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Subject: Duke Energy Carolinas, LLC
Oconee Nuclear Station, Units 1, 2, and 3
Docket Numbers 50-269, 50-270, and 50-287,
Renewed Operating Licenses DPR-38, DPR-47, and DPR-55
Licensing Basis for the Protected Service Water System - Responses to Request for Additional Information - Supplement 4

References:

1. Letter from John Boska, Senior Project Manager, Division of Operating Reactor Licensing, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, to T. Preston Gillespie, Vice President, Oconee Nuclear Station, Duke Energy Carolinas, LLC, "Request for Additional Information (RAI) Regarding the License Amendment Requests (LARs) for the Licensing Basis for the Protected Service Water System," June 11, 2012.
2. Letter from T. Preston Gillespie, Vice President, Oconee Nuclear Station, Duke Energy Carolinas, LLC, to the U.S. Nuclear Regulatory Commission, "Licensing Basis for the Protected Service Water System - Responses to Request for Additional Information," dated July 11, 2012.
3. Letter from T. Preston Gillespie, Vice President, Oconee Nuclear Station, Duke Energy Carolinas, LLC, to the U.S. Nuclear Regulatory Commission, "Licensing Basis for the Protected Service Water System - Responses to Request for Additional Information - Supplement 1," dated July 20, 2012.
4. Letter from T. Preston Gillespie, Vice President, Oconee Nuclear Station, Duke Energy Carolinas, LLC, to the U.S. Nuclear Regulatory Commission, "Licensing Basis for the Protected Service Water System - Responses to Request for Additional Information - Supplement 2," dated August 31, 2012.
5. Letter from T. Preston Gillespie, Vice President, Oconee Nuclear Station, Duke Energy Carolinas, LLC, to the U.S. Nuclear Regulatory Commission, "Licensing Basis for the Protected Service Water System - Responses to Request for Additional Information - Supplement 3," dated November 2, 2012.
6. Emails from John Boska, U.S. NRC, to Stephen C. Newman and Timothy D. Brown, Duke Energy Carolinas, LLC, dated November 2 and 9, 2012.

By letter dated June 11, 2012, Duke Energy Carolinas, LLC (Duke Energy) formally received a Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) (Reference 1) associated with the design and licensing bases for the proposed Protected Service Water (PSW) system. Duke Energy responded to the RAI items by letters dated July 11, July 20, August 31, and November 2, 2012, (References 2, 3, 4, and 5).

In November and December 2012, there were interactions between Duke Energy and the Staff regarding seismic qualification of PSW building and the associated structures, systems and components. As a result, Duke Energy indicated that revised responses to RAI items 139(e), 141, 160 161, and 162, would be provided and the Staff issued new RAI items 168 and 169 via email (Reference 6).

This submittal contains Duke Energy's responses to:

1. RAI items 139(e), 160, 161, and 162 (revision bars indicate changes to the previous responses),
2. A complete rewrite of the response to RAI item 141. The revision supersedes previous responses to this RAI, and
3. Responses to RAI items 168 and 169.

If you have any questions in regard to this letter, please contact Stephen C. Newman, Regulatory Affairs Senior Engineer, Oconee Nuclear Station, at (864) 873-4388.

I declare under penalty of perjury that the foregoing is true and correct. Executed on April 5, 2013.

Sincerely,

Scott L. Batson
Vice President
Oconee Nuclear Station

Enclosure

cc: (w/enclosure)

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Enclosure

Responses to Request for Additional Information
Supplement 4

RAI #139(e)

Add statements that indicate that the PSW piping has been evaluated for potential interactions with nonseismically qualified systems, structures, and components (II over I).

Duke Energy Response:

Duke Energy's July 20, 2012, response to RAI item 139(e) is revised as:

e) Pipe support loads generated by the Oconee Pipe Stress Group calculations OSC-9206, OSC-9512, and OSC-9241 are transmitted to the Support Design Group for further evaluation. The interaction between the piping systems and surrounding supporting structures are assessed in the applicable support calculations. Deflections from the piping stress models are checked for interactions and all clearances less than two inches are evaluated and noted on the pipe support sketches.

Within the PSW Building are two piping systems that are at opposite ends of the building and do not interact with each other. The Eyewash and Firehose piping is designed to withstand seismic loads and their associated pipe supports are designed as safety related supports such that there are no II over I issues. Within the Auxiliary Building is the PSW Pipe Header. This pipe and its associated supports are designated as safety related and are designed to withstand seismic loads. Interaction of these piping systems with non-seismic systems has been identified by Seismic II/I walkdowns in accordance with Duke Piping Design Criteria PDC-120 Non-Seismic Interactions. Where non-seismic systems, structures and components (SSC's) were identified as potentially interacting with the safety related piping, the safety related piping was re-routed to avoid this interference. When it was not possible to re-route the safety related piping, the interfering SSC has been relocated.

RAI #141

According to the licensee's letter dated March 16, 2012, the ONS UFSAR mark-up included Section 9.7.1.2.5.1 which states the following:

"The design response spectra for the new structures correspond to the expected maximum bedrock acceleration of 0.1g (MHE). The design response spectra were developed in accordance with Regulatory Guide 1.122 (Reference 15). The dynamic analysis is made using the STAAD-PRO computer program. The structure is built on structural fill. A ground motion time history was developed based on the soil properties and amplified response spectra generated at elevations of significant nodal mass."

Provide the following:

a) Considering that the PSW building is described as founded on the structural fill, provide a detailed description of rock motion, anchoring point for the input motion, and material properties of soil profile(s) overlaying bedrock (thickness, shear wave velocity, and other relevant material properties. Also, discuss the response amplification calculation process that was used to determine the free-field horizontal and vertical ground motion at the PSW building.
b) Provide a detailed description of the procedures used for the seismic analysis of the PSW building and to develop the in-structure response spectra (floor design response spectra). If different from the methods and acceptance criteria outlined in the NRC standard review plan (SRP) 3.7.1 and 3.7.2, identify those differences and provide justification that the PSW building is adequately designed, using these alternative methods, to withstand the effects of earthquake loads.
c) Confirm and provide further information that STAAD-PRO and all features of this software related to the dynamic response analysis and static analysis have been verified and validated by its provider in compliance with 10 CFR Part 50, Appendix 8 and 10 CFR Part 21. Also, provide documentation, which demonstrates that the software provider has been audited and approved as an Appendix 8 supplier
d) Describe the method of combination of modal responses and spatial components used in the PSW building seismic response analysis. If different from the methods outlined in the NRC Regulatory Guide (RG) 1.92, identify those differences and discuss how these alternative methods provide assurance that the PSW building is adequately designed to withstand the effects of earthquake loads.

Duke Energy Response:

This revised response supersedes in its entirety the response to NRC Request for Additional Information (RAI) 141 [EMCB6] submitted via Duke Energy Letters dated July 20, 2012 and November 02, 2012.

Seismic analyses supporting this RAI response comply with guidance provided in SRP 3.7.1, Rev. 3 and SRP 3.7.2, Rev. 3 except as noted in Tables 141-5 and 141-6. Tables 141-5 and 141-6 also provide the justification for non-compliance with the SRP guidance, where applicable.

a) Input Design Response Spectra and Time Histories

Protected Service Water (PSW) building is founded on subgrade. For the PSW building design, the Maximum Hypothetical Earthquake (MHE) response spectra presented in Updated Final Safety Analysis Report (UFSAR) Figure 2-55, "Recommended Response Spectra" was used, consistent with Oconee Nuclear Station (ONS) licensing basis (UFSAR Section 3.7.1.1 "Design Response Spectra"). For the PSW building MHE In-structure response spectra (ISRS) generation, the time history record of the North-South (N-S), May 1940 El Centro earthquake normalized to a peak acceleration of 0.15g was used as the input ground motion for both the vertical and horizontal excitation consistent with the ONS licensing basis (UFSAR Section 3.7.1.2 "Design Time History"). The 5% damped response spectra of the North-South (N-S), May 1940 El Centro earthquake normalized to a peak acceleration of 0.15g essentially envelopes the design response spectra of UFSAR Figures 2-55 as shown in Figure 141-1 considering that the lowest fundamental frequency of the PSW building models is 6.23 Hz. (Tables 141-7 to 141-10).

The Design Basis Earthquake (DBE) ground response spectra and ground motion time history peak ground acceleration (PGA) are 50% of the MHE response spectra and ground motion time history PGA. ONS MHE is equivalent to the Safe Shutdown Earthquake (SSE) and ONS DBE is equivalent to the Operating Basis Earthquake (OBE) in today's terminology.

The use of 0.15g PGA response spectra presented in the UFSAR Figure 2-55 for the PSW building is consistent with that used for design of CT4 Block House, the only other Class 1 ONS structure founded on subgrade.

The subsurface materials underlying the PSW building location, as well as adjacent areas of the ONS site, have been investigated and are well understood. Direct soil borings and geophysical testing were performed in 2007 in support of the PSW building site evaluation. Subsurface conditions encountered in the geotechnical investigations of the PSW building site were consistent with those for the Radwaste building and are compatible with information in the UFSAR from the original ONS geotechnical investigations. Thus, the geotechnical investigations for the PSW building site satisfies the purpose and goals of Regulatory Guide 1.132 and the PSW building site is considered to be "well investigated."

Under the PSW building, structural fill constitutes the upper 23 feet of the soil profile. Beneath the fill, the soil profile gradually transitions into rock. Bedrock was established at a depth of 80 feet below the existing ground surface. Shear wave velocity (V_s) values for the subsurface materials underlying the PSW building were calculated from Seismic Cone Penetrometer Testing (SCPT) and Refraction Microtremor (ReMi) testing, together with the information provided from direct soil boring performed for the PSW building design. This information was supplemented by data obtained from the Cross-Hole Velocity (CHV) testing and soil borings performed in 1981 for the adjacent Radwaste building. The soil properties and the soil/rock profile used in the 1-dimensional (1-D) site response analysis are shown in Table 141-1. The Table presents the soil unit weights, the best estimate (BE) low strain (10^{-4} percent) shear modulus (G), the Poisson's ratio, and the low strain BE, the lower bound (LB), and the upper bound (UB) shear wave velocities (V_s) for the soil profile under the PSW building. The ReMi data was used to characterize the PSW building subsurface soil profile to rock. The V_s measured in the ReMi survey were taken to be the BE shear wave velocities because the ReMi survey yields shear wave velocities averaged

over the length of the survey line and the ReMi survey line encompassed the length of the PSW building. The BE shear modulus values were calculated from the corresponding BE shear wave velocities. The LB and the UB shear modulus values obtained using an assigned coefficient of variation (COV) of 0.5 were used to calculate the low strain LB and UB shear wave velocities, respectively. Figure 141-17 presents the values of shear wave velocities versus depth for the PSW building site. As shown in Figure 141-17, the shear wave velocities values obtained from independent geophysical tests are consistent, and the LB and UB values of shear wave velocities reasonably bracket the values of shear wave velocities calculated from the various measurements (ReMi, SCPT, and CHV). For this reason, the use of a COV value of 0.5 for shear modulus is justified.

One-dimensional site response analyses were performed using SHAKE2000, "A Computer Program for 1D Analysis of Geotechnical Earthquake Engineering Problems," (Sargent & Lundy Program 03.7.402-3.50) to obtain strain compatible soil properties for the 0.15g MHE ground motion using low strain soil properties in Table 141-1 and strain dependent modulus reduction and damping coefficients from Idriss (1990). Water Table at elevation 752 feet was used in the site response analyses. These strain compatible soil properties obtained from the SHAKE2000 V3.5 site response analyses are shown in Tables 141-2, 141-3, and 141-4 for the LB, BE, and UB soil properties, respectively.

The PSW seismic design inputs are as specified in the ONS UFSAR Sections 2.5.2 and 3.7.1. Table 141-5 presents the compliance of the seismic design inputs used for the PSW building seismic evaluations with guidance provided in SRP Section 3.7.1 Revision 3. The PSW building seismic design inputs are compliant with the ONS UFSAR and, in general, different from those in the current SRP guidance.

The use of the 0.15g MHE ground motions in ONS UFSAR for the PSW building response analysis is at variance with that described in the July 20, 2012 RAI 141 response. The July 20, 2012 response to RAI 141 described the development of the MHE surface horizontal response spectra through a 1-D site response analysis. The vertical surface response spectrum was scaled from the horizontal surface response spectra. For the 1-D site response analysis, the recorded N-S, May 1940 El Centro earthquake time history normalized to 0.1g was used as rock outcrop motion 80 ft. below ground surface. This method for developing the MHE surface response spectra shape is not appropriate for the PSW site because the N-S, May 1940 El Centro earthquake motion is a surface motion recorded at a firm soil site (United States Geological Survey (USGS) Site Classification C 180-360 meters/second [590-1180 feet/second] Shear wave velocity). Top of rock under the PSW building is 80 ft. below the ground surface. Use of the N-S, May 1940 El Centro earthquake time history as the rock outcrop motion to develop MHE surface motion is not appropriate because it has effectively amplified the soil motions twice – once in the original El Centro recorded time history and second in the 1-D site response analysis performed to develop the PSW building horizontal and vertical MHE ground design response spectra.

b) Seismic Design Procedures for PSW Building Design and ISRS Generation

The PSW building design has been reevaluated for this revised response to NRC RAI 141 [EMCB6]. For this reevaluation, reanalysis of the PSW building has been performed using the "as built" configuration. For the reanalysis, the response spectra method of analysis was used to determine maximum design forces of various structural components of the PSW building and maximum foundation soil bearing pressures. The response spectra specified in ONS UFSAR Figure 2-55 for structures on subgrade was used as the MHE

foundation input spectra in the seismic analysis for PSW building design as noted in paragraph a) above.

For PSW building ISRS generation, the time history method of analysis was used to develop absolute acceleration time histories at the various nodes where equipment is located. The ground motion input (El Centro N-S 1940 time history normalized to 0.15g) for the time history response analysis is described in paragraph a) above.

For both the building design and ISRS generation, the PSW building model and analysis parameters were as follows:

i) The PSW building is a reinforced concrete structure approximately 124 feet long by 33 feet wide. The total building height is about 30 feet (7.75 feet is below grade). The building consists of concrete and steel grating floors, a concrete roof, concrete shear walls, and interconnected multiple concrete spread footings. The roof is supported by the exterior walls. The concrete slabs are supported by concrete walls and beams around their perimeters. The steel grating is supported on steel floor framing members spanning between exterior and interior walls with the main steel girders supported at their mid spans by steel columns. All walls and steel columns are supported directly on reinforced concrete spread footings. The battery room foundation on the South end of the building is a slab on grade. The center wall is supported directly on a spread footing approximately 2 feet below grade. All exterior walls are supported on spread footings at elevation 789'-3" (7.75 feet below grade). All spread footings are 24 inches thick and were cast monolithically or with intentionally roughened joints and continuous reinforcement. The east exterior wall footing is supported on concrete fill that extends below the adjacent CCW pipes. The spread footing of the remaining walls and the battery room foundation slab are founded on compacted structural fill. Drawings O-398-A2-101 Rev. D, O-398-A2-102 Rev. N, O-398-A3-401 Rev. C, and O-398-A3-403 Rev. D show the details of the PSW building and its foundation. These drawings are accessible through the Duke Energy's Share Point system.

ii) The structure was analyzed using a three dimensional (3-D) Finite Element (FE) model representing the superstructure and the foundations. The concrete elements were modeled using 4-noded thin plate (shell) elements with 6 degrees of freedom (DOF)/node. The steel elements were modeled using 2-node beam elements with 6 DOF/node. Figure 141-2 shows the FEM model used for the seismic analysis of the PSW building. In this figure, the building shell elements are shown in blue. The black circles are member end moment releases at the end of beam elements. The shell elements for the two entry ways and the Battery Room wall foundation are shown in red.

iii) Nodal mass included contributing mass from static loads on the structure. For the mass calculations, 100% of the dead (permanent) loads (e.g., weight of structure and equipment), 50 psf for minor equipment/piping/raceways, 25% of the floor live (short term) loads (e.g., general live load), and 75% of the roof snow load were considered. The equipment mass was lumped at the location of the equipment. The mass of cable tray, HVAC ducts, and piping and their supports were modeled as distributed mass on floors and walls.

iv) The PSW building model described above was used for the seismic response analysis with two sets of boundary conditions to model the PSW building foundation. The first was a fixed base model where the foundation nodes were fixed consistent with the current seismic design basis (CDB) of other ONS Class I structures. The second was a confirmatory model that used Lumped Soil Springs (LSS) to model soil structure interaction (SSI) effects.

For the CDB model, all the foundation nodes at elevation 789'-3" are fixed in all six degrees of freedom. For the entry ways and Battery Room wall foundation at elevation 797' (shown in red in Figure 141-2), springs to approximately model the elastic restraint provided to these small foundations by the soil under the foundations at elevation 797' were used. Vertical and horizontal soil spring constants were calculated using the ASCE 4-98 Section 3.3.4.2.2 formulation. Fixed boundary condition for the battery room wall and entry way foundation was not used because if the entry way and Battery Room wall foundation nodes at elevation 797' are fixed, the response for the operating floor at elevation 797', where most of the equipment is located, will be nonconservative (same as the input ground motion). In addition, the fixed boundary condition will force the majority of lateral load from the operating floor to be resisted by the fixed nodes of the small entry way foundation (approximately 9'x11'). This would not be representative of the "designed" load path where the majority of the operating floor inertia (seismic) loads will be transferred to the building foundation at elevation 789'-3" through supporting shear walls during a seismic event. Free boundary condition at the entry way and Battery Room wall foundation nodes at elevation 797' would result in the entry way structure and Battery Room wall inertia loads transferred to the PSW walls or the Battery Room roof respectively. This also is not representative of the "designed" load path where the inertia loads from the entry way and the Battery Room wall will be partially transferred to the respective foundations at elevation 797'. The modal frequencies and participation factors for the CDB model are presented in Table 141-7. The CDB model mode shape for mode 1 (predominant Z-direction mode), mode 2 (predominant Y-direction mode), mode 72 (first dominant X-direction mode) are presented in Figures 141-3, 141-4, and 141-5, respectively.

For the LSS models, Tables 141-2, 141-3, and 141-4 soil profile and strain compatible soil properties were used to calculate the LB, BE, and UB LSS parameters for the PSW building response analysis. The methodology detailed in Christiano (1974) was followed to compute the equivalent shear modulus for the layered soil profile under the PSW foundation. In this procedure, average shear modulus value is developed whereby each layer is weighted in accordance with the strain energy in that layer. This method quantifies the diminishing effect of the soil layers on the overall impedance of the foundation soil with increasing depths from the bottom of the foundation. The soil spring parameters (spring constant and damping) were computed based on the formulation in ASCE 4-98 Section 3.3.4.2.2 using the equivalent shear modulus for the layered soil profile. The PSW building foundation consists of interconnected multiple strip footings. The box shaped monolithic N-S and E-W shear walls supported on these strip footings provide the rigidity to the foundation for all the horizontal, vertical, rocking, and torsional degrees of freedom. The LSS vertical and horizontal springs and dampings were computed for the various strips of PSW building foundations. In the 3-D FEM

model, these vertical and horizontal springs also provide the equivalent rocking and torsional lumped soil spring parameters consistent with the spatial distribution of the foundation strips. The modal frequencies and participation factors for the LSS BE, LB, and UB models are presented in Tables 141-8, 141-9, and 141-10, respectively. The LSS BE model mode shapes for mode 1 (predominant Z-direction mode), mode 2 (predominant Y-direction mode), mode 19 (predominant X-direction mode) are presented in Figures 141-6, 141-7, and 141-8, respectively.

v) Consistent with ONS UFSAR Section 3.7.1.3, 2% damping for steel elements and 5% damping for reinforced concrete elements were used for MHE. The 2% steel and 5% concrete MHE damping values are lower (conservative) when compared to the 4% steel and 7% concrete SSE dampings specified in Regulatory Guide 1.61. Composite modal damping (stiffness proportional) was used for both the CDB (steel and concrete) and LSS (steel, concrete, and soil) response analyses. However, for the LSS response analysis, if the calculated composite modal damping exceeded 20% for any mode, the LSS soil spring damping was reduced so that composite modal dampings for all modes were less than or equal to 20% as required by the SRP. No material damping for soil was considered. Table 141-6 notes the compliance of damping values used for the PSW building analysis. Except for the 5% damping for concrete elements for DBE, all other damping values either comply or are conservative when compared to the SRP 3.7.2 guidance. For ONS, the DBE corresponds to the present day OBE.

vi) Consistent with CDB seismic analysis of all ONS safety related structures, un-cracked concrete properties were used for the seismic analysis of the PSW building for the CDB and LSS models. Cracked concrete properties were not used.

vii) For the CDB time history response analysis for ISRS development, 100 modes (up to 42 Hz.) were considered. The modal frequencies, participation factors, and the total participating mass in the X-, Y-, and Z-directions for the CDB model are presented in Table 141-7. For the CDB response spectra analysis, for shear force calculation, 59 modes (up to 24 Hz.) together with the effect of the missing mass was considered to account for 100% of the total system mass in the three orthogonal directions [X (N-S), Y (Vertical), and Z (E-W)]. The 24 Hz frequency corresponds to the rigid frequency of the input ground response spectra (UFSAR Figure 2-55). For the CDB response spectra analysis, for moment calculations, a large number of modes (771 modes) accounting for 96% of the X-directional mass, 90% of the Y-directional mass, and 96% of the Z-directional mass were considered because for moment calculations STAAD-PRO 2007 V8i software does not have the capability to account for the missing mass.

For the LSS response analysis (both response spectra and time history), sufficient number of modes were considered (61 modes for LB, 76 modes for BE, and 107 modes for UB) to account for at least 95% of the total system mass in each of the three orthogonal directions [X (N-S), Y (Vertical), and Z (E-W)]. The modal frequencies, participation factors, and the total participating mass in the X-, Y-, and Z- directions for the LSS BE, LB, and UB model are presented in Tables 141-8, 141-9, and 141-10, respectively.

The PSW building seismic forces and moments from the CDB and the LSS response spectra analyses were used to evaluate the adequacy of the PSW

building seismic design (shear walls, slabs, steel framing, column, etc.). Accidental torsion (an eccentricity of ±5% of the maximum building dimension per SRP 3.7.2) was considered in the PSW building design. The PSW finite element model used for CDB and LSS response analysis accurately models the inherent eccentricity of the PSW structure layout. In addition, all significant equipment masses were modeled at their physical locations within the building.

viii) The CDB and the LSS models seismic foundation bearing pressures meet the minimum factor of safety (FOS) of 3.0 for static loading and FOS of 2.25 for static plus MHE seismic loading. There is no foundation uplift due to the MHE seismic loading.

ix) The PSW building FOS against sliding and overturning meet the minimum required FOS of 1.1 for MHE or Tornado loading. The PSW building MHE base forces and moments are shown in Table 141-11.

x) The ISRS generation complies with RG 1.122 guidance relative to the frequency intervals for ISRS generation and ISRS peak widening. For developing the PSW building ISRS, the nodal accelerations time histories were developed for the X-, Y-, and Z-excitations individually for 19 selected locations in the PSW building. The selected locations included the location of major equipment, centers and corners of operating floor and roof slabs, and centers of exterior walls panel. At each of the 19 selected locations, each of the X-, Y-, and Z- direction excitation yields three (X-, Y-, and Z- directions) response time histories. Unwidened response spectra were developed for these 9 time histories at each of the 19 selected nodes and combined to generate the X-, Y-, and Z-directional ISRS at each node using the combination method described in paragraph d) below. The X-, Y-, and Z-directional ISRS at each of the 19 nodes were then widened ±15% on the frequency scale. The frequencies for ISRS generation included structural modal frequencies in addition to the frequencies based on Table 1 of RG 1.122. However, periods (1/frequency) closer than 0.0007 seconds were eliminated from the combined RG 1.122 and structural frequencies list. This elimination of extremely close periods has practically no effect on the widened (±15%) ISRS used for equipment qualification. ISRS were developed for all applicable damping values for equipment and support qualifications as specified in UFSAR Section 3.7.1.3.

The ISRS were developed for both the CDB and LSS analyses at the 19 selected nodes as describe above. In addition, the ISRS for all nodes on the operating floor, battery room roof, PSW building roof, and exterior walls were enveloped to develop enveloped ISRS for the operating floor, the battery room floor, the PSW roof, and the exterior walls, respectively. Finally, the enveloped ISRS for the operating floor, the battery room roof, the PSW building roof, and the exterior walls from the CDB and the LSS analyses were enveloped. These enveloped CDB and LSS horizontal and vertical ISRS for the operating floor, the battery room roof, the PSW roof, and the exterior walls are shown in Figures 141-9 through 141-16, respectively. The horizontal ISRS in these figures are the envelope of the X- and Z- direction ISRS.

The DBE ISRS are one-half (1/2) of the corresponding MHE ISRS. This is justified because the percent of critical damping for steel and concrete structural elements are the same for MHE and DBE (UFSAR section 3.7.1.3) and the design ground

motion for DBE is one-half of the MHE ground motion (UFSAR sections 3.7.1.1 and 3.7.1.2).

xi) The seismic II/I interaction between the PSW building and adjacent structures was addressed in RAI 148. No additional information was developed in response to this RAI.

c) Duke Energy contracted Sargent & Lundy (S&L) to perform the PSW building seismic response analysis and ISRS development as a safety related scope to be performed under the S&L QA Program. S&L QA program complies with 10 CFR Part 50 Appendix B and 10 CFR Part 21 requirements and has been approved by the NRC (Accession No. ML090750737, ML090750638, and ML12142A195). S&L QA program is audited by NUPIC as a matter of course. Duke Energy subscribes to NUPIC audits. The S&L QA Program and Standard Operating Procedure (SOP)-204 implementation has also been audited by the NRC on past S&L projects (example: South Texas Project, Units 3 and 4 Combined Operating License Application, Docket Number 52-12 and 52-13).

For the PSW building seismic analysis and ISRS development STAAD-PRO 2007 V8i (S&L Program No. 03.7.745-7.4) and RSG V2.0, "Response Spectra Generator" (S&L Program No. 03.7.414-2.0) software were used (OSC-9230). For the 1-D site response analysis SHAKE2000 V3.5, "A Computer Program for 1D Analysis of Geotechnical Earthquake Engineering Problems" (S&L Program 03.7.402-3.50) was used. STAAD-PRO 2007 V8i, RSG V2.0, and SHAKE2000 V3.5 software have been validated in accordance with Sargent & Lundy SOP-0204. SOP-0204 governs all software validation and verification (V&V) at S&L and is the implementing procedure for the S&L NQA-1 1994 compliant Nuclear QA Program. S&L has validated STAAD-PRO 2007 V8i for development of the ISRS using the time history method of analysis. S&L has also validated the STAAD-PRO 2007 V8i response spectra method of analysis to calculate element forces and base forces when modal response combinations are performed using the complete quadratic combination (CQC) method.

STAAD-PRO 2007 V8i software was used for the PSW building finite element modeling and seismic analyses. The PSW ISRS were developed using the time history method of analysis. The PSW building element design forces were developed using the response spectra method of analysis. The CQC method was used to combine modal responses when the response spectra method was used.

The RSG V2.0 software was used for ISRS generation from time history responses at selected nodes of the PSW building model. RSG V2.0 software has been validated for response spectra generation from acceleration time histories and to combine the ISRS using the absolute sum or the SRSS method.

SHAKE2000 V3.5 software was used for 1-D site response analysis to compute strain compatible soil properties for the 0.15g MHE ground motions.

d) For the response spectra method of analysis (used for the PSW building design), the responses were calculated for the X-, Y-, and Z- excitations individually. The modal responses for these individual analyses were combined using the complete quadratic combination (CQC) method in accordance with Regulatory Guide (RG) 1.92, Section C.1.1.

For the time history analysis (used for developing the PSW building ISRS), the response was calculated for the X-, Y-, and Z- excitations individually. The modal responses for these individual time history analyses were combined algebraically at each time step.

The co-directional responses (maximum element forces and ISRS at selected nodes) from the individual X-, Y-, and Z- direction excitation analysis (using the response spectra method or the time history method) were summed using absolute sum rule to obtain the summed X-component, Y-component, and Z- component of the design responses (maximum element forces and ISRS at selected nodes) as follows:

$$R_X = (R_{XX} + R_{XY} + R_{XZ})$$
$$R_Y = (R_{YX} + R_{YY} + R_{YZ})$$
$$R_Z = (R_{ZX} + R_{ZY} + R_{ZZ})$$

Where:

R_X = summed X-component of the design response (maximum element force or unwidened ISRS at the selected node)
R_Y = summed Y-component of the design response (maximum element force or unwidened ISRS at the selected node)
R_Z = summed Z-component the design response (maximum element force or unwidened ISRS at the selected node)
R_{XX} = X-component of design response (maximum element force or unwidened ISRS at the selected node) due to X-excitation
R_{XY} = X-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Y-excitation
R_{XZ} = X-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Z-excitation
R_{YX} = Y-component of the design response (maximum element force or unwidened ISRS at the selected node) due to X-excitation
R_{YY} = Y-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Y-excitation
R_{YZ} = Y-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Z-excitation
R_{ZX} = Z-component of the design response (maximum element force or unwidened ISRS at the selected node) due to X-excitation
R_{ZY} = Z-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Y-excitation
R_{ZZ} = Z-component of the design response (maximum element force or unwidened ISRS at the selected node) due to Z-excitation

ONS is a two-directional earthquake motion plant according to ONS UFSAR, Section 3.7.2.5. All ONS structures, systems, and components (SSCs) were designed for the two-directional earthquake with the exception of the SSCs for the Standby Shutdown Facility (SSF) where the three spatial components of the earthquakes were combined using the square root of the sum of the squares (SRSS) rule. Therefore, the PSW SSCs are designed/qualified for the two-directional earthquake using the absolute sum combination, i.e., maximum of the absolute sum of (R_x plus R_Y) or (R_Z plus R_Y).

Table 141-1: PSW Soil Profile and Low Strain (10^{-4} percent) Soil Properties								
Layer Name	**Depth (ft)**	**Elevation (ft)**	**Unit Weight (pcf)**	**BE V_S (fps)**	**Poisson's Ratio**	**BE G (ksf)**	**LB V_S (fps)**	**UB V_S (fps)**
Fill	0 - 16	Surface - 779	121	897	0.30	3024	732	1099
	16 - 23	779 - 772	122	897	0.30	3049	732	1099
Residual Soil	23 - 43	772 - 752	125	1042	0.40	4215	851	1276
	43 - 51	752 - 744	127	1042	0.40	4282	851	1276
Partially Weathered Rock	51 - 65	744 - 730	135	1674	0.40	11749	1367	2050
Weathered Rock	65 - 75	730 - 720	160	2559	0.40	32539	2089	3134
Transitional Rock	75 - 80	720 - 715	170	4659	0.40	114598	3804	5706
Rock	80+	<715	170	6942	0.40	254426	5668	8502

Legend:

BE = Best Estimate
LB = Lower Bound
UB = Upper Bound

ft = feet
pcf = pounds per cubic foot
fps = feet per second

ksf = kips per square foot
V_S = Shear Wave Velocity
G = Shear Modulus

Table 141-2: Lower Bound Strain Compatible Soil Properties for Input Motion at Ground Surface with ZPA 0.15 g								
Layer Name	**Layer Thickness (ft)**	**Depth (ft)**	**Elevation (ft)**	**Unit Weight (pcf)**	**Poisson's Ratio**	**Shear Modulus (ksf)**	**Shear Wave Velocity (fps)**	**Damping Ratio**
Fill	5.0	0 - 5	Surface - 790	121	0.30	1971	724	0.01
	5.0	5 - 10	790 - 785	121	0.30	1847	701	0.018
	6.0	10 -16	785 - 779	121	0.30	1739	680	0.026
	7.0	16 - 23	779 - 772	122	0.30	1604	651	0.033
Residual Soil	6.0	23 - 29	772 - 766	125	0.40	2259	763	0.032
	6.0	29 - 35	766 - 760	125	0.40	2123	740	0.037
	8.0	35 - 43	760 - 752	125	0.40	1990	716	0.041
	8.0	43 - 51	752 - 744	127	0.40	1909	696	0.047
Partially Weathered Rock	7.0	51 - 58	744 - 737	135	0.40	6830	1276	0.025
	7.0	58 - 65	737 - 730	135	0.40	6742	1268	0.026
Weathered Rock	10.0	65 - 75	730 - 720	160	0.40	20646	2038	0.015
Transitional Rock	5.0	75 - 80	720 - 715	170	0.40	75648	3785	0.008

Legend:

ft = feet
pcf = pounds per cubic foot
fps = feet per second
ksf = kips per square foot

Table 141-3: Best Estimate Strain Compatible Soil Properties for Input Motion at Ground Surface with ZPA 0.15 g

Layer Name	Layer Thickness (ft)	Depth (ft)	Elevation (ft)	Unit Weight (pcf)	Poisson's Ratio	Shear Modulus (ksf)	Shear Wave Velocity (fps)	Damping Ratio
Fill	5.0	0 - 5	Surface - 790	121	0.30	2994	893	0.008
	5.0	5 - 10	790 - 785	121	0.30	2897	878	0.014
	6.0	10 -16	785 - 779	121	0.30	2733	853	0.019
	7.0	16 - 23	779 - 772	122	0.30	2639	835	0.025
Residual Soil	6.0	23 - 29	772 - 766	125	0.40	3670	972	0.025
	6.0	29 - 35	766 - 760	125	0.40	3585	961	0.028
	8.0	35 - 43	760 - 752	125	0.40	3395	935	0.032
	8.0	43 - 51	752 - 744	127	0.40	3280	912	0.036
Partially Weathered Rock	7.0	51 - 58	744 - 737	135	0.40	10630	1592	0.019
	7.0	58 - 65	737 - 730	135	0.40	10496	1582	0.021
Weathered Rock	10.0	65 - 75	730 - 720	160	0.40	31462	2516	0.012
Transitional Rock	5.0	75 - 80	720 - 715	170	0.40	113798	4643	0.007

Legend:

ft = feet
pcf = pounds per cubic foot
fps = feet per second
ksf = kips per square foot

Table 141-4: Upper Bound Strain Compatible Soil Properties for Input Motion at Ground Surface with ZPA 0.15 g								
Layer Name	**Layer Thickness (ft)**	**Depth (ft)**	**Elevation (ft)**	**Unit Weight (pcf)**	**Poisson's Ratio**	**Shear Modulus (ksf)**	**Shear Wave Velocity (fps)**	**Damping Ratio**
Fill	5.0	0 - 5	Surface - 790	121	0.30	4510	1096	0.006
	5.0	5 - 10	790 - 785	121	0.30	4406	1083	0.011
	6.0	10 -16	785 - 779	121	0.30	4287	1068	0.015
	7.0	16 - 23	779 - 772	122	0.30	4146	1046	0.019
Residual Soil	6.0	23 - 29	772 - 766	125	0.40	5760	1218	0.018
	6.0	29 - 35	766 - 760	125	0.40	5627	1204	0.022
	8.0	35 - 43	760 - 752	125	0.40	5505	1191	0.025
	8.0	43 - 51	752 - 744	127	0.40	5489	1180	0.027
Partially Weathered Rock	7.0	51 - 58	744 - 737	135	0.40	16625	1991	0.015
	7.0	58 - 65	737 - 730	135	0.40	16412	1979	0.016
Weathered Rock	10.0	65 - 75	730 - 720	160	0.40	47676	3098	0.01
Transitional Rock	5.0	75 - 80	720 - 715	170	0.40	171192	5694	0.005

Legend:

ft = feet
pcf = pounds per cubic foot
fps = feet per second
ksf = kips per square foot

Table 141-5 : SRP 3.7.1 COMPLIANCE MATRIX					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Design Ground Motion	**I.1**	**II.1**	The design ground motion for OBE and SSE should be consistent with the description of the free field ground motion at the site as provided in SRP Section 2.5.2.	N/A	Seismic design ground motions are specified in Oconee UFSAR, Section 3.7. ONS licensing predates NRC SRP.
Design Response Spectra	**I.1.A**	**II.1.A**	GMRS are determined in the free field on the ground surface.	N/A	Seismic design Response Spectra used are as specified in Oconee UFSAR (Section 3.7.1.1 and Figure 2-55).
			For soil sites excavated to expose competent material (1000 fps shear wave velocity), GMRS is specified on an outcrop or a hypothetical outcrop after excavation.	N/A	
			Motions at the hypothetical outcrop should be developed as free surface motions.	N/A	
			Minimum required response spectra specified as an outcrop at the free field with PGA for horizontal component of 0.1g or higher.	N/A	
Design Time Histories	**I.1.B**	**II.1.B**	Real time Histories or artificial time histories.	Yes	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-5 : SRP 3.7.1 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Design Time Histories	**I.1.B**	**II.1.B**	Three mutually orthogonal directions shown to be statistically independent (correlation between a pair does not exceed 0.16).	Yes	
			For linear structural analyses, the duration of artificial time histories should be long enough to include Fourrier components at low frequency (SRP Section 2.5.2)	Yes	
			For single time history analyses, the response spectra generated from the artificial time history at the free field envelop the free field design response spectra.	Yes	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-5 : SRP 3.7.1 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Percentage of Critical Damping Values	**I.2**	**II.2**	Consistent with RG 1.61.	No	Except for the 5% damping for concrete elements for DBE, all other damping values either comply or are conservative when compared to the SRP 3.7.2 guidance. The damping used are consistent with ONS UFSAR Section 3.7.1.3.
			Maximum soil damping value is 15 percent.	Yes	
Supporting Media for Seismic Category I Structures	**I.3**	**II.3**	Adequate description of soil media, foundation, structure and soil properties.	Yes	
Review Considerations for DC and COL Applications	**I.4**	**II.4**		N/A	
Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)	**I.5**	**II.5**		N/A	
COL Action Items and Certification Requirements and Restrictions	**I.6**	**II.6**		N/A	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Seismic Analyses Methods	**I.1**	**II.1**	Use suitable dynamic analyses that account for the effects of SSI and considers the torsional, rocking, and translational responses of the structures.	Yes	
			Seismic analyses should be performed for three orthogonal directions of earthquake with all modes with frequencies less than ZPA represented in the dynamic solution.	Yes	
			High frequency modes should be included in the dynamic solution in accordance with RG 1.92 Revision 2.	Yes	
			Dynamic analyses should consider relative displacements between adjacent supports of seismic category I SSCs.	N/A	No significant displacements between adjacent supports of seismic category I structures.
			Dynamic analyses should include significant effects such as piping interactions, externally applied structural restraints, hydrodynamic loads, and non-linear responses.	N/A	No significant effects of piping interactions, externally applied structural restraints, hydrodynamic loads, and non-linear response.
Natural Frequencies and Responses	**I.2**	**II.2**	Dynamic analyses should provide a summary of modal masses, effective masses, natural frequencies, mode shapes, modal and total responses.	Yes	
			Dynamic analyses should include the calculated time histories or response spectra used in design, at the major plant equipment elevations and point of support.	Yes	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Procedures Used for Analytical Modeling	I.3	II.3	The analytical models should represent the adequate stiffness, mass, and damping characteristics of the structural systems. Three dimensional finite element models should be used in general and should consider local regions of the structure such as walls and slabs.	Yes	
			Mesh size should be selected on the basis that further refinement has only negligible effect on the solution results.	No	Refined mesh size used is 2' x 2' and meets or exceeds ASCE 4-09 requirements (Commentary Section C3.1.3.2).
			The analytical models should adequately represent the seismic systems and sub-systems and use the de-coupling criteria in accordance with SRP Section II.3.B.	Yes	
			In addition to structural mass and equipment, 50 psf for minor equipment/piping/raceways, 25% of floor design live load, and 75% of roof design snow load if applicable should be included in the analytical models.	Yes	
			A methodology is needed to transfer the seismic response loads from the dynamic models to the structural models that will be used for detailed design.	Yes	
Soil-Structure Interaction	I.4	II.4	For SSI analyses should consider:		
			1- Effect of embedment of structure	No	PSW building has a shallow foundation. Embedment less than 8 feet. Emb. SSI effects are small.

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Soil-Structure Interaction	**I.4**	**II.4**	2- Ground water effects	No	Variation of water table was not considered in the site response analyses (water table at EL. 752' used in site response analysis). Since the analyses cover fixed base, LB, BE, and UB soil profiles, the effect of the water table are implicitly included in the analyses from the wide range of soil profiles considered.
			3- Layering effects of soil media	Yes	
			Soil spring and the compliance function methods are acceptable provided that frequency variations and layering effects are incorporated.	Yes	
			The mesh size should be adequate for representing the static stress distribution under the foundation and transmitting the frequency content of interest.	N/A	Soil spring method was used.

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	Section Number	SRP Acceptance Criteria	SRP Requirements	Comply with SRP Requirements	Justification for the Exception
Soil-Structure Interaction	I.4	II.4	For deep soil sites, model depth should be at least twice the base dimension below the foundation level. The frequency of the soil should be well below the structural frequencies of interest. All structural modes of interest should be included.	N/A	Oconee is not a deep soil site (80 feet deep soil to bedrock and approximately 8 feet building embedment).
			The soil properties used should be consistent with soil strains developed in free field site response analyses.	Yes	
			Fixed based analyses are acceptable for structures founded on material with minimum shear wave velocity of 8000 fps.	N/A	PSW building is founded on soil subgrade. Calculation includes both fixed base and Lumped Soil Spring (LSS) analyses. Fixed base analysis is the UFSAR licensing basis.
			At least 3 soil/rock profiles should be used: BE, LB, UB	Yes	
			LB shear modulus should not be less than value that yields foundation settlement under static loads exceeding design allowables.	Yes	
			UB shear modulus should not be less than the BE value defined at low strain and as determined from the geophysical testing program.	Yes	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Soil-Structure Interaction	I.4	II.4	For well investigated sites (RG 1.132 and RG 1.138), COV for soil profiles should not be less than 0.5. For sites that are not well investigated sites, COV shall be at least 1.	No	Shear wave velocity (Vs) values for the subsurface materials underlying the PSW building were calculated from Seismic Cone Penetrometer Testing (SCPT) and Refraction Microtremor (ReMi) testing, together with the information provided from direct soil boring performed for the PSW building design. This information was supplemented by data obtained from the Cross-Hole Velocity (CHV) testing and soil borings performed in 1981 for the adjacent Radwaste building. The geotechnical investigations for the PSW building site satisfies the purpose and goals of Regulatory Guide 1.132 and the PSW building site is considered to be "well investigated".

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Soil-Structure Interaction	**I.4**	**II.4**	For well investigated sites (RG 1.132 and RG 1.138), COV for soil profiles should not be less than 0.5. For sites that are not well investigated sites, COV shall be at least 1.	No	The shear wave velocities (Vs) measured in the ReMi survey were taken to be the BE shear wave velocities because the ReMi survey yields shear wave velocities averaged over the length of the survey line and the ReMi survey line encompassed the length of the PSW building. The BE shear modulus values were calculated from the corresponding BE shear wave velocities values. The LB and the UB shear modulus values obtained from the BE shear modulus using an assigned coefficient of variation (COV) of 0.5. Figure 141-17 presents the values of shear wave velocities versus depth for the PSW building site. As shown in Figure 141-17, the shear wave velocities values obtained from independent geophysical tests are consistent, and the LB and UB values of shear wave velocities, calculated from the LB and UB shear modulus, reasonably bracket the values of shear wave velocities calculated from the various measurements (ReMi, SCPT, and CHV).

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Soil-Structure Interaction	I.4	II.4	For well investigated sites (RG 1.132 and RG 1.138), COV for soil profiles should not be less than 0.5. For sites that are not well investigated sites, COV shall be at least 1.	No	For this reason, the use of a COV value of 0.5 for LB and UB shear modulus is justified.
			Soil damping should not exceed 15%.	Yes	
			Control Motion should be in accordance with SRP 3.7.1	See SRP 3.7.1 Matrix	
Development of In-Structure Response Spectra	I.5	II.5	RG 1.122 should be used augmented by SRP Section guidance in Section II.5	Yes	
Three Components of Earthquake Motion	I.6	II.6	Responses from three earthquake directions should be combined in accordance with RG 1.92.	No	ONS is a two directional plant according to UFSAR, Section 3.7.2.5.The two-directional earthquake with the absolute sum rule yields design responses that are comparable to those obtained using the SRSS rule. For example, if a design response has the same response magnitude (say 1.0) from each of the three spatial excitations (X, Y, and Z), the absolute sum rule will yield a combined design response of 2.0 compared to 1.73 for the combined design responses using the SRSS rule.

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Combination of Modal Responses	**I.7**	**II.7**	For modal superposition time history analyses, modal responses should be combined algebraically at each output time step. Modes with frequencies less than ZPA should be included in the modal superposition. Higher modes responses should be calculated using the missing mass approach. This contribution is treated as one additional modal response, scaled to the input time history normalized to ZPA, and combined algebraically with the modal superposition solution at each time step.	Yes	
Interaction of Non-Category I Structures with Category I SSCs	**I.8**	**II.8**	Provide technical basis and formally document non-collapse of the non-Category I structure or that the collapse of the non-Category I structure will not impair the integrity of Category I SSCs, nor results in incapacitating injury to control room occupants.	Yes	
Effects of Parameter Variation on Floor Response Spectra	**I.9**	**II.9**	Analyses should consider effects of expected variation in structural properties, damping values, soil properties, and SSI on response spectra. For concrete structures, the effect of potential concrete cracking on the structural stiffness should be addressed.	No	Comply with all SRP requirements except for concrete cracking. Concrete cracking was not considered for any of the existing Category I structures at ONS.
Use of Equivalent Vertical Static Factors	**I.10**	**II.10**		N/A	Dynamic analyses were performed.

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Methods Used to Account For Torsional Effects	**I.11**	**II.11**	Dynamic analyses should include the effects of accidental torsion by including torsional degrees of freedom in the analytical models. An additional eccentricity of +/- 5% of the maximum building dimensions should be assumed for both horizontal directions. The eccentricities should be determined separately for each building floor.	Yes	
Comparison of Responses	**I.12**	**II.12**	The peak responses obtained from time history and response spectrum methods should be compared to demonstrate approximate equivalency between the two methods.	N/A	For buiding design, the response spectra method was used. The time history method is only used for generation of In-Structure Response Spectra (ISRS).
Analysis Procedure for Damping	**I.13**	**II.13**	Composite modal damping is limited to 20%. Acceptable techniques for the calculation of composite modal damming should be in accordance with SRP Section II.13.	Yes	
Determination of Seismic Overturning Moments and Sliding Forces for Seismic Category I Structures	**I.14**	**II.14**	Should incorporate three components of input motion and conservative consideration of the simultaneous action of vertical and horizontal seismic forces. Load combination in accordance with SRP 3.8.5.	Yes	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-6: SRP 3.7.2 COMPLIANCE MATRIX (Continued)					
Section Title	**Section Number**	**SRP Acceptance Criteria**	**SRP Requirements**	**Comply with SRP Requirements**	**Justification for the Exception**
Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)	**I.15**	**II.15**		N/A	
COL Action Items and Certification Requirements and Restrictions	**I.16**	**II.16**		N/A	

N/A = Not Applicable to PSW Building Seismic Analyses.

Table 141-7: Modal Frequencies and Mass Participation Factors for the PSW CDB Model					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	10.182	0.098	0.01	0.136	48.58
2	10.927	0.092	0	11.969	0.563
3	11.872	0.084	0	0.013	0.039
4	12.02	0.083	0	0.006	0.008
5	12.033	0.083	0	0.008	0.186
6	12.045	0.083	0	0	0
7	12.126	0.082	0	0	0.005
8	12.232	0.082	0	0.014	0.068
9	12.361	0.081	0	0	0.002
10	12.397	0.081	0	0.001	0.024
11	12.545	0.08	0.004	0.042	0.006
12	12.761	0.078	0	0.001	0.055
13	12.766	0.078	0	0	0.003
14	12.935	0.077	0	0.001	0.068
15	13.16	0.076	0	0	0.016
16	13.286	0.075	0	0	0.034
17	13.582	0.074	0	0.001	0.091
18	13.656	0.073	0	0	0
19	13.759	0.073	0	0.003	0.047
20	13.961	0.072	0	0	0.023
21	14.101	0.071	0	0	0.033
22	14.468	0.069	0	0	0.11
23	14.476	0.069	0	0.001	0.015
24	14.741	0.068	0.006	2.957	0.068
25	14.96	0.067	0	0.004	0.027
26	15.008	0.067	0	0	0.011
27	15.031	0.067	0	0	0
28	15.424	0.065	0	0	0.059
29	15.518	0.064	0	0	0
30	15.688	0.064	0.28	0	0
31	15.787	0.063	0.001	0	0
32	15.875	0.063	0	0	0.026
33	15.927	0.063	0	0	0.027
34	15.932	0.063	0	0	0.006
35	16.015	0.062	0.131	0	0
36	16.028	0.062	0	0	0
37	16.379	0.061	0	0	0.106
38	16.461	0.061	0	0	0.003
39	16.541	0.06	0	0	0.006
40	16.713	0.06	0	0	0.034
41	16.793	0.06	0	0	0
42	16.876	0.059	0.517	0	0
43	17.093	0.059	0.037	0	0
44	17.112	0.058	0.027	0	0
45	17.192	0.058	0.002	0	0
46	17.247	0.058	0	0	0.021
47	17.316	0.058	0.019	0	0

Table 141-7: Modal Frequencies and Mass Participation Factors for the PSW CDB Model (Continued)					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
48	17.362	0.058	0.032	0	0
49	17.545	0.057	0.001	0	0.023
50	17.582	0.057	0.028	0.021	0.007
51	17.763	0.056	0	0	0.062
52	17.775	0.056	0	0	0.014
53	18.296	0.055	0	0	0.028
54	20.04	0.05	0	0	0.024
55	20.457	0.049	0.095	0.01	0.643
56	20.84	0.048	0.006	0.002	0.134
57	21.438	0.047	0.002	0.003	0.041
58	21.584	0.046	0.007	0.806	0.031
59	24.129	0.041	0.113	0.228	0.058
60	25.372	0.039	0.043	0.006	0.351
61	25.61	0.039	0.334	0.389	3.386
62	26.26	0.038	0.793	0.03	0.107
63	26.577	0.038	0	0.022	0.938
64	26.724	0.037	0.015	0.883	1.741
65	26.96	0.037	0.032	0.012	0.541
66	28.14	0.036	0.279	2.18	0.314
67	28.391	0.035	0.593	0.687	1.622
68	28.714	0.035	0.002	0.006	0.059
69	29.909	0.033	0.143	0.079	0.035
70	30.241	0.033	0.611	0.068	2.207
71	30.338	0.033	0.004	0.07	1.157
72	30.552	0.033	21.759	0.011	0.525
73	31.155	0.032	3.43	0.002	5.982
74	31.811	0.031	11.783	4.358	0.026
75	31.953	0.031	0.078	0.685	0.107
76	32.144	0.031	0.985	2.055	1.779
77	32.441	0.031	25.098	0.972	0.739
78	32.657	0.031	0.02	0.626	0
79	33.235	0.03	0.327	0.388	0.007
80	34.129	0.029	0.035	0.029	0.166
81	34.277	0.029	0.331	0.016	2.857
82	34.441	0.029	0.001	0.001	0.142
83	34.682	0.029	0.046	0.017	0.001
84	35.433	0.028	3.757	0.167	0.006
85	35.706	0.028	0.04	0.018	0.001
86	35.821	0.028	0	0.15	0
87	36.04	0.028	3.201	0.081	0.691
88	36.777	0.027	0.099	0.033	1.314
89	37.585	0.027	0.034	0.001	0.27
90	37.593	0.027	0.052	0.037	0.448
91	38.198	0.026	0.106	0.688	0.847
92	38.621	0.026	0	0.633	0.028
93	38.73	0.026	0	0.101	0.014
94	39.473	0.025	0.095	0.001	0.514

Table 141-7: Modal Frequencies and Mass Participation Factors for the PSW CDB Model (Continued)

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
95	39.746	0.025	0.247	0.805	0.194
96	39.951	0.025	0.147	0.995	1.892
97	40.515	0.025	0.083	1.405	0.01
98	41.351	0.024	0.002	0.181	0
99	41.761	0.024	0.118	0.01	0.169
100	42.422	0.024	0.034	0.087	0.007
Total Participating Mass (%)			**76.075**	**35.212**	**82.629**

Table 141-8: Modal Frequencies and Mass Participation Factors for the PSW LSS BE Model					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	7.089	0.141	0.035	0	59.766
2	10.52	0.095	0	18.211	0.036
3	11.688	0.086	0.203	0.007	0.914
4	11.796	0.085	0.015	0.09	0.218
5	11.931	0.084	0.061	0	0.316
6	12.042	0.083	0.001	0	0.002
7	12.072	0.083	0.043	0.001	0.047
8	12.12	0.083	0.139	0	0.009
9	12.143	0.082	0.53	0.005	0.026
10	12.25	0.082	3.57	0.319	0.043
11	12.349	0.081	0.055	0.013	0.134
12	12.364	0.081	0.002	0.001	0.031
13	12.564	0.08	0.083	0.007	0.544
14	12.753	0.078	0.074	0.001	0.015
15	12.806	0.078	0.005	0.005	0.012
16	13.125	0.076	0.044	0.002	0.055
17	13.226	0.076	0.001	0.001	0.052
18	13.463	0.074	20.666	0.051	0.039
19	13.479	0.074	58.084	0.059	0.192
20	13.627	0.073	1.451	0.009	0
21	13.714	0.073	0.216	0.025	0.039
22	13.944	0.072	0.057	0.003	0.071
23	14.062	0.071	0.026	0.014	0.061
24	14.377	0.07	0.053	0.434	0.354
25	14.432	0.069	0.074	0.022	0.001
26	14.463	0.069	0.091	6.541	0
27	14.837	0.067	0.001	0.001	0.095
28	14.996	0.067	0.002	0.001	0.006
29	15.028	0.067	0.001	0	0
30	15.283	0.065	0.001	0.003	0.171
31	15.517	0.064	0	0	0
32	15.708	0.064	0.29	0.013	0.001
33	15.779	0.063	0.001	0.008	0.215
34	15.787	0.063	0	0	0.014
35	15.894	0.063	0.008	0	0.134
36	15.921	0.063	0.001	0.001	0.007
37	16.023	0.062	0.071	0.008	0.002
38	16.027	0.062	0.016	0.001	0
39	16.191	0.062	0.01	0.019	0.462
40	16.452	0.061	0	0.009	0.002
41	16.468	0.061	0.001	0.008	0
42	16.602	0.06	0.001	0.016	0.056
43	16.777	0.06	0	0.005	0.003
44	16.886	0.059	0.002	0.135	0.021
45	17.08	0.059	0.085	0.084	0.083
46	17.108	0.058	0.027	0.023	0.024
47	17.141	0.058	0.028	0.072	0.537
48	17.192	0.058	0.028	0.007	0

Table 141-8: Modal Frequencies and Mass Participation Factors for the PSW LSS BE Model (Continued)					
Mode	**Frequency Hz**	**Period seconds**	**Participation X %**	**Participation Y %**	**Participation Z %**
49	17.236	0.058	1.393	0.282	0.085
50	17.32	0.058	0.045	0.007	0.028
51	17.363	0.058	0.002	0.001	0.121
52	17.423	0.057	1.956	0.03	0.934
53	17.502	0.057	0.295	0.069	0.349
54	17.704	0.056	0.056	0.044	0.686
55	18.05	0.055	0.079	0.244	3.73
56	18.164	0.055	0.12	0.1	3.786
57	18.309	0.055	0.007	0.072	7.827
58	18.994	0.053	0.355	1.166	0.294
59	20.082	0.05	1.13	35.136	1.481
60	20.324	0.049	0.106	4.152	0.056
61	20.928	0.048	0.098	0.053	5.073
62	21.457	0.047	0.034	0.343	0.057
63	21.72	0.046	1.963	1.608	2.011
64	22.127	0.045	2.456	8.119	1.128
65	22.741	0.044	0.264	0.368	0.688
66	23.493	0.043	0.292	15.31	0.566
67	24.925	0.04	0.009	0.011	0.034
68	25.145	0.04	0.258	0.58	0.629
69	25.514	0.039	0.083	0.363	0.006
70	25.893	0.039	0.178	0.031	0.318
71	26.124	0.038	0.02	0.221	0.117
72	26.756	0.037	0.12	0.557	0.047
73	26.855	0.037	0.006	0.666	0.044
74	27.034	0.037	0.05	0.39	0.031
75	27.266	0.037	0.01	0.186	0.027
76	28.211	0.035	0.007	0.018	0.069

Total Participating Mass (%)			**97.545**	**96.362**	**95.032**

Table 141-9: Modal Frequencies and Mass Participation Factors for the PSW LSS LB Model					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	6.234	0.16	0.032	0.001	63.989
2	9.975	0.1	0.395	0.061	0.122
3	10.279	0.097	0.025	26.611	0.058
4	10.855	0.092	75.796	0.255	0.172
5	11.554	0.087	1.027	0.048	2.207
6	11.87	0.084	0.005	0.069	0.059
7	11.944	0.084	0.117	0.021	0.133
8	12.041	0.083	0.037	0	0.003
9	12.119	0.083	0.194	0.001	0.013
10	12.139	0.082	0.561	0	0.02
11	12.214	0.082	11.339	0.39	0.054
12	12.315	0.081	0.022	0.001	0.185
13	12.362	0.081	0.003	0.001	0.003
14	12.482	0.08	0.036	0	0.345
15	12.747	0.078	0.041	0.002	0.021
16	12.8	0.078	0.001	0.006	0.001
17	13.116	0.076	0.003	0.003	0.077
18	13.216	0.076	0	0.002	0.059
19	13.448	0.074	0.002	0.018	0.209
20	13.599	0.074	0.013	0.024	0.003
21	13.7	0.073	0	0.096	0.071
22	13.93	0.072	0.007	0.05	0.154
23	14.042	0.071	0.009	0.897	0.143
24	14.123	0.071	0.392	14.708	0.014
25	14.341	0.07	0	0.162	0.63
26	14.398	0.069	0.014	0.023	0.026
27	14.805	0.068	0	0.001	0.161
28	14.993	0.067	0.002	0.002	0.012
29	15.025	0.067	0	0	0
30	15.241	0.066	0	0.004	0.504
31	15.517	0.064	0	0	0.001
32	15.575	0.064	0.007	0	2.007
33	15.673	0.064	0.095	0.147	0.039
34	15.786	0.063	0	0.002	0.181
35	15.79	0.063	0.019	0.001	3.057
36	15.912	0.063	0	0.003	0.261
37	15.991	0.063	0.412	0.372	0.423
38	16.026	0.062	0	0	0.03
39	16.046	0.062	0.038	0.024	3.649
40	16.084	0.062	0.303	0.495	3.273
41	16.268	0.061	3.014	2.826	3.197
42	16.31	0.061	1.323	1.785	0.828
43	16.459	0.061	0.004	0.013	0
44	16.558	0.06	0.05	0.369	0.133
45	16.652	0.06	0.058	0.544	0.001
46	16.802	0.06	0.017	0.219	0.039
47	16.939	0.059	0.394	0.545	0.002
48	17.095	0.058	0.031	0.044	0.005

Table 141-9: Modal Frequencies and Mass Participation Factors for the PSW LSS LB Model (Continued)					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
49	17.116	0.058	0.044	0.119	0.003
50	17.138	0.058	0.001	0.167	0
51	17.193	0.058	0.002	0.003	0
52	17.313	0.058	0.127	10.813	5.98
53	17.318	0.058	0.033	0.275	0.282
54	17.364	0.058	0.025	0.006	0.023
55	17.481	0.057	0.002	2.676	0.024
56	17.646	0.057	0.005	0.518	0.267
57	17.784	0.056	0.016	17.479	0.885
58	17.885	0.056	0.015	3.471	1.605
59	18.145	0.055	0	1.958	0.074
60	18.515	0.054	0	0.26	0.197
61	19.001	0.053	2.379	7.061	0
Total Participating Mass (%)			**98.487**	**95.652**	**95.914**

Table 141-10: Modal Frequencies and Mass Participation Factors for the PSW LSS UB Model

Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
1	7.86	0.127	0.034	0.002	55.52
2	10.657	0.094	0	14.624	0.047
3	11.773	0.085	0.018	0.032	0.562
4	11.926	0.084	0	0.019	0.078
5	11.965	0.084	0.009	0.017	0.177
6	12.042	0.083	0	0	0.001
7	12.123	0.082	0.001	0.001	0.006
8	12.159	0.082	0.015	0.006	0.039
9	12.351	0.081	0.012	0.001	0.04
10	12.365	0.081	0	0	0.019
11	12.387	0.081	0.196	0.118	0.013
12	12.587	0.079	0	0	0.234
13	12.756	0.078	0.002	0	0.003
14	12.811	0.078	0	0.002	0.005
15	13.128	0.076	0	0	0.019
16	13.232	0.076	0	0	0.023
17	13.473	0.074	0	0	0.045
18	13.632	0.073	0.004	0.003	0.009
19	13.721	0.073	0.004	0.011	0.04
20	13.929	0.072	0	0.045	0.043
21	14.021	0.071	0.004	0.278	0.574
22	14.074	0.071	0.003	0.038	0.158
23	14.413	0.069	0	0.198	0.367
24	14.445	0.069	0.022	0.051	0.013
25	14.613	0.068	0.016	3.967	0.008
26	14.873	0.067	0.001	0.015	0.121
27	14.998	0.067	0.004	0.001	0.008
28	15.029	0.067	0.002	0.001	0
29	15.314	0.065	0.005	0.001	0.155
30	15.517	0.064	0.103	0	0
31	15.524	0.064	27.844	0.037	0.011
32	15.786	0.063	0.032	0	0.001
33	15.814	0.063	0	0.003	0.117
34	15.896	0.063	11.015	0.03	0.009
35	15.913	0.063	5.6	0.011	0.072
36	15.925	0.063	1.109	0.004	0
37	16.027	0.062	0.003	0	0
38	16.143	0.062	22.135	0.087	0.005
39	16.248	0.062	1.348	0.001	0.355
40	16.458	0.061	0	0.001	0.001
41	16.492	0.061	0.017	0.004	0.001
42	16.622	0.06	0	0.005	0.029
43	16.784	0.06	0.005	0	0
44	16.982	0.059	3.058	0.056	0
45	17.098	0.058	0.18	0.008	0
46	17.12	0.058	0.394	0.018	0
47	17.179	0.058	0.001	0.012	0.112

Table 141-10: Modal Frequencies and Mass Participation Factors for the PSW LSS UB Model (Continued)					
Mode	Frequency Hz	Period seconds	Participation X %	Participation Y %	Participation Z %
48	17.193	0.058	0.009	0.001	0
49	17.317	0.058	0	0.006	0
50	17.36	0.058	0.013	0.011	0.001
51	17.518	0.057	0.03	0.019	0.237
52	17.536	0.057	3.382	0.057	0.122
53	17.659	0.057	8.643	0.002	0.061
54	17.748	0.056	0.842	0.003	0.066
55	18.223	0.055	0	0.051	0.3
56	18.44	0.054	0.291	0.162	0.254
57	19.853	0.05	0.48	0.011	0.17
58	20.273	0.049	0.055	0.481	16.784
59	20.538	0.049	0.177	0	3.288
60	21.262	0.047	0.123	5.313	0.001
61	21.476	0.047	0.026	0.05	0.008
62	23.101	0.043	0.305	20.263	1.902
63	23.8	0.042	0.004	0.219	0.053
64	24.924	0.04	4.21	7.737	0.455
65	25.322	0.039	0.249	0.287	1.42
66	25.396	0.039	0.663	0.058	3.148
67	25.684	0.039	0.13	7.992	0.635
68	26.243	0.038	0.01	3.235	0.15
69	26.418	0.038	0.005	5.141	0.251
70	26.77	0.037	0.028	0.431	0.891
71	27.044	0.037	0.138	0.008	0.002
72	27.194	0.037	0.032	0.095	1.471
73	27.887	0.036	0.047	1.915	0.053
74	28.509	0.035	0.993	8.642	0.004
75	28.619	0.035	0.097	3.862	0.304
76	29.383	0.034	0.67	2.362	0.28
77	29.647	0.034	0.002	0.393	0.426
78	29.845	0.034	0.027	0.322	0.154
79	29.989	0.033	0.045	0.08	0.63
80	30.702	0.033	0.1	0.218	0.185
81	30.827	0.032	0.025	0.96	0.449
82	31.241	0.032	0.036	0.248	0.11
83	31.419	0.032	0.08	1.951	0.118
84	32.128	0.031	0.211	0.526	0.068
85	32.955	0.03	0.005	0.024	0.002
86	33.438	0.03	0.103	0.02	0.002
87	33.647	0.03	0.034	0.136	0.012
88	33.861	0.03	0.861	0.173	0.011
89	34.167	0.029	0.065	0.007	0.048
90	34.3	0.029	0.202	0.023	0
91	34.588	0.029	0.359	0.024	0.061
92	34.72	0.029	0	0.12	0.43
93	35.075	0.029	0.018	0.039	0.004
94	35.424	0.028	0.166	1.563	0.023

Table 141-10: Modal Frequencies and Mass Participation Factors for the PSW LSS UB Model (Continued)					
Mode	**Frequency Hz**	**Period seconds**	**Participation X %**	**Participation Y %**	**Participation Z %**
95	35.641	0.028	0.003	0.249	0
96	36.042	0.028	0.002	0.11	0.154
97	36.53	0.027	0.121	0.005	0.057
98	36.815	0.027	0.003	0	0.102
99	37.388	0.027	0	0.059	0.012
100	37.467	0.027	0.003	0.001	0.003
101	38.155	0.026	0.01	0.321	0.268
102	38.649	0.026	0.006	0.004	0.002
103	38.971	0.026	0.003	0.163	0
104	39.177	0.026	0.121	0.025	0.036
105	39.458	0.025	0.12	0.004	0
106	40.22	0.025	0.22	0.071	0.139
107	40.588	0.025	0.011	0	0.547
Total Participating Mass (%)			**97.81**	**95.961**	**95.404**

Table 141-11: Maximum Base Forces and Base Moments[1]				
	Base Forces (kips)		Base Moments (ft-kips)	
CQC	VX	765	MX	21799
	VZ	589	MZ	24838

Note (1): Maximum from Fixed Base and Lumped Soil Spring Models for all the soil cases: LB, BE, and UB.

Legend:

CQC = Complete Quadratic modal combination for Response Spectrum Analyses.

FIGURE 141-1: Comparison of ONS UFSAR Figure 2-55 and El Centro Time History 5 % Damped Response Spectra

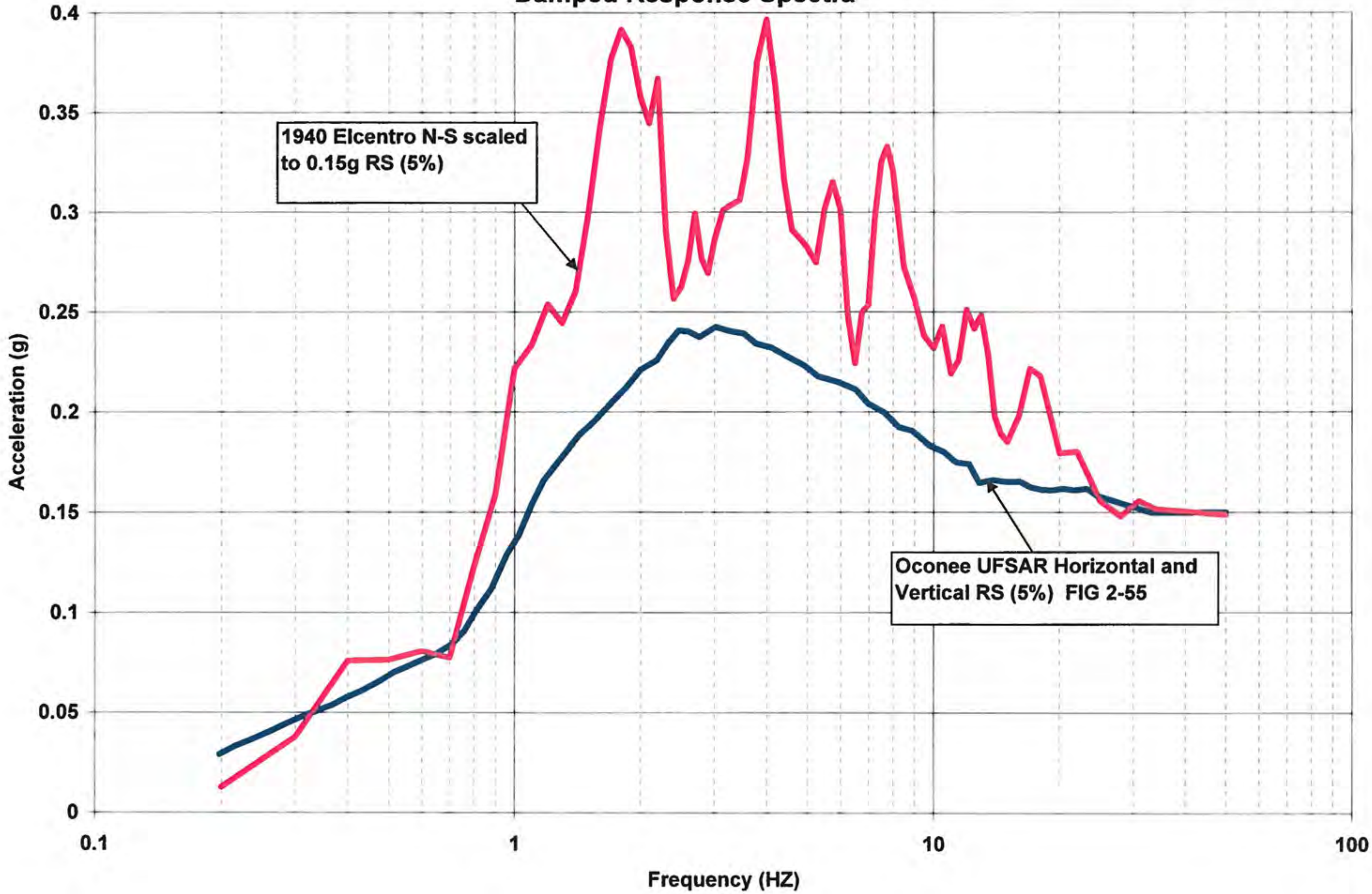
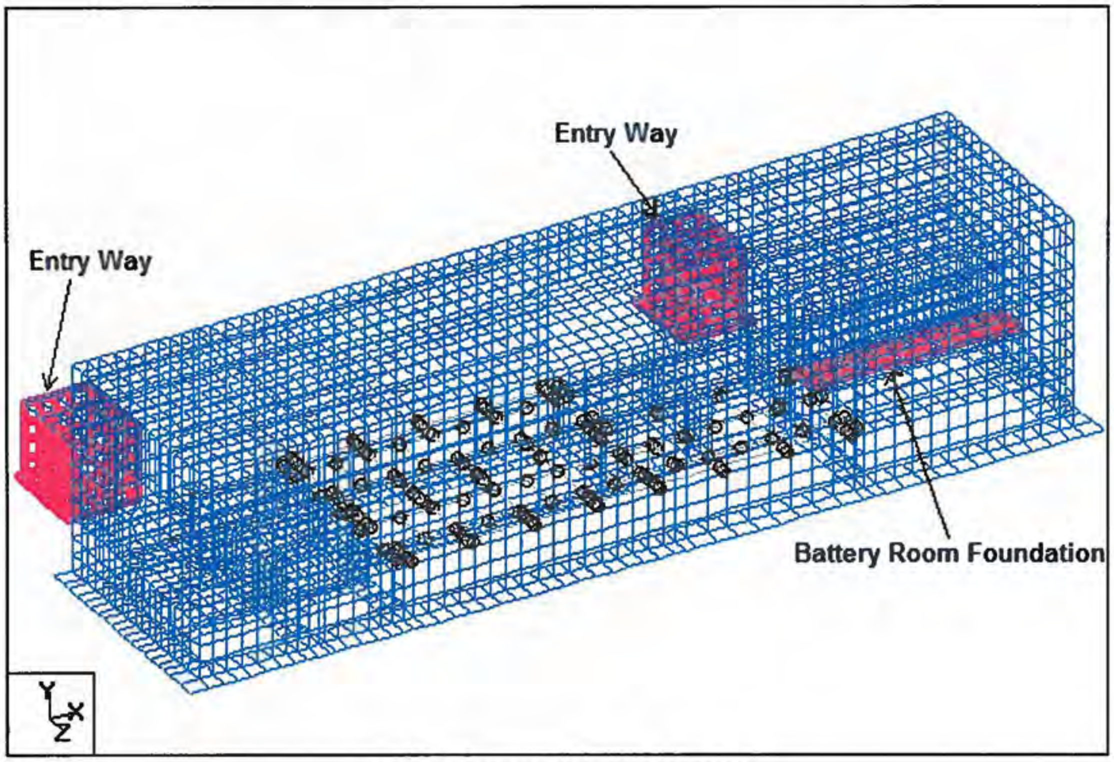
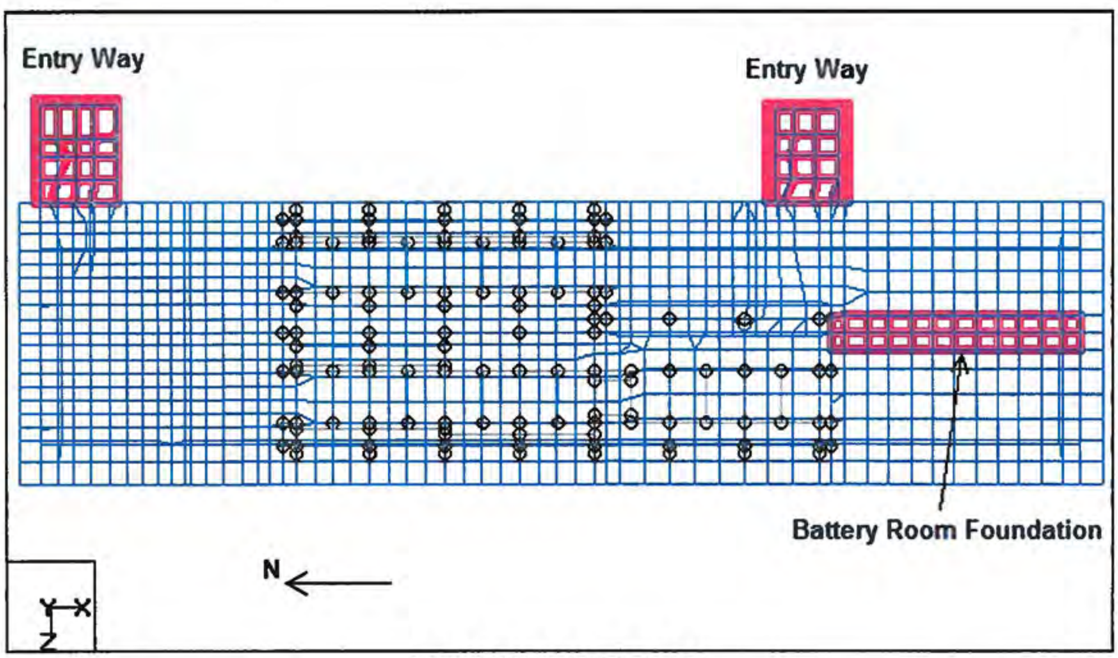


FIGURE 141-2: PSW BUILDING FEM MODEL



PSW BUILDING ELEVATION



PSW BUILDING PLAN

FIGURE 141-3: PSW Building CDB Model Mode Shape for Mode 1 (Z-Direction Predominant Mode)

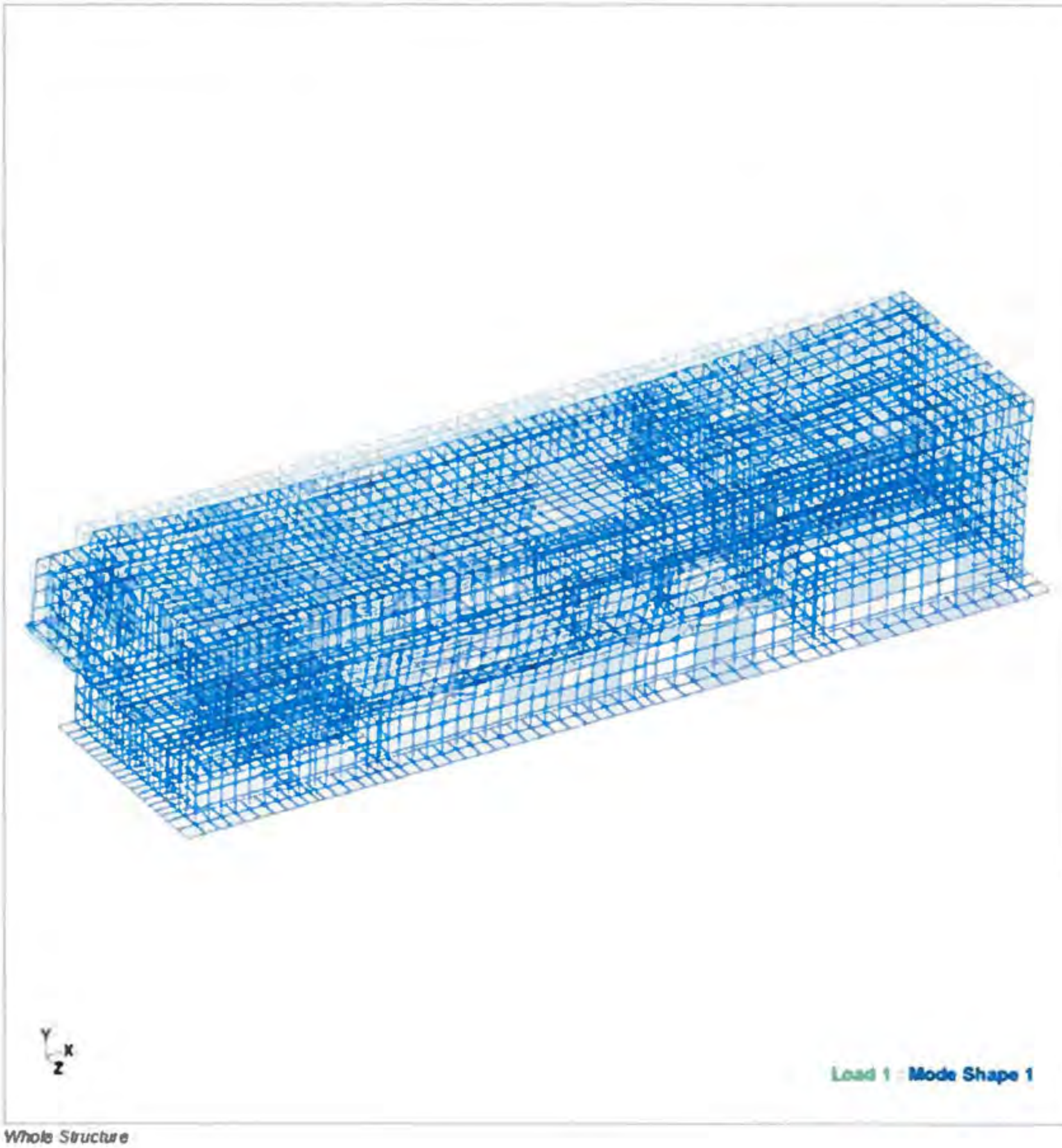


FIGURE 141-4: PSW Building CDB Model Mode Shape for Mode 2 (Y-Direction Predominant Mode)

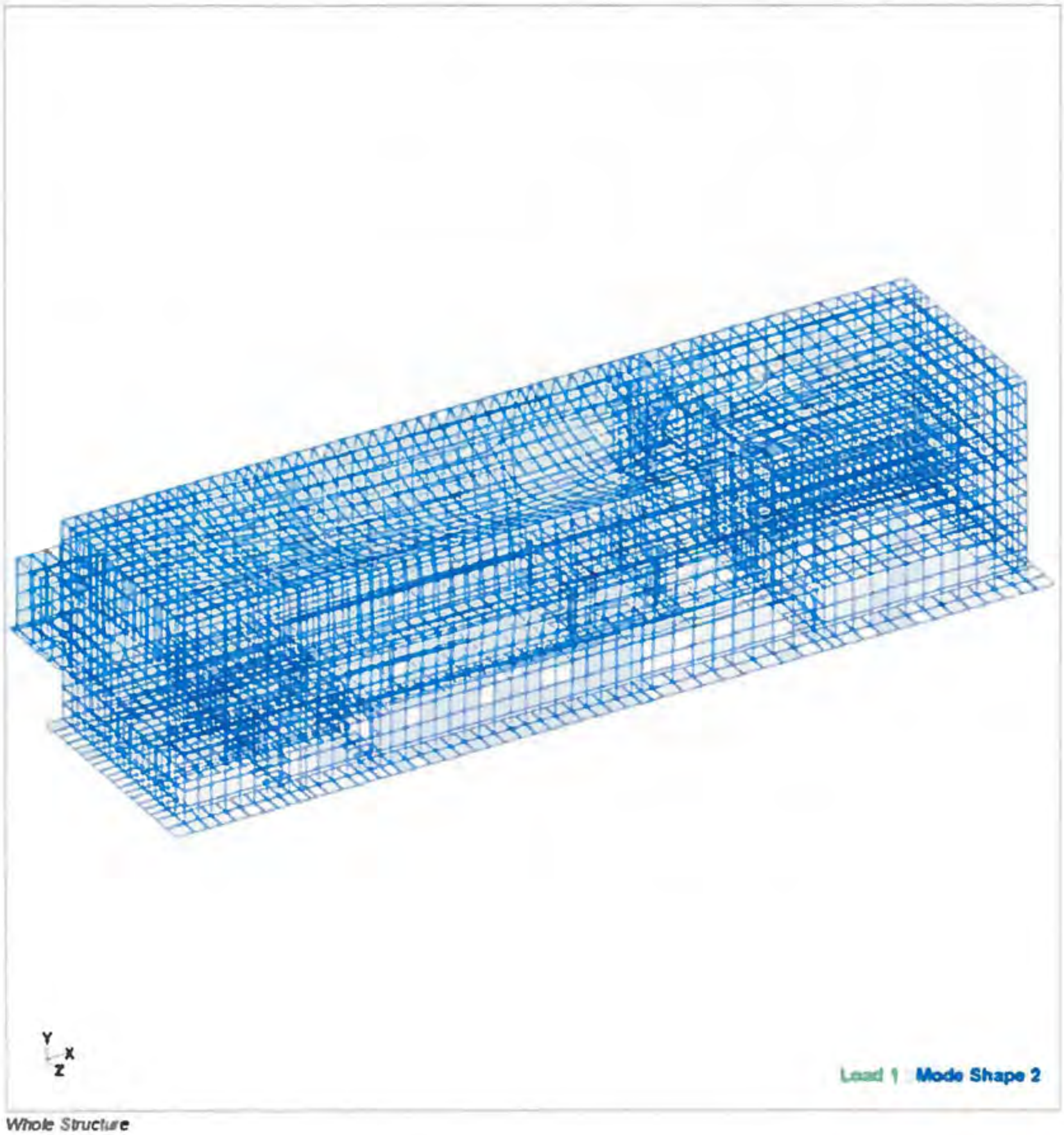


FIGURE 141-5: PSW Building CDB Model Mode Shape for Mode 72 (X-Direction Predominant Mode)

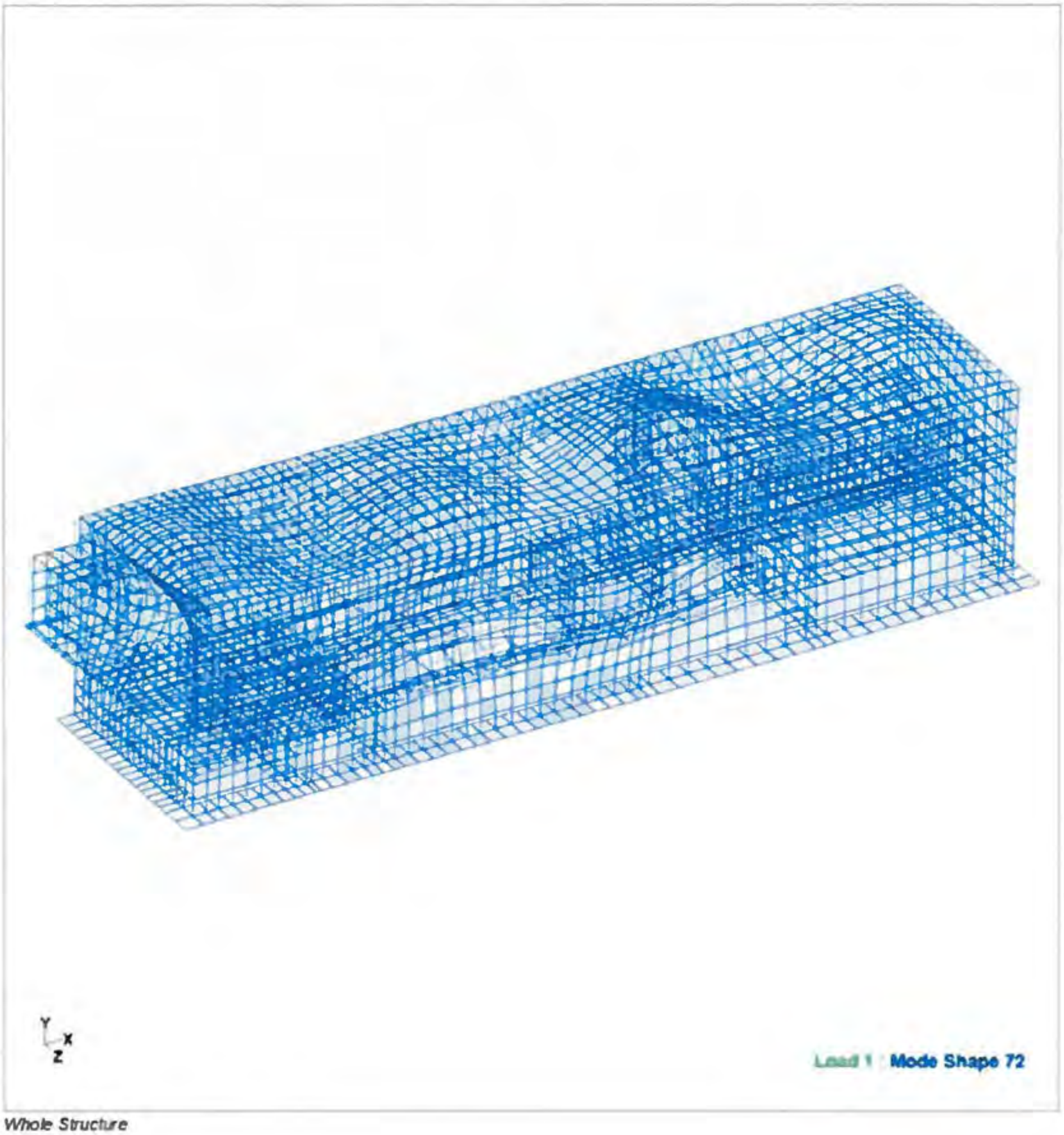
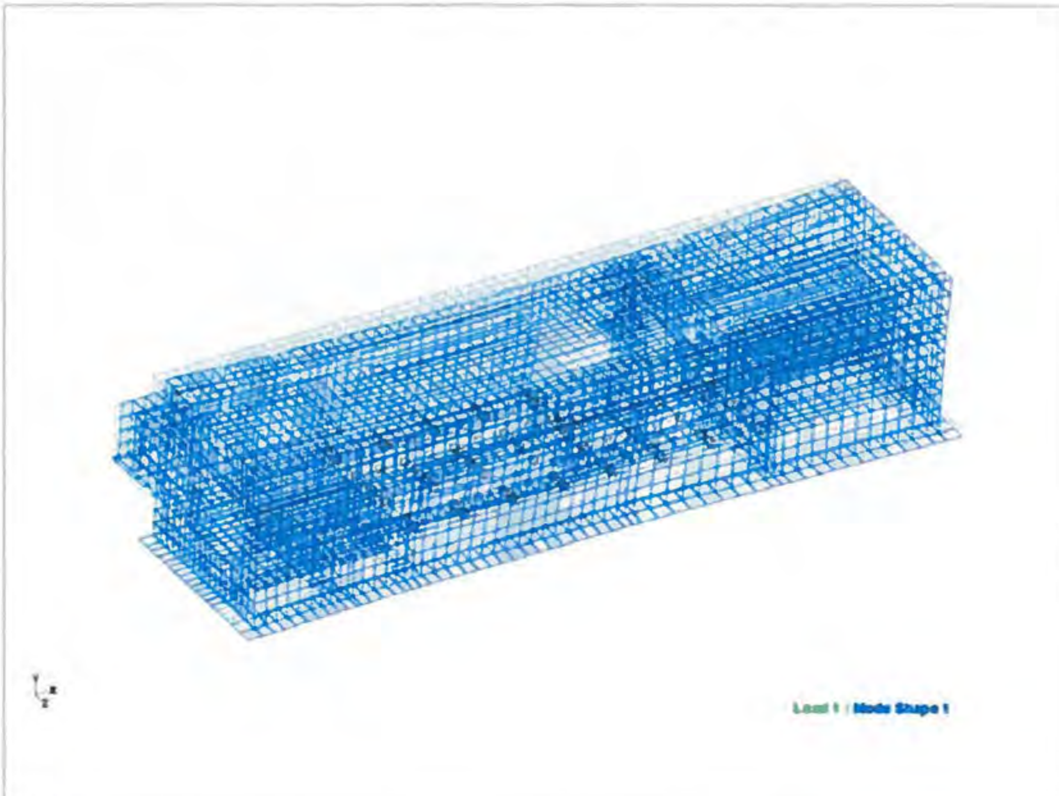
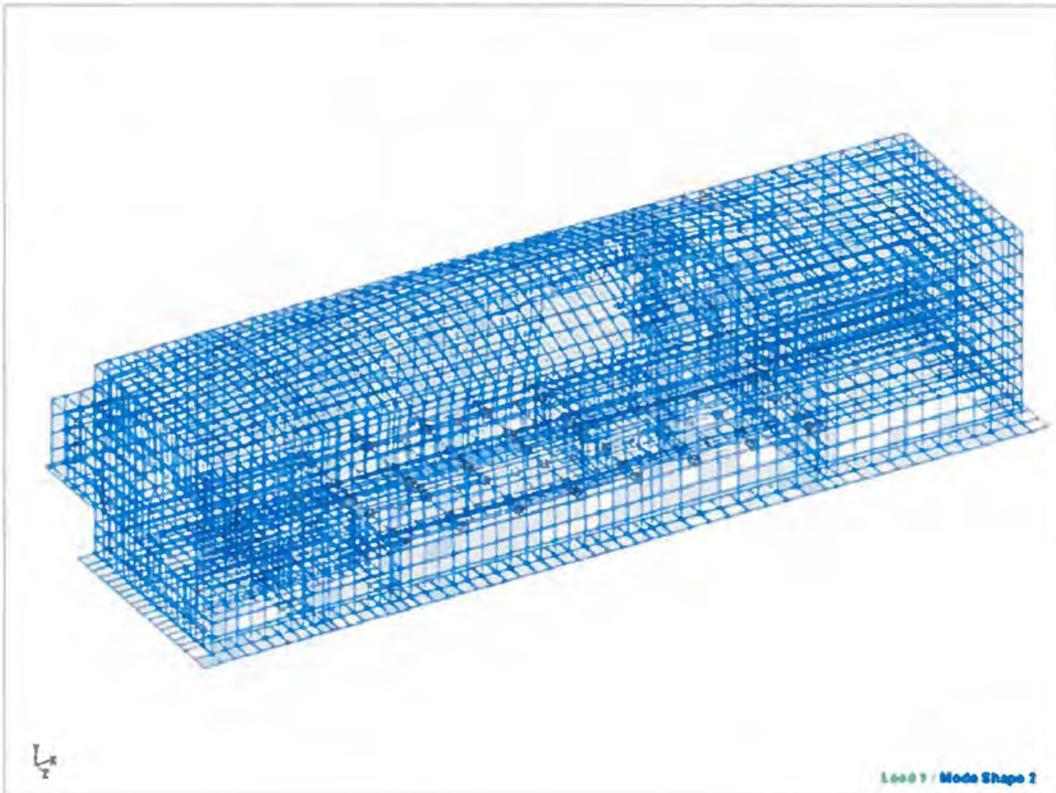


FIGURE 141-6: PSW Building LSS BE Model Mode Shape for Mode 1 (Z-Direction Predominant Mode)



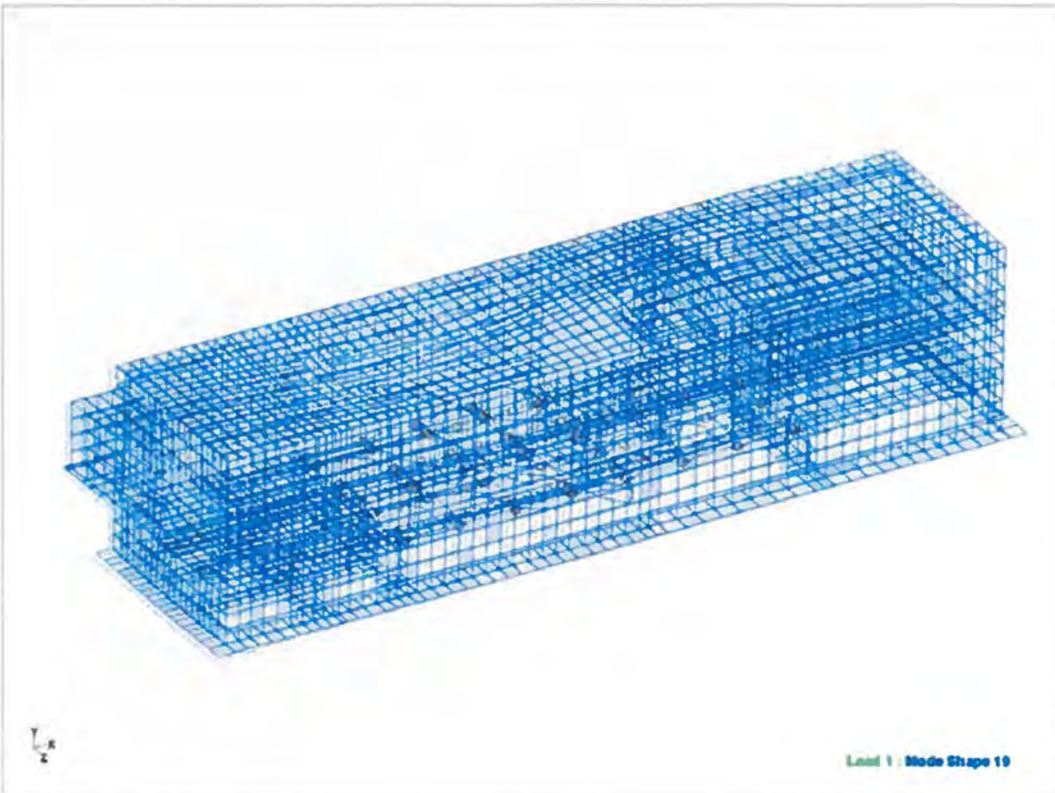
Mode 1

FIGURE 141-7: PSW Building LSS BE Model Mode Shape for Mode 2 (Y-Direction Predominant Mode)



Mode 2

FIGURE 141-8: PSW Building LSS BE Model Mode Shape for Mode 19 (X-Direction Predominant Mode)



Mode 19

FIGURE 141-9: ISRS for PSW Building Operating Floor (EL 797'-0") - MHE Horizontal Direction, CLB-LSS Envelop

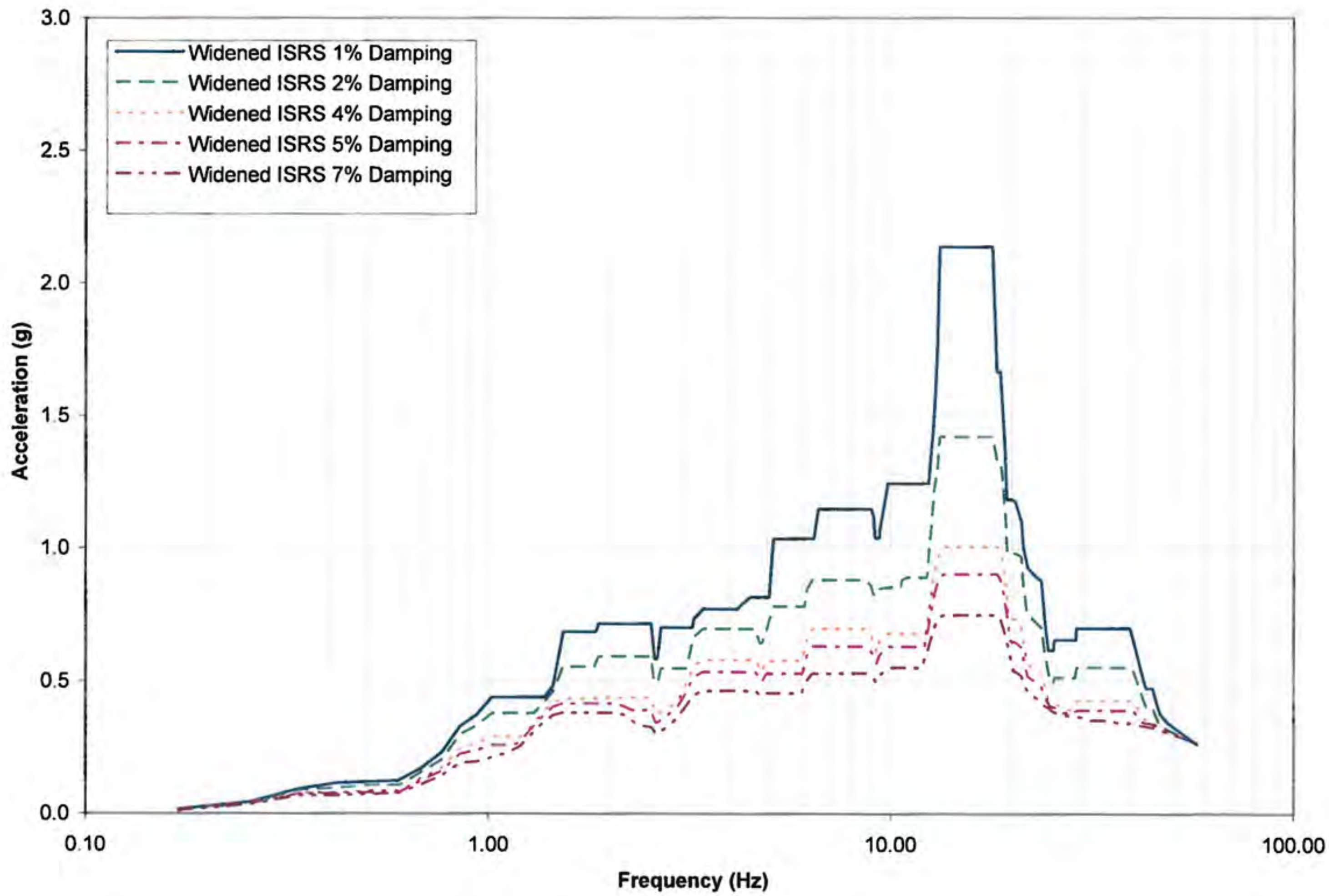


FIGURE 141-10: ISRS for PSW Building Operating Floor (EL 797'-0") - MHE Vertical Direction, CLB-LSS Envelop

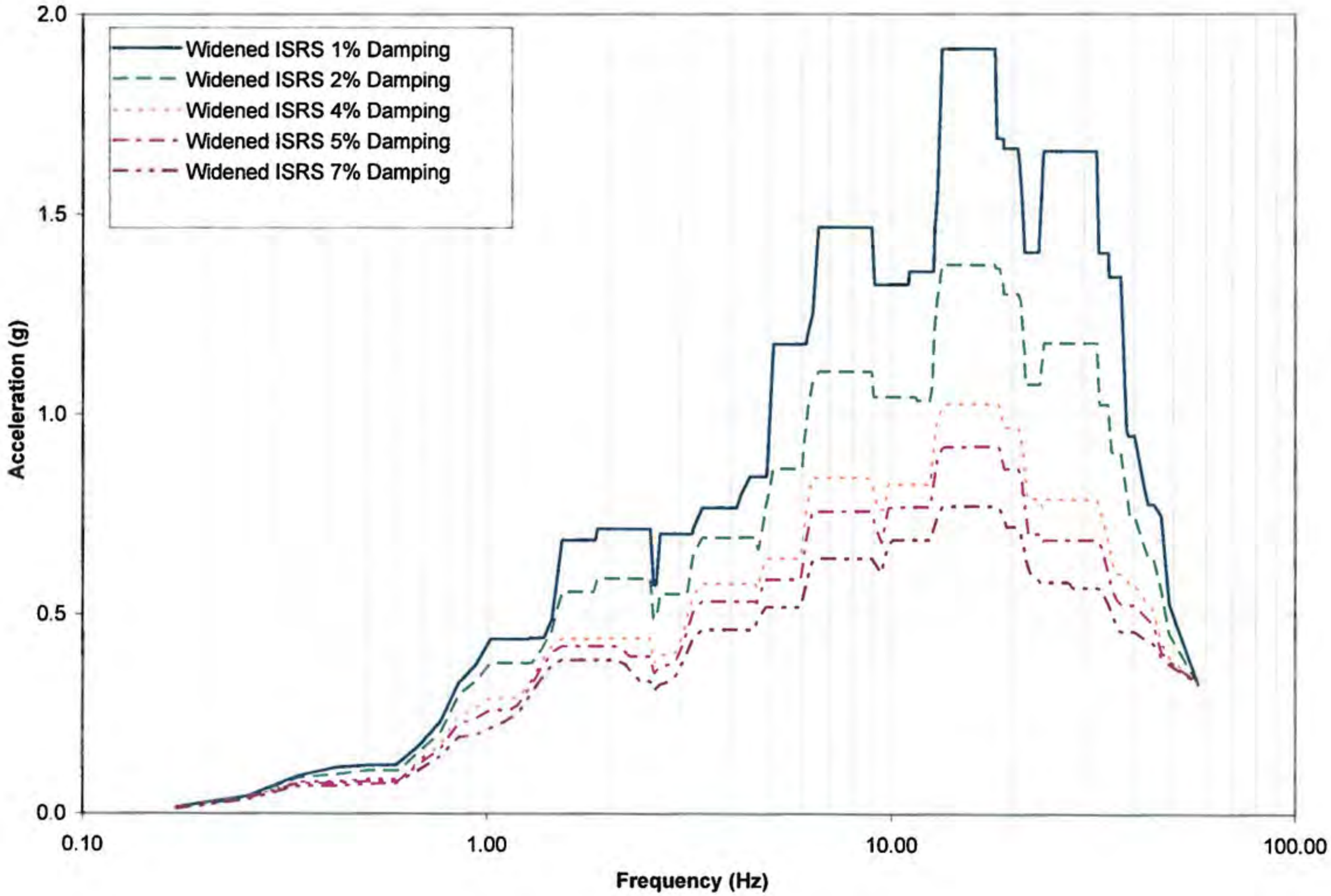


FIGURE 141-11: ISRS for Battery Room Roof EL. 807' - 0" - MHE Horizontal Direction, CLB-LSS Envelop

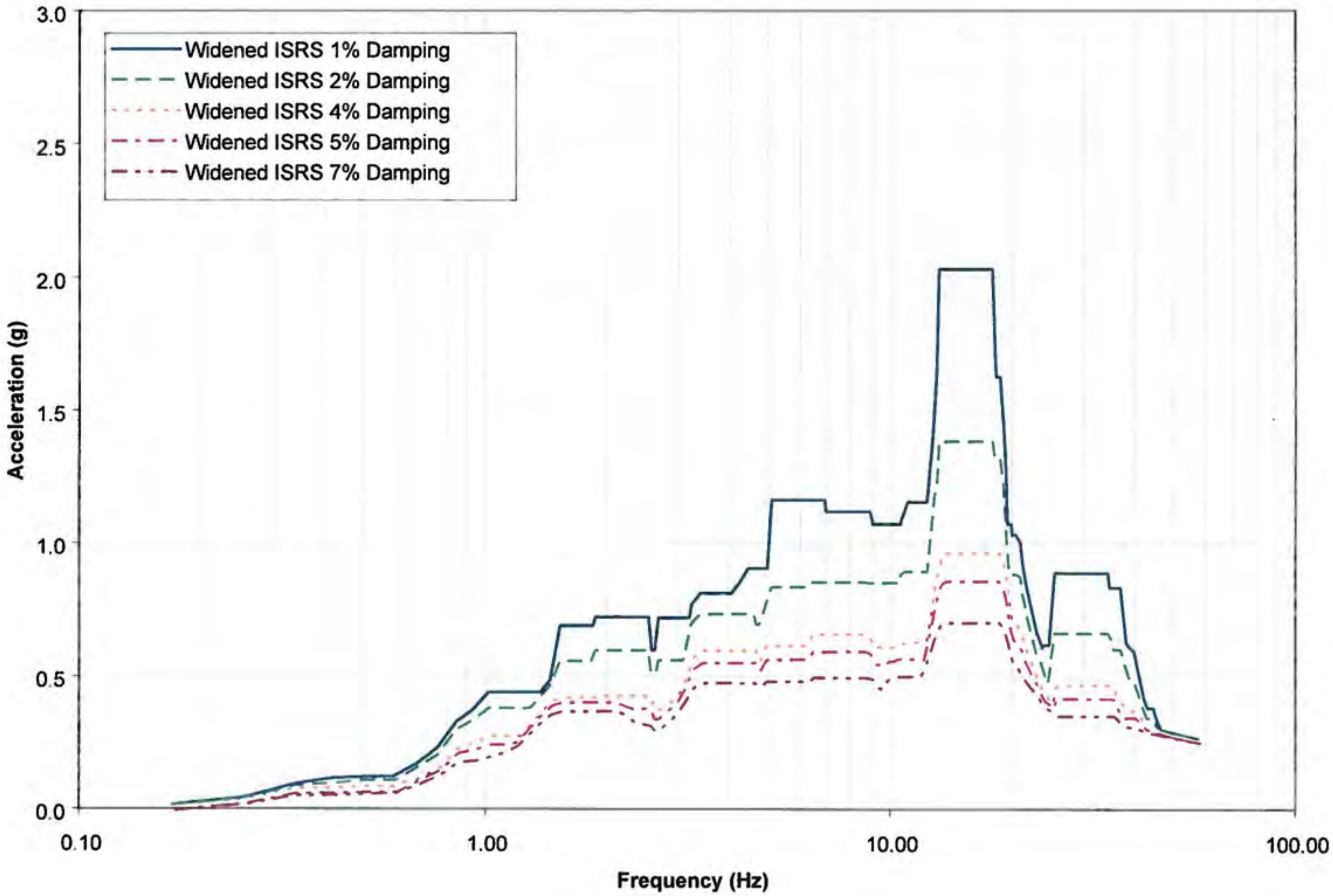


FIGURE 141-12: ISRS for Battery Room Roof EL. 807' - 0" - MHE Vertical Direction, CLB-LSS Envelop

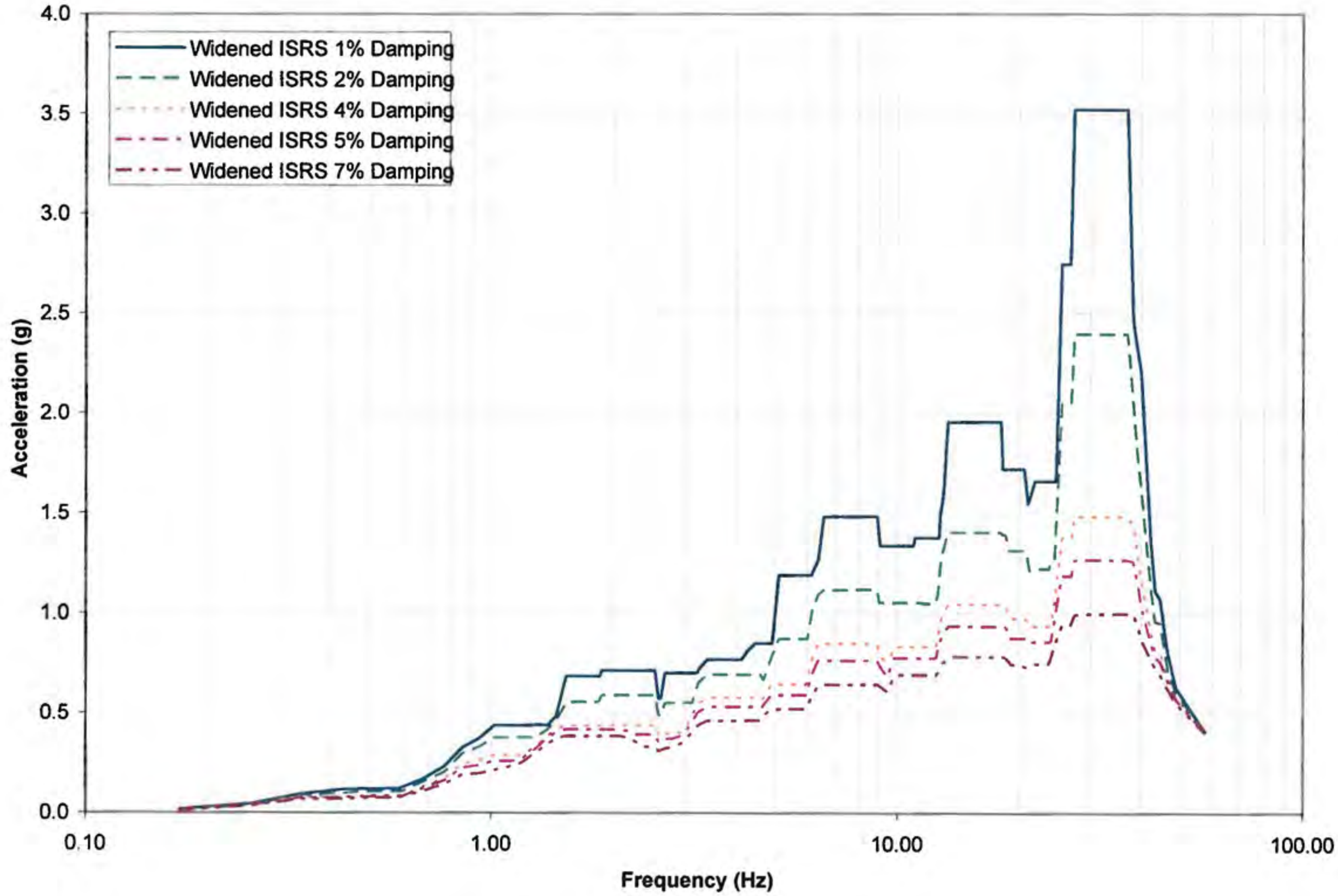


FIGURE 141-13: ISRS for PSW Building Roof EL. 818' - 0" – MHE Horizontal Direction, CLB-LSS Envelop

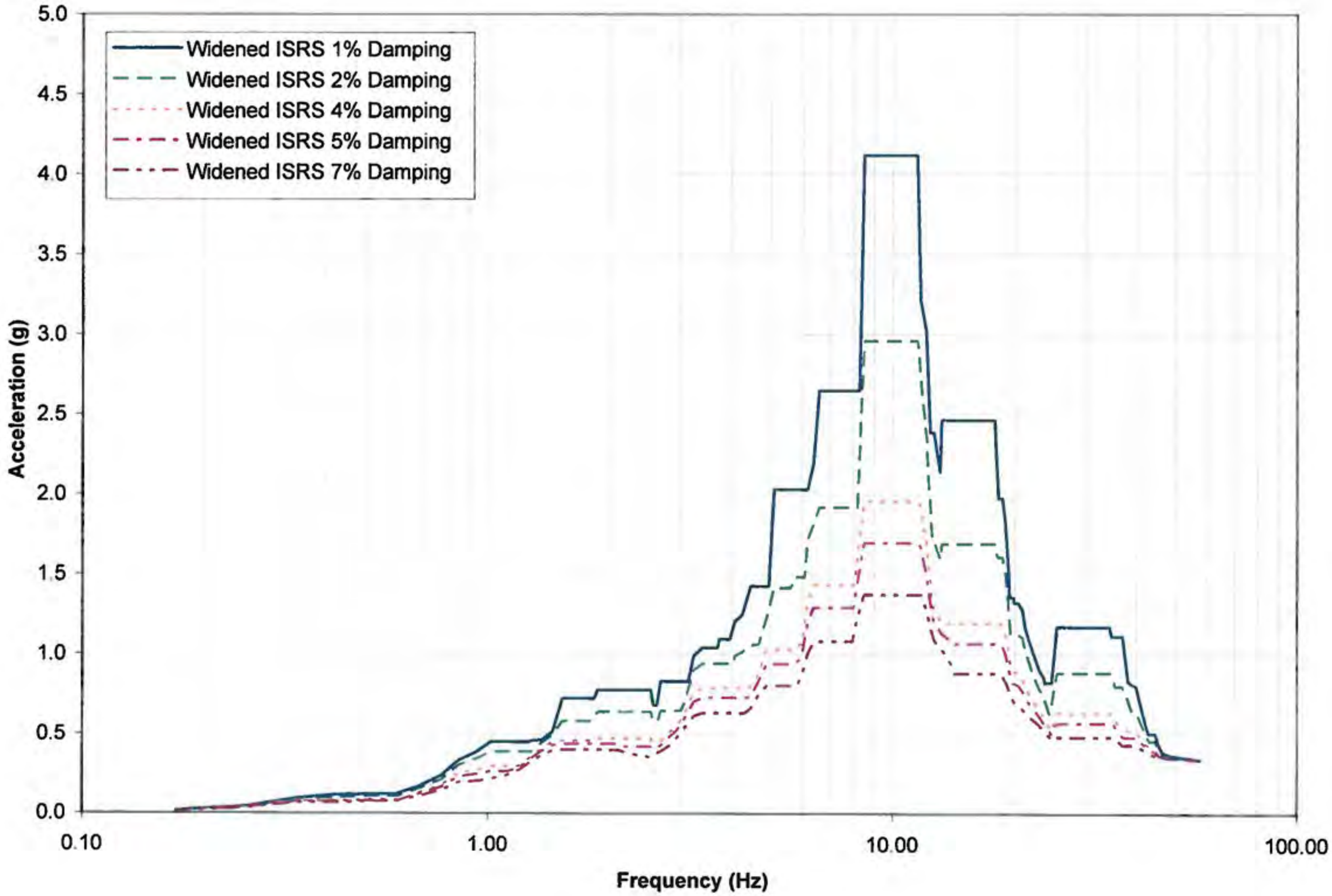


FIGURE 141-14: ISRS for PSW Building Roof EL. 818' - 0" – MHE Vertical Direction, CLB-LSS Envelop

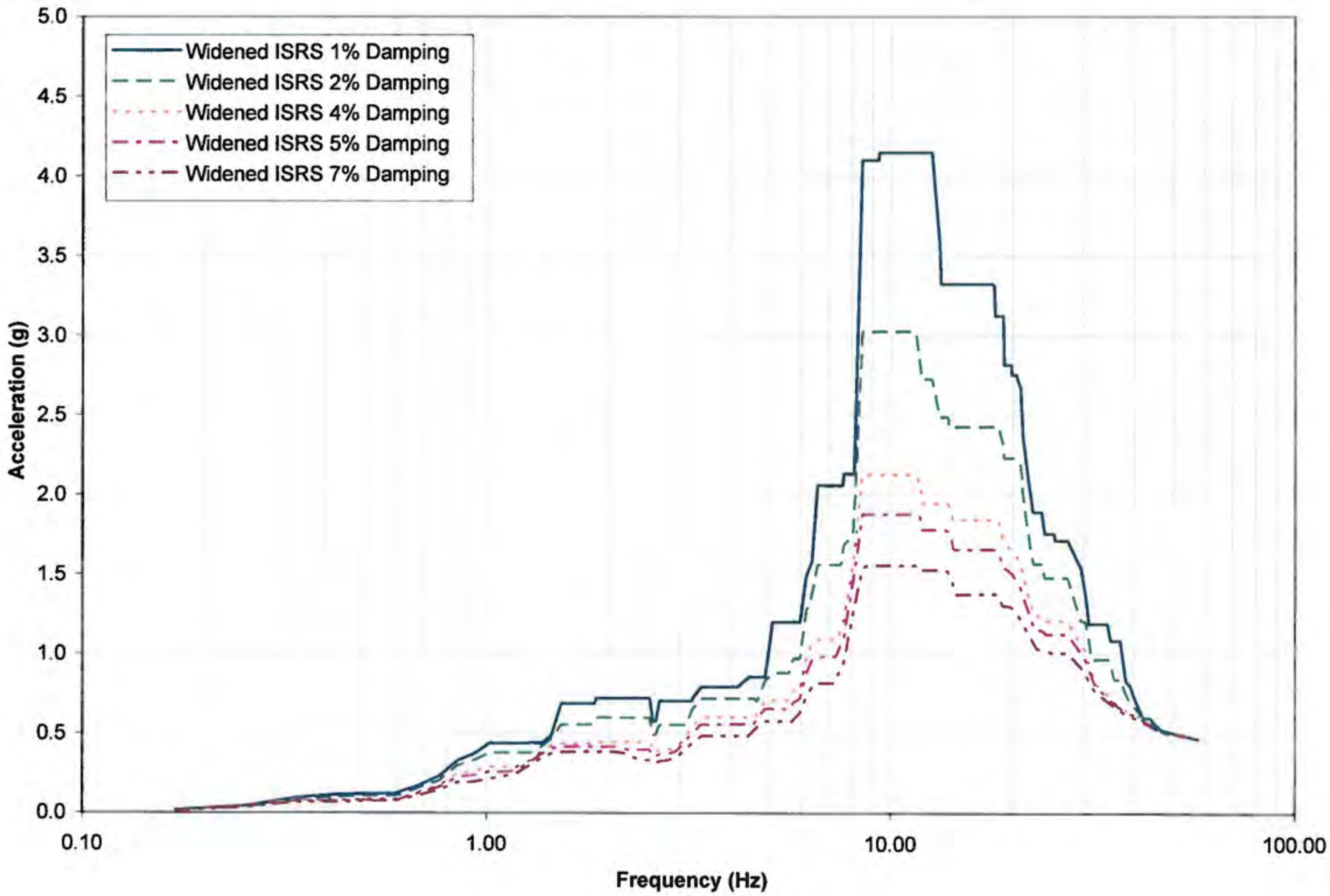


FIGURE 141-15: ISRS for Perimeter Wall EL. 811' - 0" - MHE Horizontal Direction, CLB-LSS Envelop

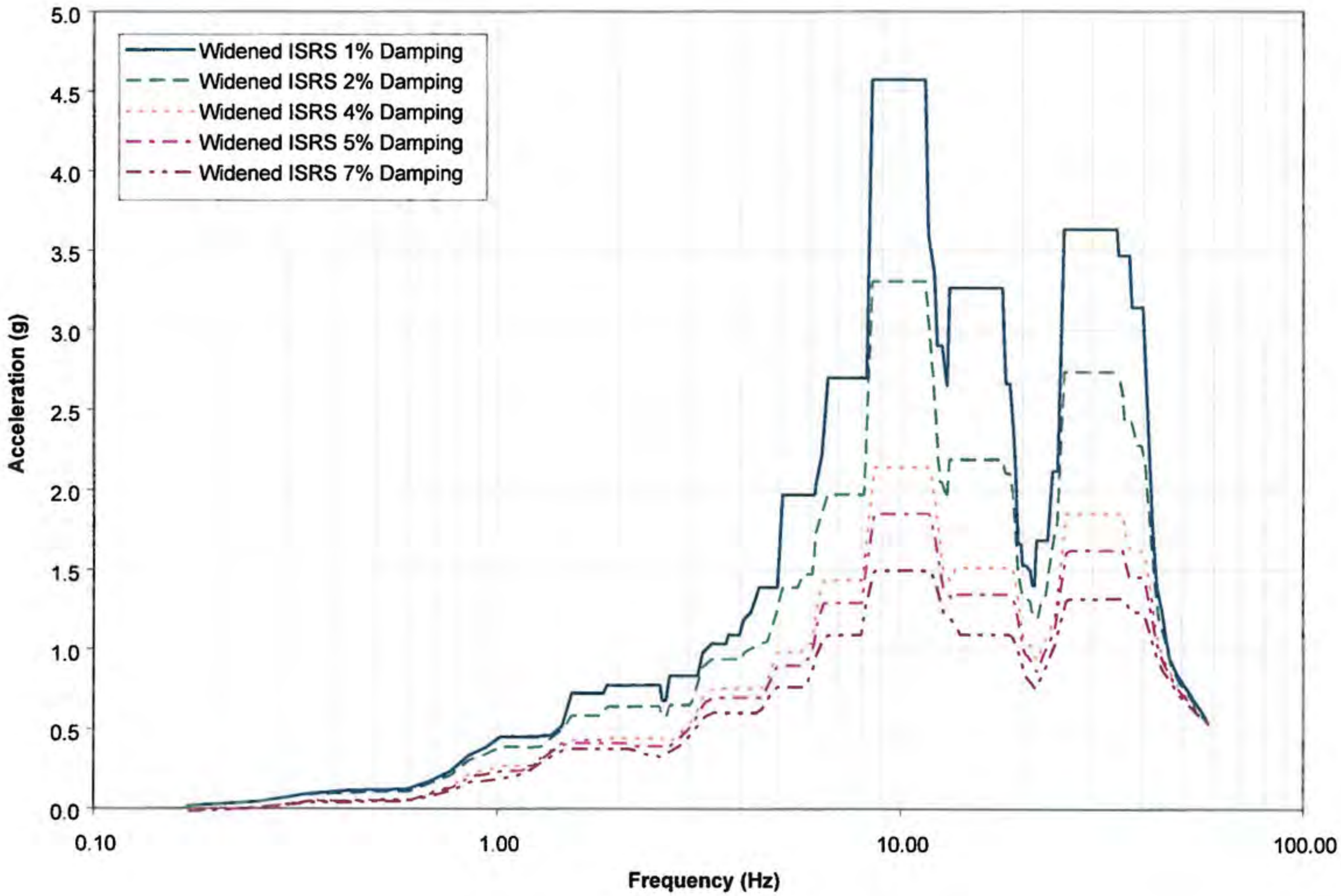


FIGURE 141-16: ISRS for Perimeter Wall EL. 811' - 0" - MHE Vertical Direction, CLB-LSS Envelop

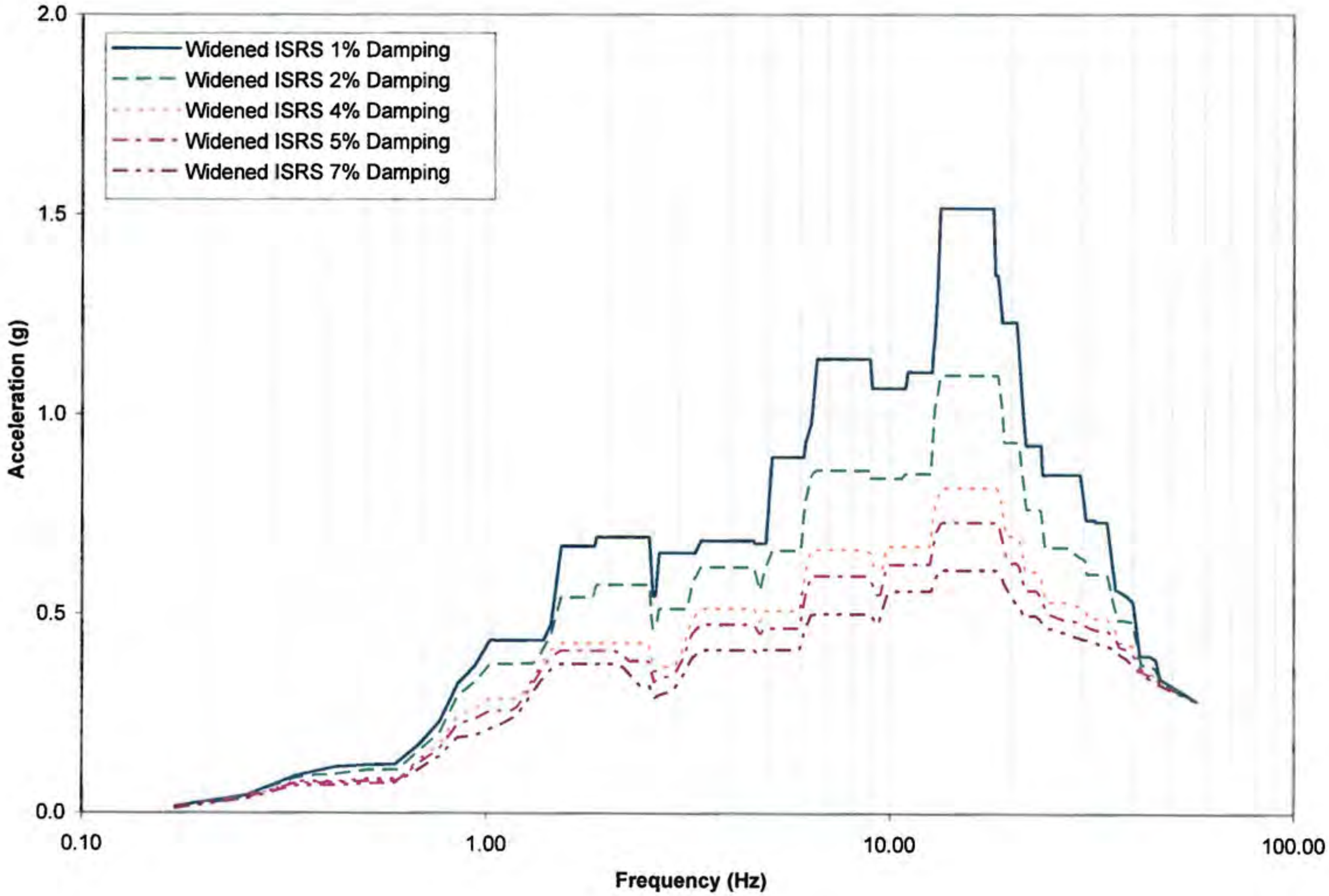
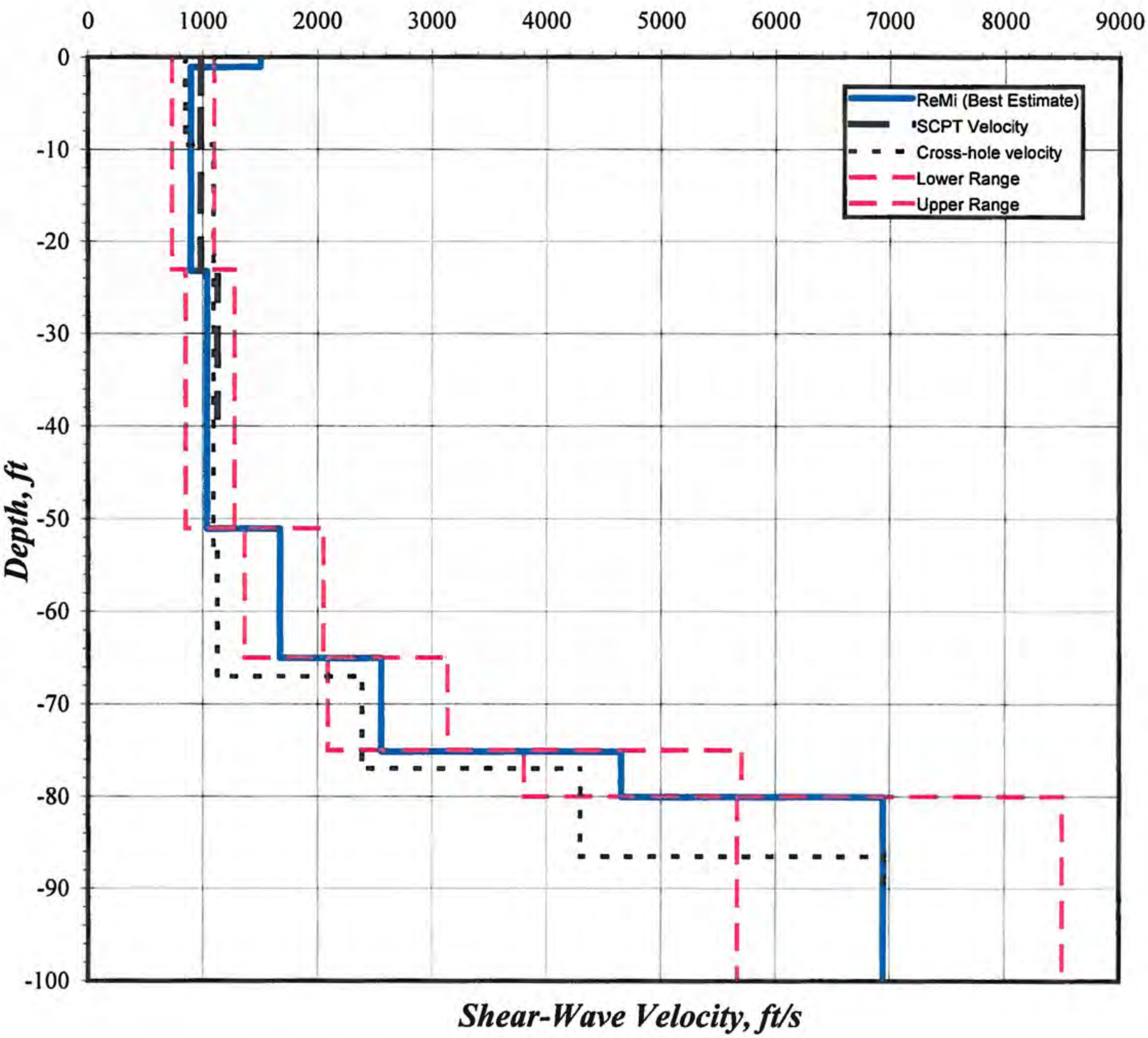


Figure 141-17: Shear-Wave Velocity Data at PSW Building Locality



RAI #160

In response to RAI-62, the licensee included, in its letter dated January 20, 2012, Institute of Electrical and Electronic Engineers (IEEE) 344-1975 as one of the industry standards that is being used for the PSW system design. Discuss the seismic qualification method(s) used for electrical and mechanical equipment credited for the PSW system. Provide a summary of the seismic qualification results to demonstrate that all equipment credited for the PSW system including their subcomponents (relays, contacts, breakers etc.) are capable to perform their intended design function in the event of a safe shutdown earthquake (SSE) after a number of postulated occurrences of the operating basis earthquake (OBE). The response to this RAI, as a minimum, should include the test response spectra (if applicable), the required response spectra, the method of mounting of equipment to the shake table, and the equipment mounting configuration in service condition. Also, discuss the methodology, the industry codes and standards, the level of earthquake, and the acceptance criteria used for the structural design of the PSW equipment mounting.

Duke Energy Response:

The Duke Energy response to this request for information has three parts: I) Seismic qualification of electrical equipment, II) seismic qualification of mechanical equipment and III) anchorage as discussed below.

I. Seismic Qualification of Electrical Equipment

Seismic qualification of electrical equipment is outlined in Section 3.10 of the Oconee Updated Final Safety Analysis Report (UFSAR). For the PSW project, QA-1 electrical equipment was seismically qualified in accordance with IEEE 344-1975, which meets or exceeds the Oconee UFSAR requirements for qualification by testing or analysis. Qualification is performed for all electrical equipment using shake table testing, analysis or a combination of testing and analysis.

The NRC endorsed IEEE 344-1975, with exceptions, in Regulatory Guide 1.100, Revision 1. The exceptions were:

1) Section 5.3 – Use of the 1.5 static coefficient was found acceptable but a requirement was imposed for justifying its use.
2) Section 6.6.2.1 – This concerns single-frequency test input motion and that the resultant Test Response Spectrum (TRS) at the test frequencies must equal 1.5 times the acceleration of the required response spectrum (RRS). This section also allowed the TRS to not envelope the RRS, if the 1.5 factor was used. Justification is therefore required to use single frequency testing and for the TRS to not envelope the RRS.
3) Section 6.6.2.5 – For sine sweep testing, the TRS was again allowed to fall below the RRS by reference to Section 6.6.2.1. Sine sweep testing was deemed not suitable for equipment qualification unless justification was provided.
4) Section 8 – Documentation. Supplemental documentation is required related to equipment malfunction data.

For QA-1 electrical equipment, procurement documents were generated in accordance with Duke Energy's directive EDM-140 "Procurement Specifications for Equipment." Seismic demand at the equipment mounting location was included in those procurement

documents. For new floor- and wall-mounted electrical enclosures, the applicable in-structure response spectra demand was used for the equipment mounting location. For components added to existing safety-related electrical enclosures, such as the electrical components added to the Oconee Main Control Boards, in-cabinet response spectra demand for the electrical component mounting locations was specified.

Procurement documents were used by the selected vendors to perform the qualification. Whether testing, analysis or a combination of testing and analysis was used; the vendors assured the resulting seismic capacity of the equipment enveloped the specified seismic demand. For testing, the 10% margin specified in IEEE 323 was included. Pre- and post-seismic functional testing was performed. All shake table testing consisted of five OBE earthquakes followed by SSE testing taking into account the electrical safety function of the equipment (i.e. contactors were evaluated in energized and de-energized states and for transition between those states and chatter was monitored in excess of 2 msec). In addition, random multi-frequency input was used for the testing as opposed to single-frequency and sine-sweep testing noted in the RG 1.100 exceptions #2 and #3 above. Any anomalies found through testing were documented in the qualification reports and given a disposition. Therefore, RG 1.100, Revision 1 Exceptions #2, #3 and #4 were addressed.

Qualification by analysis was used for some of the equipment following the methods given in IEEE 344-1975. The 1.5 multimode factor was used as appropriate and justified. Therefore, RG 1.100, Revision 1 Exception #1 has been addressed.

As part of the procurement, Duke Energy required an owner review and approval of the qualification plans prior to the qualification to insure the vendor's qualification method would meet the owner's requirements. Vendor qualifications were documented in vendor qualification reports that were again owner reviewed. Final qualification reports were entered into Oconee Document Control and Records Management to maintain a record of the qualification. Qualification reports met the documentation requirements of IEEE 344-1975 and included seismic capacity versus demand comparisons. Because of the extensive list of electrical equipment, there is a corresponding extensive list of qualification documents.

The procurement documents also required the vendor to determine anchorage requirements. The qualifications documented the adequacy of that anchorage design and each vendor developed drawings to transmit the anchorage design. The drawings were used to anchor the equipment to the structures during implementation of the engineering changes. If problems arose with the vendor-defined anchorage, then site civil was contacted and they worked with the vendor to determine the acceptability of any changes.

Appendix AW of ONS calculation OSC-9506, "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 0, includes a figure on P. AW2 identified as PAW1 "Seismic Horizontal and Vertical FDS (5% Damping) and EPS, Elevation 818'." The purpose of that figure is to compare the final horizontal and vertical envelopes of the in-structure response spectra calculated for the center of the roof of the PSW Building against the conservative estimate of worst-case in-structure spectra referred to as "Equipment Procurement Spectra" (EPS). It should be noted that the EPS was determined, and used for procurement purposes for equipment with long lead-times, as the PSW Building response spectra analyses were being performed. When the final enveloped results were created for the operating floor, mezzanine, mid-height of the walls and the roof of the PSW Building, they were compared to the EPS in Appendices AT through AW. As shown in those plots,

the EPS did indeed bound all of the PSW Building locations except for the vertical response at the center of the PSW Building roof.

Wherever the EPS was used for the procurement of electrical equipment, the procurement specifications included hold points to validate the seismic input(s). The hold points were removed by either revising the procurement specification to add the corresponding final envelopes from OSC-9506 or in some cases deviations to the procurement specifications were issued with the corresponding final envelopes from OSC-9506. In either case, the equipment that was initially procured using the EPS was qualified using the appropriate seismic in-structure spectra.

In the Duke Energy Response to RAI-141 dated July 20, 2012, it was determined that the PSW Building in-structure response spectra, that was originally included with the procurement specifications, required revision. Therefore, the PSW Building was reanalyzed and the results documented in Oconee Calculation OSC-10764 "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 1.

As a result of the PSW building reanalysis a reevaluation of the electrical equipment was required. A comprehensive seismic capacity versus demand evaluation was completed via Oconee Calculation OSC-10824 "Evaluation of New In-Structure Response Spectra for the PSW Building on Electrical Equipment Qualification," Revision 0 to verify the seismic capacity of electrical equipment located in the PSW Building bounded the new seismic demand listed in OSC-10764 Revision 1. In cases where the capacity did not completely envelope the new in-structure demand response spectra, either an appropriate engineering justification was made, or the equipment was requalified using the new in-structure response spectra.

Seismic Qualification of Electrical Equipment

Specific Example – Motor Control Centers in the PSW and Auxiliary Buildings

Motor Control Centers (MCC) were included with the scope of PSW electrical equipment and are located in the Auxiliary and PSW Buildings. The requirements for procurement of the MCCs were documented in OSS-0308.00-00-0007, "Procurement Specification for the Design, Fabrication and testing of the QA-1, 600 VAC Motor Control Centers (MCCs) for the Protected Service Water (PSW) System," Revision 2. Nuclear Logistics Incorporated (NLI) was selected as the supplier and their qualification plan was documented in QP-29412392-1, "Qualification Plan for Motor Control Centers," Revision 3. Duke Energy approved that qualification plan and NLI performed the qualification. Seismic qualification of the equipment was documented in NLI Qualification Report QR-29412392-1, "Qualification Report for Motor Control Centers," Revision 4 which was filed as an Oconee vendor manual and placed in Oconee Document Control and Records Management. The vendor manual number is OM 308.--531.001, "PSW – Seismic Qualification Report for Motor Control Centers XPSW, 1XPSW, 2XPSWA, 2XPSWB and 3XPSW," Revision 4.

The MCCs were qualified by a combination of shake table testing and analysis in accordance with IEEE 344-1975. Shake table testing was used to qualify the enclosures and equipment and analysis was used to qualify additional changes made after the completion of the shake table testing. For example, analysis was used to address vertical barriers added to the enclosures for personnel safety.

The MCCs consist of two different types based on physical location: 1) NEMA 3R MCCs for the Auxiliary Building and 2) NEMA 1 MCCs for the PSW Building. All of the MCCs were Freedom 2100 Series with a 600A main bus and were joined in sets connected on their sides. The largest sets have five sections bolted together and the smallest set has two sections bolted together.

One representative NEMA 1 enclosure was bolted to one representative NEMA 3R enclosure using the standard inter-cabinet bolting used for these enclosures. The bolted enclosure set was welded to a base plate to simulate the installed configuration in the final design drawings. The as-tested layout is shown on NLI Drawing 29412392-LDTS-1, "MCC Test Specimen Outline," Revision 3 that is given in Appendix D of the NLI Qualification Report. The base plate containing the set of two enclosures was fastened to the shake table using four 3/8" diameter bolts. The report states that four bolts used to anchor the set of two enclosures bounds the proposed field installation where four bolts were specified for each individual section (i.e. a set of two sections has a total of eight anchors in the field).

Each enclosure specimen included a representative set of electrical equipment. The equipment was selected by considering all of the equipment in all of the MCC enclosures and the relative mounting locations of that equipment within the enclosure. Traceability between the test specimens and the production units was given in Section 2.2 of the qualification report.

In-structure response spectra for the Auxiliary and PSW Buildings were included in the procurement specification. NLI created a composite envelope of those spectra and used it as the Required Response Spectra (RRS) input for the shake table testing. The Operating Basis Earthquake (OBE) at Oconee is one-half the Safe Shutdown Earthquake (SSE) so the RRS was factored by 0.5 for the OBE and taken as the full value for the SSE.

A comparison of the Test Response Spectrum (TRS), obtained from the control accelerometers, to the RRS for the SSE is shown in Figures 160.1 and 160.2 for the horizontal and vertical excitation directions respectively (Note: Figures 160.1 and 160.2 are provided in the RAI #160 supplemental information section of the Attachment to the July 20, 2012, RAI response letter).

An anomaly documented the fact that the TRS did not fully envelope the RRS below approximately 2 Hz for both excitation directions. Before the OBE and SSE testing, however, the vendor performed low-level sine-sweeps to determine the resonant frequencies of the enclosure set. Because the enclosure set did not have resonant frequencies in that range, the exceedance was deemed acceptable.

The testing consisted of five OBE tests followed by three SSE tests that covered the energized, de-energized and transition states of the electrical equipment. Two of the SSE tests were substituted for two of the OBE tests. The test series was conducted in four different specimen orientations at 0, 90, 180 and 270 degrees to capture the in-phase and out-of-phase response due to the dependent biaxial shake table.

QA-1 electrical equipment was subjected to pre- and post-seismic functional testing and was monitored for contact chatter in excess of two milliseconds during the shake table testing. The list of equipment, functional state, type of monitoring and acceptance criteria was given in Section 4.2.6 of the report for the three SSE tests. Equipment with no moving contacts (i.e. terminal blocks and fuse blocks) was monitored for continuity and non-safety equipment

was evaluated for structural integrity (mounting) only. All of the equipment met the acceptance criteria except that the door on the NEMA 3R enclosure popped open during some of the testing. NLI resolved this issue by adding a small padlock to the door and then later qualified a hitch pin proposed by Duke Energy. The requirement to include the hitch pin to maintain seismic qualification was included on the final design drawings.

Anomalies were identified and addressed in an appendix to the test report.

Additional analysis was used to quantify anchorage loads to be used by Duke Energy. The qualification report references a separate NLI anchorage qualification report. The anchorage qualification report is QR-29411642-4, Revision 3 and was filed as an Oconee Vendor Manual OM 302.A-0072.004, "Mounting Base Design and Anchorage Loads for NLI Supplied Equipment," Revision 3.

An additional capacity versus demand comparison was performed in OSC-10824, Revision 0. This verified that the new in-structure response spectra (ISRS) from OSC-10764, Revision 1, Appendix AX and AY did not negatively impact the seismic qualification of the 600V MCC that is located in the PSW Building. The qualification of the 600V MCC located in the Auxiliary Building is not impacted by the new ISRS for the PSW Building.

<u>Specific Example – Batteries and Battery Racks in the PSW Building</u>

See Duke Energy's response to RAI-161 (submitted to the NRC on July 11, 2012) for the details of the qualification of the PSW batteries and racks.

II. <u>Seismic Qualification of Mechanical Equipment</u>

Specification ECV-0601.00-00-0005, Rev.1 "Specification for the Seismic Qualification of Equipment" by Duke Energy Carolinas, LLC, Oconee Nuclear Station Units 1, 2 and 3 describes acceptable methods for seismic qualification of electromechanical equipment. The following governing design criteria documents and references are used, among others, as a basis for the seismic qualification:

- UFSAR:

  Section 3.7 "Seismic Design", Section 3.9 "Mechanical Systems and Components", Section 3.10 "Seismic Qualification of Category I Instrumentation and Electrical Equipment".

- Codes and Standards:

  IEEE Standard 344-1975.
  IEEE Standard 323-1974.
  IEEE Standard 627-1980,

- Specifications:

  OSS -254.00-00-4010 "Design Basis Specification for Seismic Design," Rev. 4.
  OSS-0235.00-00-0013, "Procurement Specification for the QA-I Heating and Ventilation System of the Protected Service Water Building". Revision 2.

- Regulatory Document:

  USNRC R.G. 1.100, Rev 1.

As QA Condition 1 (QA-1), the PSW mechanical equipment (ME) seismic qualification is governed by the QA program requirements of 10CFR50, Appendix B, and applicable Oconee's procurement, design, fabrication, and installation specifications supplemented by industry codes, standards, and US NRC regulatory guides. Procurement specifications cover the design, fabrication, testing, delivery, and quality assurance documentation of the equipment. Seismic qualification of Class 1E equipment is governed by detailed requirements stipulated in IEEE Standards 344-1975 and IEEE Standards 323-1974. Class 1-E equipment are identified as essential to emergency reactor shutdown, containment isolation, reactor core cooling, containment and reactor heat removal, and preventing significant release of radioactive material to the environment.

IEEE Standards 344-1975 provide procedures which verify that Class 1-E equipment can meet its performance requirements during and following one SSE preceded by a number of OBE specified seismic events. Section 4 of IEEE 344 details acceptable methods used for seismic qualification as follows:

1. Analysis that would predict equipment performance (safety margins against code allowable for various operating and accident loading conditions).
2. Testing under simulated seismic conditions (for operability, and overall structural integrity determination).
3. Qualification by combined test and analysis.

Choice of qualification method is based on the type, size, shape, and complexity of the equipment and the desired reliability of the conclusion.

IEEE Standard 323-1974, Section 4, lists operating experience as a method of limited use as a sole means of seismic qualification but of great use for supplementation of testing. In addition, Section 6.3.1.5 lists margins (suggested factors) to be applied to service conditions (e.g., temperatures +15°F, pressure +10% ≤10 psi, etc.).

For the Duke Energy PSW Project, Mechanical Equipment procurement specifications were issued to Duke Energy approved vendors. These specifications provided detailed seismic qualification requirements for the vendors to use. It should be noted that the EPS was determined, and used for procurement purposes for mechanical equipment with long lead-times, as the PSW Building response spectra analyses were being performed. When the final enveloped results were created for the operating floor, mezzanine, mid-height of the walls and the roof of the PSW Building, they were compared to the EPS in Appendices AT through AW of OSC-9506, Rev. 0. As shown in those plots, the EPS did indeed bound all of the PSW Building locations except for the vertical response at the center of the PSW Building roof.

Wherever the EPS was used for the procurement of mechanical equipment, the procurement specifications included hold points to validate the seismic input(s). The hold points were removed by either revising the procurement specification to add the corresponding final envelopes from OSC-9506, Rev. 0 or in some cases deviations to the procurement specifications were issued with the corresponding final envelopes from OSC-9506, Rev. 0. In either case, the equipment that was initially procured using the EPS was qualified using the appropriate seismic in-structure spectra.

In the Duke Energy Response to RAI-141 dated July 20, 2012, it was determined that the PSW Building in-structure response spectra, that was originally included with the

procurement specifications, required revision. Therefore, the PSW Building was reanalyzed and the results documented in Oconee Calculation OSC-10764 "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 1.

As a result of the PSW building reanalysis a reevaluation of the safety related mechanical equipment in the PSW Building was required. An additional seismic capacity versus demand evaluation was performed to verify the seismic capacity of the safety related mechanical equipment located in the PSW Building bounded the new seismic demand listed in OSC-10764 Revision 1. All mechanical equipment was requalified for the appropriate in-structure response spectra in OSC-10764 Revision 1. In cases where the capacity did not completely envelope the new in-structure demand response spectra, either an appropriate engineering justification was made, or the equipment was requalified using the new in-structure response spectra. The final qualification reports for the safety related mechanical equipment, OM 235-0624.001, OM-235-0687.002, and OM-235-0633.002 were revised to include the new seismic evaluation.

The following are examples of qualification by analysis and testing.

<u>Seismic Qualification of Mechanical Equipment</u>

<u>Specific Example 1 – Booster Pump in the Auxiliary Building</u>

Booster Pump seismic qualification is documented in Report No. PVA1000294590010-01, Rev. 3. Details seismic testing requirements for any PSW mechanical equipment are provided in pertinent procurement specification. Specification OSS-0208.00-00-0015, "Protected Service Water Booster Pump", Rev. 2 addresses seismic requirements, quality assurance requirements, supplier's documents, test, inspection and conformance with specification.

The seismic qualification analysis of the PSW system Booster Pump was performed using general purpose finite element code ANSYS. A three-dimensional (3-D) Finite Element Model (FEM) detailing mass, stiffness, and bolted connections of various components of the pump, motor and mounting steel frame was developed. The model included contact elements to simulate bolted connections preload conditions and potential separation between contacted surfaces.

A natural frequency analysis was performed on the FEM and the results indicated that all calculated natural frequencies were above the Zero Point Acceleration (ZPA) frequency of 20 Hz. Accordingly, the pump assembly was, therefore, considered rigid and equivalent static analysis method was used to determine effects of OBE and SSE seismic loading conditions. The method includes the use of applicable ZPA accelerations, a static coefficient of 1.5, and the SRSS method to combine seismic responses in the three orthogonal directions (2 horizontal and 1 vertical).

The dead weight, thermal, internal pressure, nozzle loading and Seismic OBE and SSE loads are considered in the qualification of the pump assembly. The detailed calculations have been performed to determine Load/Capacity, (L/C) ratios (i.e., Calculated/ Allowable) for various pump assembly components (i.e., Casing, Cover, Bearing Housing, Bolting, Base Plate, Rotor Evaluation, Pipe Work and Flange).

Based on documented results, it is concluded that the capacity, C, of the evaluated components (as specified by the pertinent allowable values) far exceeds the seismic demand (i.e., the calculated load, L, values). Therefore, ample margins of safety exist against specified operating and seismic load combinations.

Section 3.1 of Sulzer's seismic analysis report lists applicable OBE seismic response spectra (RS) (where the Booster Pump will be mounted) for the Auxiliary Building, Floor El. 771', N-S, E-W, and vertical directions. The applicable RS are provided in procurement specification OSS-0208.00-00-0015, Rev. 2 of the PSW Booster Pump.

Specific Example 2 – Greenheck Fan Motor Assemblies in the PSW Building

Equipment Tested:

- Fan Model No: VAD-24FI7-32-AI0, 1,770 RPM, 24.38" diameter Axial Flow Fan, Direct Drive Baldor Motor, 10 HP TEAO, 575/60/3
- Fan Model No. AX41-190-0409-M3, 3,500 RPM, 16.25" diameter Axial Flow Fan, Direct Drive Baldor Motor, 3 HP TEAO, 575/60/3

Applicable Specifications:

Duke Energy Specification No. OSS-0235.00-00-0013, Revision 2, dated September 15, 2010, "Procurement Specification for the QA-I Heating and Ventilation System of the Protected Service Water Building".

Duke OM 235-0687.002, Rev. DC, test report (Vendor report No. EGS-TR-23050-0611-05) documents methodology, procedures and results for environmental and seismic qualification of Commercial Grade (CG) Heating and Ventilation (HV) equipment for nuclear safety-related (QA-I) in use at the PSW Building per the applicable requirements outlined in the IEEE 344-1975 and 323-1974; and Regulatory Guide (RG) 1.100, Revision 1. Specifically, this report documents the seismic/environmental results pertaining to the qualification of the commercial grade Greenheck fan/motor assemblies. The fan/motor assemblies are part of the PSW Building HV system and are designated as Oconee QA Condition, which specifies structures; systems or components (SSC) subject to the quality assurance requirements of 10CFR50, Appendix B.

The two sacrificial fan/motor assemblies were subjected to the seismic qualification testing and pre-and post-seismic operational verification testing per the procedures and requirements outlined in the seismic test procedure of fan/motor assemblies.
The testing was performed at QualTech NP's Cincinnati, Ohio test facility and was witnessed by Bahnson and Flour QA personnel. The test fan/motor assemblies were mounted per test procedure utilizing appropriately sized ASTM-A307 mounting bolts, washers, lock washers and nuts. All bolts were torqued snug-tight.

The fan motors were electrically powered and accelerometers were mounted. Subsequently, the test units were subjected to the following tests:

- Pre-Seismic Operational/Functional Check
- Resonance search testing
- Full-Level Qualification Tests
- Post-Seismic Operational/Functional Check

The fan assemblies were tested operational (with nominal 575 VAC applied during the performance of all seismic tests.

No structural deteriorations (such as loose or detached mounting hardware, dislodged motor attachment, cracked welds, loose or detached sub-assemblies or components thereof, loose electrical interface connections etc.) were detected. Additionally, no physical interference between the fan blades and the fan housing occurred during any of the performed tests and no drift or change in blade pitch occurred as a result of the imposed seismic test environment. The motor assemblies maintained their electrical integrity (fan/motor RPM (s) remained consistent and no deterioration of the Insulation Resistance (IR) occurred. Therefore, the tested fan/motor assemblies possessed sufficient structural, electrical, and operational integrity, to successfully withstand the imposed OBE-level and full SSE-level simulated seismic environments within the specified acceptance criteria.

The following minimum acceptance criteria apply. There shall not be any loss of:

- Structural integrity resulting in mounting detachment of the fan assemblies and/or subcomponents thereof.
- Electrical integrity (short or open circuits).
- Operational integrity caused by either structural, electrical, or mechanical defects

Test setup details, data sheets containing results for the performed pre- and post-seismic operational checks, seismic test summary including data plots and photographs are documented in the Appendix I of this report.

Based on the seismic test results documented in this test report, the successful qualification of the tested representative sacrificial fan/motor assemblies is extended to include all the PSW production fan/motor assemblies which will be delivered for use at the PSW Building.

An additional study was performed in Appendix V of this report to address qualification of fan/motor assemblies for the applicable In-Structure Seismic Response Spectra from OSC-10764, Rev.1. This study verified that the applicable new in-structure response spectra from OSC-10764, Revision 1, are bounded by the previous test spectra; therefore, new in-structure response spectra did not negatively impact the seismic qualification of the fan/motor assemblies of HV system in the PSW Building.

III. Seismic Qualification of Equipment Mounting

Load combinations and structural design criteria for anchorage of components in the PSW, Auxiliary, and SSF Buildings are given in Duke Energy specification OSS-0292.00-00-0001, Specification for Design and Implementation Support of the Protected Service Water System, for SSE and OBE earthquakes.

Methodology:

All Buildings

- Attachments are Nuclear Safety Related
- Seismic analysis of the attachment of electrical equipment uses a static coefficient factor of 1.5 for new designs.

- The design of concrete expansion anchors used to attach new and/or existing equipment are in accordance with specifications OSS-0020.00-00-0004, Specification for the Design, Installation and Inspection of Concrete Expansion Anchors, and OSS-0020.00-00-0006, Specification for the Design, Installation, and Inspection of Hilti Concrete Expansion Anchors.

PSW Building and Auxiliary Building

- Attachment of equipment is evaluated for worst-case resultant seismic loads by summing forces/moments produced by the vertical seismic acceleration and the controlling horizontal (east/west or north/south) seismic acceleration based on acceleration magnitude and attachment geometry. (See Section 3.7.2.5 of the Oconee UFSAR)
- Critical damping values (used for the seismic analysis of the attachment of new and/or existing equipment) are as specified in Section 3.7.1.3 of the Oconee UFSAR.
- For PSW building seismic equipment mounting qualification, the in-structure response spectra documented in OSC-9506, Rev. 0 was utilized. Following the Duke Energy Response to RAI-141 dated July 20, 2012, it was determined that the PSW Building in-structure response spectra, that was originally used in the PSW building equipment mounting calculations, required revision. Therefore, the PSW Building was reanalyzed and the results documented in Oconee Calculation OSC-10764 "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 1. As a result of the PSW building reanalysis a re-evaluation of the PSW building equipment mounting was required. All pertinent equipment mounting calculations (See Table I) were revised to verify the original seismic design load (i.e., peak acceleration of appropriate in-structure response spectra) of existing equipment anchorage located in the PSW Building bounded the new seismic load listed in OSC-10764 Revision 1. In cases where the original design load did not completely envelope the new seismic load in OSC-10764, Rev. 1, the equipment mounting was re-qualified using the peak acceleration of the new in-structure response spectra.

SSF Building

- The seismic analysis of the attachment of equipment is performed in accordance with Section 6.3.8 of specification OSS-0176.00-00-0002, Design Specification for Standby Shutdown Facility and shall be evaluated for worst-case resultant seismic loads obtained by the square-root-of-the-sum- of-the-square (SRSS) of forces/moments produced by all three components of earthquake motion: vertical acceleration and both horizontal (east/west and north/south) accelerations. (Regulatory Guide 1.92, Revision 1 and Sections 9.6.3.1 and 9.6.4.3 of the Oconee UFSAR).

<u>Structural Acceptance Criteria:</u>

PSW Building

- Subsection II.5 of SRP Section 3.8.4, DRAFT Revision 2

Aux. Building

- Section 20.2.3 of OSS-0254.00-00-3007, Design Basis Specification for the Auxiliary Building

SSF Building

- Section 4.2.1 of OSS-0176.00-00-0002, Design Specification for Standby Shutdown Facility

Loads and Load Combinations:

PSW Building

- Dead loads consist of the weight of the structure plus all equipment and materials permanently fastened to, and supported by, the structure/component.
- Live loads are the loads produced by the use and occupancy of the building or structure. They include the weight of all movable loads, including personnel, tools, miscellaneous equipment, movable partitions, cranes, hoists, parts of dismantled equipment, and stored material.
- Seismic in-structure response spectra as specified in OSC-10764, Revision 1. Critical damping values as specified in Section 3.7.1.3 of the Oconee UFSAR. Components of earthquake motion applied as specified in Section 3.7.2.5 of the Oconee UFSAR.
- Load Combinations are as specified in NUREG-800, SRP 3.8.4, DRAFT Revision 2.

Aux. Building

- Sections 20.2.1 and 20.2.2of OSS-0254.00-00-3007, Design Basis Specification for the Auxiliary Building

SSF Building

- Section 6.2.1 of OSS-0176.00-00-0002, Design Specification for Standby Shutdown Facility

Codes and Standards:

PSW Building

- Structural steel and plates: Subsection II.2 of Standard Review Plan (SRP) Section 3.8.4, DRAFT Revision 2 (i.e., ANSI/AISC N690-1984 as supplemented by Appendix F of SRP Section 3.8.4)
- Anchoring components and structural supports in concrete: Subsection C of Regulatory Guide 1.199 (i.e., Appendix B (February 2001) to ACI 349-01 as supplemented by Regulatory Guide 1.199)

Aux. Building

- Section 20.2.4 of OSS-0254.00-00-3007, Design Basis Specification for the Auxiliary Building

SSF Building

- Section 4.3.1 of OSS-0176.00-00-0002, Design Specification for Standby Shutdown Facility

Examples:

PSW Building

- OSC-9818, "PSW Battery and Battery Racks 0 PSW BC CPSW001 and 0 PSW CPSW002 Seismic Mounting Qualification," Revision 1.

Auxiliary Building

- OSC-9357, "Terminal Cabinet 1PSWCA0001 Seismic Mounting Qualification," Revision 0.

SSF Building

- OSC-1371, "Seismic Mounting of Electrical Equipment for the Standby Shutdown Facility," Revision 33.

RAI #161

Discuss the method of seismic qualification of DC batteries associated with the PSW system and the supporting battery rack structure(s). Describe the procedures used to account for possible amplification of vibratory motion through the battery rack structure.

Duke Energy Response:

DC Batteries and Battery Racks for the PSW system are located in two adjacent Battery Rooms in the PSW building. The method of Seismic Qualification of electrical equipment is discussed generically within the Duke Energy Response to RAI-160. The requirements for procurement of the Batteries and Battery Racks were documented in OSS-0320.00-00-0023 "Specification for the Design, Fabrication and Testing of the QA-1, 125 VDC Batteries for the Protected Service Water (PSW) System", Rev 1 with Deviations 1 and 2. The equipment vendor C&D Technologies (C&D), performed the seismic qualification and supplied both a Test Plan and Final Report per Deviation 2 in C&D Report QR-2312237 "Seismic & Environmental Qualification Report of 125 Volt DC LCY-39 Batteries & 2-Step Battery Racks", Rev 4 which was filed as an Oconee vendor manual. The vendor manual number is OM 320.–0239.001 "PSW - Seismic & Environmental Qualification Report of 125VDC LCY-39 Batteries & 2-Step Battery Racks", Rev 4.

Qualification was by similarity to previous shake table testing in accordance with IEEE 344-1975. The previous shake table test, performed by Wyle Laboratories and documented in Report 43450-1, "Seismic Simulation Test Program on a Battery Rack and Batteries", dated December 7, 1976, is contained in Attachment 2 of QR-2312237. This test used a similar 2-Step Battery Rack and was fully loaded with naturally aged, artificially aged and un-aged batteries of various ratings. Any test anomalies were documented and justified within the body of the 43450-1 report. Any differences between the previously tested batteries and battery racks and PSW production Batteries and Battery Racks were justified fully within the QR-2312237 report.

The in-structure response spectra for the PSW Battery Room were specified in Deviation 1 of OSS-0320.00-00-0023 Rev 1. C&D performed a comparison of the Test Response Spectrum (TRS) from the previous test in 43450-1 against this Required Response Spectrum (RRS), after adjusting for both the 10% margin required by IEEE 323-1974, and to account for a weight difference between the tested and supplied Batteries and Battery Racks. The TRS vs. RRS for the Safety Shutdown Earthquake (SSE) is shown in Figure 161.1 and Figure 161.2 (Note: Figures 161.1 and 161.2 provided in the RAI #161 supplemental information section of the attachment to

the July 20, 2012 RAI response letter). The small excursion in Figure 161.2 where the TRS did not fully envelope the RRS is justified within QR-2312237 as being acceptable as the batteries and battery racks are not dynamically responsive at low frequency.

The testing consisted of five Operational Basis Earthquake (OBE) tests followed by an SSE test. The battery cells were connected in series to a resistive load and monitored during all phases of the test program. The battery output voltage and current were recorded on an oscillograph recorder to determine electrical continuity, current and voltage levels, and to detect any spurious operation during seismic testing. There are no moving contacts in the batteries or battery racks that would necessitate chatter monitoring. The test program was conducted in two separate specimen orientations at 0 and 90 degrees due the bi-axial independent motion seismic table with phase in-coherent vertical and horizontal inputs.

The batteries and battery racks were subjected to pre- and post-seismic functional testing as well as monitoring during the shake table testing. A summary of the results is listed in Section 5.7 of QR-2312237.

An additional capacity versus demand comparison was performed in Oconee Calculation OSC-10824, "Evaluation of New In-Structure Response Spectra for the PSW Building on Electrical Equipment Qualification," Revision 0. This verified that the new in-structure response spectrum (ISRS) from Oconee Calculation OSC-10764 "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 1, Appendix AX and AY did not negatively impact the seismic qualification of the DC Batteries and Battery Racks located in the PSW Building.

RAI #162

Discuss the methodology, the industry codes and standards, the level of earthquake, and the acceptance criteria used for the structural design of the battery rack structure and its anchorages.

Duke Energy Response:

1. Seismic Qualification of Electrical Equipment

   The battery racks were seismically qualified by seismic shake table testing and dynamic similarity in accordance with IEEE 344-1975 as discussed in the Duke Energy response to RAI-161. Because analysis was not used for this equipment qualification, the development methodology or industry codes and standards used by C & D Technologies, Inc (C&D) are not required as part of this qualification. This is acceptable because the structural design of the battery racks was successfully challenged via proof testing in accordance with IEEE 344-1975. The level of earthquake and acceptance criteria are discussed in the Duke Energy Response to RAI-161 (from the RAI response letter dated July 11, 2012).

2. Anchorage

   Load combinations and structural design criteria for anchorage of the Battery Racks in the PSW Building are given in ONS specification OSS-0292.00-00-0001, "Specification for Design and Implementation Support of the Protected Service Water System, for SSE and OBE earthquakes."

   Methodology:

   Buildings

- Attachments are QA-1.
- Seismic analysis of the attachment of electrical equipment uses a static coefficient factor of 1.5 for new designs.
- The design of concrete expansion anchors used to attach new and/or existing equipment are in accordance with existing Oconee anchor design specifications.
- Attachment of equipment is evaluated for worst-case resultant seismic loads by summing forces/moments produced by the vertical seismic acceleration and the controlling horizontal (east/west or north/south) seismic acceleration based on acceleration magnitude and attachment geometry (See Section 3.7.2.5 of the Oconee UFSAR).
- Critical damping values (used for the seismic analysis of the attachment of new and/or existing equipment) are as specified in Section 3.7.1.3 of the Oconee UFSAR.
- Welds to embedded plates were specified by the vendor and confirmed within calculation OSC-9818, "PSW Battery and Battery Racks 0 PSW BC CPSW001 and 0 PSW CPSW002 Seismic Mounting Qualification," to be conservative.

Structural Acceptance Criteria:

- Subsection II.5 of SRP Section 3.8.4, DRAFT Revision 2.

Loads and Load Combinations:

- Dead loads consist of the weight of the structure plus all equipment and materials permanently fastened to, and supported by, the structure/component.
- Seismic design response spectra as specified in OSC-9506, "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building."
  Note: Following the Duke Energy Response to RAI-141 dated July 20, 2012, it was determined that the PSW Building in-structure response spectra, that was originally used in the PSW building equipment mounting calculations,OSC-9506 required revision. Therefore, the PSW Building was reanalyzed and the results documented in Oconee Calculation OSC-10764 "Generation of SSE In-Structure Seismic Response Spectra for the PSW Building," Revision 1. As a result of this reanalysis a re-evaluation of the PSW Building equipment mounting was completed. All pertinent equipment mounting calculations were reviewed and/or revised to verify the original seismic design load (i.e., peak acceleration of appropriate in-structure response spectra) of existing equipment anchorage located in the PSW Building bounded the new seismic load listed in OSC-10764 Revision 1. This re-evaluation included OSC-9818, "PSW Battery and Battery Racks 0 PSW BC CPSW001 and 0 PSW CPSW002 Seismic Mounting Qualification." In the re-evaluation of OSC-9818 it was determined that the accelerations documented in OSC-10764, revision 1, when increased by the static coefficient factor of 1.5 were bounded by the original acceleration values used in OSC-9818, revision 0, where a static coefficient factor of 1.0 was used.
- Load Combinations are as specified in NUREG-800, SRP 3.8.4, [DRAFT] Revision 2.

Codes and Standards:

- Structural steel and plates: Subsection II.2 of Standard Review Plan (SRP) Section 3.8.4, DRAFT Revision 2 (i.e., ANSI/AISC N690-1984 as supplemented by Appendix F of SRP Section 3.8.4).

- Anchoring components and structural supports in concrete: Subsection C of Regulatory Guide 1.199 (i.e., Appendix B (February 2001) to ACI 349-01 as supplemented by Regulatory Guide 1.199).

RAI #168:

RAI-139 requested design inputs (DI) (including loads and load combinations) for HVAC system components and component supports, ductwork and duct supports. The response to RAI-139(b), in reference to HVAC, shows loads and load combinations considered for HVAC supports only. Please provide requested design inputs for PSW System credited HVAC system ductwork and components (such as AHUs, Fans, AC refrigeration units etc) and component supports.

Duke Energy Response:

Similar to the response for RAI-139(b) the Structural Design Input Loads and Load Combinations for the HVAC System (Refer to Specification OSS-0235.00-00-0013, "Procurement Specification for the QA-1 Heating and Ventilation System of the Protected Service Water Building", Rev 2.)

- Normal:

  DW

- Upset:

  DW +/- OBE

- Faulted:

  DW +/- SSE

  Where:

  DW = Deadweight of ductwork, fans, mountings, insulation, miscellaneous, and attachments.

  OBE = Operating Base Earthquake loading determined by multiplying the appropriate OBE acceleration by the participating mass.

  SSE = Safe Shutdown Earthquake loading determined by multiplying the appropriate SSE acceleration by the participating mass.

RAI #169:

RAI-138 requested the following: "Identify the codes and code edition utilized for the structural design of the HVAC system components and component supports, ducts and duct supports and whether these codes are in the ONS CLB or current design basis (CDB). If these codes are not in the ONS CLB or CDB, please provide the basis for justifying use of these codes."

The response to RAI-138 provides the requested information for HVAC duct supports, but not for HVAC system components or ducts.

The response to RAI-138 states that "*For details on the codes and editions used for the qualification of HVAC equipment, see the response to RAI 160.*" Review of the response to RAI-160 shows that it does not include HVAC.

The response to RAI-62 designated standard ASME AG-1, 2003 as the Code for HVAC system design. The response to RAI-138, for the design of HVAC ducts, makes reference to the SMACNA HVAC Duct Construction Standards - Metal and Flexible, 2005. Please provide clarification and verify which HVAC codes have been utilized for the PSW system credited HVAC system ductwork and components (such as AHUs, Fans, AC refrigeration units etc) and component supports. If these codes are not in the ONS CLB or CDB, please provide the basis for justifying use of these codes.

Duke Energy Response:

The PSW System utilizes ASME AG-1, 2003 for the HVAC System Ductwork and ductwork components such as AHUs and fans. AC refrigeration is Non-QA and no HVAC codes are utilized. Ductwork supports utilize American Institute of Steel Construction (AISC) 6th Edition with material properties from other editions.

The Code and Code Edition used for the design of the safety related HVAC system is ASME AG-1, 2003, Code on Nuclear Air and Gas Treatment. Use of this ASME code revision is justified by comparison of it with ASME AG-1, 1997. ASME AG-1, 1997 was endorsed by the NRC in Regulatory Guide 1.52 revision 3 and Regulatory Guide 1.140 revision 2. It is also included in the Westinghouse AP1000 application that has been accepted by the NRC. Comparison of ASME AG-1, 2003 to ASME AG-1, 1997 was made by a line by line review of the sections that are applicable to the design of the PSW building HVAC system, ductwork and ductwork components.

Two reference documents listed in ASME AG-1, 2003 are shown as later revisions than what is listed in ASME AG-1, 1997. These documents are ASME B31.1 Power Piping,1988 and ASME NQA-1 Quality Assurance Program Requirements for Nuclear Facilities, 2000. Even though later versions of these documents are referenced, the content in both AG-1 1997 and 2003 was reviewed entirely for purposes of the aforementioned line by line comparison. Therefore, direct reference(s) to content in either ASME B31.1 Power Piping or ASME NQA-1 Quality Assurance Program Requirements for Nuclear Facilities was evaluated as part of the comparison.
In Section CA Conditioning Equipment, ASTM A90 and ASTM A653 standards for zinc coated materials were added. Also reference to ASTM A525 was superseded by ASTM A653 and editorial change to replace reference from ASME NQA-1 to ASME NQA-2.

The remaining differences identified were editorial in nature and have no technical impact on the PSW ductwork design. Examples of these differences are: change in spacing, replacing words with their mathematical symbol, changing phrasing to better convey meaning, renumbering paragraphs, tables and figures, adding publisher names and addresses, and author's names to references.

The sections of ASME AG-1, 1997 applicable to the design of the PSW HVAC systems were not changed by the 2003 revision. Therefore, use of ASME AG-1, 2003 in lieu of ASME AG-1, 1997 is acceptable.