VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

October 18, 2011

10 CFR 100, Appendix A

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Serial No.:	11-577A
NL&OS/GDM	R1
Docket Nos.:	50-338/339
	72-16
License Nos.:	NPF-4/7
	SNM-2507

VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION)
NORTH ANNA POWER STATION UNITS 1 AND 2
NORTH ANNA INDEPENDENT SPENT FUEL STORAGE INSTALLATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION (RAI)
RESTART READINESS DETERMINATION PLAN

By letters dated September 30, October 6 and 13, 2011, the NRC requested additional information regarding Dominion's Restart Readiness Determination Plan for North Anna Power Station following the August 23, 2011 Central Virginia earthquake. By letters dated October 3, 2011 (Serial No. 11-566) and October 10, 2011 (Serial Nos. 11-566A and 11-577), Dominion responded to many of the RAI questions provided by the NRC technical review branches. Dominion's responses to several of the remaining NRC questions, as well as subsequent clarifications requested by the NRC staff on previously submitted responses, are provided in Attachment 1 to this letter. Attachments 2 and 3 provide additional information that supplements Dominion's responses to many of the NRC questions. The specific NRC RAI letter date, the associated NRC technical review branch, and the corresponding questions being answered are listed below for reference:

NRC RAI Letter Date	NRC Technical Review Branch	RAI Questions
NRC letter dated September 30, 2011	EMCB (Piping)	Q 1 Clarifications to Qs 2 – 6
	License Renewal	Qs 1- 4
NRC Letter dated October 6, 2011	EMCB (Structures)	Qs 3, 10, 12, 13 - 17, 19 - 24, 26, 27, 32 - 35
NRC letter dated October 13, 2011	Licensing	Qs 1 and 2
	EMCB (Piping Supplemental Question)	Short Term Question - Steam Generator and Reactor Vessel Supports

Dominion's response to the remaining unanswered RAI questions will be provided in subsequent correspondence.

A001
NMSS26

If you have any questions or require additional information, please contact Mr. Gary D. Miller at (804) 273-2771 or Mr. Thomas Shaub at (804) 273-2763.

Sincerely,

E. S. Grecheck
Vice President – Nuclear Development

Attachments:

1. Response to Request for Additional Information – North Anna Restart Readiness Determination Plan
2. Evaluation of the Influence of the August 23, 2011 Central Virginia Earthquake on North Anna Power Station Units 1 and 2
3. Evaluation of North Anna SSCs Following the August 23, 2011 Central Virginia Earthquake

Commitments made in this letter:

1. As a long term action, Dominion plans to perform sampling analysis of ASME Class 1, 2 and 3 piping systems in accordance with EPRI NP-6695, Section 6.3.
2. As a long term action, in accordance with the EPRI guidance in NP-6695, a sampling analysis of equipment located in the Auxiliary Building will be completed.
3. Dominion plans to incorporate RGs 1.166 and 1.167, and the referenced EPRI Technical Report NP-6695, into the licensing basis for North Anna Power Station once the installation of upgraded seismic instrumentation has been completed to meet the requirements of RG 1.12, Revision 2, "Nuclear Power Plant Instrumentation for Earthquakes."

COMMONWEALTH OF VIRGINIA)

COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by E. S. Grecheck who is Vice President – Nuclear Development, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 18th day of October, 2011.

My Commission Expires: 4/30/2015.

Ginger Lynn Rutherford
NOTARY PUBLIC
Commonwealth of Virginia
Reg. # 310847
My Commission Expires 4/30/2015

Notary Public

cc: Regional Administrator
U.S. Nuclear Regulatory Commission - Region II
Marquis One Tower
245 Peachtree Center Ave. NE
Suite 1200
Atlanta, Georgia 30303-1257

NRC Senior Resident Inspector
North Anna Power Station

M. Khanna
NRC Branch Chief – Mechanical and Civil Engineering
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop 08 G-9E3
11555 Rockville Pike
Rockville, MD 20852-2738

R. E. Martin
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop 08 G-9A
11555 Rockville Pike
Rockville, MD 20852-2738

P. G. Boyle
NRC Project Manager
U. S. Nuclear Regulatory Commission
One White Flint North
Mail Stop 08 G-9A
11555 Rockville Pike
Rockville, MD 20852-2738

J. E. Reasor, Jr.
Old Dominion Electric Cooperative
Innsbrook Corporate Center
4201 Dominion Blvd.
Suite 300
Glen Allen, Virginia 23060

Attachment 1

Response to Request for Additional Information North Anna Restart Readiness Determination Plan

Virginia Electric and Power Company (Dominion) North Anna Power Station

Response to NRC Request for Additional Information
Restart Readiness Determination Plan
North Anna Power Station Units 1 and 2

Background

By letters dated September 30, October 6 and 13, 2011, the NRC requested additional information (RAI) regarding Dominion's Restart Readiness Determination Plan for North Anna Power Station following the August 23, 2011 Central Virginia earthquake. By letters dated October 3, 2011 (Serial No. 11-566) and October 10, 2011 (Serial Nos. 11-566A and 11-577), Dominion responded to many of the RAI questions provided by the NRC technical review branches. Dominion's responses to several of the remaining NRC questions, as well as subsequent clarifications requested by the NRC staff on previously submitted responses, are provided below.

NRC Request for Information

PIPING

1. *Describe in detail how the pipe stresses of ASME Class 1, 2, and 3 piping systems and any non-safety related piping systems which connect or could affect ASME Class 1, 2, or 3 piping systems have been evaluated considering the loading from the recent earthquake and aftershocks. The licensee should identify the pipe systems evaluated and discuss acceptance criteria, results, and corrective actions.*

Dominion Response

A quantitative comparison of two parameters, Cumulative Absolute Velocity (CAV) and Base Shear loading on the Containment basemat, was performed to establish that the influence of the August 23, 2011 earthquake was less severe than the Design Basis Earthquake (DBE) for the Units 1 and 2 Containments. This comparison is provided in Attachment 2. In accordance with Regulatory Guide (RG) 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event," EPRI Technical Report NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake," and the finding that the event resulted in an EPRI Damage Intensity of '0' for the plant, no additional analyses of piping systems and supports is warranted prior to restart. However, preliminary analyses have been performed to assess the impact of this earthquake on several piping systems in Unit 1 Containment. The analyses are also applicable to Unit 2 piping systems and Containment due to the similarity of design.

A representative sampling of Unit 1 Containment piping systems was evaluated for the purpose of determining the effects of the August 23, 2011 earthquake. Six cases were chosen for analysis. They include piping from various safety related systems and encompass a wide range of sizes (large and small bore), classes (ASME Class 1, 2, and 3), operating temperatures (hot and cold), and elevations (high and low) in the North Anna Power Station Unit 1 Containment. Containment systems were selected because the recorded time-histories from the Kinemetrics instruments for the August 23, 2011 earthquake at the Containment basemat are believed to be more representative compared to the recorded data at other locations. Each case compares the results of the previous design basis response spectra (from the analysis of record) with the results from the recorded response spectra that occurred on August 23, 2011.

Considerations in Sampling

The following criteria were considered in the selection of piping systems for this study:

- Various safety related systems in Containment are considered – Main Steam, Feedwater, Component Cooling, Steam Generator Blowdown, and Reactor Coolant Loop.

- High temperature and low temperature systems – High temperature systems are generally supported with fewer rigid supports making them more flexible and thus more susceptible to seismic loading.

- High elevation and low elevation systems – It is important to consider as many elevations as possible, since the North Anna Containment showed spectral exceedances in the lower elevations, and to also consider the amplification in the Containment structure in the higher elevations as shown in the design basis response spectra.

- Highly stressed piping – the analyses of record were reviewed to ensure the sampling includes cases where the piping is highly stressed due to seismic loading, and therefore has limited margin to Upset and/or Faulted Code allowables.

- Analyses that show low first mode frequencies were selected to ensure that the piping system would show the effects of seismic loading in the frequencies most likely to cause damage (approximately 2 Hz to 10 Hz).

- ASME Piping Classes 1, 2, and 3 were considered.

- Large and small bore piping systems were considered.

For each case, pipe support loads and pipe stresses were evaluated against the DBE analyses of record with most cases showing lower stresses when the August 23, 2011 recorded earthquake spectra was applied. In a few instances, there were marginal increases in some support loads and pipe stresses. However, the overall impact to the system was minimal, and no exceedances of Code allowables were identified.

Based on the representative sample of piping selected for analytical evaluation, it is reasonable to conclude that the earthquake on August 23, 2011 had no significant impact on piping systems in the North Anna Containments. As a long term action, Dominion plans to perform a sampling analysis of ASME Class 1, 2 and 3 piping systems in accordance with EPRI NP-6695, Section 6.3 for which floor spectra are generated by applying the August 23, 2011 earthquake recorded response spectra.

CLARIFICATION OF PREVIOUSLY PROVIDED PIPING-RELATED RESPONSES

During a conference call between the NRC and Dominion personnel on October 12, 2011, the NRC requested certain clarifications associated with Dominion's responses to Piping Question Nos. 2 through 6 that were provided in Dominion letter dated October 10, 2011 (Serial No. 11-577). The requested clarifications are provided below.

Requested Clarification - Piping Question 2 – What percentage of ASME Class 1, 2 and 3 piping systems were inspected vs. not inspected? Was non-safety related piping that connects to or is on top of safety related piping inspected, and, if so, how much? Was pipe insulation removed for the above inspections? Did you inspect for pipe movement?

Dominion Clarification

As noted in Dominion letters dated September 17, 2011 (Serial No. 11-520) and October 10, 2011 (Serial No. 11-577), comprehensive system inspections were performed on over eighty systems for Unit 1 (which includes common systems) and over fifty systems for Unit 2. These numbers represent 100% of the safety related (ASME Class 1, 2 and 3) and 100% of the non-safety related piping systems. These inspections were performed in accordance with station procedure 0-GEP-30, "Post Seismic Event System Engineering Walkdown," which was developed using the guidance provided in EPRI NP-6695. Some of the systems inspected included sections of insulated piping; however, the insulation was not removed for these inspections. This is considered acceptable for the following reasons: 1) the extensive amount of un-insulated piping that was inspected with satisfactory results, 2) the pipe supports on insulated piping are typically not insulated and were available for inspection, 3) the insulated piping was inspected for any evidence of earthquake related damage to the insulation or system leakage through the insulation, and 4) the lack of any earthquake related damage to piping or supports that had its insulation removed for in-service examination or maintenance.

Some other sections of system piping were inaccessible for inspection, such as buried piping and piping located in locked, high radiation areas. Inaccessible portions of piping systems were dispositioned based on inspections of associated system components that resulted in no significant damage attributable to the earthquake and/or other piping in the same building or structure with similar supports that was inspected with satisfactory results. Buried piping integrity was also verified based on the satisfactory performance of system pressure tests and/or unimpaired system flow tests (in accordance with ASME Section XI, IWA-5244), as well as by direct and indirect inspection of sections of excavated buried pipe. The testing and inspections did not identify any earthquake related damage. (Reference Dominion letter dated October 10, 2011, Serial No. 11-577.)

Inspection for pipe movement was encompassed in the piping inspections. Pipe movement would have been indicated during the inspections by damage indicators such as support damage, cracked paint, insulation damage, identified leakage, or damage to local structures, systems or components. No indication of unanticipated pipe movement was identified and no damage attributable to the earthquake was noted.

Requested Clarification - Piping Question 3 – *What is the total amount of buried pipe? What is the total amount of buried pipe that could contain significantly contaminated fluid and how much was tested? How much buried pipe was excavated and inspected? What are the performance frequencies for Periodic Tests 1/2-PT-302QS, 1/2-PT 302RS and 1/2-PT 301SW listed in your response? What were the test pressures, hold times and acceptance criteria for these PTs, as applicable? Why was the buried Unit 2 SI piping not tested?*

Dominion Clarification

North Anna Power Station has approximately 6.9 miles of buried pipe. Of that length, only approximately 1120 feet of buried piping carries, or has the potential to carry, contaminated fluid. Approximately 100 of the 1120 feet of this buried piping was directly inspected, which included the piping associated with the Unit 1 Refueling Water Storage Tank (RWST). As noted in Dominion's letter dated October 10, 2011 (Serial No. 11-577), this piping consisted of the Quench Spray (QS) piping to the QS pumps' suction, the QS pump recirculation piping, the Safety Injection (SI) system piping to the High Head and Low Head Safety Injection pumps' suction, the RWST recirculation pumps' suction and discharge piping, and the Refueling Purification (RP) and blender make-up piping to the RWST, and the RWST recirculation piping. In addition, over 650 feet of SI, RS and QS system piping was pressure tested with satisfactory results. Also, approximately 6,650 feet (~1.25 miles) of non-contaminated, safety related Service Water (SW) piping was pressure tested with satisfactory results. There is no buried Unit 2 SI piping.

The system pressure tests (SPTs) identified in the previous response are required each period in accordance with ASME XI requirements, or approximately every three years. However, they were performed specifically to test buried safety related piping following the earthquake, not necessarily to satisfy the SPT program requirements.

- For 1/2-PT-302QS, the pressure drop test is performed using the hydrostatic head developed by the Refueling Water Storage Tank (RWST). The buried pipe is subjected to an approximately 60 ft head. No decrease in RWST level is allowed over a minimum eight hour hold time.
- For 1/2-PT-305RS, the pressure drop test is performed using the hydrostatic head developed by the Casing Cooling Storage Tank (CCST). The buried pipe is subjected to an approximately 40 ft head. No decrease in CCST level is allowed over a minimum eight hour hold time.
- For 1/2-PT-301SW, the unimpaired flow test is performed using the pressure developed by the Auxiliary Service Water pump during performance of its functional test. The buried pipe sees approximately 75 psig at approximately 6,500 gpm. There is no hour hold time associated with an unimpaired flow test.
- For 1/2-PT-302SW, the pressure drop test is performed using the pressure developed by the Service Water pump(s) during normal operation. There is a 48 hour hold time associated with these pressure drop tests, and SW reservoir leakage must be maintained within specified limits.

In summary, well over one half of the 1120 feet of buried piping that carries, or has the potential to carry, contaminated fluid was pressure tested, and 100 feet was directly inspected visually. An additional 1.25 miles of buried, non-contaminated, safety related pipe was pressure tested. Both the testing and inspection results were satisfactory.

Requested Clarification - Piping Question 4 - Did you remove insulation from the pipe supports when you performed your system inspections? Were all pipe supports inspected? Did you inspect the support attachment lugs and clamps?

Dominion Clarification

The pipe supports on insulated piping systems are typically not insulated and were available for inspection. Readily accessible pipe supports, attachment lugs, and clamps were inspected as part of the overall system inspections. The only portions of the piping systems that were not inspected were those areas of piping located in locked, high radiation areas and buried piping. No earthquake related damage was identified on any of the inspected supports that would have prevented the support from performing its design function.

Requested Clarification - Piping Question 5 – What were the sizes of the inspected flaws?

Dominion Clarification

The Unit 2 Outside Recirculation Spray piping flaw was a surface indication as opposed to an imbedded flaw. The flaw was inspected and compared with the results of the previous inspection of this flaw and it remained a non-recordable indication (NRI).

The Unit 2 pressurizer girth weld (Weld 4) and the Unit 2 "B" Steam Generator (SG) girth weld (Weld 6) flaws were re-inspected following the August 23, 2011 earthquake with satisfactory results. A summary of this effort is provided below.

- Weld 4 is a Code Category B-B/Item B2.11 circumferential shell to bottom head weld on the Unit-2 Pressurizer. The 2007 examination of this weld recorded an acceptable subsurface indication when compared to the ASME Section XI, IWB-3510-1 acceptance standards. This indication was characterized using amplitude based sizing techniques, which recorded dimensions of 0.09 inch through-wall and 0.4 inch length. This indication was re-examined as part of the post seismic event examinations during the 2011 outage and found to be essentially unchanged. This indication was characterized using the same amplitude based sizing technique that was used during the 2007 examination. In addition, more accurate indication characterization techniques were applied using ASME Section XI, Appendix VIII demonstrated tip diffraction techniques to determine the through-wall extent of this indication. When compared to the ASME Section XI, IWB-3510-1 acceptance standards this flaw is evaluated as an acceptable subsurface indication.

- Weld 6 is a Code Category C-A/Item C1.10 circumferential vessel weld in the Unit 2 "B" SG. This weld recorded an acceptable weld inclusion during the 1995 examination. The initial examination in 1995 was performed from the outside surface using amplitude based sizing techniques, which recorded dimensions of 0.55 inch through-wall and 1.06 inches in length. Access was available to the inside surface at the time of this examination, and additional NDE was performed from the inside surface to assist with the characterization of the indication. Supplemental magnetic particle and ultrasonic examinations were performed from the inside surface to better determine the proximity of the flaw to the inside surface. The results of these supplemental examinations showed that the flaw was not inner diameter connected to the inside surface with indication to surface dimension of 0.435 inch. The supplemental ultrasonic examination using amplitude based sizing techniques dimensioned this indication with a through-wall of 0.065 inch and a length of 1.06 inches. This indication was evaluated as an acceptable subsurface indication when compared to the ASME Section XI, IWC-3510-1 acceptance standards.

This weld was re-examined during the 2007 refueling outage. The 2007 examination results were essentially unchanged and considered to be within the tolerance of the examination techniques from the 1995 outside surface examination. This indication was also re-examined as part of the post seismic event examination scope during the 2011 outage. The initial examination utilized amplitude based sizing techniques similar to the examinations performed for the 1995 and 2007 examinations. The amplitude based indication dimensions for the 2011 examination are similar to the dimensions from the 1995 and 2007 examinations, and the indication is considered unchanged from the initial detection examination performed in 1995. In addition, more accurate indication characterization techniques were applied using ASME Section XI, Appendix VIII, to determine the through-wall extent of this indication. When compared to the ASME Section XI, IWC-3510-1 acceptance standards, this flaw is evaluated as an acceptable subsurface indication with dimensions of 0.163 inch through-wall and 1.05 inches in length.

Requested Clarification - Piping Question 6 – When is Periodic Test 1/2-PT-46.21 performed? Is insulation removed? Please provide information describing the Boric Acid program walkdown that is performed.

Dominion Clarification

Periodic test (PT) 1/2-PT-46.21, "RCS Pressure Boundary Components Affected by Boric Acid Accumulation," is normally performed during Modes 1, 2, or 3 during each cooldown to Mode 5 prior to a refueling outage to identify any active or inactive RCS pressure boundary leakage, and during each startup from Mode 5 following a refueling outage to perform the ASME Section XI RCS System Pressure Test. Insulation is not removed for this inspection; however, the inspection is performed by VT-2 qualified inspectors.

As noted in our letter dated October 10, 2011 (Serial No. 11-577) periodic test 1/2-PT-46.21 will also be used during unit startup for both Units 1 and 2 to perform an ASME XI RCS system pressure test. This test requires a 4-hour hold time for insulated components and a 10-minute hold time for non-insulated components. Comprehensive system leakage inspections are then performed by VT-2 qualified personnel. Performance of 1/2-PT-46.21 will serve as one of the final confirmations of RCS system integrity prior to the units returning to service. Note this procedure also includes VT-2 inspections of Main Steam and Feedwater piping inside and outside Containment.

During refueling outages, PT 1/2-PT-48, "Visual Inspection of Reactor Coolant Pressure Boundary Components," is used to perform visual examinations of bolted connections of ASME XI, Class I, pressure boundary components to identify leakage sources and fastener degradation due to boric acid. This procedure also inspects a small number of Class 2 and 3 components due to their relationship and safety significance to the RCS (e.g., Residual Heat Removal Pumps, Component Cooling line connection to the RCP thermal barrier.) Insulation is removed from bolted connections to facilitate the inspections. This procedure was performed for Unit 2 and no damage attributable to the earthquake was identified.

LICENSE RENEWAL

1 For all time-limited aging analyses (TLAA) submitted with the License Renewal Application and its amendments:

a) State whether the recent seismic activity has resulted in a change to the disposition of any TLAA such that the original conclusions do not remain the same.

b) For any dispositions that have changed, state the current TLAA disposition (i.e., 10 CFR 54.21(c) (1) (i), 10 CFR 54.21(c) (1) (ii), or 10 CFR 54.21(c) (1) (iii)).

c) State the basis for the acceptability of the change in disposition. For example, if a disposition changed from 10 CFR 54.21(c) (1) (i) to 10 CFR 54.21(c) (1) (iii), state how the aging effects will be adequately managed throughout the period of extended operation.

Dominion Response

The time-limited aging analyses (TLAAs) discussed in Chapter 4.0 of the NUREG-1766 (Safety Evaluation Report Related to the License Renewal for North Anna Power Station), Chapter 4.0 of the North Anna License Renewal Application (LRA), and Chapter 18 of the North Anna Updated Final Safety Analysis Report (UFSAR) were reviewed. It has been determined that the original conclusions remain unchanged by the earthquake, i.e., there are no changes to the disposition of any TLAA. The following clarifications apply:

- SER Section 3.3.3.2, LRA Section B3.2 and UFSAR Section 18.4.2 indicate that Dominion has established and maintains a transient cycle counting program to provide reasonable assurance that the number of design transient cycles is not exceeded for selected equipment during the operating life of the nuclear units. The Transient Cycle Counting program applies to the RCS pressure boundary components for which the design analysis assumes a specific number of design transients. The August 23, 2011 earthquake caused both reactors to trip, and full power reactor trips are included in the transient cycle counting program. In accordance with the ASME Nuclear Power Plant Components code, and as noted in UFSAR Table 5.2-4, faulted conditions (such as the DBE) are not included in fatigue evaluations. However, the impact of the August 23, 2011 earthquake on fatigue has been evaluated as explained below.

Five Operating Basis Earthquake (OBE) events were considered in the evaluation of components sensitive to low cycle fatigue. Cycling due to seismic stresses is not by itself a cause of fatigue, because the range of stress associated with seismic loading is far below the range at which fatigue can occur. Consequently, both the August 23, 2011 earthquake and the aftershocks are not fatigue causing.

In the design process, the seismic loading on the components are combined with the worst possible design thermal transient events to determine design load cycles for computing cyclic stresses to evaluate the fatigue life of components. Unlike the conservative loading conditions used in the design process, the August 23, 2011 earthquake occurred during normal steady-state operation, resulting in a less limiting thermal loading condition. However, since the earthquake exceeded DBE peak accelerations at certain frequencies, a quantitative comparison of two seismic parameters was performed and established that the influence of the August 23, 2011 earthquake was less severe than the DBE. The quantitative comparison is provided in Attachment 2 and notes that, since the CAV values are low, and only the CAV in the North-South direction exceeded the OBE exceedance threshold of 0.16 g-sec by about 8%, no significant damage was expected. This was consistent with the findings from the comprehensive walkdowns and inspections of both safety and non-safety structures, systems and components (SSC) performed and the functional and surveillance tests that have been and are being conducted at North Anna Power Station.

Therefore, it is concluded that the August 23, 2011 earthquake and the much smaller aftershocks have negligible impact on the time-limited aging analysis of the plant.

- SER Section 4.6 and UFSAR Section 18.3.4 indicate that the fatigue of the Containment liner plate was originally evaluated assuming 20 DBE cycles, and was subsequently evaluated relevant to License Renewal for 30 DBE cycles. Since the recent earthquake exceeded some DBE design limits, the impact on the safety related SSCs was evaluated and inspections were performed. The results of the evaluations and inspections for the Containment (including the metal liner) are summarized in the responses to Containment Questions 1 through 5, which were forwarded to the NRC in Dominion letter dated October 3, 2011 (Serial No. 11-566). Those inspections and evaluations concluded there was no visual evidence of any significant physical or functional damage to any safety related SSCs (including the liner), and that no hidden damage is expected. Dominion letter dated October 10, 2011 (Serial No. 11-577) confirmed that an IWE inspection of the Containment liner was conducted on each unit and compared with previous inspection results. No issues resulting from the earthquake were identified.

- SER Section 4.7.3, LRA Section 4.7.3, and UFSAR Section 18.3.5.3 discuss the results of the leak-before-break (LBB) evaluation performed in support of License

Renewal. The overall conclusion was that under the worst combination of loading, including the effects of a safe shutdown earthquake, a crack will not propagate around the circumference and cause a guillotine break. Since the recent earthquake exceeded some DBE design limits for the station, the impact on LBB evaluation was considered. The results of that evaluation are summarized in Dominion letter dated October 3, 2011 (Serial No. 11-566). The response concluded that "the evaluation supporting LBB remains valid after considering the August 23, 2011 earthquake." Additional information on the LBB analysis is provided in Dominion letter dated October 18, 2011 (Serial No. 11-566B).

2. *While the staff acknowledges that a seismic event is a near singular aging event, given that the recent seismic activity exceeded the current seismic licensing basis with multiple aftershocks, state how:*

   a. *It was concluded that no existing flaws or defects sizes were impacted such that augmented license renewal inspections need not be conducted.*

   b. *It was concluded that no new flaws or defects occurred such that augmented license renewal inspections need not be conducted.*

Dominion Response

The objective of 10 CFR 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," is to ensure that important systems, structures, and components (SSCs) will continue to perform their intended function in the period of extended operation. To ensure that passive, long-lived SSCs in the scope of License Renewal (54.4) continue to perform their intended functions during the period of extended operation (PEO), Dominion has established aging management programs (AMPs) that are summarized in Chapter 18 of the North Anna Updated Final Safety Analysis Report. The renewed licenses for North Anna Units 1 and 2 were issued on March 20, 2003. Unit 1 completed 30 years of operation on April 1, 2008 and Unit 2 completed 30 years of operation on August 21, 2010. North Anna is currently in the process of implementing AMPs to prepare for entering the PEO. To manage aging of License Renewal SSCs, North Anna relies on twenty-one (21) existing programs and four (4) new programs created specifically to meet License Renewal (LR) commitments.

Engineering Programs, including LR, were reviewed by the fleet program leads to determine the impact of the North Anna earthquake. The Aging Management (License Renewal) Program was reviewed by the LR fleet program lead with input from the North Anna site LR program owner. It was concluded that only one North Anna AMP may be affected by the earthquake: LR-1760/LR-2760, Transient Cycle Counting, Surry and North Anna Power Stations. The potential impact to this program was dispositioned in the response to License Renewal Question No. 1 above.

In addition, as discussed in Dominion letter dated October 10, 2011, three locations were selected for ultrasonic testing (UT) or liquid penetrant (PT) examination that had pre-existing flaws. These locations were: 1) the Unit 2 Outside Recirculation Spray (RS) suction piping (surface indication), 2) the Unit 2 pressurizer circumferential weld (embedded flaw), and 3) the Unit 2 'B' SG girth weld (embedded flaw). Testing results confirmed that the two embedded flaws were essentially unchanged as a result of the August 23, 2011 earthquake, and the RS surface indication remained non-recordable. These results are directly applicable to Unit 1 as the overall loading environment would have been the same during the earthquake.

Furthermore, since extensive and comprehensive inspections and testing of plant safety related and non-safety related SSCs have not identified earthquake related damage that would prevent any of the SSCs from performing their design functions, and, since the August 23, 2011 earthquake was of short duration and low energy, the development of new flaws or defects would not reasonably be expected to occur.

3. *State what augmented license renewal inspections will be conducted for structures and piping/component supports to ensure that seismic displacements did not result in significant cracking for concrete and masonry walls, or loss of form for soil, or state the basis for why such inspections are not required.*

Dominion Response

The North Anna License Renewal (LR) Program takes credit for the existing Civil Engineering Structural Inspection Program as described in technical procedure ER-NA-INS-104, "Monitoring of Structures North Anna Power Station." This procedure implements the Maintenance Rule (10 CFR 50.65) requirements for structural monitoring. The scope of this procedure has been expanded to include inspections required by LR. Extensive and comprehensive post-earthquake structural inspections have been performed using ER-NA-INS-104. No significant cracking of concrete or masonry walls was identified that would have prevented a structure from performing its design function. The accessible portions of 100% of the plant safety related and non-safety related piping systems were inspected, including supports, with no significant issues identified related to the earthquake. This included an inspection of 100% of the safety related snubbers on both units as well.

Also, safety related buried piping associated with the Unit 1 Refueling Water Storage Tank (RWST) was excavated and formally inspected, and no issues attributable to the earthquake were found. Several individual pipes were inspected, including ultrasonic testing (UT) of the pipe wall thickness. Areas where pipes are anchored through wall penetrations were also examined, and there were no indications of high stress at the penetrations nor were any cracks present. In addition, areas where piping systems penetrate the soil or penetrate building walls into the soil were reviewed during system walkdowns and inspections with no signs of stress on the penetrations or movement of the pipes within the soil. No ground settlement issues or cracks in the soil or roadways were noted around the station. Furthermore, as discussed in Dominion letter dated October 10, 2011 (Serial No. 10-577), operational gaps to allow movement of major equipment and piping systems were inspected, as were seismic gaps between structures (i.e., rattle spaces). No concerns with operational gaps or seismic gaps were identified during the plant SSC inspections.

The North Anna LR Program also takes credit for the Inservice Inspection (ISI) Program and Buried Pipe Monitoring Program to manage aging of exposed piping and supports and buried piping. For the ISI Program, qualified examiners performed sample weld inspections of reactor coolant loop drain lines, service water tie-in vault, and penetration area pipe lines with anchors. These inspections were documented in Dominion letter dated September 27, 2011 (Serial No. 11-520A). A significant amount of buried piping was pressure tested and inspected consistent with the requirements of the Buried Pipe Monitoring Program, and no earthquake related concerns were identified. The buried pipe testing and inspection that were performed are discussed in Dominion letter dated October 10, 2011 (Serial No. 11-577) and in the clarification to Piping Question No. 3 above.

Therefore, based on the significant amount of inspection and testing that has already been completed as discussed above, additional Augmented LR inspections for the SSCs included in the programs previously mentioned are not required.

4. *State what augmented license renewal inspections will be conducted at displacement sensitive locations (e.g., tank nozzle connections, piping transitioning between buildings or from a building to the soil, where differential seismic movements occur) to confirm that there was no impact to the pressure boundary function, or structural and/or support function, or state the basis for why augmented inspections are not required for programs such as tank inspection activities, and buried piping and valve inspection activities.*

Dominion Response

No augmented license renewal inspections are planned for the locations described in Question 4, because inspections for these areas are already addressed by procedure ER-NA-INS-104, "Monitoring of Structures North Anna Power Station," or by ER-AA-BPM-101, "Underground Piping and Tank Integrity Program." Furthermore, these inspections have already been completed using the two procedures noted above, as well as station procedure 0-GEP-30, "Post Seismic Event System Engineering Walkdown," as discussed in the response to Question 3 above and as detailed in Dominion letters dated September 27, 2011 (Serial No. 11-520A) and October 10, 2011 (Serial No. 11-577).

EMCB QUESTIONS

3. *As depicted in the NAPS Updated Final Safety Analysis Report (UFSAR), a partial height of the Containment structure is below grade and is not readily accessible for visual inspection. Please provide information, prior to restart, to confirm its structural adequacy.*

Dominion Response

Comparison of Containment Base Shears from Actual Earthquake vs. DBE:

Total base shear, evaluated at the top of the Containment basemat, can provide a relative measure of the severity of a seismic event upon the Containment structure, as well as upon the equipment housed within. An evaluation was performed in which North Anna Containment total base shear from the August 23, 2011 earthquake was compared to that of the DBE. The results of this evaluation, as discussed in Attachment 2, showed the total Containment base shear from the August 23, 2011 earthquake was slightly less than that of the DBE. Based on this comparison, it is concluded that the North Anna Containment structures remained within their elastic range and no permanent deformation occurred.

This comparison of Containment total base shears helps to explain the EPRI Damage Intensity Level of '0' that was reported for the August 23, 2011 earthquake, despite the fact that some DBE acceleration spectral limits were exceeded. Since it has been demonstrated that total base shear from the DBE bounded that of the August 23, 2011 earthquake, the structural adequacy of the below grade portions of the North Anna Containment structures are confirmed.

10. *In reference to Enclosures 4 and 5 to your letter dated September 17, 2011, please confirm that during the inspection of the spent fuel pool (SFP) structure no sign of distress in the SFP structure, the SFP liner and the liner welds was identified. Also since the presence of the liner does not allow direct inspection of the reinforced concrete SFP structure, please provide further information to demonstrate its structural adequacy.*

Dominion Response

The structural adequacy of the spent fuel pool liner can be demonstrated in the results from the following post-shutdown inspections in the North Anna spent fuel pool:

- No indications of sliding or contact were observed between adjacent spent fuel rack arrays and between rack arrays and adjacent spent fuel pool liner walls,

- No observed liner bulges or liner buckling were observed on any spent fuel pool liner wall from the top of the pool to the top of the spent fuel racks (i.e. accessible portions of spent fuel pool liner), and
- No anomalous increase was observed in isotopic activity, leak rate or total collected volume from the tell-tale drain samples taken from the spent fuel pool.

Furthermore, it is noted that there is significant design margin available beyond normal operating conditions.

Following the August 23, 2011 earthquake, visual inspections using an underwater camera were performed of the North Anna spent fuel pool. The purpose of this inspection was to determine if there was any evidence that the spent fuel rack arrays had slid or if the racks had tipped and contacted the liner wall. From the results of these visual inspections, there was no indication of sliding or contact (i.e., tipping) between adjacent spent fuel rack arrays or between rack arrays and the adjacent spent fuel pool liner wall.

Following the August 23, 2011 earthquake, general visual inspections using an underwater camera were made of the accessible portions of the spent fuel pool liner (i.e., from the top of the pool to the top of the racks) to look for areas of liner bulging or liner buckling. No areas of liner bulging or buckling were observed.

On August 27, 2011, four days after the earthquake, samples were taken from the tell-drains of the spent fuel pool. There are six tell-tale drains, one for each zone of the spent fuel pool structure. These drains are normally sampled every 90 days, but they were sampled four (4) days after the earthquake (i.e., 25 days since the last sampling) for comparison purposes. No anomalous increases were observed in isotopic activity, leak rate or total collected volume from any of the six tell-tale drain samples taken from the spent fuel pool on August 27, 2011.

The spent fuel pool liner has been analyzed for local impact effects from various fuel assembly drop scenarios on the rack arrays. These fuel assembly drop scenarios involve impact loading well beyond what would be expected from the DBE load case. It may be concluded from the results of this impact analysis that while concrete directly underneath the liner and rack array support leg would suffer localized crushing, the liner would not be perforated. Hence, there is no concern for local impact effects upon the liner as a result of the August 23, 2011 earthquake.

The spent fuel pool is a highly redundant structure that can transfer load demand to the foundation, via both horizontal and vertical load pathways. Significant margin exists in these horizontal and vertical load pathways, since the spent fuel pool bulk water temperature at the time of the earthquake was approximately 90 °F, which corresponds to Service Load temperature conditions. The spent fuel pool has been analyzed for Abnormal Load temperature conditions, in which the peak spent fuel pool bulk water temperature reaches 170 °F. Hence, there was significant available analytical margin and redundant load paths in the spent fuel pool structure at the time of the earthquake to accommodate a potential increase in DBE. Post-shutdown inspections have confirmed the satisfactory condition of the visible portions of the spent fuel pool structure exterior concrete and liner following the August 23, 2011 earthquake.

As further quantification of the available margin to accommodate potential increases in DBE load, a review of the stress summary in North Anna UFSAR, Table 9A-2 was made for two (2) critical areas in the spent fuel pool:

- Counterfort on the north wall, and
- Central span of the south wall.

The counterfort is a critical primary load-carrying element that was built into the central span of the north wall (i.e., longest spanning wall) to reduce calculated stresses in the north wall. Reported spent fuel pool reinforcing steel stresses versus allowable stress, from the governing DBE load combination in North Anna UFSAR, Table 9A-2, reveals that the basemat at the face of the counterfort is stressed to approximately 70% of its allowable stress (i.e., 27.54 ksi / 39.6 ksi = 0.695 ≈ 70%).

The central span of the south wall of the spent fuel pool is another primary load-carrying element. A review of the reported reinforcing steel load demand stresses versus allowable stress, from the governing load combinations in North Anna UFSAR, Table 9A-2, reveals that the south wall is stressed to approximately 75% of its allowable stress under DBE, with Abnormal Load temperature conditions also present (i.e., 29.73 ksi / 39.6 ksi = 0.751 ≈ 75%).

Both of the above reported reinforcing steel (demand/allowable) stress ratios were calculated for the spent fuel pool load combination, which includes the DBE load case, coincident with Abnormal Load temperature conditions. At the time of the August 23, 2011 earthquake, a spent fuel pool normal bulk water temperature of 90 °F was recorded; hence, the thermal load demand on the spent fuel pool structure was minimal. The absence of Abnormal Load temperature conditions freed up the corresponding accident thermal load capacity, in addition to the reported unused member capacity, which was estimated to be between 25% - 30% of these critical member capacities. This total available spent fuel pool capacity more than accommodates the potential DBE load increases from the August 23, 2011 earthquake. In the range of frequencies most damaging to structures, 2 to 10 Hz, the DBE was not exceeded in the East-West direction, but only exceeded, on average, in the North-South direction by about 12% and about 21% in the vertical direction. The load demand on the spent fuel pool, at the time of the August 23, 2011 earthquake, did not exceed the previously designed load combination of DBE with Abnormal Load temperature.

The other critical areas that were reported in the North Anna spent fuel pool stress summary, North Anna UFSAR, Table 9A-2, were not as severely stressed by mechanical loads (i.e., non-thermal loads) as were the two (2) critical locations, discussed above. In each of these other critical areas, there was significant available design margin, due to the absence of Abnormal Load temperature conditions in the pool at the time of the earthquake, to accommodate the potential increases in DBE load demand, within the allowable DBE reinforcing steel stress limits.

Based on the available load capacity and the satisfactory inspections of the visible portions of the spent fuel pool, the structural adequacy of the North Anna spent fuel pool liner and concrete structure has been demonstrated following the August 23, 2011 earthquake.

12. *In reference to Tables 3.7-4 and 3.7-5 of the NAPS UFSAR, please discuss your evaluation of critical SSCs (i.e., design margin close to 1.0 and design basis earthquake (DBE) contribution to the total combined stress is significant in comparison to the other loads) to assess the effects of the recent earthquake and to demonstrate that the affected SSCs will continue to perform their required design functions. If the results of this evaluation indicate that the design basis acceptance criteria may have been exceeded, please discuss your planned action to restore these SSCs in conformance with the design basis limits.*

Dominion Response

North Anna UFSAR Table 3.7-4 provides a historical, representative listing of seismic design margins in the original Stone and Webster scope of supply of mechanical items. As a historical record, the information in the table is not intended or expected to be updated. As a result, the table does not reflect the current seismic design margin for the items. The current analysis/design record for the most highly stressed item shows design margins higher than the values listed in that table. Thus, there is additional margin in the combined stresses for these components to accommodate higher seismic loads.

In an evaluation of the influence of the August 23, 2011 earthquake on North Anna Power Station (Attachment 2), it was concluded that the recent earthquake was overall less severe than the DBE. Therefore, it is not intended to analyze the seismic stresses in individual components to verify margin in each component due to the current earthquake. Furthermore, there are additional margins in the combined design loadings for the components that can correspondingly be used to accommodate a higher seismic load application. Also, the operational readiness of the items in Table 3.7-4 and other mechanical items were reviewed by inspection and testing.

In support of margin in components, the analysis/design record of the following items was thoroughly reviewed for existing additional design margin. The items in Table 3.7-4 with small reported margins were selected for detailed review.

Steam Generator (SG) Supports

The lowest margin reported in the Table 3.7-4 was 1.01 as the ratio of allowable stress to the stress due to Normal load (deadweight + thermal + internal pressure) + Square Root Sum of the Squares (SRSS) of DBE and Pipe Rupture load. The reported margin was for one member in the SG Lower Support. The minimum available margin in the analysis of record for SG lower support is 1.5 in Normal load (deadweight + thermal + internal pressure) + SRSS of DBE and Pipe Rupture loading condition. In a non-pipe rupture condition with load due to pressure deadweight, thermal and DBE, the available margin is 1.9. The minimum available margin in the analysis of record for SG upper support is 1.2 for Normal load (deadweight + thermal + internal pressure) + SRSS of DBE and Pipe Rupture loading condition. In a non-pipe rupture condition, the available margin is at least 3.3. The analyses of record thus show that adequate margin exists to carry additional seismic load.

Sufficient margin exists to sustain an earthquake of the magnitude that occurred on August 23, 2011. To further verify this fact, an analysis of a representative loop of the reactor coolant loop including the SG and Reactor Coolant Pump was performed by subjecting the model to the spectra developed from the recorded time-histories in the Containment building. The analysis showed that the load on the SG support feet for the current earthquake was less than the load on the SG support feet due to the DBE.

Reactor Coolant Pump (RCP) Supports

Similarly, the result of the analysis reported above also shows that the load on the RCP support due to the August 23, 2011 earthquake was less than the load on the RCP support due to the DBE. Therefore, no further analytical review of the RCP support due to the current earthquake is required.

However, a review of the existing margin on the RCP support shows that additional margin exists. Table 3.7-4 reported an historical margin of 1.21 when subjected to Normal load (deadweight + thermal + internal pressure) + SRSS of DBE and Pipe Rupture loading condition. The analysis of record shows that the margin is at least 1.3. In a non-pipe rupture condition, the available margin is at least 1.5. The analyses of record thus show that adequate margin exists to carry the additional seismic load associated with the August 23, 2011 earthquake.

Recirculation Spray Heat Exchangers (RSHXs)

Deadweight + Earthquake load + Operating load was considered for the RSHXs. The historical data in Table 3.7-4 reported a margin of 1.01 in OBE condition and 1.3 in the

DBE condition. Subsequently, the RSHXs were reviewed under the USI A-46 program, where the seismic demand was compared with the USI A-46 bounding spectra. Although it was shown to be acceptable by comparison, no explicit margin was determined in this evaluation. The Containment measured spectra due to the August 23, 2011 earthquake was compared with the USI A-46 bounding spectra and it was enveloped at all frequencies except a very slight exceedance at 33 Hz. Consequently, the seismic demand due to the current earthquake is still considered under the previously analyzed capacity.

UFSAR Table 3.7-4 reported a margin of 3.33 in OBE condition and 2.93 in DBE condition for RSHX seismic restraint. Restraints were reevaluated following USI A-46 walkdowns. The RSHX was analyzed to have a high-confidence-of-low-probability-of-failure (HCLPF) value greater than 0.3g peak ground acceleration (PGA).

<u>Auxiliary Feedwater Pumps (Steam-driven plus Motor-driven)</u>

Deadweight + Earthquake load + Operating load was considered for Auxiliary Feedwater Pumps. The historical data in Table 3.7-4 reported a margin of 1.17 in OBE condition and 1.11 in DBE condition. The seismic OBE load contributed only 1350 psi and the seismic DBE load only contributed 2700 psi to combined stress of 27,750 psi in the OBE condition and 29,100 psi in the DBE condition. Therefore, stress in the pumps will remain within the allowable stress of 32,400 psi with margin, even if the seismic load is doubled.

Thus, this review confirms that significant additional margin exists to accommodate an increase in stress due to seismic loading for the items listed in Table 3.7-4.

Table 3.7-5 provides a historical, representative listing of seismic design margins in the original Stone and Webster scope of supply of structural items. As a historical record, information in the table is not intended or expected to be updated. The current analysis/design record for the most highly stressed item shows design margins higher than the value listed in that table. Thus, there is additional margin in the combined stresses for these components to accommodate higher seismic loads.

In an evaluation of the influence of the August 23, 2011 earthquake on North Anna Power Station (Attachment 2), it was concluded that the recent earthquake was overall less severe than the DBE. Therefore, it is not intended to analyze the seismic stresses in individual items to verify margin in each component due to the current earthquake. Furthermore, there are additional margins in the combined design loadings for the components that can correspondingly be used to accommodate a higher seismic load application. Operational readiness of the items in Table 3.7-5 and other structural items were ensured by inspection and testing.

The analysis/design margins of the two most limiting items listed in the Table were reviewed further.

Control and Relay Room AC Coil Assembly Support

The coil assembly supports were modified after they were included in Table 3.7-5. The anchorage was evaluated in USI A-46 Program and was found to be satisfactory. It was further reviewed under the IPEEE program by performing a seismic margin assessment (SMA) with a Review Level Earthquake anchored to 0.3g PGA. A HCLPF value of 0.21g was calculated. This item has been identified for reevaluation along with other components that have calculated HCLPF capacities of less than 0.3g. (Refer to the commitment for post-startup HCLPF reevaluation in Enclosure 9 of Dominion's letter to the NRC dated September 17, 2011 (Serial No. 11-520)).

15 kVA /20 kVA Static Inverters

The design margins listed in Table 3.7-5 for these items are historical and therefore were not updated. The minimum margin in the current anchorages of the inverters is 1.44 in the design/analysis of record. The inverters were replaced and seismically qualified by testing. Significant margin exists for seismic loading to accommodate additional seismic loading beyond the design basis. The response to questions EMCB 21 and 22 below provides additional details on these inverters.

This review confirms that significant additional margin exists to accommodate an increase in seismic loading.

13. *Table 3.7-7 of the NAPS UFSAR summarizes the design margins, in terms of percentage of allowable for most highly stressed locations, for a number of components. Please discuss the results of your evaluation of these components to assess the effects of the recent earthquake and to demonstrate their ability to perform their intended design function.*

Dominion Response

Table 3.7-7 provides seismic design margins, percentage of allowables for the most highly stressed locations of the Nuclear Steam Supply System (NSSS). It has been recognized by the technical community that the components in the NSSS are inherently rugged regarding seismic capability. Because of this understanding, NSSS components and their supports were exempted for review under the USI A-46 program, and considered to have inherent capacity to accommodate seismic loads greater than those from the DBE.

In an evaluation of the influence of the August 23, 2011 earthquake on North Anna Power Station (Attachment 2), it was concluded that the recent earthquake was, in an overall sense, less severe than the DBE. Therefore, Dominion does not intend to quantify the seismic stresses in individual components to verify margin in each component due to the current earthquake prior to restart. However, there are additional margins in the combined stress in the components to accommodate higher seismic load than the design basis seismic load.

The NSSS components listed in the Table 3.7-7 are reviewed as discussed below to highlight the margins over the DBE loading:

Steam Generator, Pressurizer, and Reactor Vessel

These three components were generically analyzed by Westinghouse to multi-plant envelope spectra and design loads. The design basis spectra are shown to be below the envelope spectra used by Westinghouse. Thus, additional margin exists to sustain loads beyond the North Anna design basis.

- Reactor Coolant Pump

  For the RCPs, SSE loads were compared with the OBE allowable values and this information was presented in both columns in Table 3.7-7. Therefore, significant margin existed in the design.

- Reactor Coolant Loop

  To evaluate the influence of the August 23, 2011 earthquake, a single representative reactor coolant loop model containing the loop piping, SG with supports, and the RCP with supports was analyzed by subjecting the model to the spectra developed from the recorded time-histories of the current earthquake and also to the DBE. The loop was considered anchored at the reactor vessel. The results of the analysis showed that the loads on the piping and components due to the current earthquake were less than the loads due to the DBE. The analysis confirmed that the influence of the current earthquake is less severe than the DBE.

- Reactor Vessel Internals and Fuel

  Reactor Vessel Internals and Fuel were analyzed using the time-histories of the August 23, 2011, Central Virginia earthquake and were demonstrated to have adequate margin.

- Control Rod Drive Mechanism (CRDM) Reactor Pressure Vessel (RPV) Head Adapter

  The RPV head adapter was designed with multi-plant enveloping seismic load, and therefore has enough margin to accommodate seismic loads beyond the DBE.

Therefore, it is concluded that these components have the ability to perform their intended design functions after the recent earthquake. Dominion does not plan to update UFSAR Table 3.7-7 that lists the seismic stresses in individual components.

14. *Section 3.8.4.4 of the NAPS UFSAR states that the service water reservoir was evaluated for acceleration values of 0.18g and 0.12g in the horizontal and vertical directions, respectively. This section of the UFSAR also states that the relative displacement along the centerline of the dikes due to earthquake ground waves will not exceed 3 inches and the impervious core will sustain this relative displacement without cracking.*

    Please provide a summary of the inspection results, method of inspection and evaluation to confirm that the reservoir impervious core did not sustain any cracking due to the seismic waves and the expected relative displacement experienced during the recent earthquake.

Dominion Response

The diked portion of the Service Water Reservoir (SWR) impoundment is instrumented with eight (8) active open-standpipe piezometers and five (5) settlement monuments (see Figure 3.8-31 in the UFSAR for location plan). During rapid loading conditions, such as those that occur with seismic events, saturated soils can experience a rapid rise in pore pressures due to the inability to drain sufficiently. This can result in shear strength reduction and instability as the intergranular effective stresses decrease. Abrupt pore pressure rise, along with sudden deformation and strong shaking can also crack impervious zones in the embankment and open fissures that can convey water, creating an internal erosion threat. As part of the post-seismic event response, measurements were taken from the respective instrumentation systems and plotted to compare with recent and historical measurements, then examined for indications of significant increases that might indicate an unacceptable safety margin condition.

An examination of the measured pore pressures generally indicated that the levels remained essentially unchanged or decreased. Exceptions were noted in piezometers P-18, P-20, and P-22 where measured increases were less than 0.5 feet to 1.0 foot and were within the range of historic water level fluctuations. A comparison of the measured piezometric levels to the established high water limits stated in the North Anna Technical Requirements Manual (TRM) indicates that they were all below those limits.

Settlement monuments on the embankment indicated movements ranging from 0.048 inches to 0.33 inches since March 2011, with the monuments on the higher areas of the embankment, SM-1 through SM-3, and SM-6, settling from 0.28 to 0.33 inches. Based upon the data trends over the prior several years, it is estimated that the earthquake may have caused movements ranging from less than 0.1 inch to approximately 0.3 inch, resulting in an average of approximately 0.25 inch. The UFSAR indicates that the embankment can tolerate the three (3) inches of relative displacement it was computed that the DBE or SSE event would cause. This relative displacement would have vertical and horizontal components, meaning that there would have to have been evidence of lateral translation. Since vertical movements were limited to approximately 0.25 inch, the lateral displacement would need to be on the order of 3 inches if this limit were being approached. Lateral movements of 1.0 to 1.5 inches or less, one-half to one-third of that computed for the DBE/SSE event, would have caused cracking or heaving on the crest and at soil-structure interfaces adjacent to structures founded in the embankment. Such horizontal movement evidence was not observed during the embankment inspection, indicating that the embankment was well below the computed tolerable displacement level.

In addition to the instrument measurements, three separate visual inspections conducted along the SWR embankment and appurtenant structures did not reveal signs of concern that would indicate impending instability or earthquake induced damage such as sloughing, scarping, slumping, bulging, abrupt translation on the upstream and downstream slopes or seeps/boils. These observations corroborate well with the available instrument data that suggest little discernable deformation has occurred and that destabilizing high pore water pressure is not apparent.

15. *Section 3.8.3.5 of the NAPS UFSAR discusses instrumentation of NAPS main dam structure and continuing surveillance program to monitor the alignment and settlement of the centerline crest. Please discuss your evaluation of the data relative to the alignment and settlement of the centerline crest of the dam in response to the recent earthquake.*

Dominion Response

An elevation and alignment survey is conducted on an annual basis on monuments M-1 through M-17 and reference monuments C and D (see Figure 3.8-23 in NAPS UFSAR). Total vertical deformation from 1972 through May 2011 measured at these monuments varied from 0.000 feet to 0.182 feet. A post-seismic survey indicated changes in measurements such that total vertical deformations now varied from 0.001 feet to 0.188 feet. This reflects an elevation change ranging from 0.001 feet to 0.008 feet, or an average change of 0.003 feet. The 0.003 feet compares favorably to the recent historical trend during which year to year average deformations varied from 0.001 feet to 0.0047 feet over the last five years.

During the elevation survey at the main dam monuments (see Figure 3.8-23 in NAPS UFSAR), an alignment survey is also conducted so that translations from their original locations perpendicular and parallel to the dam axis can be tracked. From 1972 through May 2011, total perpendicular translations ranged from 0.021 feet to 0.116 feet and total parallel translations ranged from 0.002 feet to 0.105 feet. Post-seismic survey indicated total perpendicular translations ranging from 0.023 feet to 0.123 feet and total parallel translations ranging from 0.002 feet to 0.117 feet. This represents a perpendicular change ranging from 0.002 feet to 0.007 feet, and a parallel change ranging from 0.000 feet to 0.012 feet between May 2011and the most recent survey.

The vertical and horizontal deformation survey data corroborates well with inspection observations that did not detect damage. Measured translations are below the established threshold levels (0.042 feet vertical change and 0.05 feet horizontal change between surveys) for the structures, below what would be readily apparent to visual inspection, and well below what would indicate structural instability.

16. *Enclosure 2 of your summary report dated September 17, 2011, states that the service water reservoir and the main dam sustained no significant physical or functional damage. This implies that your inspection identified some damage that was considered insignificant. Please discuss the nature of the damage identified during your inspections and any corrective actions you have taken to address the as-found condition.*

Dominion Response

The several visual inspections conducted along the embankment revealed no signs of distress such as sloughing, scarping, bulging, cracking, lateral shifting, or rupturing on the crest, upstream, or downstream slopes. The concrete spillway along with the radial and skimmer gates were also inspected and no damage was noted. An additional inspection on the crest area with particular attention to items that are not typically anchored, such as a block supported maintenance trailer, indicated that they remained stable with no readily observable evidence of shifting, sliding, or toppling. No seismic related damage was evident.

17. *As stated in Section 3.8.4.5.3 of the NAPS UFSAR, Table 3.8-15 lists the structures and components which are being monitored for settlement. Please discuss actions taken, following the recent earthquake, to ensure the acceptability of settlement of these structures and components considering the baseline survey and the allowable differential settlements. Specifically, discuss any potential damages to the rubber expansion joint installed on the service water piping noted in Section 3.8.4.5.4.5 of the NAPS UFSAR.*

Dominion Response

The Pump House, Valve House, and Tie-in Vault structures each have four (4) settlement monuments. Immediately adjacent to the Pump House structure there are two (2) settlement monuments located on the expansion joint above the service water pipes (see Figure 3.8-60 in the UFSAR for location plan). Post-seismic settlement data in these areas was obtained as a part of periodic data collection that had been previously scheduled, then plotted and evaluated to ascertain a quantitative measure of deformation.

Total deflections through March 2011 in the Valve House, Pump House, and the Tie-In Vault averaged 0.348 inches, 2.718 inches, and 0.111 inches, respectively. Post-seismic survey in these areas indicated total deflections averaging 0.480 inches, 2.796 inches, and 0.225 inches, respectively. This reflected an average deflection increase of 0.132 inches, 0.078 inches, and 0.114 inches in the corresponding areas.

Monuments SM-17R and SM-18R, located on the service water pipes adjacent to the Pump House, are used to monitor movement in the expansion joint installed to protect these pipes and accommodate movement between the Pump House and these pipes. The North Anna TRM lists an allowable differential settlement across the expansion joint between monuments SM-17R and SM-18R on the Service Water pipes and monuments SM-7 and SM-10 in the Pump House of 0.220 feet or 2.64 inches. Up through March 2011, the differential settlement across this joint ranged from 0.12 to 0.36 inches and averaged 0.24 inches. Post-seismic survey indicated that the differential settlement ranged from 0.11 inches to 0.53 inches and averaged 0.32 inches. These differentials compare favorably with the established TRM limit. The expansion joints were inspected after the earthquake and no damage was found.

19. *Section 3.8.1.1.7 of the NAPS UFSAR discusses the cracks that were discovered in the reinforced concrete wing walls, subsequent modification of the wing walls to decouple these walls from the service water pump house, and a horizontal shear stress calculation to demonstrate stress transfer across the crack. This section of the NAPS UFSAR also states that "The maximum average shear stresses at the base of the wall have been calculated to be 26.1 psi for the DBE case, and 39.2 psi for the OBE case. These values are within the allowable of 60 psi and 40 psi, respectively."*

    Considering the existing condition of these walls as described in the NAPS UFSAR, exceedence of the design basis operating basis earthquake (OBE) and safe shutdown earthquake (SSE) during the recent earthquake, and minimal margin in shear stress calculation, please discuss your approach to confirm seismic adequacy of these walls and rationale that likely exceedance of design limits will not impact their ability to perform their required design functions.

Dominion Response

Dominion has reviewed the original analysis that was performed as a result of the cracking in the Service Water Pump House wing walls that were discovered in 1975. The design loads on the wing walls considered pressures due to soil, water, and seismic components.

For this structure the load combination and load factors are:

Vu= 1.4 D + 1.7 L +1.9 E	for an OBE
Vu= 1.0 D + 1.0 L +1.0 E	for a DBE

An evaluation has been performed for the two load combinations listed above for the earthquake that occurred on August 23, 2011. The evaluation for shear transfer at the base of the wing wall utilizes the shear friction concept of load transfer as described in ACI 349, "Code Requirements for Nuclear Safety-Related Concrete Structures." The same seismic load input parameters were used for both the OBE and DBE load combination.

Because the load factors are higher and the same seismic inputs were used for both load combinations, the OBE combination governs. The section capacity to load demand ratio for the OBE combination is 2.7.

It can therefore be concluded that the wing walls have adequate capacity to transfer the shear demand associated with the August 23, 2011 earthquake.

20. *Discuss the engineering evaluation and inspection activities of safety-related buried components (tanks, pipes, electrical duct banks, tunnels, etc) to provide assurance that these safety related components withstood the recent earthquake without exceeding the design basis acceptance criteria. Also, discuss the rationale for concluding that possible exceedance of design acceptance criteria does not render buried components mentioned above inoperable. The response should explain the planned testing of buried components as a measure for assuring functionality prior to restart.*

    Specifically, the response should provide (1) pertinent information relative to the interface of the buried components with structures; (2) visual inspection of these buried structures (e.g. tunnels), if practical, to supplement the engineering evaluation, and (3) planned operational testing of buried components, as appropriate, in accordance with the plant's procedures.

Dominion Response

A detailed discussion of buried piping testing and inspection was provided in the response to Piping Question No. 3 contained in Dominion letter dated October 10, 2011 (Serial No. 11-577). Additional information is also provided in the Clarification to Piping Question No. 3 above. Safety related buried piping associated with the Unit 1 RWST was excavated and formally inspected, and no issues attributable to the earthquake were found. Several individual pipes were inspected, including ultrasonic testing (UT) of the pipe wall thickness. Areas where pipes are anchored through wall penetrations were also examined, and there were no indications of high stress at the penetrations nor were any cracks present. In addition, areas where piping systems penetrate the soil or penetrate building walls into the soil were reviewed during system walkdowns and inspections with no signs of stress on the penetrations or movement of the pipes within the soil. Inspection of the Unit 2 discharge tunnel was also performed and no earthquake related issues were identified.

Also, approximately one-half of the safety related electrical vaults/duct banks were inspected with no earthquake related damage identified. The only buried tank is the Underground Fuel Oil tank which is encased in sand. This tank has experienced no abnormal decrease in fuel oil level which indicates that no earthquake related damage has occurred. In addition, the Fuel Oil piping has been visually inspected with no earthquake related damage identified. Finally, no ground settlement issues or cracks in the soil or roadways were noted around the station.

Since no earthquake related damage was identified in the: 1) inspected and tested buried piping, 2) Unit 2 discharge tunnel, 3) electrical vaults/duct banks, or 4) buried Fuel Oil tank, it is concluded that these SSCs are capable of performing their design basis functions post earthquake.

21. *For components originally qualified by testing in accordance with Institute of Electrical and Electronics Engineers, Inc. (IEEE-344, "Recommended Practice for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations," confirm their capability to withstand a future ground motion DBE, even when deemed functional following the recent earthquake. In the response, address how the testing requirements in IEEE-344 (i.e. 1 SSE and 5 OBEs) would provide the assurance of functionality during a future DBE.*

22. *For a representative sample of safety related components, please confirm, prior to restart, that the test response spectrum (TRS), or the seismic input motion used in the original seismic qualification of the component, envelop the instructure response spectra (required response spectrum (RRS)) developed using the recent earthquake input motion data. As a minimum, the sample for this evaluation should include the following:*

a. *Those components that were identified in IPEEE effort as having HCLPF capacity less than 0.3g.*

b. *The equipment listed in Table 3.7-6 of the NAPS UFSAR that have a low margin (i.e., TRS is equal to or minimally greater than the RRS).*

c. *The components listed in Table 3.7-8 of the NAPS UFSAR.*

Dominion Response to Questions 21 and 22

The primary industry standard used for seismic qualification of new and replacement mechanical, electrical, and I&C equipment is IEEE Std. 344-1975, as endorsed by Regulatory Guide 1.100, Rev. 1. If necessary, the 1987 version of this standard is also used, as endorsed by RG 1.100 Rev. 2, provided it is consistent with North Anna's licensing bases. It is noted that North Anna is a USI A-46 plant; therefore, following resolution of USI A-46, Dominion updated the UFSAR to allow use of the earthquake experienced-based approach listed in SQUG's Generic Implementation Procedure (GIP), which has been endorsed by the NRC. Therefore, the GIP can be used for seismic evaluation of 20 classes of new and replacement equipment; however, if functionality during or after an earthquake needs to be verified for a sensitive component, only shake-table testing per IEEE Std. 344-1975/87 is used for qualification. It is noted that equipment seismic qualification can also be performed by using similarity or item equivalency approach and by reviewing functional and structural failure modes to determine if a component is rugged or insensitive for a seismic event.

With respect to durations and margins in testing, seismic tests are performed to simulate five (5) OBE and one (1) DBE events, which are generally triaxial with a typical duration of 30 seconds and minimum strong motion durations of 15 seconds for each test. In comparison, the effective strong motion duration of the August 23, 2011 earthquake was about one second in the North-South direction, about 3.1 seconds in the East-West direction and about 1.5 seconds in the vertical direction. Functionality of the tested equipment is verified during and after the seismic tests. The test response spectra (TRS) in shake table testing are required to have at least 10% margin over the required response spectra (RRS) in the entire frequency range, as required by IEEE Std. 323-1974. In practice, the TRS typically include higher margins over the location-specific RRS. Further, Dominion has been a participating member of the EPRI-SQURTS (Seismic Qualification Reporting and Testing Standardization) program for shake table testing for the past several years and equipment tested under this program are routinely tested to table limits or to generic limits that are typically much higher than Dominion's site specific levels. It is noted that the EPRI-SQURTS testing database is populated with thousands of typical nuclear power plant components tested to these higher limits.

Based on the recorded time-histories of the Kinemetrics instrument at the Containment basemat, the August 23, 2011 earthquake exceeded the North Anna DBE in the 2 to 10 Hz range, on average, by about 12% in the North-South direction, by about 21% in the vertical direction and none in the East-West direction. To confirm the existing margins in shake-testing of equipment, a sampling evaluation of various items of electrical equipment was performed. Five examples of equipment qualified by shake tests performed within the past 10 years are reviewed, as discussed below.

1. Main Station Batteries

   The North Anna main station batteries have been seismically qualified by shake table test. The testing was conducted by Wyle Laboratories and the results are documented in the applicable test reports. One of the test reports documents seismic qualification of the installed Yuasa Exide 2GN-23 Batteries in accordance with IEEE Std. 344-1987; while the other report documents environmental qualification of the same model batteries including seismic shaker table testing of 20 years aged batteries.

   As shown in the test report, the Test Response Spectra in 2GN-23 battery qualification report envelops the vendor's Required Response Spectra with margin for the OBE and SSE tests conducted. The vendor's RRS also envelop the North Anna Floor Response Spectra (FRS) for the 294 feet elevation of the Service Building with substantial margin (as shown in Figure 1).

2. Emergency Diesel Generator Battery Chargers

   There are four Emergency Diesel Generator (EDG) battery chargers between North Anna Units 1 and 2. They are mounted to the wall in the EDG Rooms (Service Building, Elevation 271 feet). The model number common to all four chargers is LaMarche Part No. A12B-20-130V-C3.

   The EDG battery charger (with a Lambda EMI filter) was seismically qualified in accordance with IEEE Std. 344-1975 to the generic SQURTS Floor Levels, which envelop the spectra at the installed location of this charger with margin. As shown in Figures 2 and 3, the TRS significantly exceeds the site specific RRS with copious margin. No anomalies attributed to seismic concerns were identified during the test and the unit was qualified.

3. Solidstate Controls, Inc. 15 KVA and 20 KVA Inverters

   The North Anna Units 1 and 2 vital bus distribution panel inverters are located in the 254 feet elevation of the Service Building. The 15 KVA and 20 KVA inverters were replaced several years ago and the current inverters are made by Solidstate Controls, Inc. (SCI). The 20 KVA unit is qualified by test in accordance with IEEE

Std. 344-1987. The 15 KVA unit was qualified by the same vendor by analysis based on its similarity with the 20 KVA unit. Test results from the table control accelerometers (shown in Figures 4, 5, and 6) for the 20 KVA bus show additional margins for higher seismic demand.

4. Cutler-Hammer Model AR420A Relay

   This Cutler-Hammer Model AR420A relay is currently in-stock at North Anna and is to be installed in the Service Water Pump House in the screenwash logic panels: 1-EP-CB-27A, 1-EP-CB-27B, 2-EP-CB-27A, 2-EP-CB-27B.

   This relay has been qualified per IEEE Std. 344 – 1975 to fragility levels well in excess of Dominion required design levels, as shown in the comparison plots in Figures 7 and 8. The SQURTS Qualification Report documents that the relay was qualified to the levels without any measured contact chatter in excess of 2 milliseconds. It is noted that the TRS does not envelop the RRS below approximately 2.5 Hz, but this is acceptable per IEEE Standard 344.

5. ABB 480V Transformer

   North Anna Unit 2 480V Emergency Switchgear 2J Transformer (2-EE-ST-2J), which is located in the Unit 2 Emergency Switchgear and Relay Room (Service Building 254 feet elevation) was recently replaced. This transformer is seismically qualified by test, as documented in a Wyle labs test report provided for the replacement equipment. Comparison between the DBE RRS and the TRS indicates significant margin (Figures 9 and 10).

In each of the above cases, the TRS showed margins beyond the 10% margin that is required per IEEE Std. 323-1974. Although the in-structure response spectra (ISRS) from the August 23, 2011 earthquake are not available at various structures and elevations, based on the review of the spectra at Containment basemat and elevation 291 feet developed from the recorded time-histories, it is judged that the margins in the TRS will envelop the spectra from the August 23, 2011 earthquake. Additional justification of margins is provided in Attachments 2 and 3.

Question 22 addresses the additional plant equipment that is qualified by seismic testing (TRS vs. RRS from the August 23, 2011 earthquake):

a. Those components that were identified in the IPEEE effort as having HCLPF capacity less than 0.3g.
b. The equipment listed in Table 3.7-6 of the NAPS UFSAR that have a low margin (i.e., TRS is equal to or minimally greater than the RRS).
c. The components listed in Table 3.7-8 of the NAPS UFSAR.

In response to item "a" above, a seismic margin analysis (SMA) for North Anna was performed in the 1990s during Individual Plant Examination of External Event (IPEEE) for a beyond design basis seismic event using Review Level Earthquake spectrum of NUREG/CR-0098 anchored at a peak ground acceleration (PGA) of 0.3g. Other than a handful of components, the HCLPF capacity of components was greater than 0.3g. As indicated in our letter dated September 17, 2011, for the components that were identified in the IPEEE effort with HCLPF capacity less than 0.3g, a long term action is planned to review their seismic capacity. The only IPEEE items of equipment identified with HCLPF capacity less than 0.3g that were qualified using seismic testing were the 4160 V Emergency Buses (Mark Nos. 1-EE-SW-1H, 1-EE-SW-1J, 2-EE-SW-2H, and 2-EE-SW-2J). The capacity of these items is governed by the seismic testing of a GE – HFA relay. Review of the qualification information indicates that the relay is seismically acceptable up to a spectral acceleration of 7.5g for the non-operate mode for normally open contacts between 4 and 16 Hz at 5% damping (EPRI Report NP-7147-SL). This capacity is well above the corresponding in-cabinet peak spectral acceleration of 4g at elevation 254 feet of the Service Building. The zero period acceleration (ZPA) of the TRS is 3g as compared to the ZPA of 1.5g in the RRS based on the relay evaluation performed for USI A-46. Therefore, there is sufficient margin in the seismic qualification of this relay to offset spectral exceedances observed during the August 23, 2011 earthquake as recorded at the Containment basemat.

For the equipment listed in Tables 3.7-6 and 3.7-8 of the NAPS UFSAR, it is noted that these tables are only for historical purposes and many of these components have been replaced and qualified to different seismic spectra using IEEE Std. 344. However, a review of Table 3.7-6, *Equipment Test Summary, Stone & Webster Scope of Supply* shows for the majority of the equipment, "substantial margin exists, as shown by examination of the data" (as indicated by note "a" in the table). In other instances where more detailed review by Stone & Webster was performed (as documented in other applicable notes for the table), it was concluded that at least some margin exists. The five examples of equipment qualified by shake tests discussed above show that the margin of safety between the TRS and the RRS, if developed from the August 23, 2011 earthquake, would be sufficient.

North Anna UFSAR Table 3.7-8, which is also historical, indicates that for three of the components listed (Safety Injection accumulator, Residual Heat Removal Heat Exchanger, centrifugal Charging pump), margin exists between the accelerations used for qualification and the design accelerations. Note "b" for the Process Instrumentation and Control Rack (Component 5) indicates that the component has design margins in excess of 2. Note "c" for the Low Head Safety Injection pump (Component 4) indicates that LHSI pumps were seismically qualified by comparison to an equivalent pump that had been generically qualified by dynamic modal analysis and response spectrum methods. The note indicates that "the North Anna response spectra at the elevation of the pumps and within the frequency range of the pumps was shown to be conservatively enveloped by the design spectra used for the reference pump..." Note also that the LHSI pumps were included within the scope of USI A-46 and IPEEE. The IPEEE review indicates that the pumps had a HCLPF capacity > 0.3g for the IPEEE RLE. Therefore, there is margin to accommodate the August 23, 2011 event.

The results of North Anna UFSAR Tables 3.7-6 and 3.7-8 both corroborate the conclusions of Attachments 2 and 3 that the qualified equipment has margin. It is noted that the effective strong motion duration of the August 23, 2011 earthquake was about one second in the North-South direction, about 3.1 seconds in the East-West direction and about 1.5 seconds in the vertical direction. The aftershocks and a previous earthquake of 2003 are the only other seismic motions seen by equipment installed at North Anna Power Station, but they are all quite small in magnitude and not of any consequence. Therefore, there are substantial margins in both magnitudes and durations to conclude that equipment qualified via shake testing will maintain its structural integrity and functionality during and after another potential future earthquake of the same or even a higher magnitude than the August 23, 2011 earthquake.

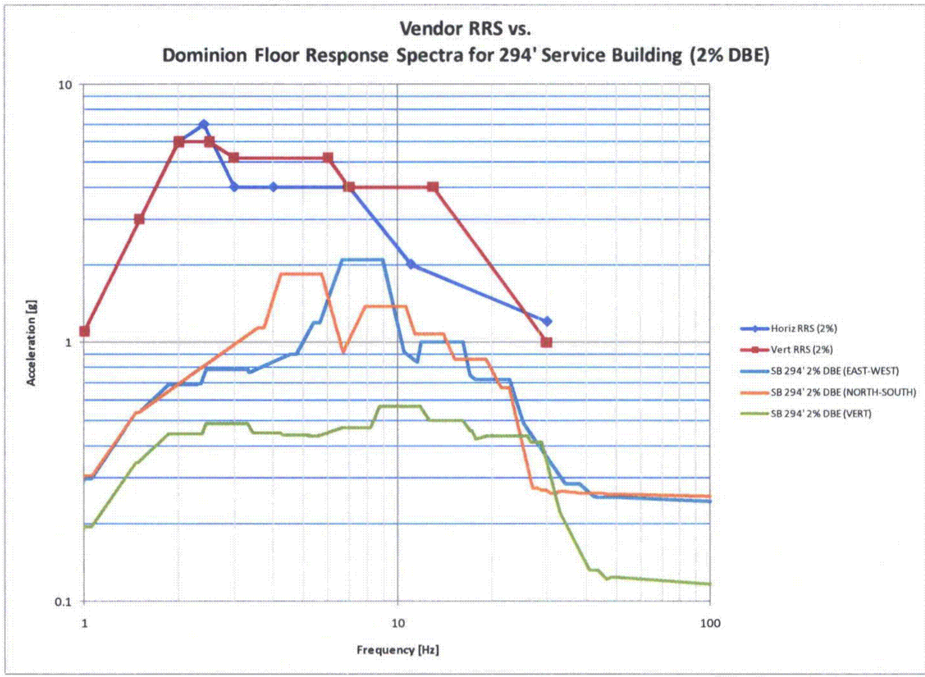


Figure 1 – Main Station Batteries

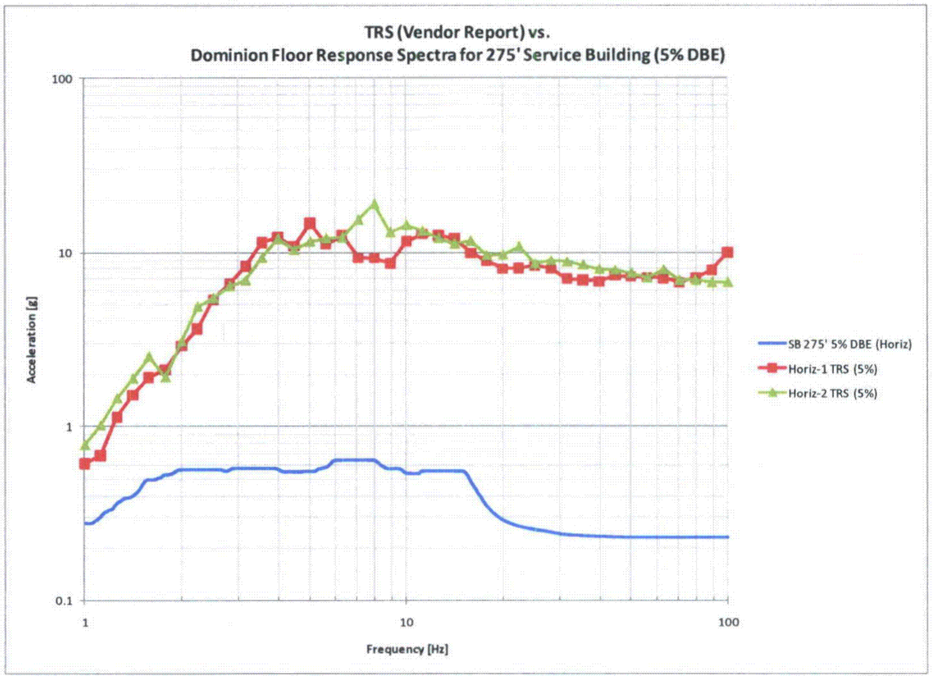


Figure 2 – EDG Battery Charger (Horizontal Comparison)

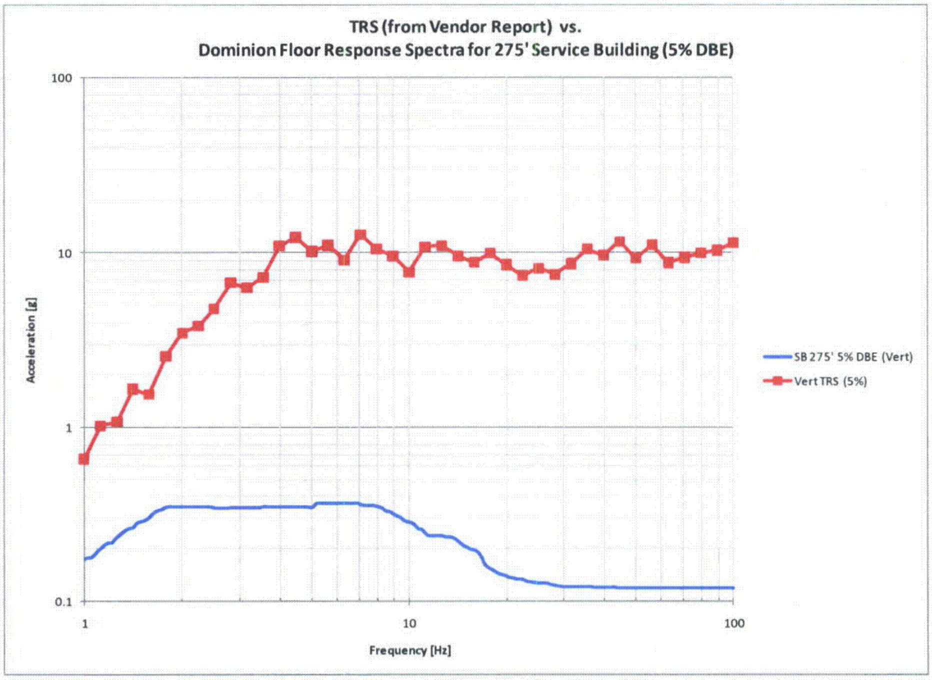


Figure 3 – EDG Battery Charger (Vertical Comparison)

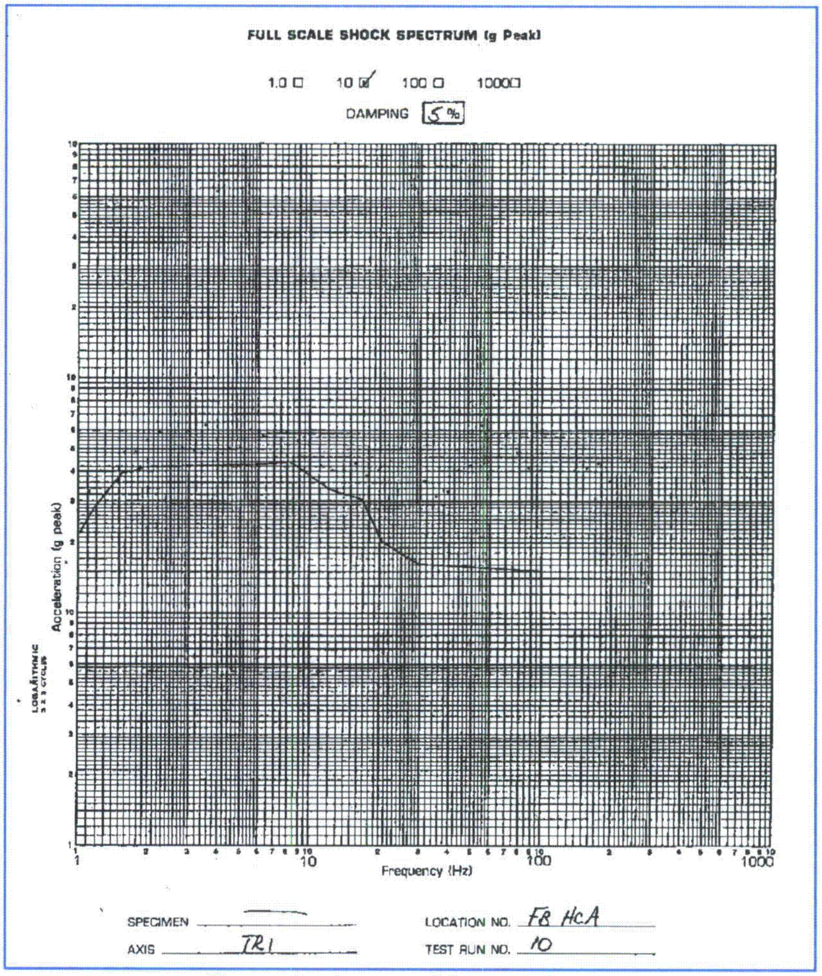


Figure 4 – Inverter (Front-to-Back)

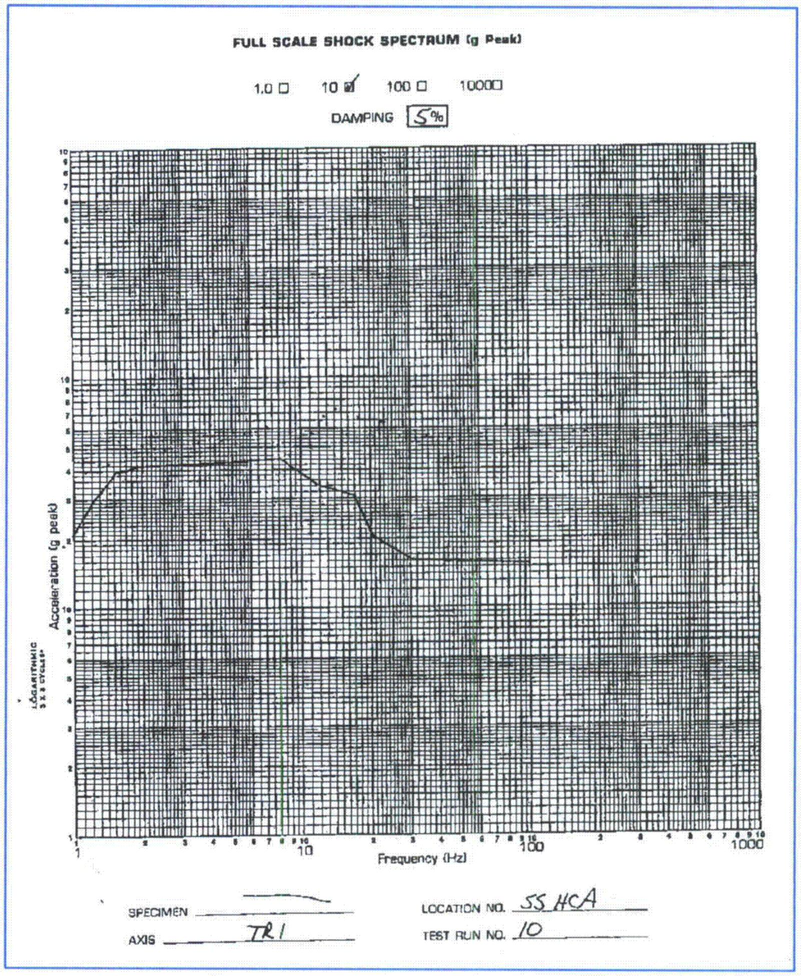


Figure 5 – Inverter (Side-to-Side)

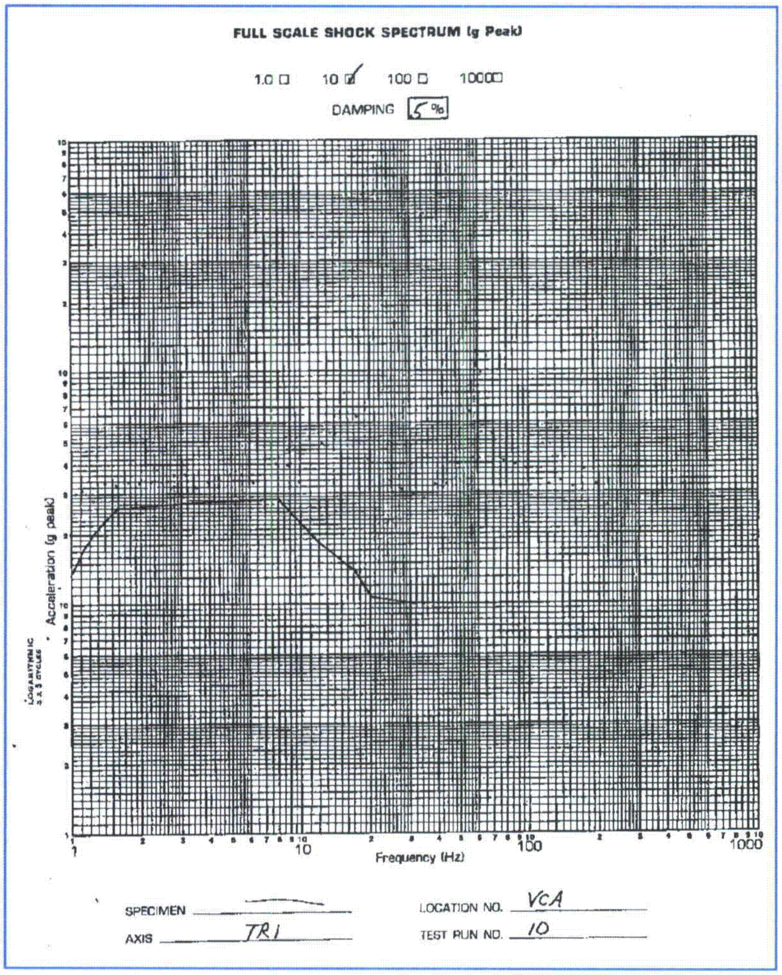


Figure 6 – Inverter (Vertical)

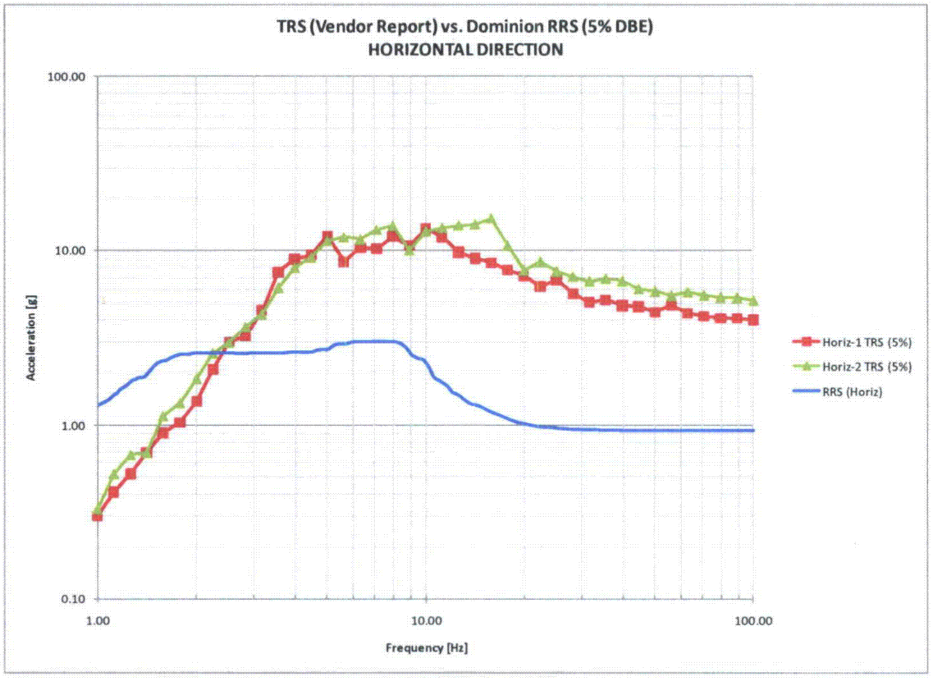


Figure 7 – ARD Relay (Horizontal)

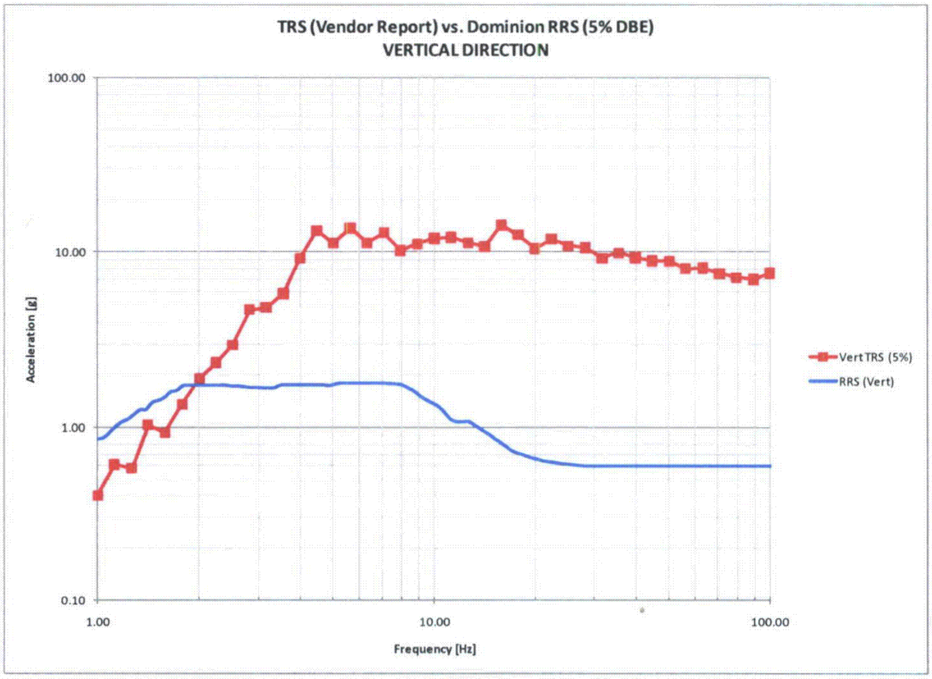


Figure 8 – ARD Relay (Vertical)

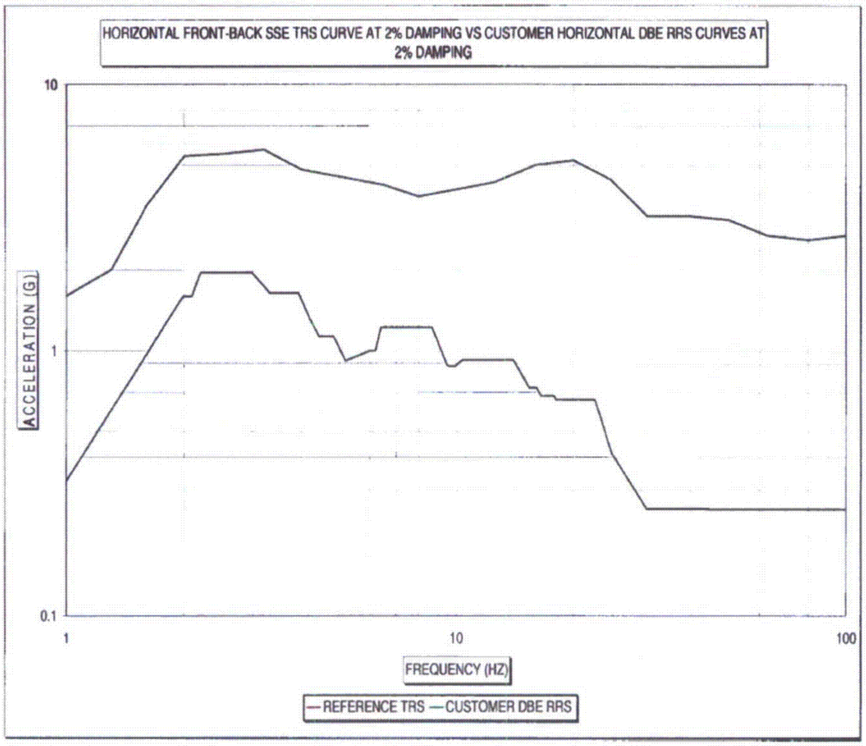


Figure 9 – ABB Transformer (Front-to-Back, Controlling Orientation)

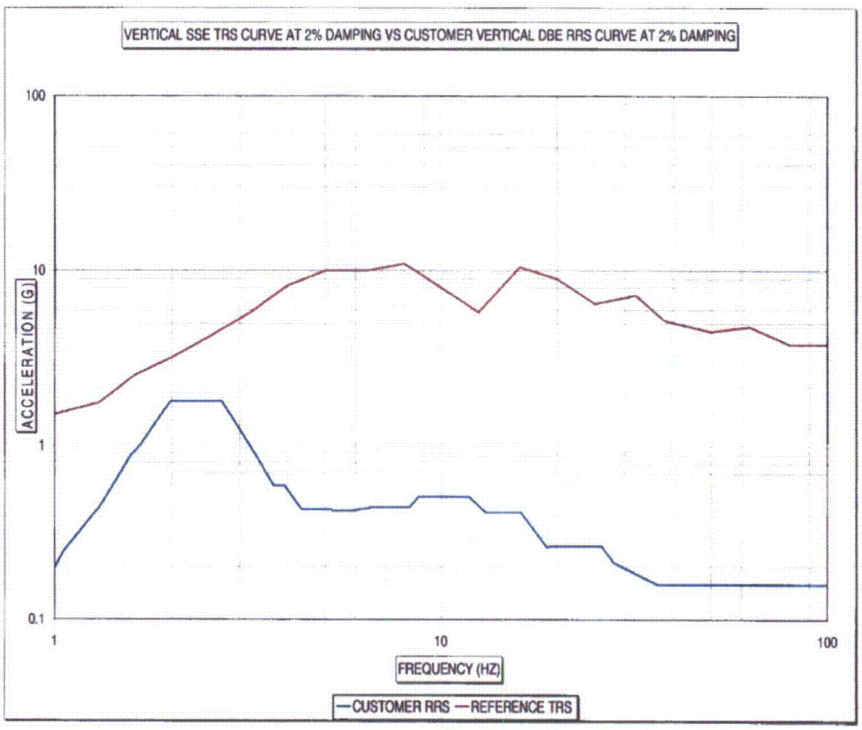


Figure 10 – ABB Transformer (Vertical)

23. *Enclosure 1 Attachment 2 of the summary report dated September 17, 2011, includes several figures that show seismic instrumentation data for auxiliary building 244-foot elevation and 273-foot elevation. In these figures, specifically Figure 2.9, there is a significant exceedance above 6 Hertz. Discuss VEPCO's plan and provide further information to address these exceedances and their effects on safety-related SSCs, prior to restart.*

Dominion Response

As documented in Attachments 2 and 3, North Anna SSCs have margin for higher seismic loading. Further, both Attachments 2 and 3 document that based on review of the recorded data and calculated parameters, such as CAV and effective strong motion durations, the August 23, 2011 earthquake had minimal damage potential. This has been corroborated by extensive post-event plant walkdowns and inspections, which confirm that the earthquake had an EPRI damage intensity level of zero. The assessments made in Attachment 3 about plant SSCs are applicable to the entire plant, including the Auxiliary Building.

As noted by the NRC, Figure 2.9 of Enclosure 1, Attachment 2 of the September 17, 2011 letter shows exceedances above 6 Hz in the spectrum recorded at elevations 244 feet and 273 feet of the Auxiliary Building. However, these readings are recorded by Engdahl scratch recorders, which are considered less representative than the Kinemetrics data. Nevertheless, a sampling review of the equipment located in the Auxiliary Building was initiated. This sample review will continue as part of Dominion's long term response in accordance with EPRI NP-6695. Initial results of sampling indicate that components that are more likely to be impacted by the reported spectra from the Engdahl recorders that show exceedances around 10 Hz are the Volume Control Tanks (1/2-CH-TK-2) and the Boric Acid Storage Tanks (1-CH-TK-1A/B/C). Intensive post-event inspections indicate that no damage was identified for these tanks. The Boric Acid Storage Tanks were also inspected by SQUG trained Seismic Capacity Engineers and no earthquake-related damage was identified.

In summary, as documented in Attachments 2 and 3, the August 23, 2011 earthquake was of short duration and had low damage potential. No damage to safety related SSCs would therefore be expected. Extensive plant inspections confirm a lack of damage to safety related SSCs, including components in the Auxiliary Building. As a long term action in accordance with the EPRI guidance in NP-6695, a sampling analysis of equipment located in the Auxiliary Building will be completed.

24. *As the level of the recent earthquake exceeded the design basis SSE, please discuss VEPCO's plan for evaluation and augmented inspection to demonstrate, prior to restart, that the anchor bolts, including expansion anchors will continue to perform their required design functions. Also discuss the significance of exceeding the original design basis capacity of anchorages.*

Dominion Response

Industry insights from EPRI research related to the effect of the Niigata Chuetsu-Oki (NCO) earthquake of 2007 on the Kashiwazaki-Kariwa Nuclear Power Station (K-K) in Japan were reviewed. Specifically, the NCO earthquake of 2007 was a Magnitude 6.6 earthquake that occurred on July 16, 2007 in the northwest Niigata region of Japan. The K-K plant is located approximately 15 miles from the epicenter of the earthquake. The NCO earthquake significantly exceeded the seismic design basis of the plant. The earthquake consisted of less than ten cycles of significant motion at frequencies generally less than 4 Hz. EPRI's post-NCO earthquake peer review and plant walkdown inspection, described in EPRI report 1016317, observed no significant damage to safety related SSCs, but did observe damage to non-safety related facilities, such as that resulting from soil collapse. As a result of the earthquake and the consequent damage to non-safety related SSCs, an extensive review of the SSCs in the K-K plant was conducted by the plant owner.

As reported during a 2010 International Atomic Energy Agency (IAEA) International Workshop on Seismic Safety of Nuclear Installations, EPRI established an expert panel to address the potential for hidden damage in SSCs that were subjected to the July 16, 2007 NCO earthquake that affected the K-K plant. The panel adopted a multi-element working approach addressing both experimental and analytical elements. The experimental elements included both seismic testing and earthquake field observations. The analytical elements included both structural analysis and physics of failure evaluations. Using the multi-element approach, the panel determined six specific equipment items and four general items that had a potential for hidden damage. The plant owner, Tokyo Electric Power Company (TEPCO), further investigated these ten items identified as significant by the EPRI panel. No abnormal findings were identified from these investigations. TEPCO shared their methods of investigation of the items and their investigation results with EPRI.

The two earthquakes, NCO and the Central Virginia, have several differences. Most notable is the fact that the K-K plant had significant damage to non-safety related SSCs, while North Anna had only limited damage to non-safety related SSCs. This is expected, as indicated by the CAV calculated from the ground motion recordings of the two earthquakes. The CAV values for the NCO earthquake are, on average, about six times higher than the CAV values for the Central Virginia earthquake. Based on the review of the hidden damage evaluation process at the K-K plant, and the lack of abnormal findings, we consider that North Anna's comprehensive walkdown and inspection effort, together with functional tests of systems and components that have been and are being completed after the August 23, 2011 earthquake, are adequate to conclude that North Anna SSCs do not have significant potential for hidden damage.

A generic area of concern identified by the EPRI expert panel is for expansion anchor bolts. There was some concern by the expert panel reviewing the NCO earthquake that expansion anchor bolts may have loosened during the earthquake. This concern stems from the fact that friction type concrete expansion anchors are not recommended where sustained vibratory loading is anticipated, (Hilti Kwik-Bolt, Hilti Kwik-Bolt II, Hilti Kwik-Bolt III). Bearing type concrete expansion anchors are acceptable for sustained vibratory loading, (Drillco Maxi-Bolt).

The North Anna design standard for drilled-in concrete anchor bolts uses a safety factor of four to average ultimate capacities for the appropriate embedment depth and concrete strength. Any evidence of overloading would be evident in cracking of the concrete around the expansion bolt. As previously reported, extensive inspections were performed of plant SSCs. Some instances of suspect expansion anchor bolting were identified, but every instance was able to be corrected by simply tightening, or resetting the bolt and retightening. Based on the absence of clear evidence of seismically induced damage, it was not evident that the identified loose bolts were caused by the earthquake.

IPEEE evaluations identified some anchorage limited equipment with HCLPF capacities less than 0.3g. These items were individually inspected by seismic review teams consisting of SQUG-trained and experienced engineers and no concerns with anchorage were noted. Additionally, extensive engineering inspections were performed of all systems that included piping/equipment supports and anchorage. As a result of the systems/structures inspections, several Condition Reports were submitted for concerns identified with anchorage. However, after evaluation, these concerns could not be categorized as associated with the earthquake. For example, an anchor support for component cooling piping to a RCP in Unit 2 Containment had loose anchor bolts on one of the three associated baseplates. The other baseplates were not damaged and no other similar situations were identified. The bolting and nuts for this baseplate were not painted, which is indicative of recent maintenance. Some spalling adjacent to the baseplate was evaluated as cosmetic, and it was determined that the support remained functional with the slightly loose anchor bolts. Another example was a non-safety related Auxiliary Steam pipe support that may have had some bolt pull-out. Even so, the line remained adequately supported.

Loosening of friction type concrete anchors requires sustained vibratory motion. The effective strong motion duration of the August 23, 2011 earthquake was 3.1 seconds in one direction, with the other two directions being 1.5 and 1.0 seconds. Consequently, this was a relatively short duration earthquake resulting in relatively few cycles of vibration. Based on the margin in our expansion anchor bolt design, the relatively insignificant number of earthquake loading cycles, and the visual inspections performed for systems at North Anna, no expansion anchor bolt hidden damage would be expected.

26. *The September 17, 2011, report states that the lack of any significant physical or functional damage to safety related SSCs and the limited damage to nonsafety-related systems are consistent with an EPRI damage intensity of 0, the indicator of least damage. However, the damage intensity discussion in the report does not address the operating experience related to the shift of TN-32 casks. Please provide further information and discuss the EPRI damage intensity in relation to this operating experience.*

Dominion Response

The TN-32 casks are independent free-standing, self-contained, passive systems for the dry storage of used fuel. Although the TN-32 casks were not expected to slide for a DBE, as a free-standing component the sliding movement of the cask would not mean they had sustained significant damage as it might for a system whose base and other components may move independently thereby causing significant damage. To address whether the TN-32 casks sustained significant damage as defined in EPRI NP-6695, it is necessary to determine whether the casks sustained damage that has the potential to adversely affect the operability, functionality, or reliability of equipment or structures required for safe operation. As discussed above the "sliding" indicator is not an appropriate indicator of significant damage for the TN-32 casks.

Post event walk downs and inspections have documented that there is no discernible damage to the TN-32 casks that would impact their ability to perform their design functions. Due to the earthquake a number of casks shifted position by as much as 4.5 inches. However, there was no visual evidence of damage to the exterior of the casks as a result of the movement. Radiological surveys indicate there has been no change from the radiological conditions prior to the event, indicating the TN-32 cask shielding design function is intact. There were no pressure monitor alarms during and subsequent to the event. The absence of alarms and subsequent checks of the pressure monitoring system provide assurance that the confinement barriers of the casks are intact and performing their design functions.

The TN-32 casks have been analyzed for a heat load of 32.7 kW and a center-to-center spacing of 16 feet. The TN-32 cask movement due to the earthquake resulted in some of the casks no longer meeting the 16 feet center-to-center spacing assumed by the current thermal analysis of record. The North Anna Independent Spent Fuel Storage Installation (ISFSI) Technical Specifications (TS) Section 4.2.3 requires a nominal 16 feet center-to-center spacing for sealed system storage casks (SSSCs) whose heat load is greater than 27.1 kW. As indicated in the summary report, dated September 17, 2011, the (27) TN-32 casks had a decay heat value below 27.1 kW at the time of the August 23, 2011 earthquake. An evaluation has been performed by Transnuclear which concluded that 15 feet is an acceptable center-to-center spacing for TN-32 casks with decay heat values equal to or less than 27.1 kW. At present, the twenty-seven TN-32 casks at the North Anna ISFSI have center-to-center spacing greater than 15 feet and are therefore capable of performing their thermal design function. Additional evaluations are being performed for cask center-to-center spacing of less than 15 feet to provide additional margin for the current configuration.

From the inspections and evaluations performed for the twenty-seven TN-32 casks in their current locations, it was concluded the cask movement did not adversely affect the operability, functionality, or reliability of equipment or structures required for the safe operation of the nuclear power plant. Therefore, per the EPRI NP-6695 definition, the movement of the TN-32 casks at the North Anna ISFSI facility does not constitute "significant damage" and an EPRI Damage Intensity Level '0' is an appropriate rating for the North Anna ISFSI facility.

27. *If there are any structures at NAPS that were designed for OBE only, provide further information relative to detailed inspection and additional evaluation of these structures for the input motion experienced during the recent earthquake to confirm their structural integrity. The results of this evaluation may indicate vulnerable areas where the design basis acceptance criteria have been exceeded. Please discuss how VEPCO confirmed that these highly stressed areas will continue to perform their intended design function.*

Dominion Response

The North Anna UFSAR, Table 3.2-1, states the "Flood protection dike" at the west end of the Turbine Building is designed for OBE loads only. Given the load cases required in Appendix A of Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants", the OBE load combinations form the critical load case rather than failure during a DBE. However, the DBE load condition was checked with the original design basis calculation.

Dominion reviewed the design basis slope stability analyses and conducted a post seismic field inspection of the dike and related appurtenances to address the issue of continued structural integrity. The flood dike was analyzed for the DBE load case and shown to have a factor of safety greater than 1.0 as a result of the modeled DBE event. The computed failure surface indicated in the analysis for the DBE event initiated on the crest, approximately 16 feet from the crest edge, and exited approximately 44 feet downstream of the slope toe, rupturing a substantial volume of embankment fill and natural foundation subgrade. The embankment, constructed with 2.5:1 slopes, is approximately 19 feet in height, meaning that such a failure surface would theoretically heave foundation material extending a distance more than twice its height from the slope toe. Under increased seismic demand, it follows that the slope distortion and displacement would be profound, resulting in very large, echelon type scarps on the slope faces, deep cracks on the crests, significant lateral translations and abrupt changes in dike alignment that would indicate substantial, non-recoverable, plastic yielding along the failure planes. Deformation on this scale would most certainly have damaged the security fences traversing along the flood dike crest. A post-seismic field inspection of the flood dike and the steel drainage culvert going through the dike revealed no discernable damage or displacement, let alone distress approaching the level one would expect given the seismic energy and horizontal acceleration the flood dike would experience in a greater than DBE event.

The lack of discernable damage at the flood dike as a result of the August 23, 2011 earthquake is not unprecedented for earth structures at North Anna Power Station considering the Main Dam forming Lake Anna and the Service Water Reservoir were also undamaged. These structures are actively subjected to a hydrostatic load and instrumented to provide additional data such as pore water pressure and small scale (less than 1 to 2 inches) deformations that would not be apparent in a visual inspection. Post-seismic instrument data for these structures corroborated well with the visual inspections and indicated that structural integrity was not compromised. Given this understanding, it would be reasonable to expect the flood dike, a structure that is normally dry and was dry at the time of the earthquake, to have performed adequately and maintained its structural integrity.

32. *Prior to restart, provide the basis for VEPCO's continued use of the cumulative absolute velocity criterion to explain the level of damage given there is no seismic recording from instrumentation located on free surface in the free field.*

Dominion Response

North Anna Power Station is essentially situated on a rock site. It is a common practice for many US nuclear plants on rock sites to locate seismic recorders at the top of the Containment basemat, a practice that is consistent with the commitments in the North Anna UFSAR Section 3.7.4.5. It was therefore reasonable to model the Containment as a fixed-base structure to determine structural loads and in-structure response spectra. Based on the analysis using the Containment model, it was determined that the in-structure response spectra at the top of the basemat are close to the corresponding free-field design basis response spectra (i.e., the spectra from which synthetic time-histories were developed and used as input) in each of the three directions. It is recognized that due to incoherency, there can be a reduction in the spectral values at the top of the Containment basemat and the time-histories recorded at the top of the Containment from an earthquake could be slightly lower than the free-field time-histories. However, the spectral reductions in large basemats due to incoherency effects are in the higher frequency range and are in the order of about 15%. Since the recorded time-histories at the Containment basemat from the August 23, 2011 earthquake contain significant low frequency content, the CAV values calculated from them would be expected to be at most 10% lower than the values that could be calculated from a free-field recorder.

Therefore, the Containment basemat at North Anna is a reasonable representation of the hard rock free-field data from the August 23, 2011 earthquake, and the CAV values calculated from the time-histories at the Containment basemat are considered reasonably accurate. This was also the conclusion of several industry experts who were peer reviewers of Dominion's technical evaluation of the characterization of the August 23, 2011 earthquake.

Additional information on this issue is provided in Attachments 2 and 3.

33. *VEPCO indicated that Engdahl seismometers are less reliable than Kinemetrics seismometers (i.e., inconsistent with Kinemetrics in readings and also missing frequency readings). But even the Kinemetrics seismometers may not have accurate timing for the recorded time history because the start time of seismic data is estimated. Address how this potential uncertainty impacts the use of the seismic time history when matching it to other recorded events (e.g., the nuclear instrumentation (NI) signal changes) for the reactor shutdown root cause analysis. Considering this issue, discuss any plans to update seismic instrumentation at the plant to provide better ground motion recordings for any future earthquake events.*

Dominion Response

The potential uncertainty regarding accurate start time for recorded seismic time-history associated with the Kinemetrics is merely an inconvenience when making comparisons with other recorded events. Use of an estimated start time is adequate for most other recorded events. For the case of matching the time-history with the nuclear instrumentation (NI) changes for the reactor shutdown root cause, it was simply a matter of overlaying the time-history and NI signal and matching accelerations with the variations in NI indication. While this is not ideal, it does not present a problem regarding the use of the seismic data. As noted in the response to Question 28 in our letter dated October 10, 2011 (Serial No. 11-577), Dominion plans to upgrade the seismic instrumentation equipment at North Anna Power Station, which will resolve this issue. In addition, temporary, free-field seismic instrumentation has been installed at the plant that will be used to provide additional, corroborating, seismic response information pending the completion of the permanent modifications.

34. *Prior to restart, confirm the operability and reliability of the seismic instrumentation (specifically, channel orientation, sensor calibration, sensitivity test implementation) and alarming systems to ensure they accurately record earthquake ground motion and provide real time alarm notifications to the plant operators during any earthquake events.*

Dominion Response

The applicable Technical Requirements Manual (TRM) technical surveillance requirements have been completed satisfactorily for the seismic instrumentation and alarming systems following the earthquake. These include channel functional testing and channel checks of installed instrumentation for functionality. This also included channel calibrations of all peak acceleration and response spectrum recorders and the associated control room alarm indications. Channel calibrations were also completed for the time-history accelerographs and the seismic switch control room alarm indications. A channel orientation issue was identified for the time-history accelerographs whereby the horizontal sensors were 90 degrees off specified orientation. This discrepancy was entered into the Corrective Action Program for resolution; however, there is no issue with either affected channel's functionality or their ability to record an earthquake event. Further investigation found no identifiable issues of a vertical recording channel interchanged for a horizontal recording channel for any of the installed systems.

A seismically qualified backup power supply has been installed in the main control room to the seismic monitoring control panel. This will ensure power is available to the alarm indications in the control room for immediate determination of OBE exceedance prompting a controlled unit shutdown. Based on completed inspections and testing following the August 23, 2011 earthquake, there are presently no concerns with the functionality or reliability of the station's installed seismic instrumentation. In addition as noted in the response to Question 33 above and Question 28 in our letter dated October 10, 2011 (Serial No. 11-577), the seismic instrumentation at North Anna will be upgraded to enhance the station's ability to monitor and assess seismic events.

35. *The September 17, 2011, report, Enclosure 1, Attachment 3, page 7 of 7, "Kinemetrics Data for Containment Elevation 291 [feet] - Vertical Direction," shows a peak recorded value at about 10 hertz that is greater than 1 g. Discuss the sensitivity of this value with respect to the methodology used (for example, sampling rates) and any other alternative calculations.*

The figure shown in Enclosure 1, Attachment 3, page 7 of 7 of the Dominion letter dated September 17, 2011 (Serial No. 11-520) plots the vertical response spectrum generated from the time-history of the August 23, 2011 earthquake recorded by the Kinemetrics Instrument located at the North Anna Unit 1 Containment Operating Deck

(291 feet elevation). The time-history was recorded to an analog tape that was sent to the vendor, Kinemetrics, for processing and baseline correction. The resulting corrected time-history was input into a finite element program (STARDYNE, Version 5.11) to generate the response spectrum plot spanning from 0.2 Hz to 50 Hz in increments of 0.2 Hz. Two outside consultants used the same input time-history and independently generated nearly identical response spectra. Kinemetrics, in their input to Dominion (which was provided to the NRC in the September 17, 2011 letter), also plotted the vertical time-history for comparison to the design basis OBE and DBE curves. According to Kinemetrics, their software requires consistent input frequencies for all response spectra plotted for comparison. Accordingly, their data analysis program plots the response spectrum generated from the recorded time-histories at only those frequencies at which the design spectra curves were digitized and were sent to them. Thus, the frequencies used by Kinemetrics in plotting the vertical response spectrum lack the refinement and are not consistent with those frequencies that Dominion and other consultants used for plotting the response spectrum.

Kinemetrics results provided in Enclosure 1 of the September 17, 2011 letter were compared to the calculations performed by Dominion. The comparison shows differences in the peak spectral acceleration for the vertical direction spectra at the 291 feet elevation. The apparent difference in this instance is attributed to the frequency points at which Kinemetrics plotted the vertical spectrum generated from the recorded time-history. Dominion's calculated peak spectral acceleration is 1.06g at 10 Hz; whereas, Kinemetrics reported peak is only 0.973g, but Kinemetrics calculated spectral ordinate at 9.57 Hz. The next discreet frequency that Kinemetrics calculated the response is 11.5 Hz. The 10 Hz value in Kinemetrics plot was an interpolated value. Note that Dominion's calculated value at 9.5 Hz is very close to Kinemetrics, 0.966g, which is a difference of less than 1%.

Therefore, the apparent error was caused because of interpolations used by Kinemetrics and not due to differences in numerical integration methodology or sampling rates. Plotted at consistent frequencies, the Kinemetrics data and the Dominion data are consistent, as is the case with the spectra developed from recorded motions by two other consultants.

LICENSING

1. *Summarize the plans during mode changes and power ascensions (e.g., any planned walk downs, inspections, or evaluations) for NAPS. Also provide the schedule for submitting its Restart Plan.*

Dominion Response

A Restart Readiness Procedure has been developed which will delineate the plant evaluation criteria prior to and during the unit restart from Mode 4 entry to full power steady state operation. This process is summarized in the response to I&C Clarification No. 2 contained in Dominion letter dated October 18, 2011 (Serial No. 11-566B).

2. *By letter dated September 17, 2011, the licensee stated that its readiness assessment was based, in part, on the guidance of Regulatory Guide (RG) 1.167, "Restart of a Nuclear Plant Shut down by a Seismic Event."*

   a. *RG 1.167, Section C.2, states that "coincident with the long term evaluations, the plant should be restored to its current licensing basis." In that same letter on pages 3 and 4, the licensee mentioned that a licensing basis review and evaluation has been performed. The staff requests that the licensee summarize the scope and results of the licensing basis review that was conducted, and plans for addressing RG 1.167, Section C.2.*

   b. *RG 1.167 states that "holders of an operating license or construction permit issued prior to January 10, 1997, may voluntarily implement the methods described in this guide..." Discuss whether VEPCO plans to implement RG 1.167 and the referenced EPRI report, in their entirety. If not, identify all planned deviations from this guidance.*

Dominion Response

2.a A review and evaluation was conducted to identify the licensing basis of the North Anna Power Station relevant to the August 23, 2011 earthquake. This identification was based on a review of the UFSAR, Technical Specifications and Bases, docketed correspondence, and project correspondence from the original construction and licensing of Units 1 and 2. Included was a historical perspective of the initial licensing requirements and how they evolved to the present day requirements.

The results of this review indicate that, after careful consideration of the August 23, 2011 earthquake and determination that it has not caused functional damage or invalidated design basis analyses, the station continues to meet its current licensing basis. This determination is based on the following information:

Section 3.7.4.6 of the UFSAR states:

> "In accordance with paragraph V(a) of Appendix A to 10 CFR 100, an orderly and sequential shutdown of the North Anna units will be carried out according to detailed written station procedures if a seismic event with vibratory ground motion equal to or exceeding that of the operational-basis earthquake occurs. Prior to resuming operations, it will be demonstrated to the NRC that no functional damage has occurred to those features necessary for continued operation without undue risk to the health and safety of the public, or that the necessary repairs to those features have been completed."

Consistent with the UFSAR, the plant was shut down in orderly fashion following the August 23, 2011 earthquake. By letters to the Commission dated September 17, 2011 and September 27, 2011, Dominion reaffirmed that North Anna Units 1 and 2 will not be restarted without NRC concurrence. Comprehensive inspections and testing have demonstrated that no functional damage has occurred to those features of the units necessary for safe operation.

The Code of Federal Regulations 10 CFR 50, Appendix A, Criterion 2, states: "Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design basis for these structures, systems and components shall reflect:

- Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

- Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

- The importance of safety functions to be performed."

UFSAR Section 3.1.2.2 addresses this Criterion: "The station structures, systems, and components important to safety have been designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, seiches, and floods, as described in Chapters 2 and 3. Tsunamis are not applicable to the North Anna site. Appropriate considerations have been made in the design basis for the most severe natural phenomena that have been historically reported for the site and surrounding area, including a margin of error for the accuracy of such reporting and the relatively short period over which data has accumulated." The analyses of the August 23, 2011 earthquake that have been performed, including the responses to the numerous RAIs, indicate that systems, structures and components remain able to withstand a DBE, and equipment remains seismically qualified.

Section 2.5.2.6 of the UFSAR documents the basis for the North Anna DBE design requirements and concludes that with respect to a DBE, the North Anna Power Station seismic design meets all safety requirements.

Section 3.7.3.1.3.1 of the UFSAR addresses ASME Code Class 1 Piping. This section requires a number of earthquake cycles and seismic events used in the analyses of the ASME Code Class 1 components to be specified as part of the piping design criteria. The specifications are as follows: 1. A total of five OBE (one-half safe-shutdown earthquake) and one DBE (safe-shutdown earthquake) seismic events will occur during the life of plant. The specified number of cycles has not been exceeded. Further, as shown in Attachment 2, the influence of the August 23, 2011 earthquake was less severe than a DBE.

A review of the docketed correspondence and associated commitments was conducted with an emphasis on post-seismic activities. We have not indentified any commitments that have not been met as a result of the review of these documents.

A review of the Technical Specifications and Bases was performed. The Technical Specifications do not specifically address seismic design. The Bases states that the Emergency Condensate Storage Tank, the Main Control Room/Emergency Switchgear Room Emergency Ventilation System, and the Main Control Room/Emergency Switchgear Room Air Conditioning System are Seismic Category I. The Bases also address allowable outage times for snubbers based on seismic event probability. No issues were identified regarding Technical Specifications or Bases compliance.

The review of the UFSAR licensing correspondence has indicated that the licensing basis as described within is intact and the current licensing basis is maintained. It is also understood that the UFSAR will require a future update to capture information related to the August 23, 2011 earthquake and to reflect modifications and actions that have and will be taken in response to the event. The specific actions will be addressed in the response to Licensing Question No. 3, which will be provided in subsequent correspondence prior to the restart of Units 1 and 2. This response will detail the long term actions that Dominion will be implementing in response to the August 23, 2011 earthquake.

2.b Dominion plans to incorporate RGs 1.166 and 1.167, and the referenced EPRI Technical Report NP-6695, into the licensing basis for North Anna Power Station once the installation of upgraded seismic instrumentation has been completed to meet the requirements of RG 1.12, Revision 2, "Nuclear Power Plant Instrumentation for Earthquakes." It has not been determined at this time whether exceptions to the RG requirements will be requested. The seismic instrumentation upgrade project is currently scheduled to begin equipment installation during the Unit 1 spring 2012 refueling outage.

EMCB (Piping Supplemental Question)

Steam Generator and Reactor Vessel Supports

1. *In Appendix 5A of the North Anna Power Station UFSAR, the licensee provide a docketed discussion between the licensee and the NRC on the topic of fabrication flaws, (e.g. laminar tears, porosity, lack of fusion, fabrication induced cracking, etc.) that were detected in some of the NAPS steam generator supports and reactor coolant pump supports. The UFSAR appendix indicates that at least some of the flaws were subject to repairs at the facility. The UFSAR appendix states that ultrasonic testing (UT) methods are the proper non-destructive methods to use for detecting and sizing flaws of this nature. The UFSAR appendix also provided a flaw evaluation to support the licensee's conclusion that the flaws would be stable under the following types of assumed loading combinations: (1) static (dead weight) loads; (2) dynamic loads associated with the occurrence of five operating basis earthquakes (OBE events), as is assumed for in the design basis; (3) loads associated with an assumed loss of coolant accident (LOCA) pipe rupture plus those that would be imparted under the assumed design basis earthquake (DBE) that was assumed for in the design basis; and (4) possible pump vibratory loads, which are expected to be small in magnitude. The UFSAR appendix indicates that the emphasis was placed on the analysis of the flaws under the combined LOCA plus DBE loads for the facility.*

   It is not evident to the staff how many of the flaw indications mentioned in UFSAR Appendix 5A for these supports were repaired or replaced as the appropriate corrective action for the components and how many of the flaws were left in service and justified for further service using the flaw tolerance evaluation that was included in UFSAR appendix. Provide your basis (using a detailed technical discussion) why the current flaw evaluation in UFSAR Appendix 5A is considered to be valid and bounding for evaluation of any relevant component support flaw indications that remain in service without repair, when compared to the option of requiring reanalysis of the flaws using the loadings from the LOCA event plus those that would have been imparted to the flaws from the August 2011 beyond design basis earthquake event. Justify why additional UT examinations of these component supports do not *need to be imposed as a condition for restart of North Anna Unit 2 and for continued operation of these components supports.*

Dominion Response

The North Anna UFSAR Appendix 5A was reviewed in consideration of weld repair work associated with the SG and RCP support structures and applicability to the ASME Section XI Program.

The decision was made to rework all welds on the SG and RCP support structures as the original workmanship was consistently poor and to provide assurance that all weld defects were identified and repaired (Reference Appendix 5A, page 7). The excavation area was dimensioned to include the original weld root and the adjacent heat-affected zone of the original weld (Appendix 5A, page 26). Each excavation area was visually examined and inspected by magnetic particle (MT) technique before re-welding (Appendix 5A, page 27). Greater detail of the welding process used is provided in the Appendix. After weld repairs, the welds were MT examined and a select group of welds were ultrasonically (UT) examined. This group included the welds most susceptible to lamellar tearing and high support stresses. UFSAR Appendix 5A, page 77, states, "We have shown that the repaired welds meet the applicable non-destructive test standards. Magnetic particle inspection has shown all the welds to be free of rejectable weld defects. Our ultrasonic test program has shown the base metal associated with the welds to be free of defects such as lamellar tears."

As summarized in NUREG-0053, Safety Evaluation Report by the Office of Nuclear Reactor Regulation (USNRC), dated June 4, 1976 and further discussed in Supplement No. 3 to NUREG-0053 dated September 15, 1976, on October 5, 1973, VEPCO informed the NRC that all the welds on the SG and RCP support structures were to be replaced due to extensive amounts of weld cracking that was discovered after fabrication of these structures and shipment to the plant site. Any weld defect found during magnetic particle, visual or ultrasonic examination techniques was excavated and repaired. As reflected on page 5-2, the NRC was satisfied with the actions taken by VEPCO to resolve this concern.

It is our understanding that no evaluations were performed to accept and leave flaws unrepaired during the initial construction of the SG and RCP support structures, and the discussion above supports the conclusion that the suspect welds were excavated and repaired prior to initial unit operation. Furthermore, these structures are included in North Anna's ASME XI ISI Program and will continue to receive periodic visual inspections in accordance with the station's ISI Schedule.

Attachment 2

Evaluation of the Influence of the August 23, 2011 Central Virginia Earthquake on North Anna Power Station Units 1 and 2

Virginia Electric and Power Company
(Dominion)
North Anna Power Station

Evaluation of the Influence of the August 23, 2011 Central Virginia Earthquake on North Anna Power Station Units 1 and 2

Purpose

To establish a quantitative measure of the influence of the Central Virginia earthquake of August 23, 2011 on North Anna Power Station, two separate evaluations are performed. They are described below.

1. Cumulative Absolute Velocity (CAV) Comparisons

An assessment of the influence of the August 23, 2011 Central Virginia earthquake was made using the damage potential of this earthquake by using the Cumulative Absolute Velocity (CAV) parameter described in EPRI NP-6695 [1], EPRI TR-100082 [2] and endorsed in RG 1.166 [3]. Since the threshold value of CAV for Operational Basis Earthquake (OBE) exceedance (0.16 g-sec) is a conservative lower bound estimate and the CAV in only the North-South direction exceeded this OBE exceedance threshold by about 8%, no significant damage was expected. This was consistent with the findings from the multi-layered comprehensive and intensive walkdowns and inspections of both safety and non-safety structures, systems and components (SSCs) and functional and surveillance tests conducted at North Anna Power Station.

It is recognized that the CAV parameter is not (and cannot be) explicitly used in the seismic design and equipment qualification at North Anna. However, CAV values can be constructed from synthetic time-histories such that their damage potential would be considered equivalent to the Design Basis Earthquake (DBE) at North Anna plant or to the Review Level Earthquake (RLE) for which the plant was reviewed in the 1990s under Individual Plant Examination of External Event (IPEEE). If synthetic time-histories are derived to be within certain constraints (e.g., the response spectrum from the synthetic time-history closely matches the target response spectrum), then the representative CAV parameter, if calculated for the postulated DBE at North Anna, can be considered as a measure of the potential damage the plant would sustain from such an event. Similarly, the representative CAV calculated from the RLE used in IPEEE would be a measure of the potential damage that the plant could sustain for a review level earthquake that is beyond the DBE.

The CAV values from the August 23, 2011 earthquake were calculated using the standard formulation described in EPRI TR-100082 [2] and RG 1.166 [3] as follows:

(1) The absolute acceleration (g units) time-history is divided into 1-second intervals,

(2) Each 1-second interval that has at least 1 exceedance of 0.025g is integrated over time, and

(3) The integrated values are summed together to arrive at the CAV.

The time-histories of the recorded earthquake at the Containment basemat for the entire duration of earthquake including the strong motion portion were used in the calculation of the CAV values. The three orthogonal, baseline corrected, time-histories from the August 23, 2011 at the Containment basemat are shown in Figures 1, 2, and 3. It is noted that although CAV is required to be calculated from free-field recorded motions, the Containment is rock founded and the design spectra at the top of the basemat are very close to the free-field DBE spectra in each of the three directions. Therefore, the development of CAV values from these time-histories is reasonable; this was also the conclusion of independent consultants. The CAV values for the August 23, 2011 event were calculated by three independent consultants and each of them calculated about the same values. The average CAV values from the three consultants in each of the three directions are presented in Table 1.

Determination of the representative CAV values from the North Anna DBE and from IPEEE RLE motions is a more challenging task. This is because a large number (in theory, an infinite number) of synthetic time-histories can be constructed to match a given DBE or RLE spectral shape using numerical techniques and these time-histories could each result in a different value of CAV. However, two parameters are important in constructing synthetic time-histories that are used for dynamic analyses of SSCs or for seismic shake-testing to qualify sensitive electrical and mechanical equipment. These parameters are: (a) the time-history should have total time duration between 10 seconds and 25 seconds and the corresponding stationary phase strong-motion duration should be between 6 seconds and 15 seconds, as required by SRP 3.7.1 [4]; a minimum strong motion duration of 15 seconds is also required by IEEE Std. 344 [5]; and (b) the time-history motions should have stationarity, i.e., each small segment of the time-history should contain the entire frequency content of the response spectrum from which the time-history is constructed, as required by IEEE Std. 344-1987/2004 and endorsed by NRC RG 1.100 Rev. 2/3. It is noted that there are additional requirements in SRP 3.7.1 [4] that provide guidance on the development of synthetic time-histories for seismic analysis and design.

Dominion reviewed the DBE synthetic time-histories that were used in an analysis of the North Anna Reactor Containment structure. These time-histories, shown in Figures 4, 5 and 6, and calculated using a Fast-Fourier Transform (FFT) subroutine, are of 20 seconds duration each including rise and decay durations such that the strong motion duration would be at least 15 seconds and the time-histories would have stationarity. The response spectra from the synthetic time-histories closely matched the target spectra for each case, as shown in Figures 7, 8, and 9. The three orthogonal time-histories were not correlated and were calculated using a different random seed. It is noted that the time-histories that are typically used to determine shake-table motions for random, multi-frequency, multi-axis seismic testing of equipment are typically of 30 seconds duration and testing is performed to simulate five OBE and one DBE events.

Therefore, it was judged that the synthetic time-histories that were used in the dynamic analysis of the North Anna Containment structure corresponding to the DBE spectral shapes are a reasonable representation of the value of CAV from a random DBE event that meets the above discussed requirements. CAV values from these time-histories were generated with an Excel spreadsheet and were checked with a computer code using the formulation discussed above. The CAV values corresponding to the North Anna DBE are tabulated in Table 1.

A dynamic analysis of the Containment was performed in the early 1990s for the RLE of IPEEE and it was difficult to retrieve the time-histories used at that time. Therefore, new synthetic time-histories, also of 20 seconds duration each, were developed using exactly the same approach as was done for the DBE. These time-histories are shown in Figures 10, 11, and 12. Comparisons of the response spectra from these time-histories to the target response spectra in the three directions are shown in Figures 13, 14 and 15. The CAV values from these time-histories are also shown in Table 1.

Table 1 - CAV Comparisons

Seismic Case	CAV (g-sec) First Horizontal Direction	CAV (g-sec) Second Horizontal Direction	CAV (g-sec) Vertical Direction
August 23, 2011 event; data at the basemat of Containment from Kinematrics recorder	0.172 (N-S)	0.125 (E-W)	0.110
DBE (Rock-founded, used for Containment structure)	0.588	0.580	0.400
Review Level Earthquake or RLE (Rock-founded, used for Containment structure)	1.230	1.312	0.875

It is noted that the slight differences in the CAV values in the two horizontal directions for the DBE and RLE are because of the random process used in developing two sets of horizontal synthetic time-histories. The CAV values for the DBE falls in line with a CAV value at which there may be initiation of damage in engineered industrial facilities not specifically designed for seismic loads. Therefore, the CAV values for the DBE would not result in any damage to SSCs, since they will, in general, remain in the elastic range for these CAV values by design. The CAV values for the August 23, 2011 earthquake are at least a factor of 3 less severe than the representative values for a DBE. The IPEEE CAV values show that RLE energy is significantly higher than the energy imparted by the August 23, 2011 earthquake. It should be noted that a few components that did not have HCLPF capacity equal to or greater than the PGA of RLE (0.3g) were thoroughly inspected by trained and experienced seismic review teams and no damage was found.

Numerically, the comparisons in Table 1 show in a macro sense that the plant as designed has the potential to absorb earthquake imparted energy significantly larger than the energy imparted by the August 23, 2011 Central Virginia earthquake without any sign of significant damage. Further, the CAV values calculated on the basis of representative time-histories of IPEEE review level earthquake show that there is margin beyond the DBE. This implies that the SSCs at North Anna plant can absorb energy imparted by an earthquake greater than the DBE with only minor permanent deformations and remain capable of performing their intended safety functions.

Therefore, detailed analyses of the plant SSCs are not required to establish operational readiness of the plant. The operational readiness of the plant is verified by comprehensive inspections and testing of these SSCs.

2. Containment Building Base Shear

As a second quantitative measure of the influence of the August 23, 2011 Central Virginia earthquake on the North Anna plant, three different analyses of the Containment building were conducted using input earthquake motions from: 1) August 23, 2011 event, 2) North Anna Plant DBE, and 3) IPEEE RLE anchored to 0.3g PGA. The Containment base shear values were calculated for the three load cases. It is reasonable to assume that the influence of these earthquake cases for the Containment base shear values will be a representation of the influence of these earthquakes on other components in the Containment building. Therefore, a comparison of the base shear values of the Containment building for these three different earthquake motions is a representative measure to assess the influence of the August 23, 2011 earthquake.

The total base shear values applied to the Containment exterior shell from different earthquake inputs are as follows:

8/23/11 Event Response Spectra from recordings at the top of the mat:	16,316 kips
Design Basis Response Spectra Translated to the top of the mat:	17,530 kips
IPEEE RLE Spectra:	30,177 kips

As evident from the above comparisons, the base shear at the Containment from the August 23, 2011 earthquake is approximately equal to the design basis base shear; therefore, no permanent deformation would be seen based on visual inspections since the DBE event requires the SSCs to remain in the elastic range. The IPEEE base shear is approximately 1.7 times the design basis shear indicating that there is substantial margin available.

References

1. EPRI NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake", December 1989.

2. EPRI TR-100082, "Standardization of the Cumulative Absolute Velocity", December 1991.

3. Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions", March 1997.

4. Standard Review Plan (NUREG-0800), Section 3.7.1, Revision 2, "Seismic Design Parameters", August 1989.

5. IEEE Std. 344-1975/1987/2004, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations".

6. Regulatory Guide 1.100, Revisions 1, 2 and 3, "Seismic Qualification of Electrical and Mechanical Equipment for Nuclear Power Plants".

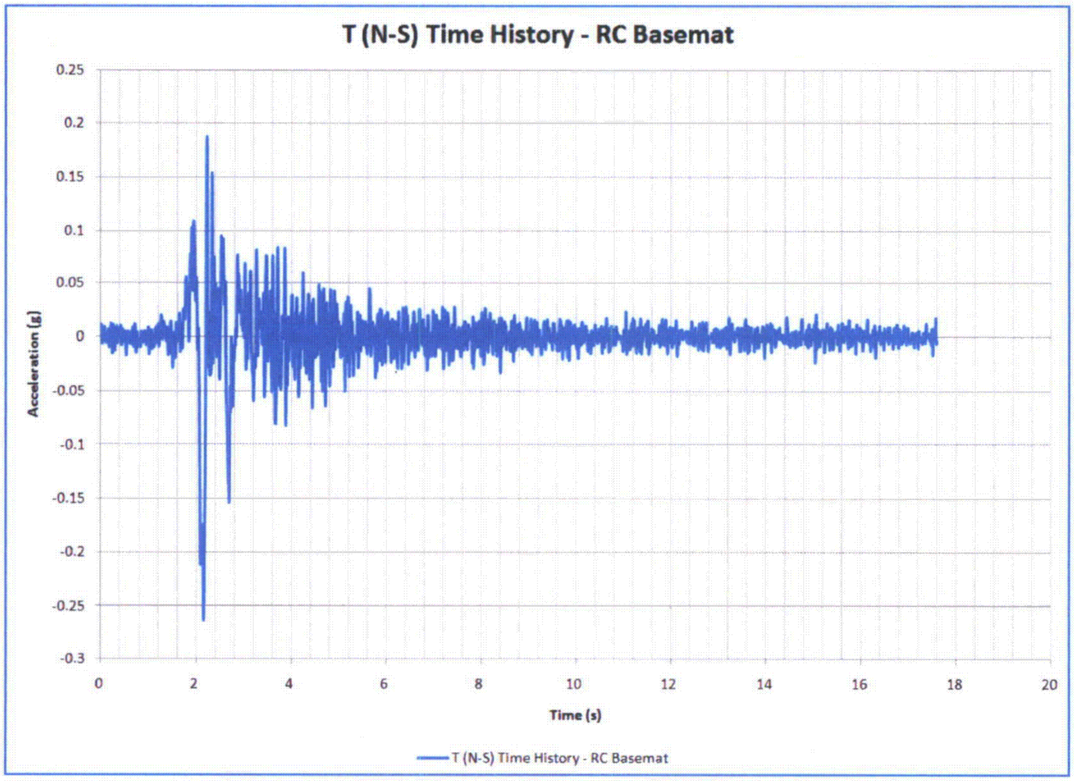


Figure 1 – Recorded Time-History, North-South Direction

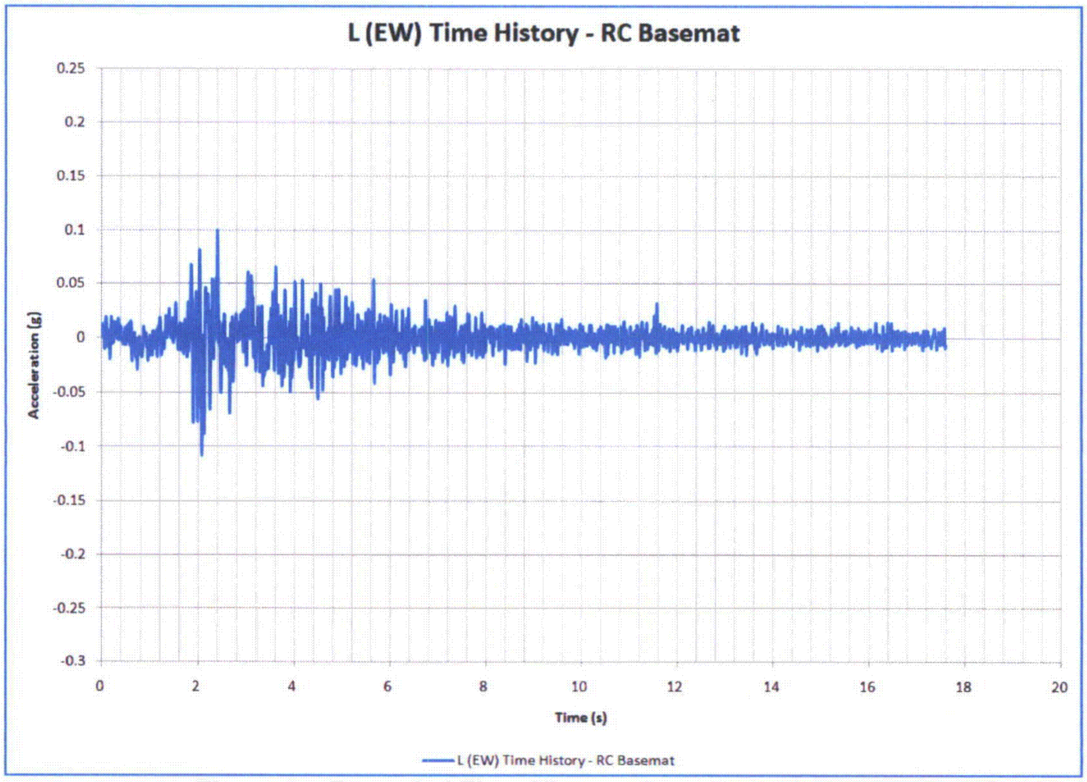


Figure 2 – Recorded Time-History, East-West Direction

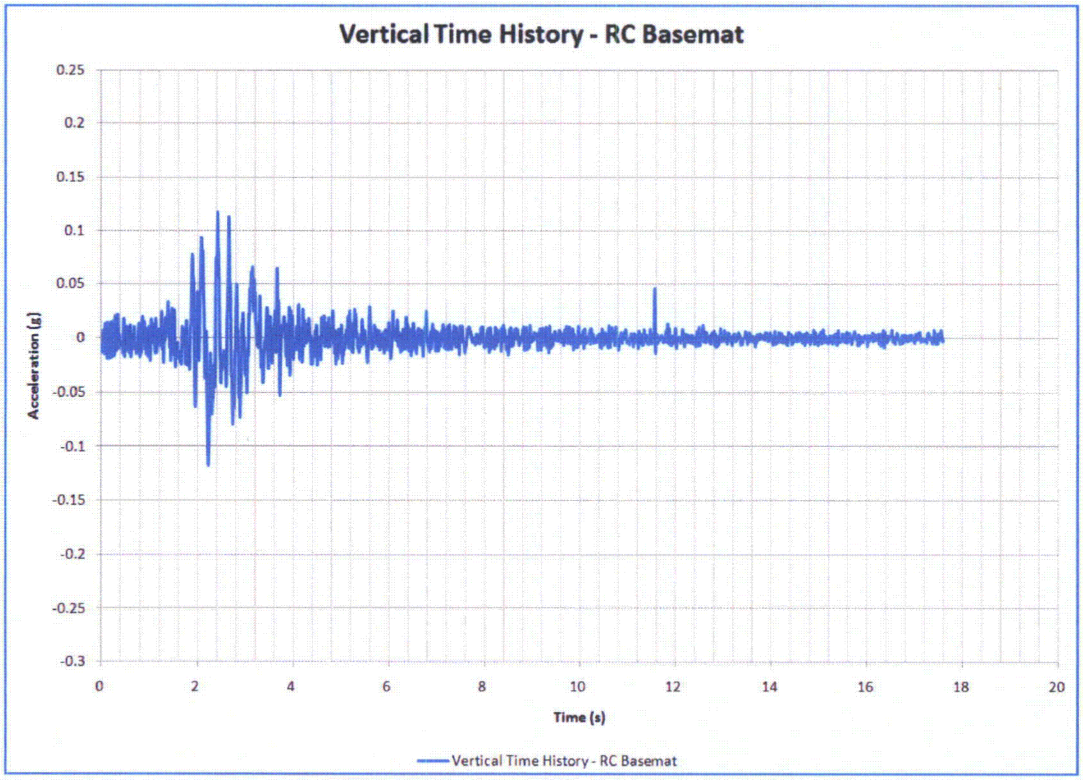


Figure 3 – Recorded Time-History, Vertical Direction

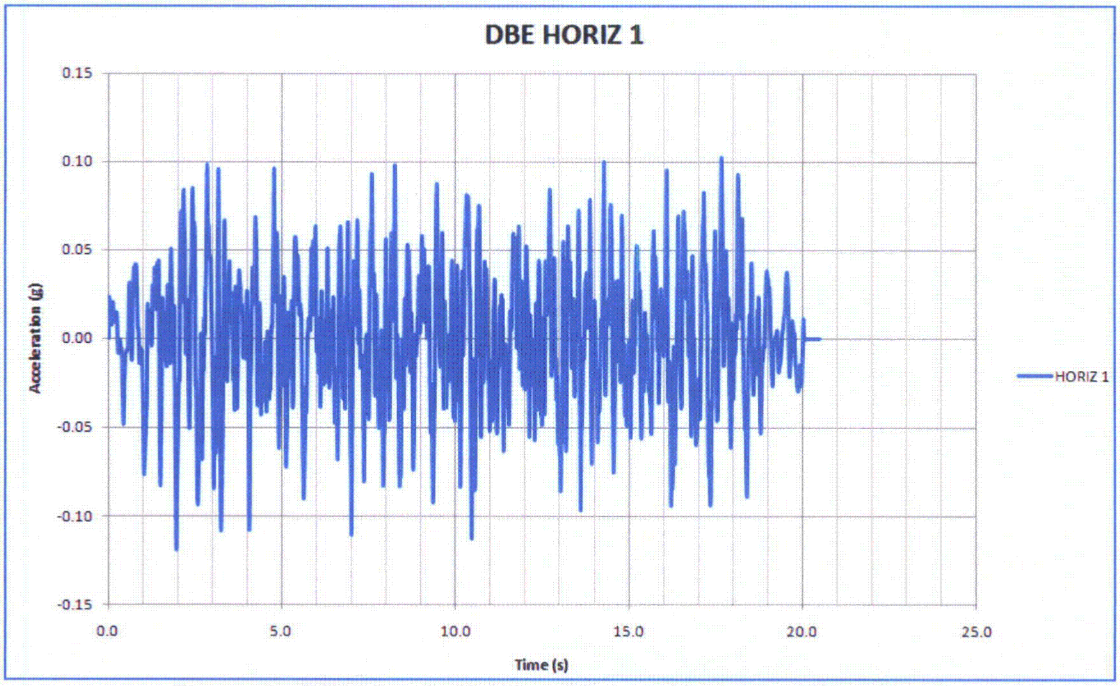


Figure 4 – DBE Synthetic Time-History, Horizontal Direction 1

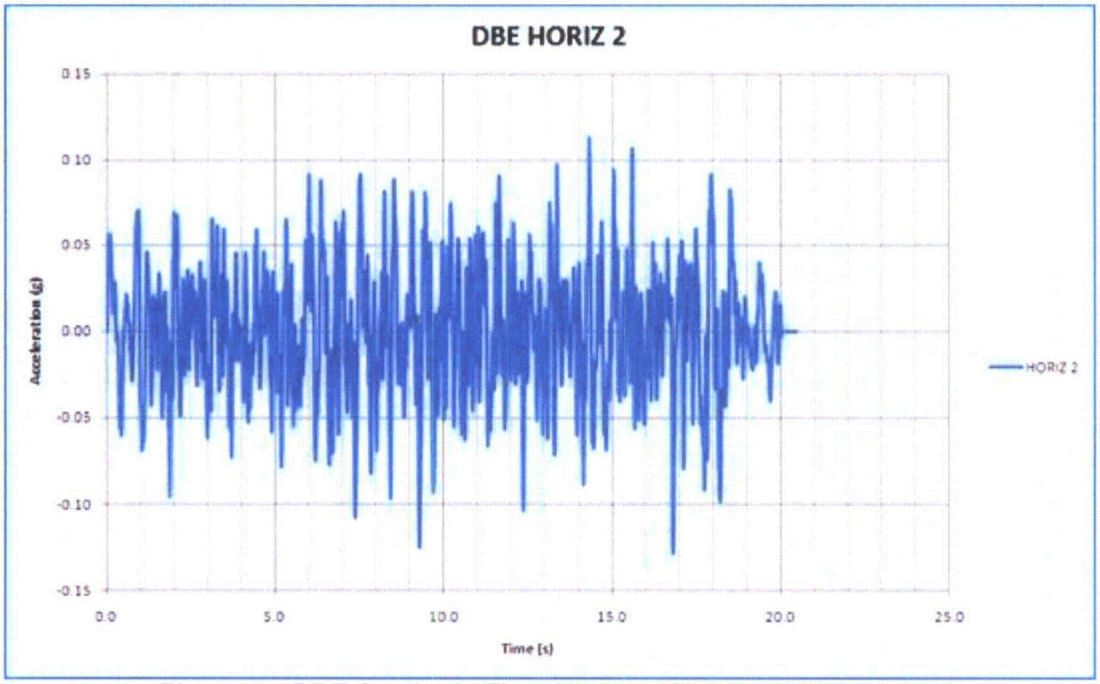


Figure 5 – DBE Synthetic Time-History, Horizontal Direction 2

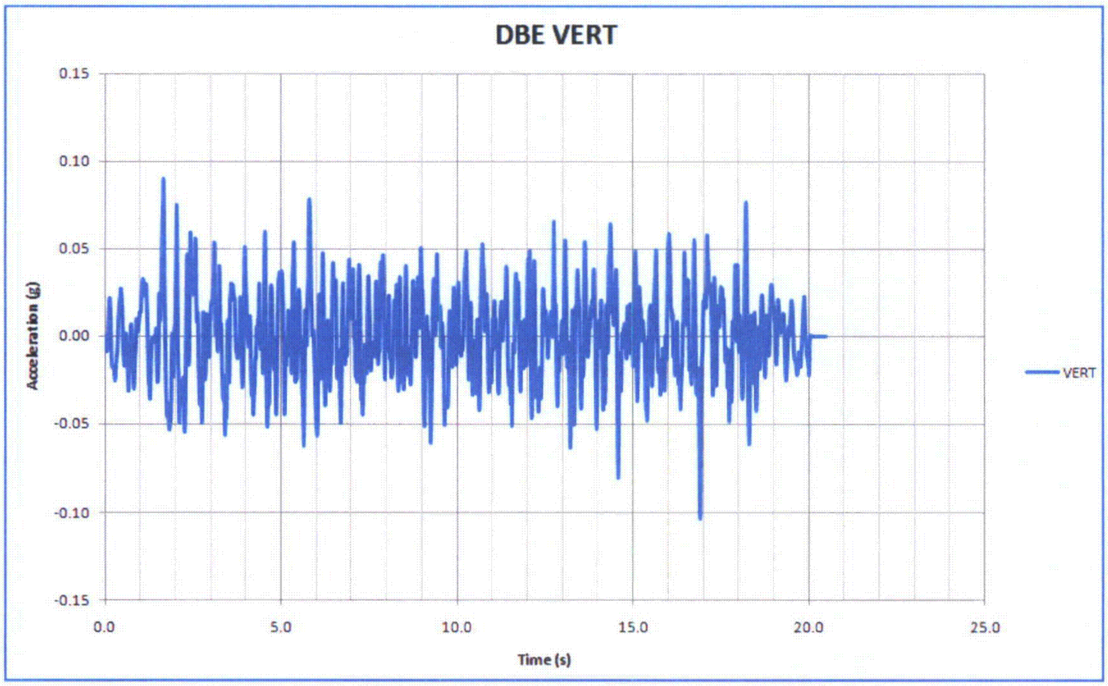


Figure 6 – DBE Synthetic Time-History, Vertical Direction

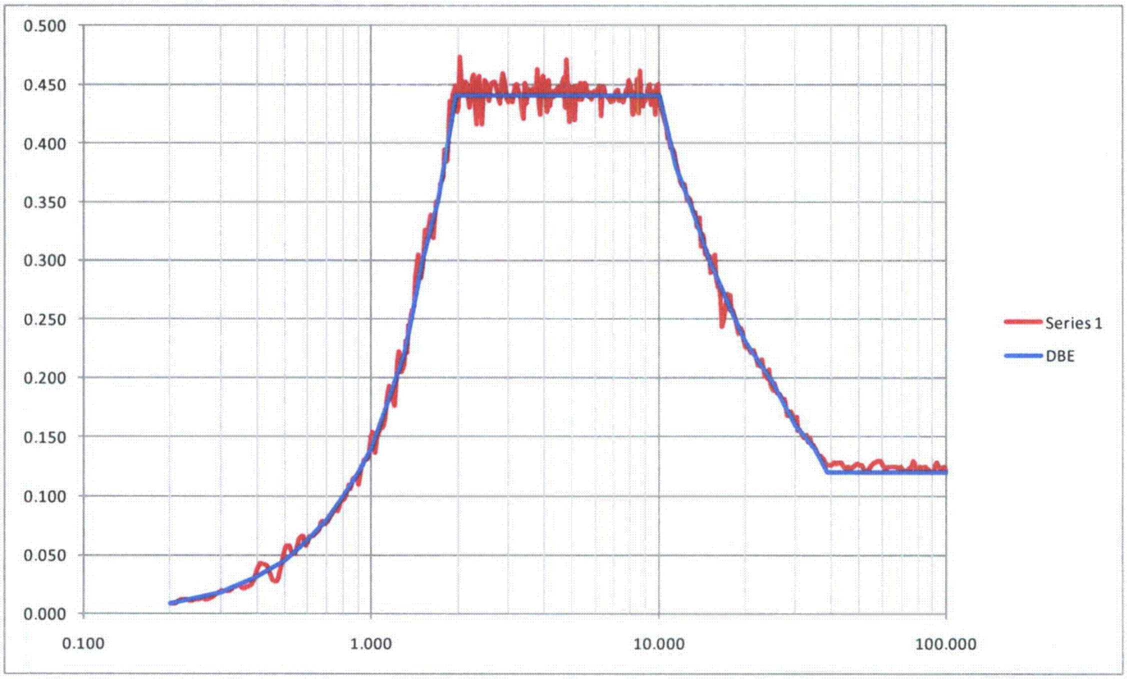


Figure 7 – Spectrum Comparison, DBE (5%) vs. Spectrum Created from Synthetic Time-History, Horizontal Direction 1

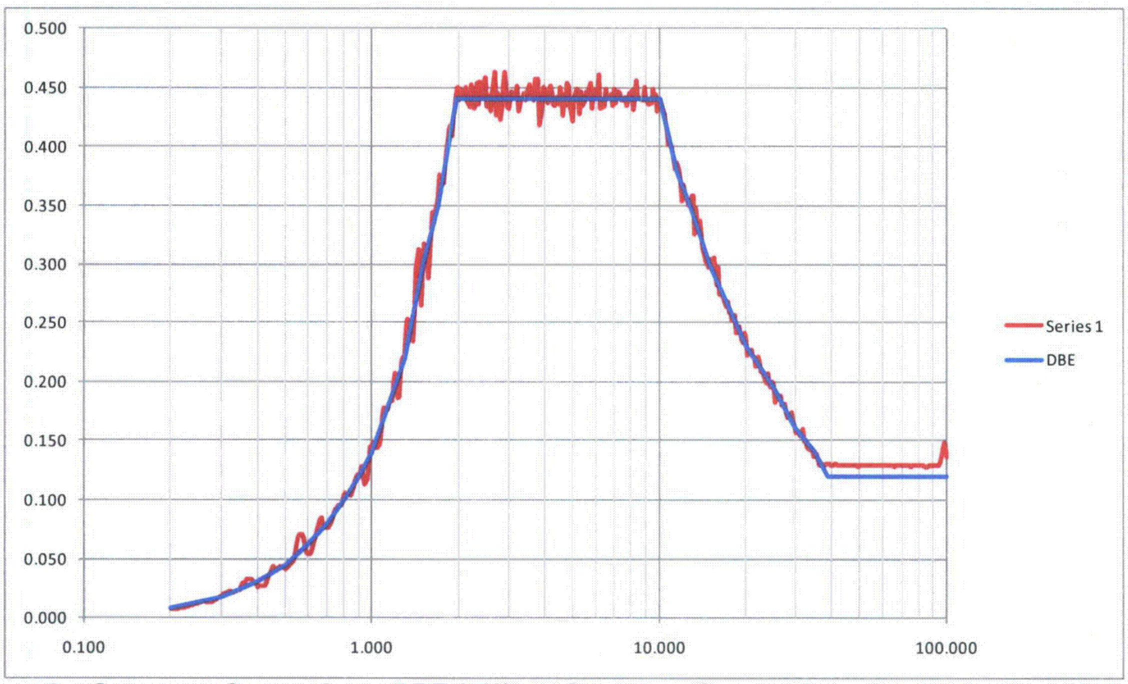


Figure 8 – Spectrum Comparison, DBE (5%) vs. Spectrum Created from Synthetic Time-History, Horizontal Direction 2

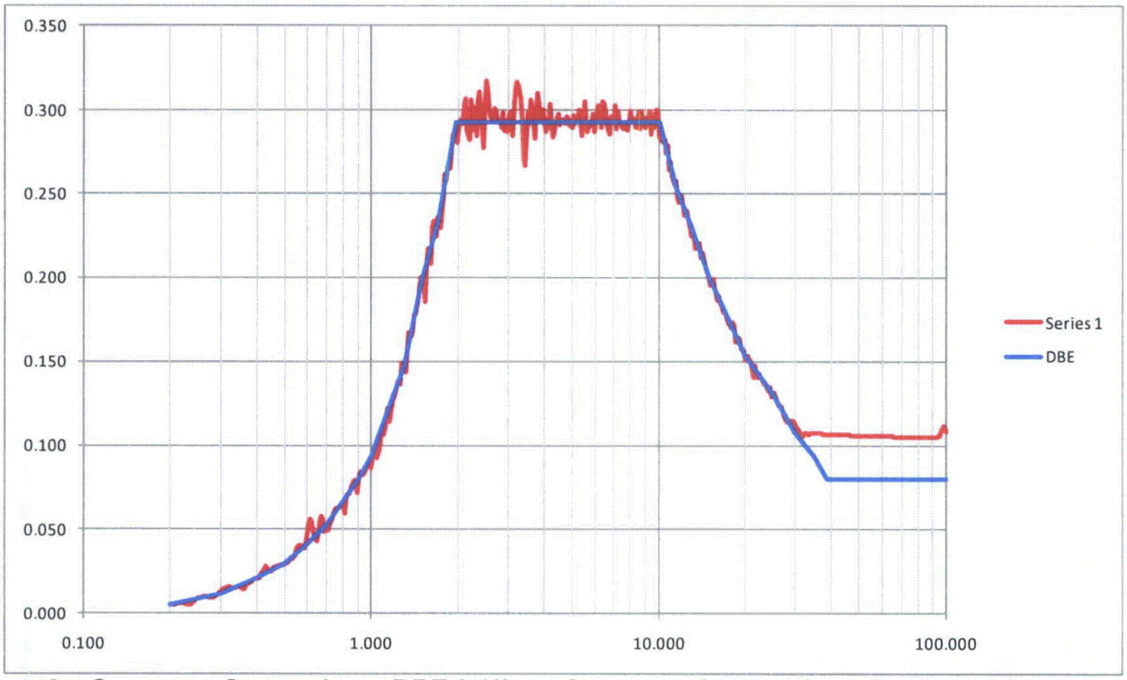


Figure 9 – Spectrum Comparison, DBE (5%) vs. Spectrum Created from Synthetic Time-History, Vertical Direction

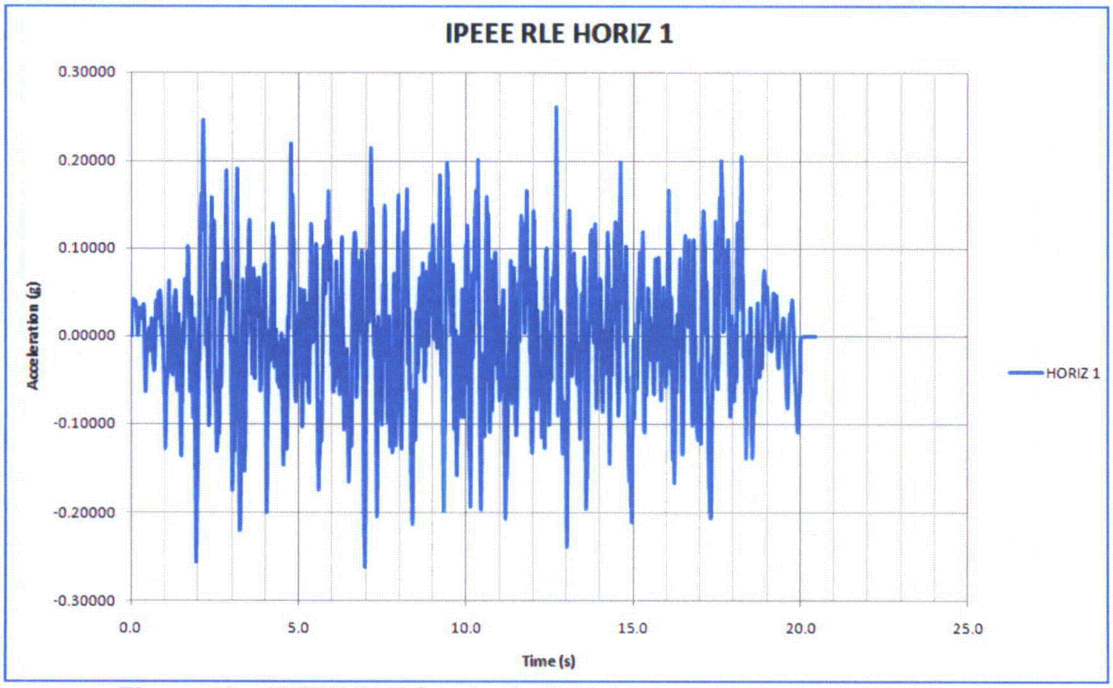


Figure 10 – IPEEE RLE Synthetic Time-History, Horizontal Direction 1

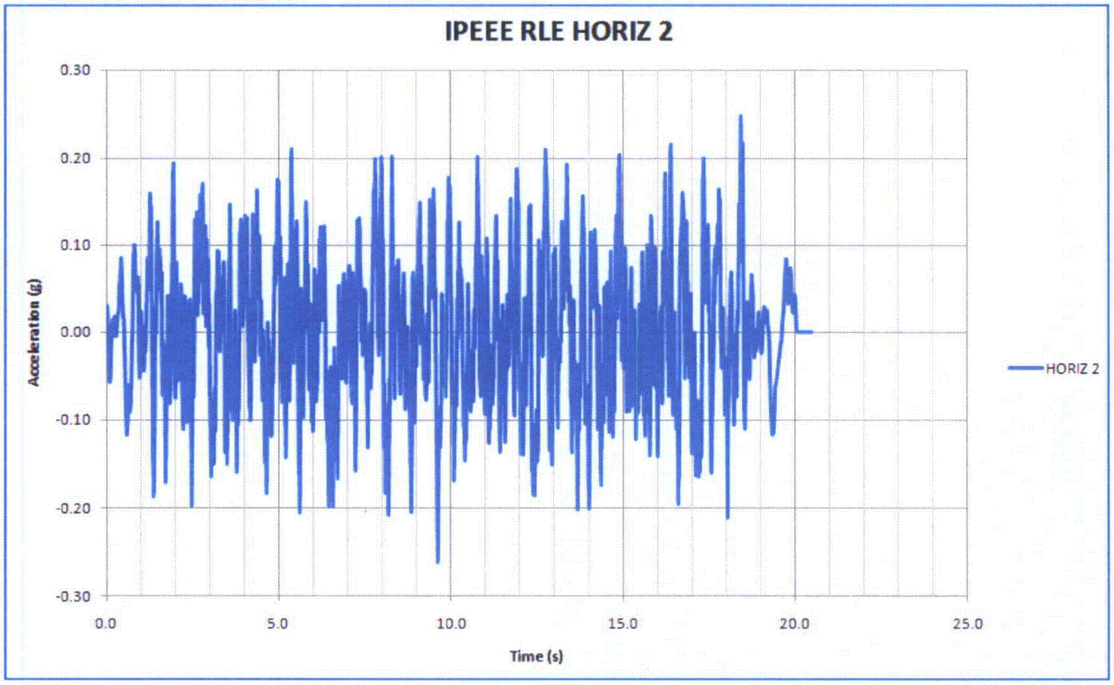


Figure 11 – IPEEE RLE Synthetic Time-History, Horizontal Direction 2

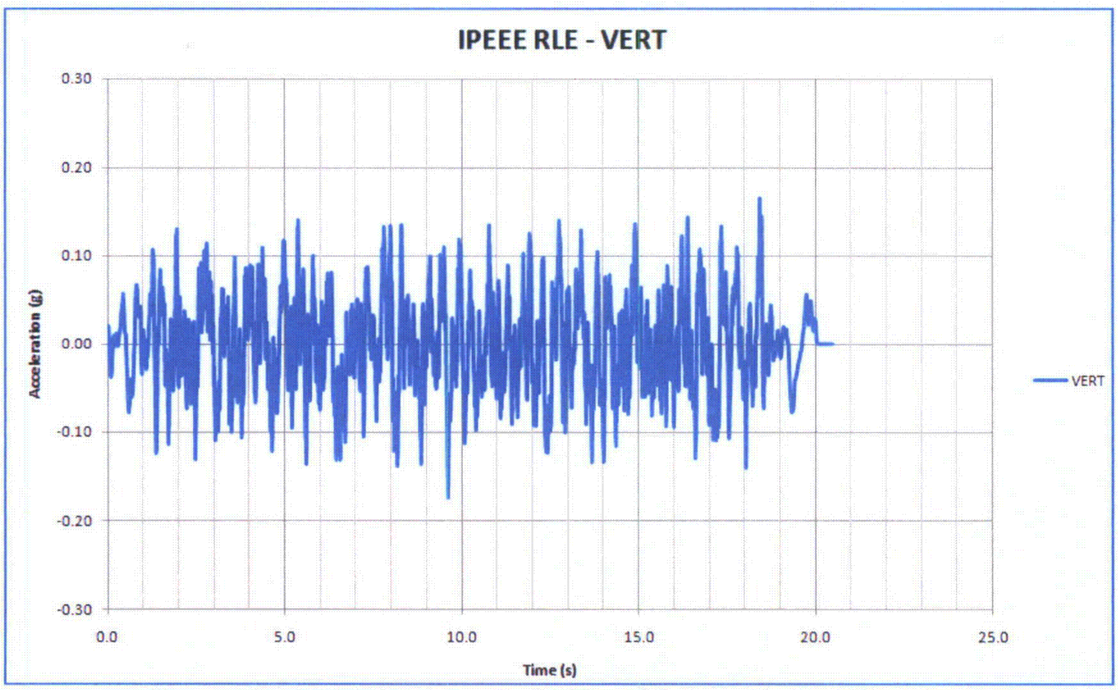


Figure 12 – IPEEE RLE Synthetic Time-History, Vertical Direction

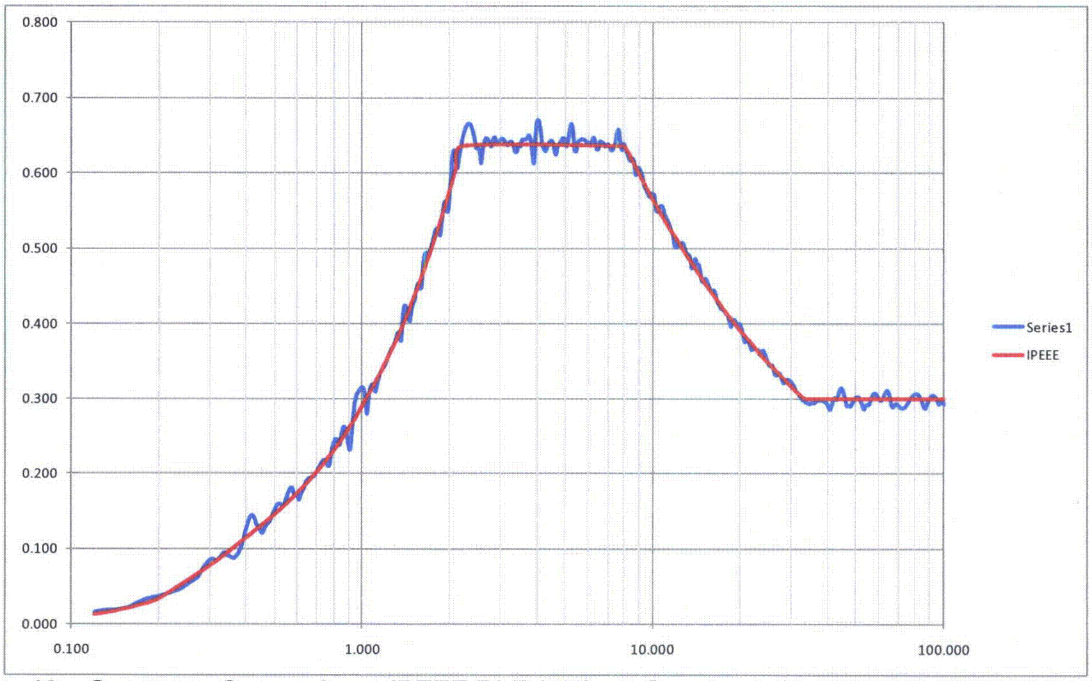


Figure 13 – Spectrum Comparison, IPEEE RLE (5%) vs. Spectrum Created from Synthetic Time-History, Horizontal Direction 1

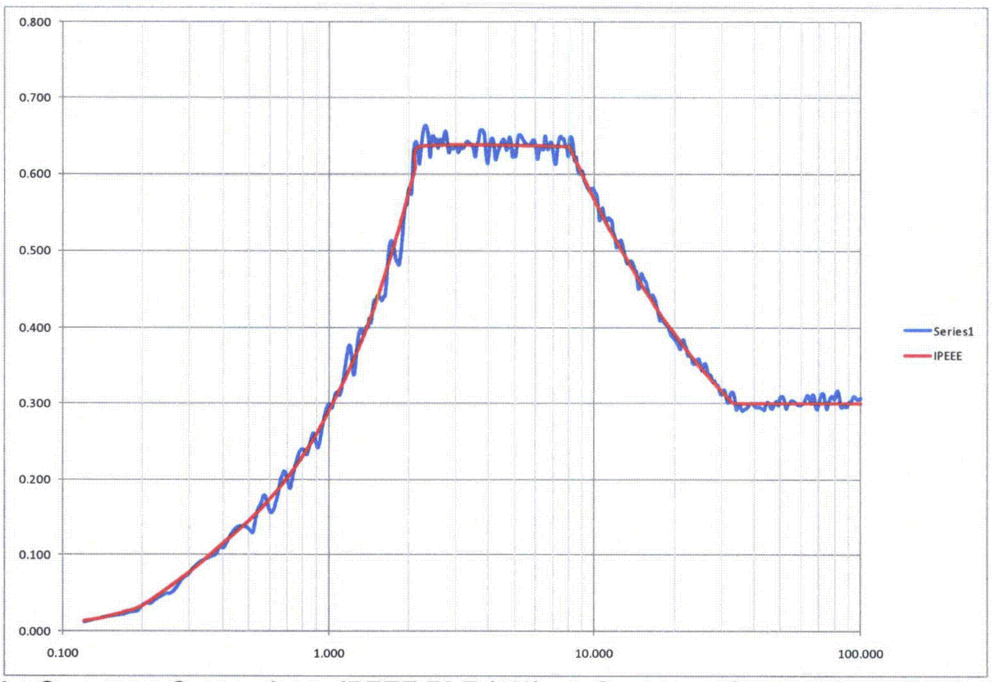


Figure 14 – Spectrum Comparison, IPEEE RLE (5%) vs. Spectrum Created from Synthetic Time-History, Horizontal Direction 2

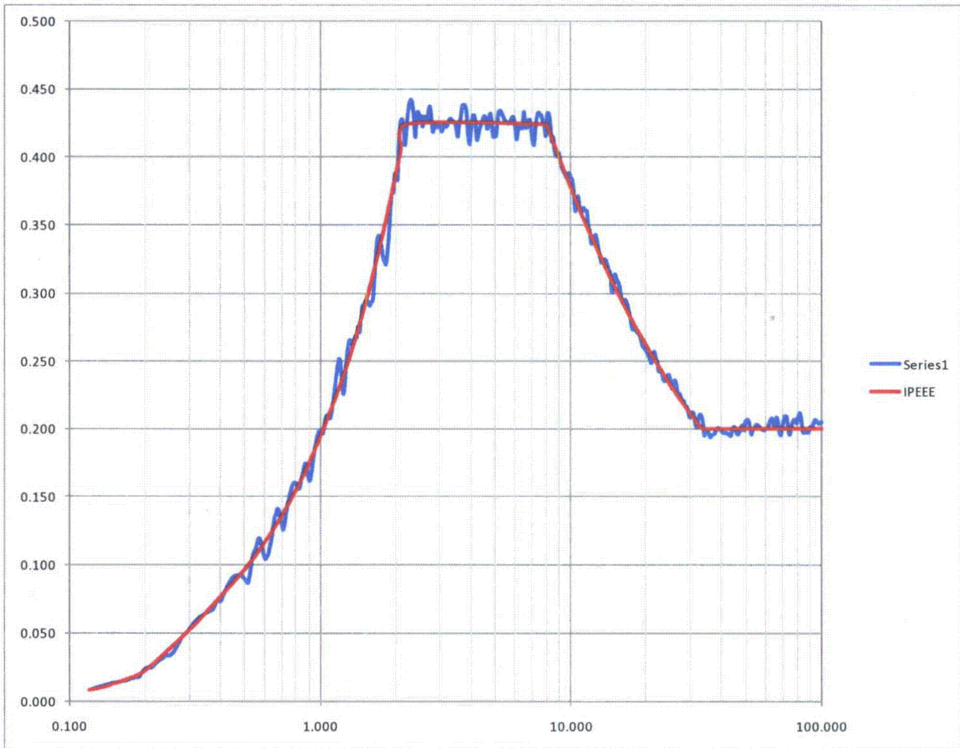


Figure 15 – Spectrum Comparison, IPEEE RLE (5%) vs. Spectrum Created from Synthetic Time-History, Vertical Direction

Attachment 3

Evaluation of North Anna SSCs Following the August 23, 2011 Central Virginia Earthquake

Virginia Electric and Power Company
(Dominion)
North Anna Power Station

Evaluation of North Anna SSCs Following the August 23, 2011 Central Virginia Earthquake

Purpose

The purpose of this evaluation is to provide the technical basis for North Anna's characterization of the earthquake of August 23, 2011 and to discuss the results of plant inspections conducted to corroborate the characterization. In addition, this evaluation addresses areas of existing margin in the seismic design and qualification of plant Structures, Systems, and Components (SSCs).

This evaluation provides a common response to support Dominion's position on reanalysis of plant SSCs to the experienced earthquake accelerations prior to restart of North Anna Units 1 and 2 following the August 23, 2011 earthquake. Responses to individual RAIs may refer to this evaluation to supplement Dominion's response to a particular question.

Discussion

As reported in Dominion's letter dated September 17, 2011 (Serial No. 11-520) to the NRC, based on the recorded plant data at the Containment basemat elevation, it was concluded that the Magnitude 5.8 Central Virginia earthquake of August 23, 2011 exceeded the spectral accelerations in certain frequency bands and peak ground accelerations for the Operating Basis Earthquake (OBE) and Design Basis Earthquake (DBE) of North Anna plant. Specifically, the Kinemetrics data shows that the OBE and DBE response spectra at the Containment basemat were exceeded in all three directions; however, in the frequency range most damaging to equipment, 2 to 10 Hz, the DBE was not exceeded in the East-West direction, and the earthquake exceeded the DBE, on average, by about 12% in the North-South direction and about 21% in the vertical direction. Even though exceedances were identified, further analysis of the recorded time-history data from the Containment basemat also indicated that the earthquake had little damage potential and was of short duration. The results of intensive plant walkdowns and inspections, which show no significant damage to safety related SSCs, corroborate this conclusion.

In accordance with the guidance provided in EPRI NP-6695, which has been endorsed by the NRC in Regulatory Guide 1.167, North Anna classified the seismic damage from the August 23, 2011 earthquake as EPRI Damage Intensity Level '0'. Therefore, in accordance with the guidance provided, explicit analytical reanalysis of North Anna plant equipment is not required prior to startup. Dominion has provided a technical basis to the NRC demonstrating that the August 23, 2011 Central Virginia earthquake was a non-damaging earthquake with little energy.

Results of the review of recorded plant data characterizing the nature of the August 23, 2011 earthquake are documented below and a summary of plant inspections performed is provided. Further, additional discussions of design margin are provided to justify that explicit reanalysis of plant SSCs for the August 23, 2011 earthquake is not required. Finally, a white paper prepared by Simpson, Gumpertz, and Heger (SGH) is provided in the attached appendix. This white paper provides supplemental technical bases for the use of the parameters used by Dominion in characterizing the earthquake and also discusses margin in plant SSCs.

Technical Basis for Characterization of the August 23, 2011 Earthquake

1. Cumulative Absolute Velocity (CAV)

   The cumulative absolute velocity (CAV) values were calculated from the recorded time-histories at the Containment basemat in each of the three orientations. Defined in EPRI TR-100082, which is referenced in NRC Regulatory Guide (RG) 1.166 for OBE exceedance, CAV is a parameter that relates measured ground motion to potential structural damage. The threshold value for the onset of damage, provided in EPRI TR-100082 and mirrored in the RG, is 0.16 g-sec. Per the EPRI report, "the adjusted CAV threshold is about a factor of five lower than the lowest CAV value associated with documented damage to an industrial/power facility. It is also about a factor of three lower than the lowest CAV value associated with documented damage to buildings of good design and construction."

   Since North Anna did not have free-field instrumentation, the most appropriate location to determine whether the plant OBE was exceeded was based on data collected from instrumentation located at the top of the basemat of the Containment structure. The Containment, which is rock founded, was analyzed as a fixed base structure and the calculated spectra at the top of the basemat are nearly the same as the free-field rock OBE that are defined in the North Anna UFSAR. Therefore, it was judged that this location is well suited to calculate the CAV values for which to relate to potential structural damage.

   It should be noted that EPRI NP-5930 (Pg. 5-2) states:

   > "The ground motion sensors should be located at the ground surface in the free field. If the plant is founded on rock then the instruments can be located either in the free field or on the foundation of the Containment structure."

   More recently, the effects of seismic wave incoherence on foundation and building responses has been researched and better understood. For rock sites, motion incoherency effects potentially reduce the responses in large basemats, but these reductions are more significant in the high frequency range, above 10-12 Hz. In light of this, industry experts were consulted on the appropriateness of using data from instrumentation located at the basemat of the Containment structure for determining CAV values. The experts considered this approach reasonable.

It is also noted that ANSI/ANS-2.2-2002, "Earthquake Instrumentation Criteria for Nuclear Power Plants" currently allows free-field instrumentation located on the Containment structure foundation if the plant is founded on rock.

The calculated CAV values, determined by three consultants, are tabulated below. The calculations by all three consultants are approximately the same. The values are well below the very conservative threshold of 0.16 g-sec defined in NRC RG 1.166 for OBE exceedance in the East-West and vertical directions, and the CAV limit was exceeded by about 8% in the North-South direction. Considering the conservatism in the determination of the threshold value of 0.16 g-sec, the August 23, 2011 earthquake would not be expected to be damaging.

Table - Cumulative Absolute Velocity Results

	East-West (g-sec)	North-South (g-sec)	Vertical (g-sec)
Kinemetrics	0.137	0.175	0.118
SGH	0.118	0.169	0.105
Bechtel	0.121	0.173	0.106
Average	**0.125**	**0.172**	**0.110**

It should be noted that if the CAV value in one direction had been about 8% lower, it would be below the very conservative threshold of 0.16 g-sec (the other two were already lower) and the plant would not have had to shut-down because of this earthquake, provided Dominion had incorporated the RG 1.166 criteria for OBE exceedance into its licensing basis and seismic instrumentation design.

2. Cumulative Energy (Effective Strong Motion Duration)

The cumulative energy calculations (Husid plots) from the Containment basemat time-history data show that the effective strong motion durations were very short. The effective strong motion duration was calculated following Equations 2-2 and 2-3 of NUREG/CR-3805. In accordance with the NUREG, the effective strong motion duration is defined as the duration between the times associated with 5% and 75% of the total cumulative energy. Based on the calculations (see below), in the East-West direction the effective strong motion duration was 3.1 seconds, in the vertical direction it was 1.5 seconds, and in the North-South direction it was 1.0 second. Along with the CAV, the short duration of effective strong motion is another indicator of the low damage potential of the August 23, 2011 earthquake.

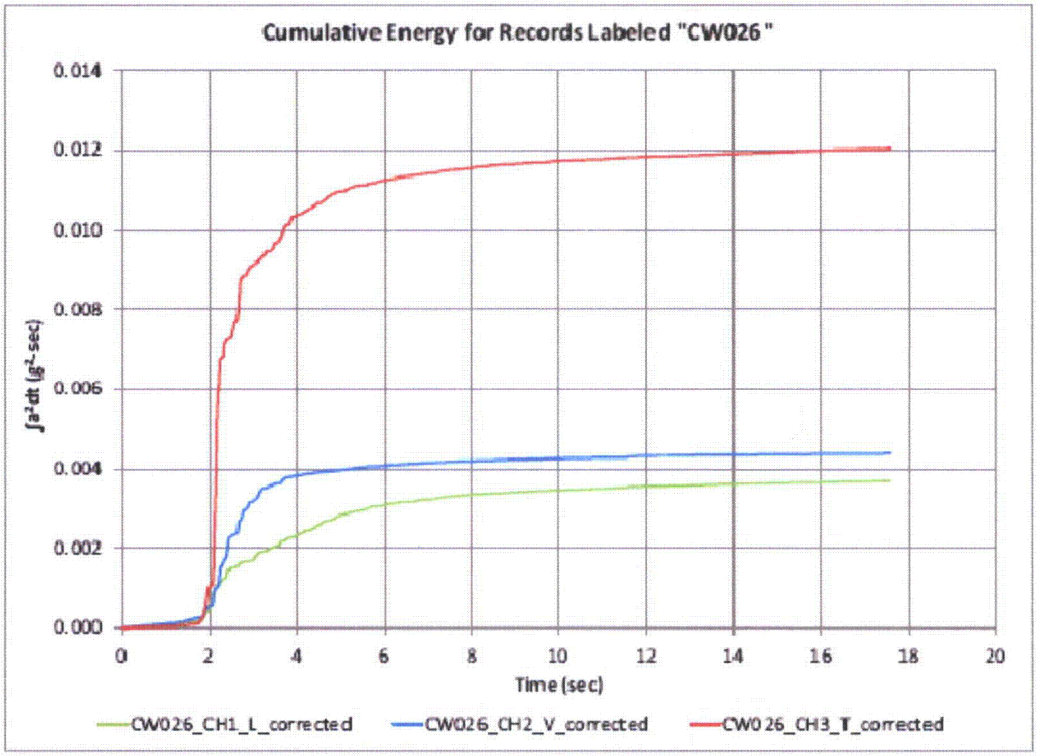


Figure 11 – Cumulative Energy (Reference NUREG/CR-3805) for the Containment Basemat Records

Table 2 – Effective Strong Motion Duration for Records Labeled "CW026"

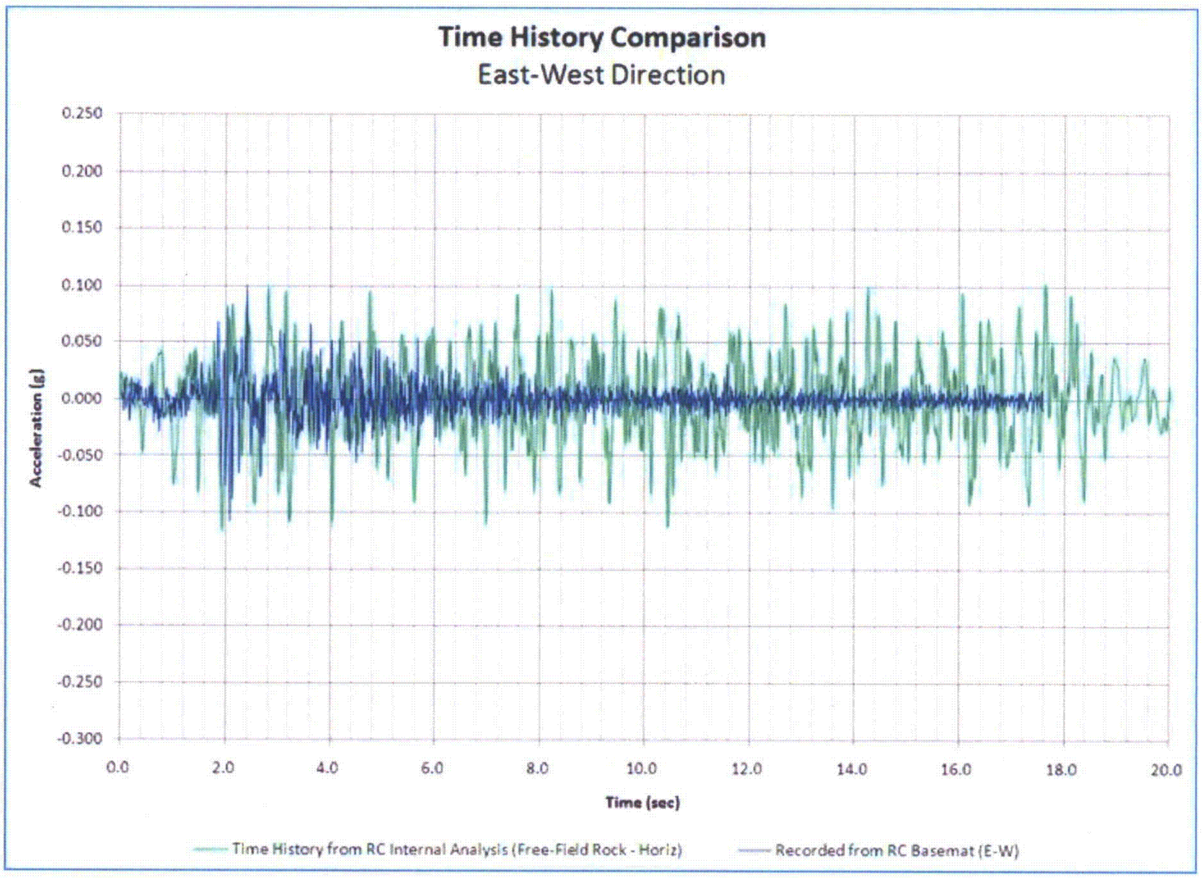
Time History	Effective Strong Motion Duration (sec)
CW026_CH1_L_corrected	3.1
CW026_CH2_V_corrected	1.5
CW026_CH3_T_corrected	1.0

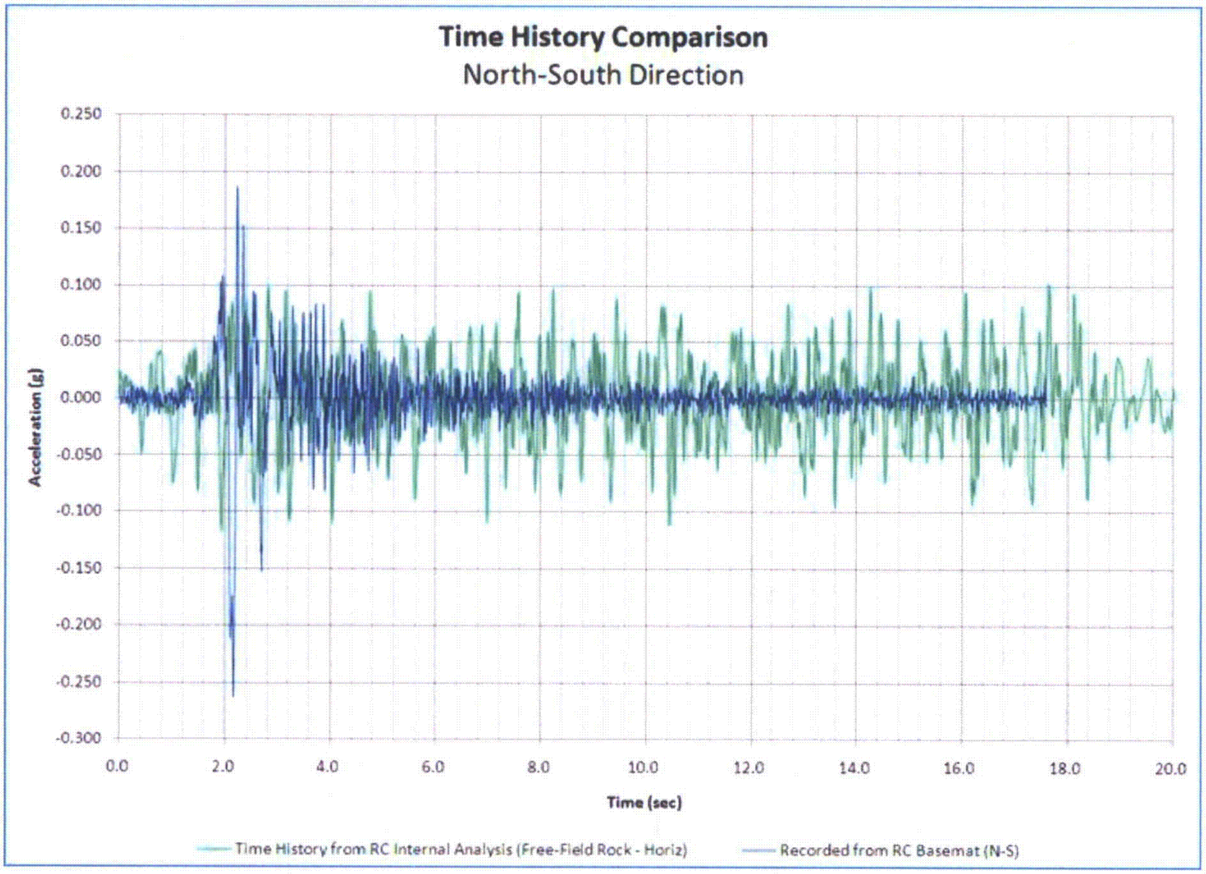
Note: The CW026 label corresponds to the North Anna Unit 1 Containment basemat. Directions: L = E-W; T = N-S; V = Vertical

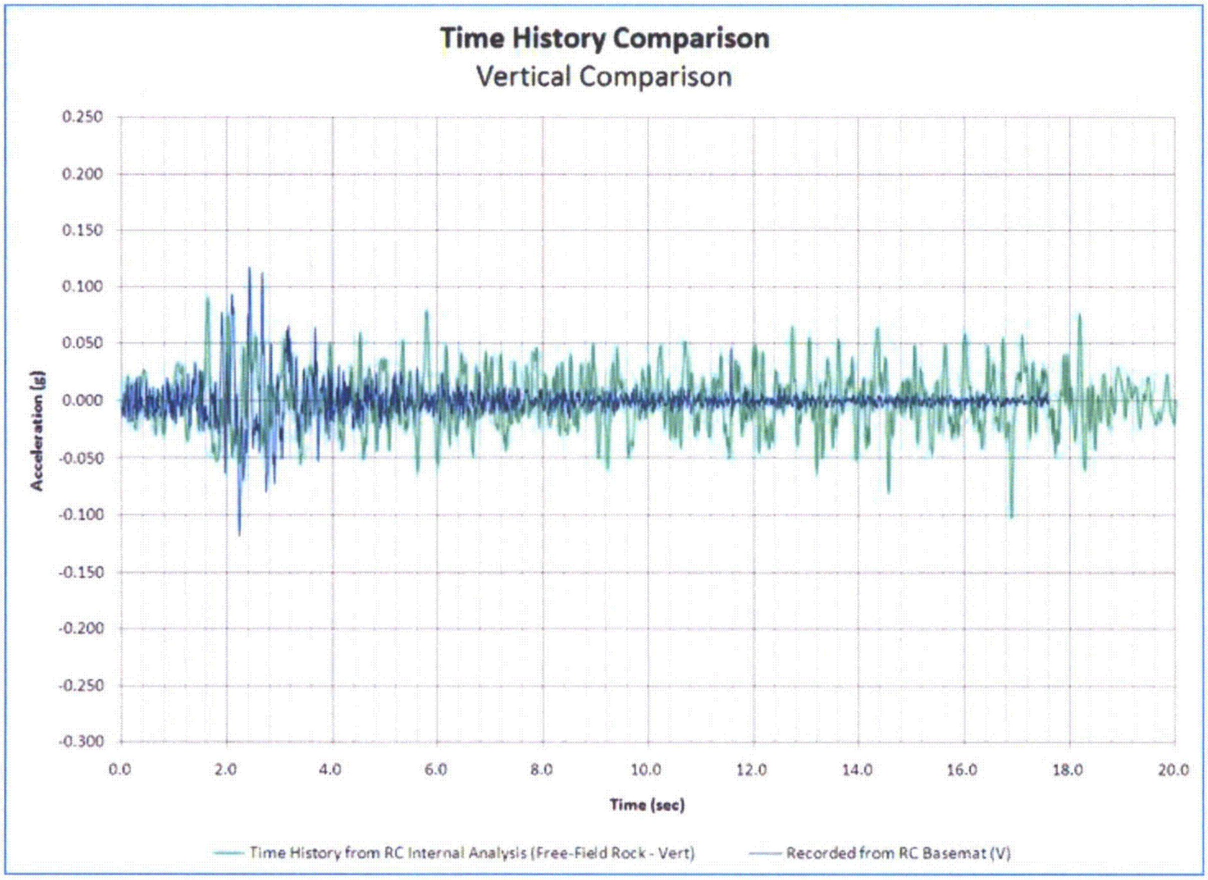
3. <u>Time-History Comparison</u>

The short duration of the August 23, 2011 earthquake is further exemplified by comparison of the recorded horizontal direction time-histories at the Containment basemat to synthetic time-histories generated from the site ground rock DBE spectra used in the analysis of the North Anna reactor Containment model. These synthetic time-histories last for approximately 20 seconds, in accordance with the requirements of the Standard Review Plan. By comparison, the recorded data durations are approximately 17.6 seconds, but have a very limited duration of strong motion.

Though the synthetic time-histories in the figures below are those that were used in the analysis of rock-founded structures at North Anna, it is noted that the time-histories used for shake-testing of electrical equipment are similar – they are typically 30 seconds in duration for each of the 1 DBE and 5 OBE tests, have stationarity, e.g., if the time-history is divided into ten equal 3-second segments, the required frequency content will be present in each segment. Therefore, the energy content imparted to equipment that is qualified by shake table tests has strong motion content several times that of the August 23, 2011 event.




Time History Comparison
North-South Direction
0.250
0.200
0.150
0.100
0.050
0.000
-0.050
-0.100
-0.150
-0.200
-0.250
-0.300
Acceleration (g)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
Time (sec)
Time History from RC Internal Analysis (Free-Field Rock - Horiz)
Recorded from RC Basemat (N-S)



Intensive Plant Inspections and Functional and Surveillance Tests

Comprehensive and systematic plant inspections were conducted at North Anna Power Station following the August 23, 2011 earthquake. These include: (a) Initial plant operator walkdown inspections, and (b) expanded and focused inspections. The August 23, 2011 earthquake and aftershocks did not reveal any significant physical or functional damage to safety related SSCs and only limited damage to non-safety related, non-seismically designed SSCs. It is noted that the results of the initial inspections supported an EPRI damage intensity level of '0' (as defined in Table 2-1 of EPRI NP-6695); however, North Anna decided to take conservative measures and follow the EPRI guidance for performing comprehensive and methodical expanded inspections of the plant assuming an EPRI Damage Intensity Level of 1.

Expanded inspections included the following:

- Systems Inspections – comprehensive system inspections that included 82 systems for Unit 1 (including common systems) and 57 systems for Unit 2. Inspection teams included system engineers responsible for the inspected system. Inspection personnel had training on identifying seismic related damage.

- Structural Component Inspections – consisted of safety related and non-safety related structural components that meet regulatory requirements for Maintenance Rule and contribute to the operation of the station. Components are identified in procedure ER-NA-INS-104, "Monitoring of Structures North Anna Power Station" and inspections were conducted in accordance with the procedure by qualified individuals.

- Detailed Inspections – inspections of equipment determined to have high-confidence-of-low-probability-of-failure (HCLPF) capacity < 0.3g during the Individual Plant Examination of External Event (IPEEE) effort in the 1990s. Since calculations showed that these components had the lowest capacities, they would be expected to be most vulnerable in a seismic event. Inspections of low HCLPF capacity components were performed by seismic review teams that consisted of EPRI SQUG-trained and experienced engineers.

- Electrical Inspections – comprehensive electrical inspections. Safety related systems received near 100% internal inspections; non-safety systems were inspected on a sampling basis.

- Assessments for Hidden Damage – detailed criteria were established and implemented to assess hidden damage. Inspections incorporated the guidance developed by an EPRI expert panel for the Kashiwazaki-Kariwa plant in Japan in assessing areas subjected to hidden damage and not readily identifiable by visual inspection.

In addition, Dominion engineers, along with several industry seismic experts, performed inspections of selected plant SSCs. The intent of these inspections was to assess areas of the plant and plant equipment likely to have suffered damage as the result of a seismic event. Several items of equipment reported during IPEEE to have HCLPF capacity < 0.3g were inspected. Also, non-safety SSCs (e.g., the Auxiliary Boiler Building, unreinforced masonry walls, Primary Grade Water Tanks, etc.) were inspected. None of the structures or components inspected had earthquake-related damage.

Dominion is performing required functional and surveillance testing in accordance with the North Anna Technical Specifications prior to and during each unit's restart.

It is concluded that the expanded, comprehensive inspections did not reveal any significant physical or functional damage to safety related SSCs and only limited damage to non-safety related, non-seismically designed SSCs. There was no damage to safety related SSCs that would render them incapable of performing their design function. The results of the expanded inspections confirmed the initial classification of this earthquake as EPRI Damage Intensity Level '0'. This result is not unexpected based on the low CAV and effective short duration of the August 23, 2011 earthquake.

Review of Seismic Design Margins

As previously stated, per the guidance of EPRI NP-6695, explicit reanalysis of plant equipment is not required prior to restart for an EPRI Damage Intensity Level of '0' or '1'. In the absence of explicit reanalysis for the August 23, 2011 earthquake, Dominion performed intensive plant inspections, surveillances and functional testing to assess the continued adequacy of the plant SSCs. Since there was no damage to any safety related SSCs that would render them incapable of performing their design functions, explicit reanalysis is not warranted prior to restart.

To address concerns over seismic margin in existing design analysis, consider the following:

- The North Anna Power Station Units 1 and 2 were reviewed in the 1990s under USI A-46 for DBE and under the IPEEE program for a Review Level Earthquake (RLE) as required by Generic Letter (GL) 88-20 Supplement 4 to determine vulnerabilities for a beyond design basis event. The USI A-46 program evaluated components in a safe shutdown equipment list (SSEL) that included 20 classes of equipment, tanks and heat exchangers, cable trays and conduits and relays. IPEEE used a seismic margin assessment which consisted of an enhanced SSEL with two success paths to achieve safe shutdown.

  Several plant and procedural improvements and modifications were made during these efforts to improve the seismic safety of the plant. Some of the significant modifications included tying safety related electrical cabinets together to prevent banging or relay chatter in the side to side direction for many rows of cabinets, modification of the anchorage of three tanks, improving anchorage of electrical cabinets and other components, improving the control room ceiling, improving seismic housekeeping and implementing a housekeeping procedure, reorienting valves to prevent higher stress along weak axis, and cable tray and conduit support improvements. For the IPEEE, a review level earthquake anchored to 0.3g peak ground acceleration was used. It is noted that in the IPEEE evaluations, only a small number of components were found to have a HCLPF capacity < 0.3g. Further, a few masonry block walls were also reported during IPEEE with a capacity < 0.3g. As noted above, detailed inspections of these low capacity SSCs did not identify any earthquake related damage.

  Based on the improvements made to the plant during the USI A-46 and the IPEEE programs, the plant has substantial seismic margin over its initial design. In addition, after USI A-46 was completed, North Anna's procedure for seismic qualification of equipment was updated to use the later versions of IEEE standard 344 (1975 or 1987 version) for seismic qualification of equipment, which also provides improved safety margins (as discussed below).

- The use of recorded data from the August 23, 2011 earthquake would be conservative, as indicated by NRC sponsored research documented in NUREG/CR-0098, prepared by N. M. Newmark and W. J. Hall. Section 3.1 of NUREG/CR-0098 states the following:

  "Although peak values of ground motion may be assigned to the various magnitudes of earthquake, especially in the vicinity of the surface expression of a fault or at the epicenter, these motions are in general considerably greater than smaller motions which occur many more times in an earthquake. Design earthquake response spectra are based on "effective" values of the acceleration, velocity and displacement, which occur several times during the earthquake, rather than isolated peak values of instrumental reading. The effective earthquake hazards selected for determining design spectra may be as little as one-half the expected isolated peak instrument readings for near earthquakes, ranging up to the latter values for distant earthquakes."

  Therefore, the use of the recorded data as a new design criterion may be highly conservative and is not appropriate as realistic input for design verification.

- North Anna's seismic design basis and analyses include design codes and criteria that are conservative. Recent design codes, Standard Review Plan and Regulatory Guides (such as RG 1.61 for damping) have reduced conservatisms that existed in earlier codes and criteria. For example, the 2008 addenda to the ASME Section III code, which has been approved by the NRC, revised the analysis methods for non-reversing dynamic analysis.

  For short term evaluations prior to startup, the use of realistic criteria would show additional margins. Physically, damage to components experiencing forces and moments beyond yield, such that a permanent plastic deformation occurs, would have been visible from inspections. Results of intensive inspections and testing have indicated no signs of permanent deformation for piping, pipe supports, or equipment supports. For longer term evaluations, following startup, the guidance of EPRI NP-6695, Section 6.3.4.1, which addresses the long term evaluation of equipment and structures qualified by analysis, recommends code based acceptance criteria; however, per the guidance, Level D criteria may be employed and items of equipment may be acceptable even if these criteria are exceeded. If calculated stresses are greater than Level D, the guidance recommends that the determination of continued acceptability of the equipment be based on a detailed visual inspection, an engineering evaluation of the effects of the calculated stresses on the functionality of the item, the results of equipment operability tests, the results of additional nondestructive examinations of specific areas (as required for locations of high stresses), and repair or replacement of potentially damaged areas (as required).

- With regard to piping assessments during IPEEE for which a seismic margin assessment (SMA) was used, Table 2-4 of the SMA guidance document EPRI NP-6041-SL states that piping can be screened out (with walkdown of representative piping and ducting systems) if spectral peak from the ground DBE at 5% damping is < 1.2g. For North Anna, this is the case and representative walkdowns of piping systems were performed by the seismic review teams and the peer reviewer. Therefore, piping was considered to have sufficient margin for the RLE used in IPEEE and was screened out from explicit analyses.

- Analytical methods in the design basis of North Anna are conservative for predicting the response of plant structures and equipment to the August 23, 2011 earthquake. Analytical methods used are excellent design tools, but they are not well-suited for failure analysis. Linear analysis methods will generally under predict the true capacity of an SSC. A standard static or dynamic analysis is therefore not a good tool to assess or predict damage. It is for this reason the CAV criteria was developed by EPRI, which was endorsed by the NRC in RG 1.166. As an example, the non-safety, non-seismically designed Station Blackout (SBO) diesel building, which is a simple, single-story structure with heavy loads on the roof utilizing simple cross bracing, was analyzed using standard linear analysis methods using the recorded East-West time-history from the August 23, 2011 earthquake. While this analysis is preliminary, the results indicate that the bracing should have buckled. Inspections, however, revealed no damage to the structure. Another example is the Reactor Purification (RP) System piping. Currently, the RP system includes non-safety, non-seismic piping routed from the discharge of the RP pumps to Containment penetrations in the Auxiliary Building. Preliminary analysis of the Auxiliary Building RP piping for design response spectra shows that the piping system is highly overstressed. This is not unexpected, since the supports for this piping system consist primarily of rack supports providing only vertical support in addition to a few rod hangers. However, post seismic inspection of the RP piping in the Auxiliary Building revealed no damage to the piping or supports. There are other examples of non-safety, non-seismic SSCs that were considered prone to damage, yet no damage was identified. For example, the large, unanchored Primary Grade Water Storage Tanks and several unreinforced masonry walls located throughout the plant remained intact without damage.

- Existing North Anna design in-structure response spectra are likely conservative and over-predict structural responses. For example, the spectra developed from the Kinemetrics recorders at the 291 feet elevation of the Containment building shows amplifications in spectral accelerations (from the basemat spectra) that are significantly lower than those predicted from design analyses. This would indicate margin for components located on upper elevations of the structure.

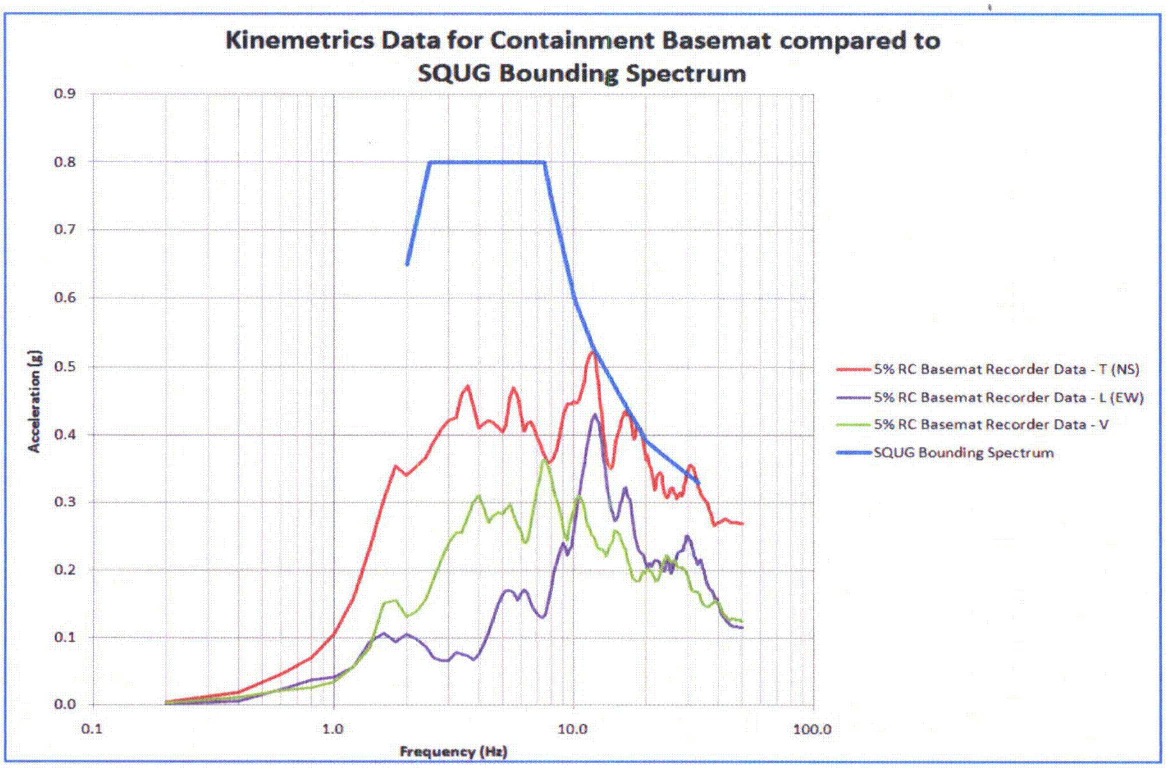
- For plant equipment qualified by seismic testing (i.e., using IEEE Std. 344), there is additional margin. Seismic testing typically subjects equipment to 15 to 30 seconds of strong motion. For the August 23, 2011 earthquake, the effective strong motion duration was limited to 1 to 3.1 seconds. Dominion follows IEEE Std. 323 – 1974 that requires 10% margin in test response spectrum (TRS), above the required response spectrum (RRS). Invariably, the TRS envelops the RRS with margins significantly over the required 10% margin. Further, the seismic simulation testing sequence, when conducted in accordance with IEEE Std. 344, requires 5 OBEs and 1 Safe Shutdown Earthquake (SSE) (i.e., DBE). Therefore, fatigue is induced in the tested equipment prior to SSE level testing. Note that per IEEE Std. 344 – 2004, as endorsed by RG 1.100, Revision 3, it can be stated that in terms of number of stress cycles for fatigue, 5 OBE events are approximately equivalent to one SSE event. Therefore, plant equipment qualified by shaker testing would be at least good for another SSE event.

- It is noted that the August 23, 2011 earthquake resulted in no chatter to safety related relays causing spurious signals or actuation of equipment. North Anna's experience is similar to the experience of the Perry NPP, as documented in EPRI Report NP-6472, which indicates that of a total of 6,968 relays in energized systems, including 1,901 auxiliary relays and 218 protective relays, all safety related relays continued to operate normally throughout the event. This is in spite of spectral exceedances above their plant SSE in the frequency range of 18 to 30 Hz (by as much as a factor of three around 22 Hz). Perry NPP contributed good performance of their relays to test margin and to unquantified conservatisms known to exist in the seismic qualification process. As detailed in the EPRI report, these conservatisms include the use of conservative broadband response spectra, the conservative contact chatter pass/fail criterion, and the conservative definition of safety functions employed in qualifying relays.

- North Anna is licensed to use earthquake experience based seismic qualification based on the Generic Implementation Procedure (GIP) prepared by the Seismic Qualification Utility Group (SQUG) in conformance with NRC Generic Letter (GL) 87-02 on USI A-46 (with certain exceptions, as outlined in North Anna's UFSAR). The GIP method provides an alternative to the previous licensing basis methods for verifying the seismic adequacy of electrical and mechanical equipment.

Per EPRI NP-6695, Section 6.3.4.2, which addresses long term evaluations for electrical and mechanical equipment qualified by methods other than analysis (including experience-based methods) may be acceptable if "the equipment is considered to be qualified for further operation on the basis of experience data." The guidance then explicitly references the Bounding Spectrum values for comparison. For equipment qualified by the SQUG GIP method, a "Bounding Spectrum" was developed which represents the seismic capacity of equipment in the earthquake experience equipment classes. The Bounding Spectrum can be used to represent the seismic capacity of the equipment in a nuclear power plant when this equipment is determined to have characteristics similar to earthquake experience equipment class and meets the intent of the caveats of the equipment, as defined in the GIP.

As shown below, the Bounding Spectrum effectively envelops the response spectra created from the recorded time-histories from the basemat elevation of the Containment, which are considered equivalent to the free-field since the Containment is rock-founded. There is only a very slight exceedance in the North-South direction around 33 Hz. Therefore experience data would indicate that the equipment qualified using the GIP Bounding Spectrum will remain acceptable (assuming that the load path and anchorage remains acceptable and that any sensitive electrical equipment has been evaluated using shake-test data).



Conclusions

It is concluded that while the recorded earthquake data from August 23, 2011 indicated exceedance of the OBE and DBE acceleration response spectra, analysis of the time-history motions indicates that this earthquake had minimal damage potential based on calculated parameters (CAV and effective strong motion durations). Further, as is demonstrated in this white paper, plant SSCs have considerable margin in their design. Therefore, this earthquake should not have caused significant physical or functional damage to North Anna SSCs. Results of comprehensive and systematic plant inspections have corroborated Dominion's characterization of the August 23, 2011 earthquake. Inspections and functional tests have revealed no significant physical or functional damage to safety related SSCs and only limited damage to non-safety related SSCs. There was no damage to any safety related SSC that would render it incapable of performing its design function.

Appendix

Simpson, Gumpertz, and Heger: White Paper on Beyond Design Basis Seismic Adequacy of Nuclear Power Plant Structures, Systems, and Components (10 pages)

Appendix

White Paper on Beyond Design Basis Seismic Adequacy of Nuclear Power Plant Structures, Systems, and Components

(Simpson, Gumpertz, and Heger)

Virginia Electric and Power Company
(Dominion)
North Anna Power Station Units 1 and 2

White Paper on Beyond Design Basis Seismic Adequacy of Nuclear Power Plant Structures, Systems, and Components

During the 1980s and the 1990s the U.S. Nuclear Regulatory Commission (USNRC) conducted several programs focused on demonstrating the seismic adequacy of existing nuclear power plant (NPP) structures, systems, and components (SSCs) for ground motion levels beyond their original design basis.

- In 1975, the requirements for seismic qualification of equipment underwent significant changes which put into question the qualification status of nuclear plant equipment designed prior to 1975. This was designated by the USNRC in 1980 as Unresolved Safety Issue (USI) A-46. The resolution of this issue involved demonstrating that, when properly anchored, power plant equipment has substantial ruggedness beyond the original seismic design basis.
- During the mid-1980s, the USNRC recognized that the results of Probabilistic Seismic Hazard Analyses conducted for various NPP sites indicated that the expected seismic motions were quite different from the deterministic levels used in the original plant design and were associated with large uncertainty. Thus the USNRC initiated the Individual Plant Examination of External Events (IPEEE) program to identify the seismic margin of each plant beyond the original seismic design basis.
- During the late 1970s and mid-1980s, at least two U.S. nuclear plant sites (Perry and Summer) were subjected to the ground motions caused by nearby earthquakes. The recorded motions at the plant sites yielded response spectra that exceeded the site OBEs, and, in one case, the site Safe Shutdown Earthquake (SSE) in a limited frequency range. There was no damage to any plant SSCs at these sites. The USNRC revised the criteria and procedures used to determine if the OBE of a plant has been exceeded by an earthquake occurring in the vicinity of a plant by defining a conservative exceedance threshold value of Cumulative Absolute Velocity (CAV).

Each one of these programs and their conclusions are discussed in the following sections.

Development of Experience Based Seismic Capacity

In the early 1980s the Seismic Qualification Utility Group (SQUG) was formed to develop a generic methodology to resolve USI A-46, which was concerned with verifying the seismic adequacy of equipment that was already installed in operating nuclear power plants. Working in conjunction with the regulatory authorities and industry, SQUG developed a methodology and procedure to apply earthquake experience data to demonstrate the seismic capability of electrical and mechanical equipment for resolution of USI A-46. The primary source of experience data collected by SQUG was from non-nuclear facilities which had experienced earthquakes. SQUG developed the "Generic Implementation Procedure for Seismic Verification of Nuclear Plant Equipment" (GIP) [1]. The GIP provides a generic means of applying this experience to evaluate the seismic adequacy of mechanical equipment, electrical equipment, distributive systems (ducting, cable trays, conduit, etc.) and passive items (tanks, heat exchangers, etc.) that are typically part of the balance of plant of a NPP. The GIP implements this SQUG approach and includes the technical approach, generic procedures, and engineering guidance. During the development of the GIP, the Senior Seismic Review and Advisory Panel (SSRAP), an independent group of recognized seismic experts from industry, academia, and national laboratories was engaged by the USNRC to serve as peer reviewers of the experienced based methodology. The SSRAP concluded [2] that equipment installed in NPPs is generally similar to equipment in conventional plants and that such equipment, when properly anchored, had a demonstrated capability to withstand substantial seismic motion without significant damage. The USNRC embraced use of experience-based methods for resolution of USI A-46 in Generic Letter (GL) 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46", issued in 1987 [3], and Supplement No. 1 to the Generic Letter issued in 1992 [4], which transmitted "Supplemental Safety Evaluation Report No. 2 on Seismic Qualification Utility Group's Generic Implementation Procedure."

Using the earthquake experience data collected on the equipment (now maintained by EPRI), SQUG was able to develop an earthquake Seismic Capacity Spectrum, which is referred to as the Reference Spectrum in original SQUG documents. The Seismic Capacity Spectrum assumes 5% damping and represents the estimated average free-field ground motion to which the database facilities were actually exposed at an estimated mean peak ground accelerations in excess of approximately 0.4g. As depicted in Figure 1 as the bolded spectra, the Seismic Capacity Spectrum is the average of various response spectra that are generated using data collected from past earthquakes. The Seismic Capacity Spectrum is a demonstrated level at which failure or malfunction of equipment has not occurred in past earthquakes. It does not represent a limiting capacity but rather a level for which there is a high confidence of a low probability of failure (HCLPF). The actual seismic fragility or failure/malfunction level is at least a factor of 2 to 4 times the Seismic Capacity Spectrum level [5]. This Seismic Capacity Spectrum can be compared to actual earthquake response spectra to assess whether plant-specific equipment has been subjected to ground motions that are comparable to those experienced by the database facilities.

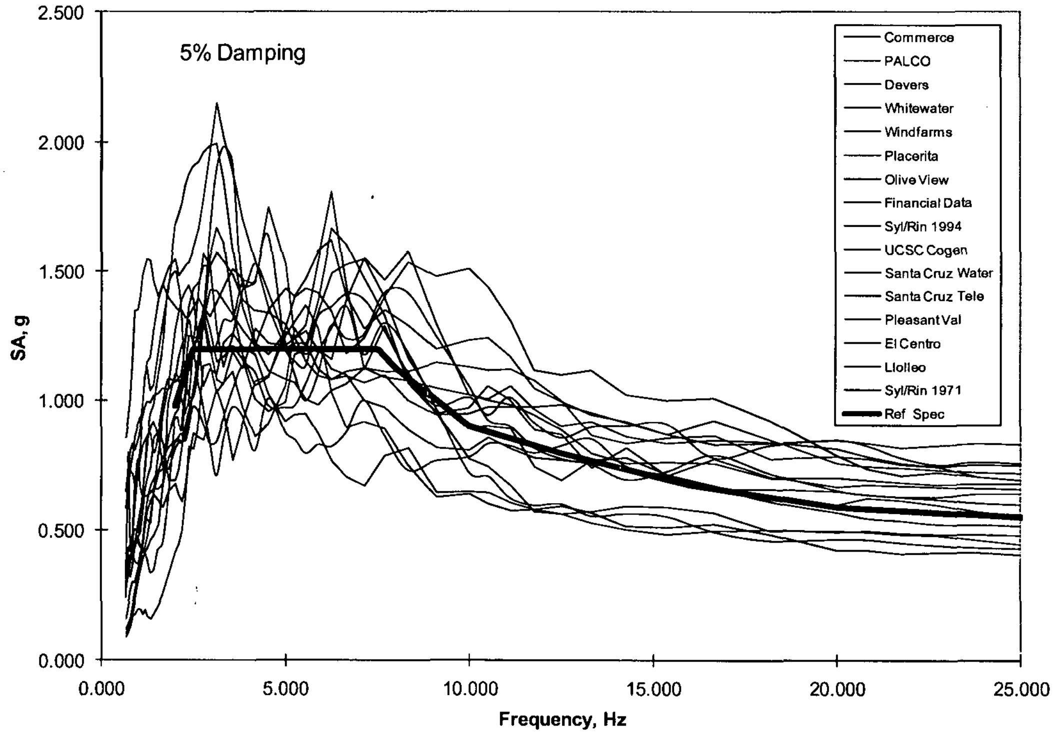


Figure 1. Average Horizontal Response Spectra for EPRI Database Sites Compared to Seismic Capacity Spectrum (also known as the Reference Spectrum)

SSRAP concluded that a screening walkdown by a team of trained seismic capability engineers is the best way of identifying SSCs that have potential seismic vulnerabilities. To simplify the walkdown screening effort, SSRAP further defined a Bounding Spectrum which was taken as 0.67 times the Seismic Capacity Spectrum and allowed the comparison of a plant's SSE to the Seismic Capacity Spectrum. Alternatively, the in-structure spectra of a given plant, associated with the SSE, could be directly compared to the Seismic Capacity Spectrum. Given that the equipment, itself, could be screened as adequate, the review team could then focus on the adequacy of the equipment anchorage which earthquake experience had indicated was the most important indicator of equipment adequacy. Thus, while the USI A-46 issue was associated with verifying that NPP equipment was adequate to meet the safe shutdown of a given plant, the resolution involved demonstrating that the equipment had an inherent HCLPF capacity greater than the design basis.

Demonstration of Seismic Margin

The focus of the IPEEE program was to demonstrate that a given plant could sustain an earthquake greater than the original design basis. Plants were given choice of conducting a Seismic Probabilistic Risk Assessment or a Seismic Margin Assessment (SMA). Most plants chose to perform a SMA and the USNRC selected [6] a review level earthquake (RLE) for each plant which was chosen depending upon the plant's seismicity. Most plants in the Eastern United States were assigned a NUREG/CR-0098

[7] median spectral shape anchored to 0.3g as the RLE. Many plants were also concurrently addressing the USI A-46 issue. Figure 2 compares the NUREG/CR-0098 spectrum which the Bounding spectrum used to resolve A-46. As can be noted, the Bounding Spectrum is slightly greater than the NUREG/CR-0098 spectrum, thus plants which were also addressing A-46 could demonstrate equipment seismic adequacy for the IPEEE RLE; however, the anchorage capacity of the equipment had to be equal to or greater that the RLE level rather than the plant SSE level. In the IPEEE program, plants had to identify all cases where equipment capacity was less than the selected RLE.

The guidance for the conduct of an SMA is provided in Reference 10. Piping in NPPs was judged to have a HCLPF associated with a ground motion with a Peak Ground Acceleration (PGA) of at least 0.5g. Since the IPEEE RLE for most NPPs was associated with PGA of 0.3g, the guidance indicated that the evaluation of piping should be conducted on a walkdown basis to identify any issues that might cause interaction or flexibility/restraint concerns for piping runs.

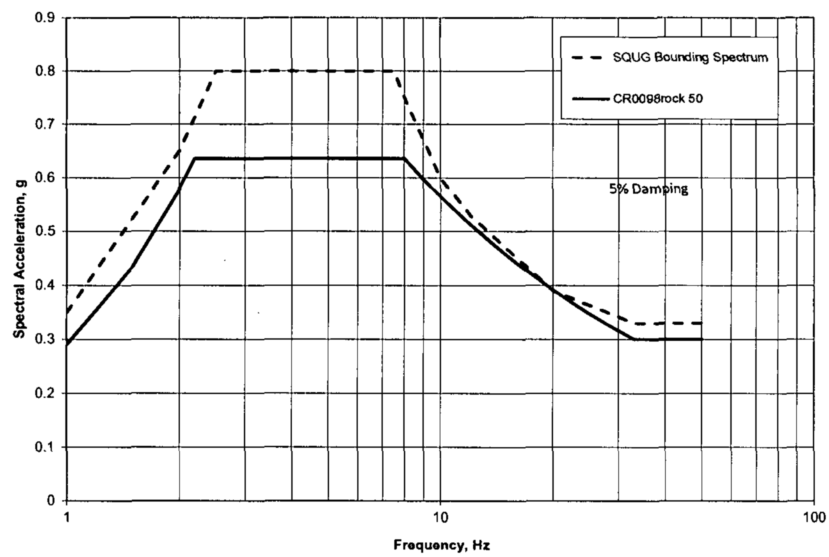


Figure 2. Comparison of Bounding Spectrum and NUREG/CR-0098 (Median) Spectrum

Selection of the CAV Threshold Damage Value

The CAV concept was developed in an EPRI research project [8] conducted in the late 1980s and early 1990s. The study concluded that the CAV was the best single parameter for determining the damage *threshold* of earthquake ground motion. The procedure for determining the CAV was further refined in a follow-on study [9] which standardized the computational algorithm to be used to determine the CAV value associated with a given free-field acceleration time-history record. The USNRC participated in the review of this project and endorsed its results in Regulatory Guide 1.166 [11] as part of the OBE exceedance criteria.

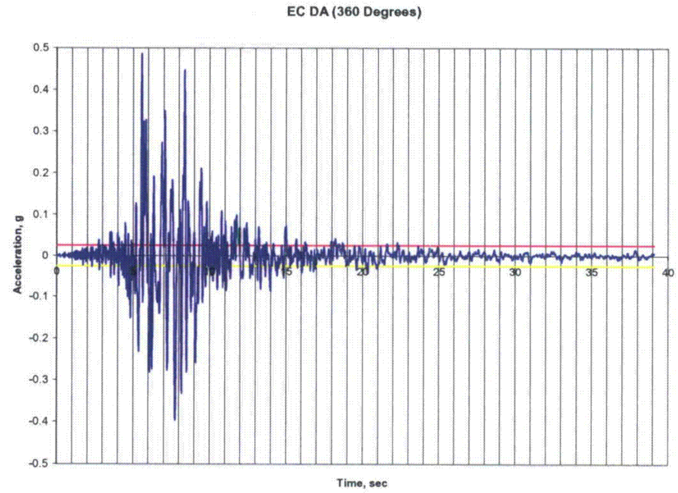
The CAV is the integration of the absolute value of ground acceleration over successive one second intervals of a free-field acceleration time-history for which the absolute value of the recorded acceleration exceeds 0.025g. In general, the CAV is a function of the duration of the strong motion portion of the time-history record. If the cumulative value of the CAV is plotted as a function of time using the equation,

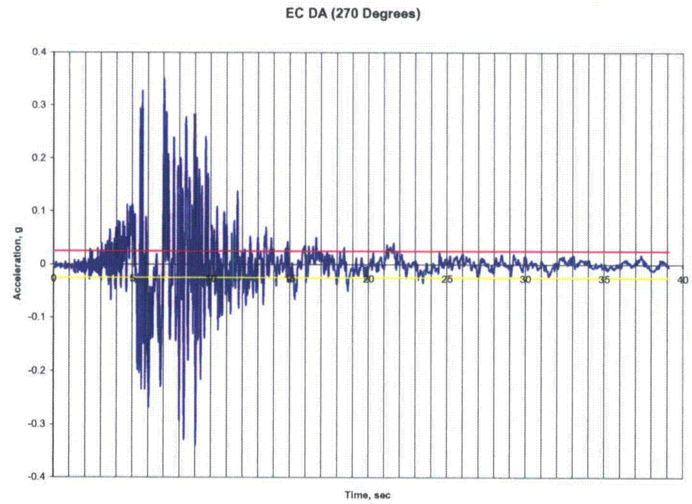
$$\mathrm{CAV}(t) = \sum_i \int_{ti}^{ti+1} W_i \,|\, a \,|\, dt \quad \text{where } W_i = 0 \text{ for } |a| < 0.025\text{g and}$$

$W_i=1$ for $|a| \geq 0.025$g and zero otherwise, the generation of the total CAV value may be generated for the entire acceleration time-history record. For this calculation, the integration limits, t_i , are taken as integer values of time in seconds. Figure 3 shows a cumulative CAV function plot corresponding to the closest free-field acceleration records associated with the El Centro Steam Plant (1979 Imperial Valley CA Earthquake). This type of presentation indicates that the strong motion portion of each time-history record yields a region where the CAV value accumulates at an approximate constant rate. As can be noted in Figure 3, the cumulative CAV function for the El Centro Steam Plant includes the strong motion portion (5-10 sec) that contributes approximately 60% of the total CAV value. Thus, the computed CAV value is always larger than the strong motion contribution, resulting in a conservative damage measure when used as a lower bound exclusion criterion.

Over 177 seismic records were used in the study [9], along with a Modified Mercalli Intensity (MMI) value assigned to each record site. In general, the assignment of the MMI intensity associated with each record site was based on published isoseismic maps for a given earthquake event. In some cases, the MMI intensity associated with a given record site was based on actual damage noted in the vicinity of the site. Reference 8 provides full documentation of the sources used for determination of MMI intensity for the record sites. The CAV value was computed for each site record and then correlated with the assigned site intensity value. The threshold of damage potential was chosen conservatively as MMI intensity VII for which there is "negligible damage to buildings of good design and construction" (see Reference 8 for definition). Reference 9 determined that the threshold CAV value associated with MMI VII was 0.16 g-sec. This value was chosen as the lowest CAV value associated with site MMI intensity VII, which is the record associated with (i.e., closest to) the Pasadena Power Plant in the 1987 Whittier, CA earthquake. The plant had no damage due to the earthquake.

Figure 4 shows the entire set of 177 CAV values from Reference 9 plotted against the assigned site MMI intensity. Note that CAV values as high as 3 occur for sites with MMI site intensity VII. The goal of the studies documented in References 8 and 9 was to establish a screening value which could be used as justification for continued nuclear plant operation following an earthquake, given that the threshold CAV determined from site (free-field) records was not exceeded.





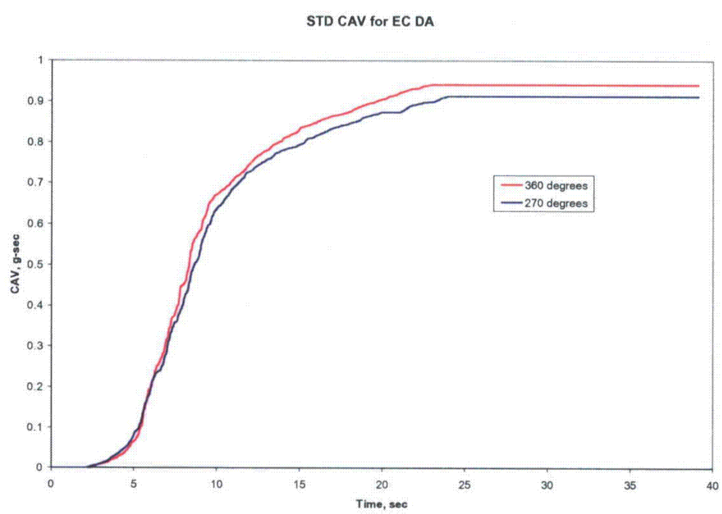


Figure 3. Time-History Records and Computed CAV Values Associated with the El Centro Steam Plant (Differential Array, 1979 Imperial Valley, CA Earthquake; closest record to plant)

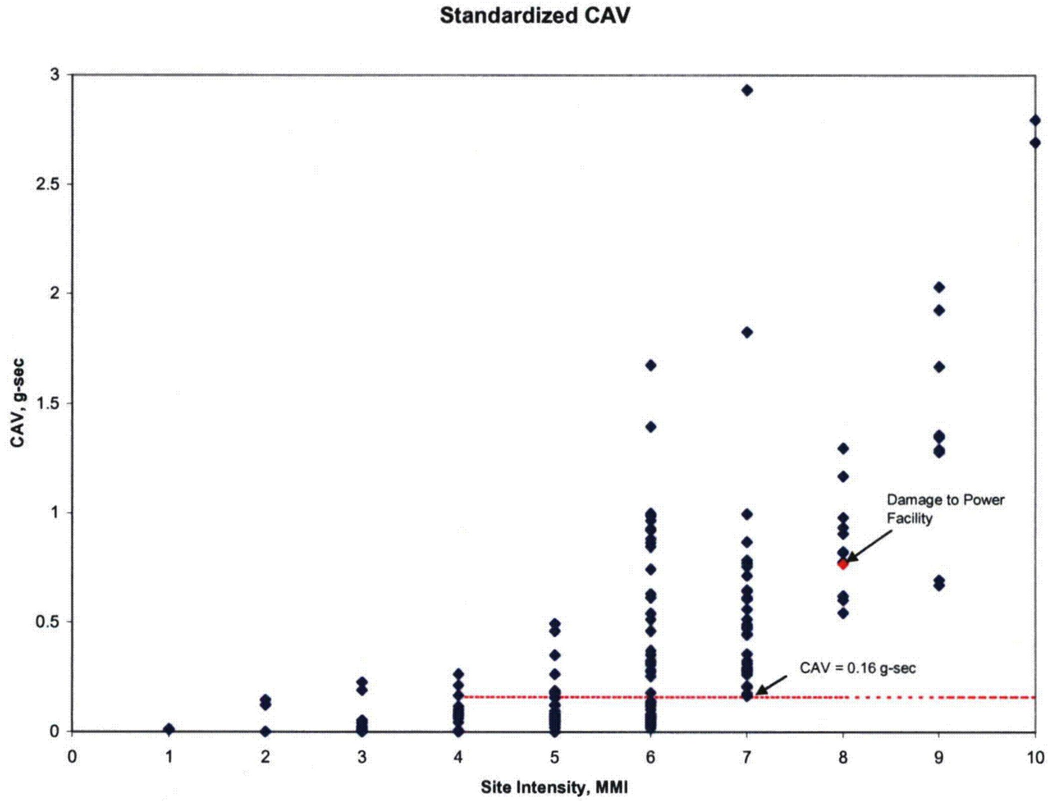


Figure 4. Plot of CAV vs. Site MMI Intensity for 177 Records (Reference 9)

Reference 9 identifies the records associated with the El Centro Steam Plant during the 1979 Imperial Valley earthquake as having the lowest CAV values (0.77 - 0.94) associated with minor damage to a power plant facility. The site intensity was identified as MMI VIII. There were four horizontal strong motion records associated with the plant site:

1) two records from the USGS Differential Array (2400 ft from Unit 4 of the plant) and
2) two records from the USGS El Centro Array No. 8 (4000 ft from Unit 4 of the plant).

The noted plant damage was structural only – minor concrete cracks and buckling of the boiler frame braces. The plant operating units were fully functional following the earthquake. The El Centro Steam Plant is one the reference data sites used by the SQUG to establish the USI A-46 resolution. The minimum CAV value for this plant is identified in Figure 4 as the lowest value for power plant structural damage (EC Array No. 8, CAV = 0.77 and 0.82; Diff. Array, CAV = 0.91 and 0.94). The other lower CAV values indicated in Figure 4 for MMI VIII are for commercial building structures with minor structural damage (CAV > 0.54).

Reference 8 concluded that power plants and other heavy industrial facilities can sustain ground motion levels associated with MMI VIII site intensities and remain functional. The threshold CAV value determined in Reference 9 was purposely chosen to be a conservatively low value associated with MMI VII records representing a non-damaging level to be used as a screening value for continued operation of a nuclear plant following an earthquake. The following table provides the Standardized CAV values computed as described in Reference 9 for the Reference SQUG sites and selected post-1985 database sites that are associated with power generation.

Table 1. CAV Values for EPRI Database Sites Associated with Power Generation

Site	Earthquake	Station	CAV (g-sec)	
Sylmar Converter Station	1971 San Fernando	Pacoima Dam (scaled by 0.5/1.12)	S16E	S74W
			0.826	0.776
El Centro Steam Plant	1979 Imperial Valley	Differential Array	360°	270°
			0.935	0.906
Coalinga Oil Facilities	1983 Coalinga	Pleasant Valley Pumping Station Switchyard	135°	045°
			1.481	1.582
Chile Facilities	1985 Valpariso, Chile	Llolleo Pumping Plant	100°	010°
			3.991	5.812
PALCO Power Plant	1992 Cape Mendocino	Rio Dell Overpass	270°	360°
			0.954	1.031
Commerce Refuse-to-Energy Power Plant	1987 Whittier	Bulk Mail Center [Bell]	010°	280°
			0.551	0.586
Whitewater Hydro Plant	1986 Palm Springs	Whitewater Fish Hatchery	270°	180°
			0.818	0.774
UCSC Cogeneration	1989 Loma Prieta	UCSC Lick Electrical Lab	090°	000°
			1.061	1.250
AES Placerita Co-Generation Plant	1994 Northridge	Newhall Fire Station	090°	360°
			1.395	1.547
Olive View Cogeneration	1994 Northridge	On-site Free-Field Record for Sylmar Medical Center	090°	360°
			1.118	1.308
Cool Water Generating Station	1992 Landers	SCE On-site Record	N/S	E/W
			1.106	1.246
Gilroy Energy Co-Generation Plant	1989 Loma Prieta	Gilroy # 3 (Gilroy Sewage Plant)	090°	000°
			0.837	0.898
Gilroy Energy Co-Generation Plant	1989 Loma Prieta	Gilroy # 4 (San Ysidro School)	090°	000°
			0.829	0.848
Manzanillo Power Plant	1995 Manzanillo, Mexico	On-site Free-Field Record for Switchyard	West	South
			2.804	2.929

CAV values for the sites range from 0.55 to 5.8, yet equipment remained functional at all sites. In general, only the minimum CAV value can be used to determine a threshold value below which equipment functionality is expected at all sites.

The damage threshold CAV value of 0.16 g-sec, selected in Reference 9, was based on the observed negligible structural damage associated with MMI VII for buildings of good design and construction. Since power plants have been subjected to earthquake motions with observed MMI VIII levels and have remained functional, the selected threshold CAV value of 0.16 g-sec which is associated with MMI VII can also be interpreted as a conservative measure of threshold functional damage. If a motion, either a design time-history or an actual acceleration record, is associated with a given power plant site, then we can state with high confidence that no functional damage should occur to components within that plant (given the primary caveats are satisfied, i.e., adequate anchorage, sufficient restraint, lack of spatial interaction, etc.). This is the underlying basis for the CAV threshold criteria included in Regulatory Guide 1.166 as an optional method for determining OBE exceedance in the case of a seismic event occurring in the vicinity of an operating nuclear power plant.

The CAV threshold value of 0.16 g-sec, included in Regulatory Guide 1.166 and based on the documented EPRI studies, represents a very conservative value for use as a threshold to determine the occurrence of a non-damaging earthquake.

Relevance to North Anna

North Anna safety related structures, systems and components (SSCs) were reviewed as a part of the USI A-46 program. Based on the USI A-46 review, upgrades to all those SSCs which did not meet the seismic review criteria were implemented. As discussed above, a more realistic damage indicating criteria for plants which have successfully met the USI A-46 program could be based on the earthquake levels to which the experience data base sites were subjected. The CAV level for the database sites ranged from 0.55 to 5.8 g-sec. Even considering the lowest CAV of this range (0.55 g-sec), the CAV for the earthquake that occurred at North Anna is less than half that value. It is thus not surprising that damage did not occur to the safety related SSCs at North Anna.

References:

1. Seismic Qualification Utility Group (SQUG), "Generic Implementation Procedures (GIP) for Seismic Verification of Nuclear Plant Equipment, Rev. 2," 1992.
2. Sandia Corporation, "Use of Seismic Experience and Test Data to Show Ruggedness of Equipment in Nuclear Power Plants," SAND92-0140, Albuquerque, New Mexico, 1992.
3. USNRC, Generic Letter (GL) 87-02, "Verification of Seismic Adequacy of Mechanical and Electrical Equipment in Operating Reactors, Unresolved Safety Issue (USI) A-46," 1987.
4. USNRC, Supplement No. 1 to Generic Letter (GL) 87-02, "Supplemental Safety Evaluation Report No. 2 on Seismic Qualification Utility Group's Generic Implementation Procedure," 1992.
5. Electric Power Research Institute, "Seismic Fragility Applications Guide Update," EPRI 1019200, 2009.

6. USNRC, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," NUREG-1407, 1991.
7. USNRC, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR-0098, 1978.
8. Electric Power Research Institute, "A Criterion for Determining Exceedance of the Operating Basis Earthquake," EPRI NP-5930, July 1988.
9. Electric Power Research Institute, "Standardization of the Cumulative Absolute Velocity," EPRI TR-100082, December 1991.
10. Electric Power Research Institute, "Nuclear Power Plant Seismic Margin", EPRI NP-6041, August 1991.
11. NRC Regulatory Guide 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions."