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MFN 06-307
Supplement 2

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 46 Related to ESBWR Design Certification Application - Seismic and Dynamic Qualification of Equipment - RAI Number 3.10-2 Supplement 2**

Enclosure 1 contains GE-Hitachi Nuclear Energy Americas LLC (GEH)'s response to the subject NRC RAI 3.10-2, Supplement 2, which was transmitted via Reference 1.

If you have any questions or require additional information, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

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NRO

Reference:

1. Transmitted to GEH by e-mail from Larry Rossbach (NRC)
2. MFN 06-307 Supplement 1, Response to Portion of NRC Request for Additional Information Letter No. 46 Related to ESBWR Design Certification Application – Seismic and Dynamic Qualification of Equipment - RAI Numbers 3.10-1 S01 through 3.10-5 S01, dated March 28, 2007
3. MFN 06-307, Response to NRC Request for Additional Information Letter No. 46 Related to ESBWR Design Certification Application – Seismic and Dynamic Qualification of Equipment - RAI Numbers 3.10-1 through 3.10-6, dated September 1, 2006

Enclosure:

1. MFN 06-307, Supplement 2, RAI Response to RAI 3.10-2 Supplement 2

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MFN 06-307, Supplement 2

Enclosure 1

RAI Response to RAI 3.10-2 Supplement 2

For historical purposes, the original text of RAI 3.10-2 and the GE responses are included. The attachments are not included from the original response to avoid confusion.

NRC RAI 3.10-2

For seismic and dynamic qualification of mechanical and electric equipment in ESBWR, the Design Control Document (DCD)/Tier 2 listed the following three versions of IEEE-344 Standards as the guidelines to be followed: (1) IEEE-344-2004, (2) Regulatory Guide (RG) 1.100, Revision 2, 1988, which endorses the IEEE-344-1987 with some conditions, and (3) Section 4.4 of GE Environmental Qualification Program, NEDE-24326-1-P, January 1983, which used IEEE-344-1975 as its guidelines. Specifically state which parts (chapters or sections) of each version of IEEE-344 guidelines that ESBWR DCD/Tier 2 will meet. Note that IEEE-344-2004 has not been endorsed by RG 1.100 (will be done in the near future) and the staff does not endorse Section 10 (Experience) of IEEE-344-2004 in its entirety.

GE Response

ESBWR will meet the IEEE-344-1987 Standard.
The DCD Table 1.9-22 will be revised as noted in the attached markup.

NRC RAI 3.10-2 S01

The response revises DCD Table 1.9-22 to replace the 2004 version of IEEE-344 with the 1987 version , and it added (R1993) and a note that more recent versions of IEEE-344 exist. The response also removes 2004 from IEEE-344 on DCD page 3.10-1. What is the purpose of adding (R1993) and the note to Table 1.9-22? Please address in DCD Section 3.10 if you commit to the conditions that Regulatory Guide 1.100, Rev. 2, places on IEEE-344-1987.

GEH Response

(R1993) means that the committee reaffirmed the 1993 edition without any changes that year.

IEEE –344-1987 (R1993) meets the Regulatory Guide 1.100 Rev. 2 (dated 6/88).

DCD Impact

No DCD changes will be made in response to this RAI.

NRC RAI 3.10-2 S02

RAI 3.10-2 S02 Comment on response to RAI 3.10-2 S01:

GE response to NRC RAI 3.10-2 S01 is incomplete. RG 1.100 Revision 2, places some restrictions on the use of criteria and procedures provided in IEEE 344-1987, in particular, on the application of the qualification by experience. Therefore, it is incorrect in stating that IEEE 344-1987 (R1993) meets the RG 1.100, Revision 2. However, in GE responses to RAIs 3.10-3 and 3.10-4, GE stated that GE does not utilize operating experience database for equipment seismic qualification and GE does not maintain a database for operating experience. GE is requested to delete all the statements related to "experience data" in DCD, Tier 2, Revision 3 (For examples, first and last paragraph of Section 3.10.1.1 and the second sentence of Section 3.10.2). Also in DCD, GE is requested to confirm that Section 9, Experience, of IEEE 344-1987 is not applicable to ESBWR.

GEH Response

Any statements related to "experience data" will be removed from the DCD, Tier 2, as identified in the attached markup.

GE confirms that Section 9, Experience, of IEEE 344-1987 is not applicable to ESBWR and this will be documented in DCD Tier 2, Section 3.10.1.1.

DCD Impact

DCD Tier 2, Section 3.10 will be revised as noted in the attached markup.

RAI 3.10-2

DCD Markup Pages

3.10.1 Seismic and Dynamic Qualification Criteria

3.10.1.1 Selection of Qualification Method

The qualification of Seismic Category I mechanical and electrical equipment is accomplished by test, analysis, or a combination of testing and analysis. Qualification by actual seismic experience, as permitted by IEEE 344-1987 is not utilized.

In general, analysis is used to supplement test data although simple components may lend themselves to dynamic analysis in lieu of full scale testing. The deciding factors for choosing between tests or analysis include:

- Magnitude and frequency of seismic and RBV dynamic loadings;
- Environmental conditions (Appendix 3H) associated with the dynamic loadings;
- Nature of the safety-related function(s);
- Size and complexity of the equipment;
- Dynamic characteristics of expected failure modes (structural or functional); and
- Partial test data upon which to base the analysis.

The selection of qualification method to be used is largely a matter of engineering judgment; however, tests, and/or analyses of assemblies are preferable to tests or analyses on separate components (e.g., a motor and a pump, including the coupling and other appurtenances should be tested or analyzed as an assembly).

3.10.1.2 Input Motion

The input motion for the qualification of equipment and supports is defined by response spectra. The Required Response Spectra (RRS) are generated from the building dynamic analysis, as described in Section 3.7. They are grouped by buildings and by elevations. This RRS definition incorporates the contribution of RBV dynamic loads as specified by the load combinations in Table 3.9-2 and 3.9-3. When one type of equipment is located at several elevations and/or in several buildings, the governing response spectra are specified.

3.10.1.3 Dynamic Qualification Program

The dynamic qualification program is described in Section 4.4 of GE's Environmental Qualification Program (Reference 3.10-2). The program conforms to the requirements of IEEE 323 as modified and endorsed by the Regulatory Guide 1.89, and meets the criteria contained in IEEE 344 as modified and endorsed by Regulatory Guide 1.100.

3.10.1.4 Dynamic Qualification Report

The Dynamic Qualification Report (DQR) identifies all Seismic Category I electrical and mechanical equipment and their supports. The DQR contains the following:

- A table or file for each system that is identified in Table 3.2-1 to be safety-related or having Seismic Category I equipment, shall be included in the DQR containing the Material Parts List (MPL) item number and name, the qualification method, the input

motion, the supporting structure of the equipment, and the corresponding qualification summary table or vendor's qualification report.

- The mode of safety-related operation (i.e., active, manual active or passive) of the equipment along with the manufacturer identification and model numbers shall also be tabulated in the DQR. The operational mode identifies the instrumentation, device, or equipment:
  - That performs the safety-related functions automatically,
  - That is used by the operators to perform the safety-related functions manually, or
  - Whose failure can prevent the satisfactory accomplishment of one or more safety-related functions.

3.10.2 Methods and Procedures for Qualifying Mechanical and Electrical Equipment

The following subsections describe the methods and procedures incorporated in the above mentioned dynamic qualification program. Described here are the general methods and procedures for qualifying by testing, analysis, or combined testing and analysis, the Seismic Category I mechanical and electrical equipment for operability during and after the SSE loads and Service Level D RBV dynamic loads and for continued structural and functional integrity of the equipment after low level earthquake loading of lesser magnitude (Section 3.7) and Service Level B RBV dynamic loads.

3.10.2.1 Qualification by Testing

The testing methodology includes the hardware interface requirements and the test methods.

Interface Requirements

Intervening structures or components (such as interconnecting cables, bus ducts, conduits, etc.) that serve as interfaces between the equipment to be qualified and that supplied by others are not qualified as part of this program. However, the effects of interfacing are taken into consideration. When applicable, accelerations and frequency content at locations of interfaces with interconnecting cables, bus ducts, conduits, etc., are determined and documented in the test report. This information is specified in the form of interface criteria.

To minimize the effects of interfaces on the equipment, standard configurations using bottom cable entry are utilized whenever possible. Where non-rigid interfaces are located at the equipment support top, equipment qualification is based on the top entry requirements. A report including equipment support outline drawings is furnished specifying the equipment maximum displacement due to the SSE loads including appropriate RBV dynamic loads. Embedment loads and mounting requirements for the equipment supports are also specified in this manner.

Test Methods

The test method is biaxial, random single- and/or multi-frequency excitation to envelop generic RRS levels in accordance with Section 7 of IEEE 344. Past testing demonstrate that Seismic Category I electrical equipment has critical damping ratios equal to or less than 5%. Hence, RRS at 5% or less critical damping ratio are developed as input to the equipment base.

Testing for SSE Loading and RBV Dynamic Loads — An SSE test including other appropriate Service Level D RBV dynamic loads is performed on all test specimens. This test is conducted to demonstrate that equipment would perform its safety-related function through a SSE (as defined in Section 3.7) combined with Service Level D RBV dynamic loads. The strong motion of the test lasts a minimum of 15 seconds in each orientation. Operability of equipment is verified as described in the next Subsection.

Qualification for Operability — In general, analyses are only used to supplement the operability test data. However, analyses, without testing, are used as a basis for demonstration of functional capability, if the necessary functional operability of the instrumentation or equipment is assured by its structural integrity alone.

Equipment is tested in an operational condition. Most Seismic Category I mechanical and electrical equipment have safety-related function requirements before, during, and after seismic events. Other equipment (such as plant status display equipment) have requirements only before and after seismic events. All equipment is operated at appropriate times to demonstrate ability to perform its safety-related function.

If a malfunction is experienced during any test, the effects of the malfunction are determined and documented in the final test report.

Equipment that has been previously qualified by means of tests and analyses equivalent to those described in this section are acceptable provided proper documentation of such tests and analyses is available.

Documentation of Testing

Qualification results are documented and include, but are not necessarily limited to the following:

- Locations of accelerometers;
- Resonant frequency, if any, and transmission ratios (if exploratory tests are applicable);
- Equipment damping coefficients if there is resonance in the 1-60 Hz range or over the range of the test response spectra (if exploratory tests are applicable);
- Test equipment used;
- Approval signature and dates;
- Description of test facility;
- Summary of results;
- Equipment seismic qualification conclusions (including RBV dynamic loads); and
- Justification for using single axis or single frequency tests for all items that are tested in this manner.

See Subsection 3.10.1.4 for additional information on the documentation of test results.

3.10.2.2 Qualification by Analysis

The discussion presented in the following subsections apply to the qualification of equipment by analysis.

Analysis Methods

Dynamic analysis or an equivalent static analysis, described in Subsection 3.7.3, is employed to qualify the equipment. In general, the choice of the analysis is based on the expected design margin, because the static coefficient method (the easiest to perform) is far more conservative than the dynamic analysis method.

If the fundamental frequency of the equipment is above the input excitation frequency, (cutoff frequency of RRS) the equipment is considered rigid. In this case, the loads on each component can be determined statically by concentrating its mass at its center of gravity and multiplying the values of the mass with the appropriate maximum floor acceleration (i.e., floor spectra acceleration at the high frequency asymptote of the RRS) at the equipment support point.

A static coefficient analysis may be also used for certain equipment in lieu of the dynamic analysis. No determination of natural frequencies is made in this case. The seismic loads are determined statically by multiplying the actual distributed weight of the equipment by a static coefficient equal to 1.5 times the peak value of the RRS at the equipment mounting location, at a conservative and justifiable value of damping.

If the equipment is determined to be flexible (i.e., with the fundamental frequency of the equipment within frequency range of the input spectra) and not simple enough for equivalent static analysis, a dynamic analysis method is applied.

Acceptance Criteria for Qualification by Analysis

The structural and functional integrity of the equipment is maintained under low level earthquake loads including appropriate RBV dynamic loads in combination with normal operating loads. Where applicable, normal operating and SSE loads including appropriate RBV dynamic loads do not result in failure of the equipment to perform its safety-related function(s).

Documentation of Analysis

Qualification results are documented and include, but are not necessarily limited to equipment specification requirements, a summary of qualification results, and justification that the methods used demonstrate that the equipment does not malfunction. See Subsection 3.10.1.4 for additional information on the documentation of qualification results.

3.10.2.3 Qualification by Combined Testing and Analysis

In some instances, it is not practical to qualify the equipment solely by testing or analysis. This may be because of the size of the equipment, its complexity, or the large number of similar configurations. The following subsections address the cases in which combined analysis and testing may be warranted.

Low Impedance Excitation

Large equipment may be impractical to test due to limitations in vibration equipment loading capability. With the equipment mounted to simulate service mounting, a number of exciters are

attached at points that best excite the various modes of vibration of the equipment. Data is obtained from sensors for subsequent analysis of the equipment performance under seismic plus appropriate RBV dynamic loads. The amplification of resonant motion is used to determine the appropriate modal frequency and damping for a dynamic analysis of the equipment.

This method can be used to qualify the equipment by exciting the equipment to levels at least equal to the expected response from the SSE loads including appropriate RBV dynamic loads, by using analysis to justify the excitation, and by utilizing the test data on modal frequencies to verify the mathematical model.

Extrapolation of Similar Equipment

As discussed in IEEE 344, the qualification of complex equipment by analysis is not recommended because of the great difficulty in developing an accurate analytical model.

In many instances, however, similar equipment has already been qualified but with changes in size or in specific qualified devices in a fixed assembly or structure. In such instances, a full test program (Subsection 3.10.2.1) is conducted on a typical piece of equipment. Assurance is obtained that changes from originally tested equipment do not result in the formation of previously non-existent resonances.

If the equipment is not rigid, the effects of the changes are analyzed. The test results combined with the analysis allow the model of the similar equipment to be adjusted to produce a revised stiffness matrix and to allow refinement of the analysis for the modal frequencies of the similar equipment. The result is a verified analytical model that is used to qualify the similar equipment.

Extrapolation of Dynamic Loading Conditions.

Test results can be extrapolated for dynamic loading conditions in excess of or different from previous tests on a piece of equipment when the test results are in sufficient detail to allow an adequate dynamic model of the equipment to be generated. The model provides the capability of predicting failure under the increased or different dynamic load excitation.

Documentation of Combined Testing and Analysis

Qualification results are documented and include, but are not necessarily limited to equipment specification requirements, a summary of qualification results, and justification that the methods used demonstrate that the equipment does not malfunction.

If qualification is by analysis and testing or by extrapolation from similar equipment, the report includes:

- Reference to the specific method of combined analysis and testing used;
- Description of equipment involved;
- Analysis data;
- Test data;
- Justification of results.

When extrapolation of data is made from similar equipment, a description of the differences between the equipment items involved is required. Justification that the differences do not

degrade the seismic adequacy below acceptable limits and any additional supporting data shall be included.

See Subsection 3.10.1.4 for additional information on the documentation of qualification results.

3.10.2.4 (Deleted)

3.10.3 Analysis or Testing of Electrical Equipment Supports

The following subsections describe the general methods and procedures, as incorporated in the dynamic qualification program (see Subsection 3.10.1.3), for analysis and testing of supports of Seismic Category I electrical equipment. When possible, the supports of most of the electrical equipment (other than motor and valve-mounted equipment supports, mostly control panels and racks) are tested with the equipment installed. Otherwise, a dummy is employed to simulate inertial mass effect and dynamic coupling to the support.

Combined stresses of the mechanically designed component supports are maintained within the limits of ASME Code Section III, Division 1, Subsection NF, up to the interface with building structure, and the combined stresses of the structurally designed component supports defined as building structure in the project design specifications are maintained within the limits delineated in Section 3.8.

3.10.3.1 NSSS Electrical Equipment Supports (Other than Motors and Valve-Mounted Equipment)

The seismic and other RBV dynamic load qualification tests on equipment supports are performed over the frequency range of interest.

Some of the supports are qualified by analysis only. Analysis is used for passive mechanical devices and is sometimes used in combination with testing for larger assemblies containing Seismic Category I devices. For instance, a test is run to determine if there are natural frequencies in the support equipment within the critical frequency range. If the support is determined to be free of natural frequencies (in the critical frequency range), then it is assumed to be rigid and a static analysis is performed. If natural frequencies are present in the critical frequency range, then calculations of transmissibility and responses to varying input accelerations are determined to see if Seismic Category I devices mounted in the assembly would operate without malfunctioning. In general, the testing of Seismic Category I supports is accomplished using the following procedure:

Assemblies (e.g., control panels) containing devices which have dynamic load malfunction limits established are tested by mounting the assembly on the table of a vibration machine in the manner it is to be mounted when in use and vibration testing it by running a low-level resonance search. As with the devices, the assemblies are tested in the three major orthogonal axes.

The resonance search is run in the same manner as described for devices. If resonances are present, the transmissibility between the input and the location of each device is determined by measuring the accelerations at each device location and calculating the magnification between it and the input. Once known, the transmissibilities could be used analytically to determine the response at any Seismic Category I device location for any given input. (It is assumed that the

- Dynamic Analysis
- Regardless of cable tray function, all supports are designed to meet Seismic Category I requirements. Seismic and appropriate RBV dynamic loads are determined by dynamic analysis using appropriate response spectra.
- Floor Response Spectra — Floor response spectra used are those generated for the supporting floor. In case supports are attached to the walls or to two different locations, the upper bound envelope spectra are used. In many cases, to facilitate the design, several floor response spectra are combined by an upper bound envelope.

Structural requirements for Conduits and Cable Tray supports are also specified in Subsection 3.8.4.1.6.

Local Instrument Supports

For field-mounted Seismic Category I instruments, the following is applicable:

- The mounting structures for the instruments have a fundamental frequency above the excitation frequency of the RRS.
- The stress level in the mounting structure does not exceed the material allowable stress when the mounting structure is subjected to the maximum acceleration level for its location.

Instrument Tubing Support

The following bases are used in the seismic and appropriate RBV dynamic loads design and analysis of Seismic Category I instrument tubing supports:

- The supports are qualified by the response spectrum method;
- Dynamic load restraint measures and analysis for the supports are based on combined limiting values for static load, span length, and computed dynamic response; and
- The Seismic Category I instrument tubing systems are supported so that the allowable stresses permitted by Section III of ASME Boiler and Pressure Vessel Code are not exceeded when the tubing is subjected to the loads specified in Subsection 3.9.2 for Class 2 and 3 piping.

3.10.3.3 Documentation of Testing or Analysis of Electrical Supports

Qualification results are documented and include, but are not necessarily limited to equipment specification requirements, a summary of qualification results, and justification that the methods used demonstrate that the equipment does not malfunction. If qualification is by analysis, testing or extrapolation from similar equipment, the report includes:

- Reference to the specific method of combined analysis and testing used;
- Description of equipment involved;
- Analysis data;
- Test data;
- Justification of results.

When extrapolation of data is made from similar equipment, a description of the differences between the equipment items involved is required. Justification that the differences do not degrade the seismic adequacy below acceptable limits and any additional supporting data shall be included.

See Subsection 3.10.1.4 for additional information on the documentation of qualification results.

3.10.4 Combined Operating License Information

3.10-1-A Dynamic Qualification Report

The COL applicant will provide a milestone for completing the Dynamic Qualification Report (DQR) per Subsection 3.10.1.4.

3.10.5 References

3.10-1 USNRC, SRP 3.10 Draft 3 (04/1996), "Seismic and Dynamic Qualification of Mechanical and Electrical Equipment."

3.10-2 General Electric Co., "General Electric Environmental Qualification Program," NEDE-24326-1-P, Proprietary Document, January 1983.