b) Start and Load Acceptance Tests
Test results of a factory test consisting of 150 valid start & load tests on a prototype unit to demonstrate the ability of the GTGs to start, attain rated speed and voltage within 100 seconds and load to 50% of the continuous rating shall be submitted. A valid start and load test is defined as a start with loading to at least 50% of the continuous rating within 100 seconds and continued operation until temperature equilibrium is obtained.
The objective, basic requirements and acceptance criteria are indicated in Subsection 7.2.2.

The test shall be performed according to the following conditions and the basis shown in Appendix F.:

- 150 starts shall be performed.
- For the purposes of the Starting Reliability testing, all starts with lube oil less then than 70°C are considered to be a valid test.
- The For the first test each test day, the GTG will be at ambient conditions; all remaining tests conducted that day will may be at or near normal operating temperatures.

A total of 150 valid start and load tests shall be performed with no failures allowed. Failure of the unit to successfully complete this series of tests will require further testing as

well as a review of the System Design Adequacy.

~~The test, as described above, shall be performed on the first unit of the design.~~

(c) Margin Tests
~~To d~~Demonstrate the capability to accept the most severe load +-10% and to maintain voltage, speed, and frequency within limits specified in Subsection C.2.1.3. For this factory test, motor loads in combination with resistance loads shall be connected to the GTG to simulate the actual loading sequence indicated in Appendix A. This test shall be performed twice.
The objective, basic requirements and acceptance criteria are indicated in Subsection 7.2.3.

(d) Load Capability Test
~~To d~~Demonstrate the capability to carry the continuous rated load for 22 hours and to carry the 110% load rating for two hours. This test will be performed once. To demonstrate the capability to reject the largest single load without exceeding the overspeed limits specified in Subsection C.2.1.3. This test will be performed twice.
The objective, basic requirements and acceptance criteria are indicated in Subsection 7.2.1.

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

(f) Functional Test
~~To d~~Demonstrate the capability of the control, surveillance and protection systems to perform in accordance with the requirements.

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

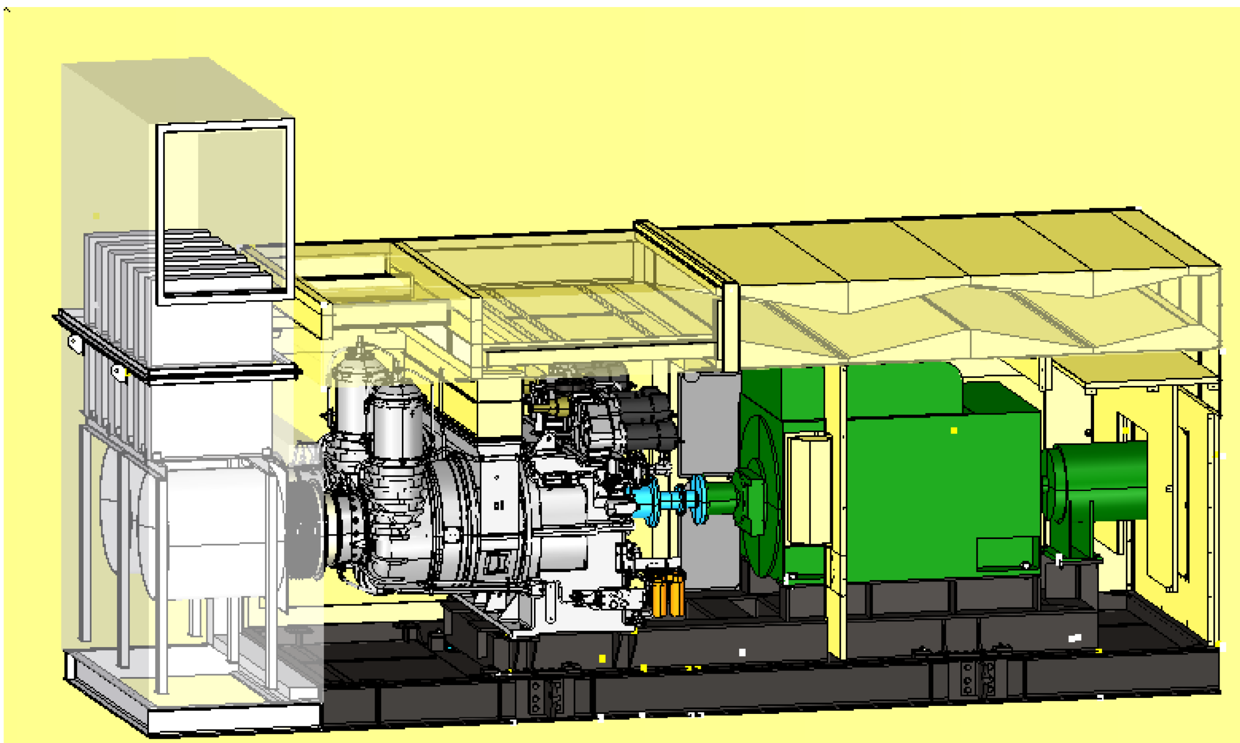
The testing, as described above, shall be performed on the first unit of the design.

(4) All the tests both mechanical and electrical ~~,~~ shall be performed in accordance with ~~in~~ written test procedures. ~~shall be listed and described.~~

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

(6) The recommended manufacturer's normal preventive maintenance shall be conducted if the maintenance interval will be exceeded during the test sequence. All recommended maintenance activity shall be conducted in accordance with the division of responsibilities, using manufacturer prepared and MHI approved procedures.

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



Non-Proprietary Version

September 2011

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

Abstract

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

This technical report describes the following:s

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

Table of Contents

6.0 INITIAL TYPE TEST

6.1 General

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

6.2 Load Capability Test

6.2.1 ~~Outline~~Objective

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

6.2.2 ~~Procedure, Test Condition~~Basic Requirements

a) Load equal to the continuous rating shall be applied for the time required to reach engine temperature equilibrium.

b) Immediately following step 7.2.1.2.a), the short-time rated load shall be applied for a period of 2 h and the continuous rated load shall be applied ~~of~~ for 22 h. The short-time rating load rejection test shall be performed.

~~b)Light-load or no-load capability, as described, shall be demonstrated by test. Light –load or no-load operation shall be followed by a load application ≧50% of the continuous kilowatt rating for a minimum of 0.5 h.~~

The detailed test procedure is ~~shown in~~provided in Appendix D.

6.2.3 Acceptance Criteria

1) ~~Maintain for duration while maintaining normal temperature limits.~~Supply 110% rated output for 2 hrs and 100% for 22 consecutive hours while maintaining normal temperature limits.

2) ~~The load rejection test will be acceptable if the increase in speed of the engine does not exceed 75% if of the difference between nominal speed and the overspeed trip set point, or 15% above nominal, whichever is lower.~~The increase in speed of the engine does not exceed 75% if the difference between nominal speed and the overspeed trip set point, or 15% above nominal, whichever is lower when rejecting a load equal to 110% of rated output.

6.2.4 Result

Parameters measured during the test are shown in Tables 6.2-1 to 6.2-3. The GTG was operated in the stable condition without incident ~~no troubles~~, failures or abnormal conditions. All the parameters remained almost constant.

~~The~~ Upon rejection of 110% load, the engine did not over speed ~~or stall~~trip. At the end of the full load operation, the load was increased to 110% of rated and immediately removed to verify the frequency excursion ~~is~~ 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 ~~results~~ were~~are~~ successful.

Table 6.2-1 Engine Lubricant Oil Parameters

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

Table 6.2-2 Engine Temperature Parameters

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

Table 6.2-3 Generator Parameters

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

6.3 Start and Load Acceptance Tests

6.3.1 ~~Outline~~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.

A total of 150 starts shall be performed.

6.3.2 ~~Procedure, Test Condition~~Basic Requirements

a) Engine cranking shall begin upon receipt of the start-diesel signal, and the diesel-generator unit shall accelerate to specified frequency and voltage within the required

time interval.

b) Immediately following step a), the diesel-generator 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) 20 Twenty starts shall be performed under the cold condition, and 130 starts shall be 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.

d)The engine manufacturer recommended maintenance at recommended intervals shall be performed during the testing sequence. Following the maintenance activity, the GTG shall be started to conduct post maintenance testing and verify proper maintenance activities. This run shall not be considered part of the 150 start tests. IEEE Std 387-1995 section 6.2.2.e) permits such scheduled maintenance to be performed during start and load acceptance

d) test.

GT manufacture defines the cold condition of is defined as and completion of 10 consecutive hours on the turning gear and cool down to near ambient temperature conditions.GT that the condition 10 hours turning performed after GT stopped run. Hot starts were may be performed immediately following shutdown of the previous test.

e) The engine manufacturer recommends the GT had have fuel nozzle maintenance performed every 50 starts. This maintenance activity involved involves removal, inspection and cleaning of each engine's fuel nozzle. fuel nozzle along with the approved procedure included Following the each maintenance activity, the GTG was started to conduct post maintenance testing and verify proper maintenance activities. This run was not considered as part of the 150 start tests. IEEE Std 387 section 6.2.2. e) permits such scheduled maintenance to be performed during start and load acceptance te

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.

Tough it is possible to make sure of maintenance activities for the third time refer to the chart in Appendix C (Figure C.1.0-135), the chart doesn't include information about maintenance activities for the first and second time, so that 11 30The test results in Appendix C contain notations of the fuel nozzle cleaning.. the daily inspection logs notice that activities in Appendix C..

6.3.3 Acceptance Criteria

All starts shall be achieved within 100 seconds. 150 starts should be performed with no failures. The EGTG 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

A part of theData charts of for the start and load acceptance test sequence of 151 starts (Starts

No.77 through No.81) are shown provided in Figures C.1.0-2 ttoThru 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 set up and not part of the permanent installation. Therefore, Test No. 128 was disregarded in accordance with IEEE Std 387-–1995 section 6.2.2.e).5). The load bank failure occurred after start #128, and 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 This failure does not invalidate the Start and Load Acceptance tests because this failure was caused by facility component. 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 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 STDtd-387-1995, the initial Test 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 was were met or exceeded, therefore, the start and load acceptance test was successfully completed.

Table 6.3-1 Starting Time

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

Table 6.3-2 Engine Parameters

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

Appendix D Initial Type Test Procedure

D.1.0 Detail Test Procedure

D.2.0 Recorded Parameter List

Table D.2.0-1 Parameters to be Monitored During Initial Type Test (1 of 2)

Table D.2.0-1 Parameters to be Monitored During Initial Type Test (2 of 2)

Table D.2.0-2 Parameters to be Monitored During Seismic Test

Appendix K Fuel Nozzle Maintenance

K.1.0 Basis of 50 Start Maintenance Interval

This maintenance activity is one of several recommended by the engine manufacturer, Kawasaki Heavy Industries (KHI). The intent is to prevent the buildup of gums and other insoluble materials, including carbon within the nozzle and the nozzle tip. This is commonly referred to as fuel nozzle "coking." The effect of severe coking is a reduction in ignition and running performance. The engine manufacturer recommends the fuel nozzle maintenance (cleaning) for all users, and routinely performs cleaning as part of its preventive maintenance program. According to the engine manufacturer, cleaning the fuel nozzle every 50 starts is conservative, based on the engine manufacturer's field experience for GTG's of its type.

The impact of not cleaning the fuel nozzles, as with any preventive maintenance activity, will affect performance over time. In the case of gas turbine engines, not cleaning the fuel nozzles will ultimately lead to a buildup of gums and other insoluble materials, including carbon that will delay the GTG start time and load capability. Although the engine manufacturer recommended fuel nozzle cleaning after 50 engine starts based on their typical industrial experiences, this cleaning activity can not be defined as essential to the successful completion of the 150 start and load acceptance tests for the US-APWR application. This is because the quality of fuel for nuclear applications, such as the US-APWR, is better than the quality of other typical industrial applications which is the engine manufacturer's basis for their maintenance procedure. However, because it is the engine manufacturer's recommended maintenance item required during the series of tests; it was included in the test sequence. The engine manufacturer strongly recommends fuel nozzle cleaning after every 50 engine starts.

K.2.0 "As found" fuel nozzle condition

There was some slight surface discoloration on the portions of the nozzle that were exposed to the high temperatures within the combustion chamber during each cleaning. Port or fuel passageway clogging was not evident or observed. The discoloration is the result of gum like deposits from the fuel that plated out as the fuel vaporized while in contact with the nozzle or condensed on the cooler parts of the nozzle during starting. The discoloration was not excessive and typical of that observed for the quality of the fuel being used. The quality of the fuel oil used in a nuclear power plant is generally better than in other industrial applications and that used during the testing. Fuel quality is usually No. 2 diesel fuel, or better.

K.3.0 An expression of the engine manufacturer's view on fuel nozzle maintenance

K.4.0 Fuel Nozzle Cleaning Procedure.

Manufacture's maintenance procedure approved by MHI is shown in Table K.3.0-1.

Table K.3.0-1 Work Instruction Sheet (Sheet 1 of 2)

Attachment 3 (74/77)

Table K.3.0-1 Work Instruction Sheet (Sheet 2 of 2)

Appendix L Load bank failure

L.1.0 Description of the event

During Start and Load Acceptance Test Number 128, the load bank failed. This resulted in a sudden unplanned reactive load addition on to the GTG. The load bank failure occurred approximately 15 minutes into Test 128, after the GTG has successfully started and accepted the test load; however, before the machine temperature stabilized within 10ºF of normal operating temperature. Consequently, the third acceptance criterion was not achieved and test 128 was classified as "Disregarded" per IEEE Std 387-1995 section 6.2.2.e).5).

The load bank failure caused an approximately 200- 300% overload of the GTG, which tripped on "under frequency". The machine responded to the load bank failure as expected and in accordance with the protection scheme established for the test.

After the under-frequency shutdown of the GTG, the Qualification Vender investigated the load bank facility. It was discovered that a major electrical fault had occurred in one of the reactive load banks. The load bank facility includes individual cabinets, each containing 375 KVAR inductive loads. The actual load available at the time of the GTG testing was 4,729 KVAR. One of the load banks had significant burn marks, sheet metal burnout, and loss of 3-phase bus work. A large sheet metal cover was found 8-10 feet away from the unit, having been explosively burned and dislodged from its normal position.

Subsequent to a visual inspection by the Qualification Vendor's, MHI and the GT engine manufacturer's representatives, the machine was barred over (purged) three times and then started. The GTG successfully started, accepted load and reached stable operating temperatures. The parameters were closely monitored and were determined to be within normal expected values. Therefore, the Starting and Load Acceptance testing was allowed to continue.

Start and Load acceptance testing was resumed by repeating Test No 128. The GTG successfully started and accepted load. During the load run, a whistling noise that had not been present during previous test runs was noticed coming from the enclosure that had not been present during previous test runs. The GTG parameters were stable and within normal values, therefore test 128 was allowed to continue to completion. During the subsequent investigation into the source of the noise, deformation of the combustion air duct was noticed. During further investigation and removal of the deformed duct, it was discovered that the Foreign Object Debris (FOD) screen had been damaged and a sound insulation component was found inside the intake air plenum. The component had been displaced from its location in the ceiling of the GTG enclosure.

According to the engine manufacturer's technical representative, the overload from the Load bank failure had created a pressure pulse within the intake air ducting that dislodged the sound insulating component. In addition to the displaced component, two other similar components were found loose but not displaced. The component that was dislodged from the ceiling consisted of an outer steel welded box, insulating material, and a perforated cover that was riveted to the box. The enclosure manufacturer failed to appropriately weld the assembly in place. During the load bank failure, the assembly became displaced from its location and fell through the Foreign Object Debris (FOD) screen, lodging in the GT engine intake air plenum. The failure to weld these sound insulating components into the enclosure frame was classified

as a manufacturing defect.

L.1.1 Probable Cause of the Load Bank Failure

Due to normal load bank maintenance, the Qualification Vendor over time had replaced many of the control contactors that were originally supplied with the equipment. The original contactors included rigid copper connectors that provided physical support for the 3-phase control bus. However as the years progressed, the original style contactors became obsolete. The newer contactors were available only with flexible conductors which provide no support to the control bus work. This had the effect of leaving the bus work susceptible to movement when energized. The Qualification Vendor believes the lack of adequate support at the end of the copper bus work allowed two phases to contact each other creating an explosive phase to phase to ground fault. The cause of load bank failure cannot be attributed to the GTG. The GTG was stable and operating well within nominal values for all parameters when the load bank failure occurred.

L.2.0 Potential for Similar Occurrence in Operating Plants

The potential effects fall into two distinct classes; electrical damage to the generator or exciter, and mechanical damage to the turbine engine.

L2.1 Potential for Electrical Damage

With regard to potential electrical damage, the load bank failure is highly similar to a sudden overload (200 to 300%) or a ground fault. In the absence of a second failure within the generator protection scheme the GTG would isolate itself. Within an actual nuclear plant application, the protection scheme is designed to protect the generator from electrical failures to avoid permanent damage to the critical components, (e.g.,. rotor and stator windings, prime mover, etc.). A methodology of selective fault protection is employed to trip the circuit breaker closest to the fault. In such a situation, the GTG would continue to supply the remaining non faulted safety related loads without interruption. The electrical protection scheme is also designed to isolate the GTG versus tripping the machine. Once the electrical problem is cleared, the GTG could be safely restarted, if necessary, and realigned to supply the loads.

The load characteristics within a plant power distribution system are different from a test load bank. Pure inductive loads rarely exist within a plant. Typical loads are mixed as in a motor for example. A typical squirrel cage induction motor has inductive as well as resistive components however, they are not distinct and separable. In a test load bank the resisters and inductors are separate and configurable to a range of real and imaginary loads with different lagging power factor. A fault on a typical plant load would be isolated by the protective scheme. A load bank does not have a similar protection scheme. The protection is designed to allow for quick sudden changes in the load characteristics for testing and to protect the test specimen. Although, a sudden load increase many occur within a plant it would not be in the range of 200% of the machine rating. There is no single load that large connected to the safety bus in the US-APWR.

L.2.2 Potential for Mechanical Damage

The manufacturing defect (loose parts in the air flow path) potentially could result in ingesting foreign objects into the turbine engine. The combustion air intake plenum is designed with a 90 turn at the bottom to preclude large and potentially damaging objects from reaching the moving parts. In such an event, the components that were not correctly attached are too large to enter the engine and potentially come into contact with moving parts. Light weight soft fibrous objects such as the sound insulation that may have been pulled into the turbine engine should pass through without damage, as they did in this case.

The most significant potential is the entry of a hard metal object small enough to be entrained in the combustion air, yet large and hard enough to physically damage (chip) the compressor turbine blades. The plenum and ducting are designed with a sufficiently large cross sectional area to keep air velocities below what would be necessary to entrain such objects.

The successful post maintenance run after the load bank failure, the successful Start and Load Acceptance test 128 (repeat) indicated that the enclosure manufacturing defect did not impact the performance of the GTG. During these two test runs and the remaining testing detectable changes in the performance of the GTG were not observed.

L.3.0 Corrective action taken

Load Bank

The Qualification Vender removed the damaged reactive load bank from service. Excess capacity allowed reconfiguration of the load bank for the remainder of the tests.

Enclosure Manufacturing Defect

The Qualification Vendor reattached the ceiling component back in its original position and temporarily installed clamps to ensure it would remain in place. A design change was not required or made because this was a manufacturing defect, not a design deficiency. The lack of welds which would have prevented the component from being dislodged is clearly a manufacturing defect. The Qualification Vender discussed this with the manufacturer to ensure it would not be repeated in future units. Additionally, future procurement specifications will clearly require welding of these assemblies to the enclosure frame.