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BELLEFONTE TECHNICAL REPORT

EXEMPTION OF OPERATING BASIS EARTHQUAKE FROM BELLEFONTE NUCLEAR PLANT DESIGN BASIS

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ACRONYMS

ACI	American Concrete Institute
ABWR	Advanced Boiling Water Reactor
ASME	American Society of Mechanical Engineers
BLN	Bellefonte Nuclear Plant
CAV	Cumulative absolute velocity
EPRI	Electric Power Research Institute
IEEE	Institute of Electrical and Electronic Engineers
NRC	Nuclear Regulatory Commission
OBE	Operating Basis Earthquake
SSCs	Structures, systems, and components
SSE	Safe Shutdown Earthquake
TVA	Tennessee Valley Authority

EXECUTIVE SUMMARY

Renewed interest in power reactor siting due to evolutionary designs of the Advanced Light Water Reactor (ALWR) program has resulted in the NRC reviewing regulations on power reactor siting. The staff has proposed to amend its regulations to update the criteria used in decisions regarding power reactor siting, including geologic, seismic, and earthquake engineering considerations for future nuclear power plants.

The NRC has evaluated the decoupling of the operating basis earthquake (OBE) from the safe shutdown earthquake (SSE), and the possibility of redefining the OBE in order to satisfy its function without an explicit response analysis as part of design basis engineering. This change would diminish the role of the OBE in design by establishing a level which, if exceeded, would require that the plant be shutdown for inspection activities.

Additionally, the NRC staff has concluded that "..... the changes," [i.e., elimination of the OBE and substitution of alternate criteria], "provide an enhancement to safety by refocusing current design requirements to emphasize those areas where failure modes are more likely to occur and precluding the need for seismic design requirements that do not significantly contribute to the overall safety of the plant."[1]

TVA considers the elimination of the OBE from the seismic design basis of Seismic Category I structures, systems, and components a reasonable approach and would like to incorporate this into the design basis for Bellefonte Nuclear Plant (BLN).

Including both the OBE and SSE in the design basis has required that two complete sets of seismic analyses be performed. Performing the two complete sets of seismic analyses and evaluating the corresponding designs for both sets of loads can add significantly to the plant costs and schedule. As was concluded by the NRC staff, including the OBE in the design basis has not contributed significantly to the overall safety of existing plants and the changes being proposed with the elimination of the OBE will provide an enhancement to the plant safety.

TVA is in the process of verifying the seismic design of Seismic Category I structures, systems, and components in BLN. The BLN verification is in accordance with TVA's Position Papers and the corresponding NRC Safety Evaluation Reports. In view of the NRC staff proposals to modify the existing regulatory guidance and the Commission's acceptance, TVA requests NRC concurrence that BLN be exempt from the 10 CFR 100 Appendix A criteria in the form of the elimination of the OBE from the design basis for which all Seismic Category I structures, systems, and components must be qualified.

BLN has developed a cost/benefit analysis to determine the impact of maintaining the present design basis criteria which includes the OBE, versus modifying the design basis criteria to eliminate the OBE. It is estimated that elimimating the OBE from the BLN design basis could reduce the present project seismic design verification effort by approximately $3.55 million.

BLN would apply the above exemption to design basis engineering completed after the approval of the exemption. Existing design basis engineering that was finalized using the OBE criteria, prior to approval of the exemption, would not need to be re-evaluated.

1.0 INTRODUCTION

Purpose

Appendix A to 10 CFR 100 requires, in part, that all structures, systems, and components of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public shall be designed to remain functional and within applicable stress and deformation limits when subject to an operating basis earthquake (OBE). Changes to Appendix A of Part 100 are being proposed by the NRC staff to redefine the OBE to a level such that the function of the OBE can be satisfied without the need to perform explicit response analyses.

The purpose of this document is to provide the technical basis for an exemption request to 10 CFR 100, Appendix A for Bellefonte Nuclear Plant (BLN).

The changes to the existing seismic design criteria as discussed in this report are equivalent to the proposed NRC changes to Appendix A to 10 CFR Part 100 and those being proposed for the evolutionary designs of the Advanced Light Water Reactors (ALWR). Consistent with NRC staff conclusions for the ALWR program, elimination of the OBE would not reduce the level of safety, but would enhance the safety of the BLN design. That is,

> ..... eliminating the operating basis earthquake from the design of systems, structures, and components in the [Advanced Boiling Water Reactor] ABWR Standard plant will not reduce the level of safety provided in current regulatory guidelines for seismic design. On the contrary, the staff finds that the changes provide an enhancement to safety by refocusing current design requirements to emphasize those areas where failure modes are more likely to occur and by precluding the need for seismic design requirements that do not significantly contribute to the overall safety of a plant.[1]

Cost Benefit Assessment

Elimination of the OBE from the BLN design basis will result in approximately $4.10 million savings to the project. These savings result from a reduction in the design verifieation effort required to complete BLN.

A modest cost increase of approximately $0.55 million to design, purchase and install upgraded seismic instrumentation and to perform and document baseline visual inspections is projected with a total net savings to BLN of approximately $3.55 million.

Background

The NRC staff has recently reviewed the basis for including the OBE in the design of Seismic Category I structures, systems, and components. The NRC staff has

concluded that eliminating the OBE from the design of structures, systems, and components (SSCs) will not reduce the level of safety provided in current regulatory guidelines for seismic design.[1]

The elimination of the OBE from BLN's design basis is consistent with the criteria that the NRC staff is presently proposing for the ALWR plants.

Present 10 CFR 100 Appendix A OBE criteria

- The OBE is that earthquake which could reasonably be expected to occur during the operating life of the plant;
- The OBE produces the vibratory motion for which the nuclear power plant is designed to remain functional without undue risk to the health and safety of the public.
- The OBE shall be one-half the Safe Shutdown Earthquake (SSE).
- If the OBE is exceeded, shutdown of the nuclear power plant will be required.

Recent NRC Staff Reviews Of Related Regulations

The staff has assessed the safety margins of various aspects of nuclear plant design based on elimination of the OBE. Their conclusion is that eliminating the OBE from the design basis would not reduce the level of plant safety.[2]

The NRC staff has proposed an amendment of Appendix A to 10 CFR 100 which would allow the option to eliminate the OBE from the design certification when the OBE is established at less than or equal to one-third the SSE. In this option, the OBE serves as an inspection level earthquake below which the effects on the health and safety of the public would be insignificant and an OBE exceedance criterion is established, above which the licensee would be required to shut down the plant and inspect for damage.

NRC staff has worked with the power industry to develop design alternatives for the ABWR to supplement the codes and standards used which require design-checks based on the OBE. Issues addressed include:

- Fatigue evaluations based on SSE cycles
- Relative seismic anchor motion effects based on SSE
- No replacement earthquake loading should be used to establish the postulated pipe rupture and leakage crack locations

2.0 METHODS

Technical Position

The present BLN design criteria, which includes the OBE, would remain an acceptable method for evaluating Safety-Related SSCs. This design criteria has been reviewed and accepted by the NRC staff. Thus, the elimination of the OBE would not make the present design unacceptable. Rather, it gives the project an alternate criteria for qualifying Safety-Related SSCs.

The specific aspects of the proposed BLN approach are summarized below.

Elimination of OBE from Design Basis

BLN would eliminate the OBE from the design basis of SSCs that are qualified to this alternate criteria. BLN would adopt modified criteria that are consistent with that presently being proposed for evolutionary ALWR designs.

Maintain Present SSE Design Criteria

BLN would maintain its present, NRC staff approved, Safe Shutdown Earthquake (SSE) criteria of a Regulatory Guide 1.60 ground response spectrum shape anchored to 0.18g for both the horizontal and vertical earthquakes.[3]

New Definition of OBE

The BLN OBE for use in this alternate criteria would be redefined as one-third (⅓) of the SSE; i.e., a Regulatory Guide 1.60 ground response spectrum shape anchored to 0.06g for both the horizontal and vertical earthquakes. The OBE would serve the function of an "inspection and shutdown" earthquake.

Maintain Effective Codes and Code Dates

The NRC staff has concluded that designs performed including the OBE within the design basis have not significantly increased overall plant safety.[1] Effective dates of the design code have not been an issue. Therefore, TVA would maintain their effective design codes and code dates, e.g.,

- ASME Boiler and Pressure Vessel Code, Section III, Division I, 1974 Edition through Summer 1974 Addenda for piping systems
- ASME Boiler and Pressure Vessel Code, Section III, Division I, 1974 Edition through Winter 1975 Addenda for piping supports
- IEEE Standard 344-1975
- ACI 318-71

Upgrade Seismic Instrumentation

BLN seismic instrumentation would be upgraded to state-of-the-art solid-state digital instrumentation meeting the guidance provided in draft revision 2 to Regulatory Guide 1.12, "Seismic Instrumentation," and draft Regulatory Guide DG-1016. This is to assure that the effects of an earthquake could be assessed promptly after the event.

BLN would develop a seismic instrumentation plan addressing the criteria identified in the revision to Regulatory Guide 1.12 and draft Regulatory Guide DG-1016.

Pre-Earthquake Inspections

In preparation of post-earthquake activities, BLN would develop a program to inspect and base-line certain structures, equipment and piping. The selection of equipment and structures for inspections and the content of the base line inspections would be in accordance with draft Regulatory Guide DG-1017 and EPRI NP-6695. The NRC staff has proposed the use of EPRI NP-6695 criteria to satisfy the requirements of the proposed Appendix S to 10 CFR 50 for assuring the safety of nuclear power plants.[13] These base-line inspection results would be utilized to differentiate between pre-existing conditions at the plant and earthquake related damage. The structures, equipment, and piping selected for these inspections would be comprised of those routinely examined by the plant operators during normal plant rounds and inspections.

Post-Earthquake Actions

BLN would develop a program to address post-earthquake actions. After an earthquake, plant operators would walk through and visually inspect accessible areas of the plant.

The post-earthquake actions program would address guidance provided in EPRI NP-6695, modified by deleting the last sentence in the first paragraph of Section 4.3.4, i.e., "Considerations to be taken into account in the timing of the shutdown following an earthquake, based on the need for continued power generation in the region are discussed in Section 1.5 of this report."

Evaluation of Seismic Data and Damage Inspections Post Earthquake

BLN would develop a program for evaluation of the seismic data and damage inspections following an earthquake, and criteria for making a decision to shutdown.

This program would address:

- Evaluation of response spectra

- Determination and evaluation of the cumulative absolute velocity value calculated according to the procedures in EPRI TR-100082

- Evaluation for significance of plant damage[8]

- Evaluation of the shutdown criteria[8,9]

- Criteria for plant shutdown

- Instrument operability checks

- Recording of the chronology of events and control room activities while the earthquake evaluation is in progress

Plant Shutdown

TVA proposes to shutdown the BLN plant when the vibratory ground motion exceeds the EPRI OBE criterion as described below or observed evidence of significant plant damage is incurred. Prior to resuming operations, BLN would demonstrate that no functional damage had occurred to those features necessary for continued operation without undue risk to the health and safety of the public.

The data from the seismic instrumentation, coupled with information obtained from the plant inspections, would be used to make the initial determination of whether the plant should be shutdown if it has not already been shutdown by operational perturbations resulting from the earthquake. EPRI guidelines[7,8,9] would be used to identify and assess earthquake effects.

Shutdown of the plant would be required if the vibratory ground motion experienced exceeds that of the OBE ground motion threshold. The two criteria for determining OBE exceedance[8] will be implemented. These include:

- a threshold response spectrum ordinate criterion; and

- a cumulative absolute velocity criterion (CAV).

The calculation of the CAV would be as provided in EPRI TR-100082. The CAV limit is exceeded if the CAV value calculated is greater than 0.16 g-sec.

If both of the OBE exceedance criteria were not exceeded and the walkdown inspection indicates no significant damage to the nuclear power plant structures, systems, and components, shutdown of the plant would not be required. The plant could continue to operate (or restart following a post-trip review, if tripped off-line due to the earthquake).

Modification to Design Criteria

Eliminating the OBE from explicit design consideration affects several aspects of the seismic qualification of safety-related mechanical and electrical equipment. The following criteria would be used in place of existing qualification criteria for safety-related mechanical and electrical equipment.

Piping Design Criteria

1. Fatigue Considerations

In order to ensure adequate design considerations for the fatigue effects of earthquakes, it is necessary to establish bounding load definition and number of earthquake cycles to account for more frequent occurrences of lesser earthquakes. For BLN, two SSE events with 10 maximum stress cycles per event for a total of 20 full range SSE stress cycles will be utilized.

2. Seismic Anchor Motion (SAM)

The effects of displacement-limited SAMs due to an SSE will be evaluated for piping systems. The SAM effects will include relative displacements between building floors and slabs, equipment nozzles, piping penetrations and at connections of small diameter piping to larger diameter piping.

3. Piping Stress Limits

ASME Code Class 1, 2, and 3 piping at BLN is designed to the requirements of the ASME Boiler and Pressure Vessel Code, Section III, 1974 Edition through Summer 1974 Addenda. Selected sections of later editions and addenda have been invoked and reconciled as permitted by the Code where clarification or specific requirements were not provided in the code of record. In addition, the following changes and additions to paragraphs NB-3650, NC-3650, and ND-3650 are necessary and shall be satisfied when the OBE is eliminated from the design.

3.1 ASME Code Class 1 Piping Stress Limits

(a) NB-3654.2

For primary stress evaluation, earthquake loads due to the OBE will not be evaluated for consideration to Upset (Level B) allowables for equation (9). The primary stresses due to SSE will be evaluated to the Faulted (Level D) allowables.

(b) NB-3653.1

For satisfaction of primary plus secondary stress intensity range, in Eq. (10), M_i shall be either (1) The resultant range of all cyclic loads considering one-half the range of the safe shutdown earthquake or (2) the resultant range of moment due to the full range of the safe shutdown earthquake acting alone, whichever is greater. The use of the SSE is intended to provide a bounding design for the cumulative effects of earthquakes of a lesser magnitude and is therefore included in the normal/upset evaluation of Eq.(10).

(c) NB-3653.2

For the evaluation of peak stress intensity , the load sets developed in NB-3653.2 based upon the discussion above in (b) should be used in calculating the peak stress intensity, S_p , and the alternating stress intensity, S_{alt}, for evaluating the fatigue effects and cumulative damage.

(d) NB-3653.6

For simplified elastic plastic analysis , if Eq. (10) can't be satisfied for all pairs of load sets, then the alternative analysis as described in NB-3653.6 should be followed with the following additional limitation imposed.

$$S_{sam} = \frac{C_2 D_o M_i^*}{2I} \leq 3.0 S_m \qquad \text{Eq. (12a)}$$

Where:

S_{sam} = the seismic anchor motion stress.

M_i^* = the range of moments due anchor motion displacements caused by a safe shutdown earthquake.

C_2, D_o and I are defined in ASME Code Subsection NB-3600.

3.2 ASME Code Class 2 and 3 Piping Stress Limits

(a) NC/ND-3653.1

For the consideration of occasional loads, earthquake loads (i.e., inertia and seismic anchor motion due to the OBE) will not be evaluated for the Normal and Upset operating condition (Level A and B) limits. The primary stresses associated with the SSE will be evaluated to the Faulted allowables (Level D).

(b) NC/ND-3653.2

For the consideration of secondary stresses, Eq.(10) and Eq.(11) will not include an evaluation of the moment effects due to earthquake anchor motions due to the OBE.

(c) For consideration of secondary stresses associated with a plant Faulted condition, (Service Level D) due to the effects of seismic anchor motion the following condition will be satisfied:

$$S_{sam} = \frac{i\, M_c'}{Z} \leq 3.0\, S_h \quad (\textit{not to exceed } 2.0\, S_y) \qquad \text{Eq. (10b)}$$

Where:

S_{sam} = the nominal value of seismic anchor motion stress.

M_c' = the range of moments equal to the greater of (1) the resultant range of thermal and thermal anchor movement plus one-half the range of the SSE anchor motion, or (2) the resultant range of moments due to the full range of SSE anchor motions alone.

i and Z are defined in the ASME Code Subsection NC\ND-3600.

4. Pipe Support Stress Limits

The design of ASME pipe supports will consider both the SSE inertia effects and the SSE anchor motion effects as part of the faulted load combinations and evaluated to the Faulted allowable (Service Level D). The OBE inertia and OBE anchor movement loads will not be considered in the design of pipe supports.

5. Pipe Break Postulation Without OBE

The following discussion and criteria for postulation of pipe breaks without OBE is consistent with the memorandum issued by the Office of Nuclear Regulation.[1] Based on recent dynamic pipe tests conducted by EPRI and NRC, the piping has been demonstrated to withstand seismic inertial loadings higher than an SSE without rupturing. Thus, the staff believes the likelihood of a pipe break in a seismically-designed piping system due to an earthquake magnitude of one-third SSE is remote. Operating experience has shown that pipe breaks are more likely to occur under conditions caused by normal operation (e.g., erosion-corrosion, thermal constraint, fatigue, and operational transients).

On the basis of the above discussion, the staff concludes that no replacement earthquake loading should be used to establish postulated pipe rupture locations.[1] Instead, the criteria for postulating pipe breaks in seismically-designed, high energy piping systems should be based on factors attributed to normal and operational transients only. The staff's review criteria for pipe break postulation transients are provided below. The revised criteria are intended to ensure the breaks are postulated to occur at the most likely locations and to reduce the number of pipe rupture mitigation devices (e.g., pipe whip restraints and jet impingement shields) that might hinder plant operation without providing a compensatory level of safety.

Postulated pipe break events would conform to the guidelines provided in Branch Technical Position MEB 3-1, "Postulated Rupture locations in Fluid System Piping Inside and Outside Containment," as modified by the following;

(1) MEB 3-1, B.1.b(1)(a) Footnote 2 would read, "For those loads and conditions in which Level A and Level B stress limits have been specified in the Design Specification (excluding earthquake loads)."[5]

(2) MEB 3-1, B.1.b(1)(d) would read, "The maximum stress as calculated by the sum of Equations (9) and (10) in Paragraph NC-3652, ASME Code, Section III, considering those loads and conditions thereof for which Level A and Level B stress limits have been specified in the system's Design Specification (i.e., sustained loads, occasional loads, and thermal expansion) excluding earthquake loads should not exceed $0.8\ (1.8\ S_h + S_A)$."[5]

Use of Regulatory Guide 1.143 and 1.27

Criteria for structures, systems, and components at BLN which are addressed by Regulatory Guides 1.143, "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," and Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants," would not change.

Seismic Equipment Qualification

Where equipment qualification for seismic loadings is performed by analysis, testing, or a combination of both, IEEE Standard 344-1975 "Recommended Practice For Seismic Qualification of Class 1E Equipment For Nuclear Power Generating Stations," as endorsed in Regulatory Guide 1.100, Revision 1 would be used. With elimination of the OBE, equipment would be qualified for five 1/2 SSE events followed by one full SSE event. Alternatively, one of the following two options can be used to satisfy this requirement:

(1) A number of fractional peak cycles equivalent to the maximum peak cycles for five 1/2 SSE events may be used as discussed in IEEE Standard 344-1987, Appendix D when followed by one full SSE.

(2) qualification may be for two full SSE events.

Concrete and Steel Structures

The staff has examined the design basis structural load combinations and the corresponding acceptance criteria. Based on the analyses, tests, and engineering judgement, the NRC staff has determined that structural designs which are developed without consideration of the OBE will not reduce the level of safety provided in current regulatory guidelines for seismic design.[2] The proposed design criteria for concrete and steel structures of the ALWR designs has eliminated the load combinations containing OBE loadings.

Therefore, the OBE can be eliminated from the design basis for concrete and steel structures without needing to include supplemental criteria. Steel structures include steel framed buildings, platforms, and cable tray, conduit, and HVAC support structures.

Technical Justification

Modification Of Design Criteria

Modifications to the design criteria for safety-related SSCs is equivalent to criteria that the NRC staff has already proposed when the OBE has been eliminated from the ALWR plants. The proposed BLN criteria results from adapting the criteria from the ALWR program to address specific BLN licensing commitments and design code editions.

3.0 CONCLUSION

The methodology outlined in this paper provides a reasonable approach to eliminating the Operating Basis Earthquake (OBE) from the BLN design basis. The proposed approach, though not identical, is consistent with that already proposed by the NRC staff.[1] Eliminating the OBE from the design of systems, structures, and components in BLN as identified in this report will not reduce the level of safety provided in current regulatory guidelines for seismic design. On the contrary, the changes provide an enhancement to safety by refocusing current design requirements to emphasize those areas where failure modes are more likely to occur and precluding the need for seismic design requirements that do not significantly contribute to the overall safety of the plant.

- Cost Benefit

  Eliminating the OBE from the BLN design basis is estimated to reduce the present project seismic design verification effort by approximately $3.55 million.

4.0 REFERENCES

1. NRC Memorandum from William T. Russell, Associate Director for Inspection and Technical Assessment, Office of Nuclear Reactor Regulation to Dennis M. Crutchfield, Associate Director for Advaneed Reactors and License Renewal, Office of Nuclear Reactor Regulation dated August 18, 1992, entitled "Preliminary Evaluation On The Use Of A Single-Earthquake Design For Systems, Structures, And Components In The ABWR."

2. SECY-93-087, NRC Staff Correspondence from James M. Taylor Executive Director for Operations to The Commissioners dated August 2, 1993 entitled "Policy, Technical, And Licensing Issues Pertaining To Evolutionary And Advanced Light-Water Reactor (ALWR) Designs."

3. Enclosure to USNRC letter from Mohan C. Thadani, NRC to Mr. Nauman, TVA dated October 4, 1991 entitled "Safety Evaluation By the Office of Nuclear Reactor Regulation Tennessee Valley Authority's Position Regarding Seismic Design of Category I Structures."

4. 10 CFR 100 Appendix A, "Seismic And Geologic Siting Criteria For Nuclear Power Plants."

5. Branch Technical Position MEB 3-1, "Postulated Rupture locations in Fluid System Piping Inside and Outside Containment," attached to NUREG-0800 Standard Review Plan Section 3.6.2.

6. ASME Boiler and Pressure Vessel Code, Section III, 1974 Edition through Summer 1974 Addenda.

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

8. EPRI NP-5930, "A Criterion for Determining Exceedance of the Operating Basis Earthquake," July 1988.

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

10. IEEE Standard 344-1975, "Recommended Practice For Seismic Qualification of Class 1E Equipment For Nuclear Power Generating Stations."

11. IEEE Standard 344-1987, Appendix D, "Recommended Practice For Seismic Qualification of Class 1E Equipment For Nuclear Power Generating Stations."

12. Draft Regulatory Guide DG-1016, "Nuclear Plant Instrumentation For Earthquakes", November 1992.

13. Draft Regulatory Guide DG-1017, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-Earthquake Actions," Novemnber 1992.

14. Regulatory Guide 1.12, "Instrumentation for Earthquakes", Draft revision 2 included in SECY-92-215, dated June 12, 1992.

15. ACI Standard 318-71, "Building Code Requirements for Reinforced Concrete (ACI 318-71)," American Concrete Institute, P.O. Box 4754, Redford Station, Detroit, Michigan, 48219.