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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: T. R. QUAY

SUBJECT: USE OF 5 PERCENT DAMPING VALUES FOR PIPING STRESS ANALYSIS

Dear Mr. Quay:

This letter is written in response to the NRC position on the damping values to be used in piping analyses when the system model includes flexible equipment. This issue is included in DSER Open Item 3.12.5.9-1. The NRC position is that the regulatory guide damping values of 2 and 3% should be used when a piping evaluation model combines piping and equipment.

The Westinghouse position is that the 5 percent damping value approved for use in AP600 (Table 3.7.1-7) should be included in such a model. Westinghouse has reviewed the FSARs of operating plants and has found precedent for this position. In Subsection 3.7N.1.3 of the FSARs for the Vogtle and Comanche Peak, use of ASME Code Case N-411 damping values (in lieu of lower Regulatory Guide 1.61 damping values) is acceptable. The Comanche Peak FSAR specifically identifies the reactor coolant loop (which contains flexible equipment) as a system analyzed using the higher damping values. The Vogtle FSAR prohibits the mixing of N-411 and R.G. 1.61 damping values in the same analysis.

The use of ASME Code Case N-411 damping in these applications supports the similar use of 5 percent damping in coupled piping analysis in AP600. The use of 5 percent damping for piping stress analysis in AP600 is consistent with the conditions in Regulatory Guide 1.84 for use of code case N-411 damping. Five percent damping is not used for evaluation of equipment.

Westinghouse requests that the NRC reaffirm the position in subsection 3.12.5.19 of the DSER that the use of 5 percent damping is acceptable for piping systems in the AP600 design.

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Portions of the Vogtle and Comanche Peak SSARs are attached.

If you have any questions, please contact Donald A. Lindgren at (412) 374-4856.

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

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Attachment

cc: D. Jackson, NRC
S. Hou, NRC
N. J. Liparulo, Westinghouse (w/o attachments)

components can experience significant permanent deformation without loss of function. Piping and vessels are examples of the latter where the principal requirement is that they retain their contents and allow fluid flow.

The seismic requirements for safety-related instrumentation and electrical equipment are covered in Section 3.10. The safety class definitions, classification lists, operating condition categories and the methods used for seismic qualification of mechanical equipment are given in Section 3.2.

3.7N.1 SEISMIC INPUT

3.7N.1.1 Design Response Spectra

Refer to Section 3.7B.1.1.

3.7N.1.2 Design Time History

Refer to Section 3.7B.1.2.

3.7N.1.3 Critical Damping Values

78 The damping values given in Table 3.7N-1 are used for the systems analysis of Westinghouse equipment and the original Westinghouse analyses. These are consistent with the damping values recommended in Regulatory Guide 1.61 except in the case of the primary coolant loop system components and large piping (excluding reactor pressure vessel internals) for which the damping values of 2 percent and 4 percent are used as established in testing programs reported in
76 Reference [1]. As an alternative and as defined in Table 3.7N-1, piping systems analyzed by the response spectrum method may use ASME Code Case N-411 damping values. Qualification analyses of the primary coolant loop equipment (steam generators; reactor pressure vessel and reactor coolant pumps) incorporate equipment damping values
78 as defined in Table 3.7N-1. ASME Code Case N-411 damping values are used for the reconciliation analyses of all NSSS scope piping stress

analysis packages, including the Primary Coolant Loop piping. ASME Code Case N-397 is not used for NSSS scope piping analysis but any subsequent usage will be detailed in the FSAR and in compliance with reference [8]. 78

The damping values for control rod drive mechanisms (CRDM's) and the fuel assemblies of the Nuclear Steam Supply

System, when used in seismic system analysis, are in conformance with the values for welded and/or bolted steel structures (as appropriate) listed in Regulatory Guide 1.61.

Tests on fuel assembly bundles justified conservative component damping values of 7 percent for OBE and 10 percent for SSE to be used in the fuel assembly component qualification. Documentation of the fuel assembly tests is found in Reference [2].

The damping values used in component analysis of CRDM's and their seismic supports were developed by testing programs performed by Westinghouse. These tests were performed during the design of the CRDM support; the support was designed so that the damping in Table 3.7N-1 could be conservatively used in the seismic analysis. The CRDM support system is designed with plates at the top of the mechanism and gaps between mechanisms. These are encircled by a box section frame which is attached by tie rods to the refueling cavity wall. The test conducted was on a full size CRDM complete with rod position indicator coils, attachment to a simulated vessel head, and variable gap between the top of the pressure housing support plate and a rigid bumper representing the support. The internal pressure of the CRDM was 2250 pounds per square inch (psi) and the temperature on the outside of the pressure housing was 400°F.

The program consisted of transient vibration tests in which the CRDM was deflected a specified initial amount and suddenly released. A logarithmic decrement analysis of the decaying transient provides the effective damping of the assembly. The effect on damping of variations in the drive shaft axial position, upper seismic support clearance and initial deflection amplitude was investigated.

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3.9N.1.4.8 Analytical Methods for RCS Class 1 Branch Lines 20

The analytical methods used to obtain the solution consist of the transfer matrix method and stiffness matrix formulation for the static structural analysis, the response spectrum method for seismic/dynamic analysis, and dynamic structural analysis for the effect of a reactor coolant loop pipe break. 20

The integrated Class 1 piping/supports system model is the basic system model used to compute loadings on components, component and piping supports, and piping. The system models include the stiffness and mass characteristics of the Class 1 piping components, the reactor coolant loop, and the stiffness of supports which affect the system response. The deflection solution of the entire system is obtained for the various loading cases from which the internal member forces and piping stresses are calculated. 20

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Static 1

The Class 1 piping system models are constructed for the WESTDYN computer program, which numerically describes the physical system. A network model is made up of a number of sections, each having an overall transfer relationship formed from its group of elements. The linear elastic properties of the section are used to define the characteristic stiffness matrix for the section. Using the transfer relationship for a section, the loads required to suppress all deflections at the ends of the section arising from the thermal and boundary forces for the section are obtained.

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After all the sections have been defined in this manner, the overall stiffness matrix and associated load vector to suppress the deflection of all the network points is determined. By inverting the stiffness 13

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13 matrix, the flexibility matrix is determined. The flexibility matrix is multiplied by the negative of the load vector to determine the network point deflections due to the thermal and boundary force effects. Using the general transfer relationship, the deflections and internal forces are then determined at all node points in the system. The support loads are also computed by mutiplying the stiffness matrix by the displacement vector at the support point.

13 <u>Seismic</u>

13 The models used in the static analyses are modified for use in the dynamic analyses by including the mass characteristics of the piping and equipment.

13 The lumping of the distributed mass of the piping systems is accomplished by locating the total mass at points in the system which will appropriately represent the response of the distributed system. Effects of the primary equipment motion, that is, reactor vessel, steam generator, reactor coolant pump, and pressurizer, on the Class 1 piping system are obtained by modeling the mass and the stiffness characteristics of the primary equipment and loop piping in the overall system model.

13 The supports are represented by stiffness matrices in the system model for the dynamic analysis. Shock suppressors which resist rapid motions are also included in the analysis. The solution for the seismic disturbance employs the response spectra method. This method employs the lumped mass technique, linear elastic properties, and the principle of model superposition.

13 The total response obtained from the seismic analysis consists of two parts: the inertia response of the piping system and the response from differential anchor motions. The stresses resulting from the anchor motions are considered to be secondary and, therefore, are included in the fatigue evaluation.

coolant loop model. The coupled model is subjected to three components of earthquake simultaneously at the basemat. The six time-history components, the north-south and east-west horizontal directions and the vertical direction, are statistically independent and are applied simultaneously for 10 s of OBE and SSE, which represents the most severe portion of the earthquake acceleration.

In order to perform the coupled building/loop analysis, it is necessary to construct a synthesized time-history motion. These time-histories are developed to conform to the three translational and three rotational response spectra from the soil-structure interaction analyses of the containment building described in section 3.7.B. The generation of these motions is accomplished by modifying existing earthquake records using spectral raising and suppressing techniques. With data from a real earthquake as input, spectral raising is accomplished by adding to the original time-history a function at the frequency of interest with a phase angle such that the response spectra value will be increased a desired amount. The time when the maximum vibration occurred will be the same. In this way, the characteristics of the required time-history will only be slightly altered. Spectral suppression is carried out by passing the time-history through a linearly damped oscillator connected in series to a second damper. This damping arrangement will reduce the response spectral value, locally, at the natural frequency of the oscillator to the desired amount. The repetitious application of the raising and suppressing techniques is used to arrive at a time-history motion whose response spectrum is sufficiently close to the design spectrum.

The statistical independence of the six synthetic acceleration time-histories is established by comparing statistical properties of the synthetic time-histories with properties derived from recorded earthquake accelerograms. In particular, the values of the normalized correlation coefficient at zero time delay and the average value of the coherence function over the seismic frequency range are calculated for the synthetic and real time-histories and shown to be comparable.

3.7.N.1.3 Critical Damping Values

The damping values given in table 3.7.N.1-1 are used in the systems analysis of Westinghouse equipment. These are consistent with the damping values recommended in Regulatory Guide 1.61 except in the case of the primary coolant loop system components and large piping (excluding reactor pressure vessel internals), for which the damping values of 2 and 4 percent are used as established in testing programs reported in reference 1.

As an alternative to Regulatory Guide 6.1.61, the damping values from ASME Code Case N-411 are used for piping system analysis with response spectra analysis techniques per reference 5. The Code Case N-411 frequency dependent damping values are illustrated in figure 3.7.N.1-1. No mixture of Regulatory Guide 1.61 criteria with the N-411 criteria is allowed in a given piping analysis. As part of the integrated piping analysis/ as-built reconciliation program, GPC was assured that piping displacements and clearances are acceptable when N-411 criteria is applied. The damping values for control rod drive mechanisms (CRDMs) and the fuel assemblies of the NSSS, when used in seismic analysis, are in conformance with the values for welded and/or bolted steel structures (as appropriate) listed in Regulatory Guide 1.61. Consistent with Regulatory Guide 1.61, damping values higher than those listed in table 3.7.N.1-1 may be used if justified by test results.

Tests on fuel assembly bundles have justified conservative component damping values of 7 percent for OBE and 10 percent for SSE to be used in the fuel assembly component qualification. Documentation of the fuel assembly tests is provided in reference 2.

The damping values used in component analysis of CRDMs and their seismic supports were developed through a testing program performed by Westinghouse. The program consisted of transient vibration tests in which the CRDM was deflected a specified initial amount and suddenly released. A logarithmic decrement analysis of the decaying transient provides the effective damping of the assembly. Documentation of the CRDM tests is provided in references 3 and 4.

The test results indicated that the damping would be greater than 8 percent for both the OBE and the SSE based on a comparison between typical deflections during these seismic events to the initial deflections of the mechanisms in the test. Component damping values of 5 percent are, therefore, conservative for both OBE and SSE.

3.7.N.1.4 Supporting Media for Seismic Category 1 Structures

Refer to paragraph 3.7.B.1.4.

This procedure produces at least twice as many load sets as transients for each point.

For all possible load set combinations, the primary-plus-secondary and peak stress intensities, fatigue reduction factors, and cumulative usage factors are calculated. The WESTDYN program is used to perform this analysis in accordance with ASME III, Subsection NB-3650. Since it is impossible to predict the order of occurrence of the transients over a 40-year life, it is assumed that the transients can occur in any sequence. This is a very conservative assumption.

The combination of load sets yielding the highest alternating stress intensity range is determined and the incremental usage factor calculated. Likewise, the next most severe combination is then determined and the incremental usage factor calculated. This procedure is repeated until all combinations having allowable cycles $<10^6$ are formed. The total cumulative usage factor at a point is the summation of the incremental usage factors.

3.9.N.1.4.3 Analytical Methods for RCS Class 1 Branch Lines

The analytical methods used to obtain the solution consist of the transfer matrix method and stiffness matrix formulation for the static structural analysis, the response spectrum method for seismic dynamic analysis, and static or dynamic structural analysis for the effect of the applicable branch nozzle breaks per section 3.6.2.1.1.A.1.

The integrated Class 1 piping/supports system model is the basic system model used to compute loadings on components, component and piping supports, and piping. The system models include the stiffness and mass characteristics of the Class 1 piping components, the RCL, and the stiffness of supports which affect the system response. The deflection solution of the entire system is obtained for the various loading cases from which the internal member forces and piping stresses are calculated.

A. Static

The Class 1 piping system models are constructed for the WESTDYN computer program, which numerically describes the physical system. A network model is made up of a number of sections, each having an overall transfer relationship formed from its group of elements. The linear elastic properties of the section are used to define the characteristic stiffness matrix for the section. Using the transfer relationship for a section, the loads required to suppress all deflections at the ends of the section arising from the thermal and boundary forces for the section are obtained.

After all the sections have been defined in this manner, the overall stiffness matrix and associated load vector to suppress the deflection of all the network points is determined. By inverting the stiffness matrix, the flexibility matrix is determined. The flexibility matrix is multiplied by the negative of the load vector to determine the network point deflections due to the thermal and boundary force effects. Using the general transfer relationship, the deflections and internal forces are then determined at all node points in the system. The support loads are also computed by multiplying the stiffness matrix by the displacement vector at the support point.

B. Seismic

The models used in the static analyses are modified for use in the dynamic analyses by including the mass characteristics of the piping and equipment.

The lumping of the distributed mass of the piping systems is accomplished by locating the total mass at points in the system which appropriately represent the response of the distributed system. Effects of the primary equipment motion, that is, reactor vessel, steam generator, RCP, and pressurizer on the Class 1 piping system are obtained by modeling the mass and the stiffness characteristics of the primary equipment and loop piping in the overall system model.

The supports are represented by stiffness matrices in the system model for the dynamic analysis. Shock suppressors which resist rapid motions are also included in the analysis. The solution for the seismic disturbance employs the response spectra method. This method employs the lumped mass technique, linear elastic properties, and the principle of modal superposition.

The total response obtained from the seismic analysis consists of two parts: the inertia response of the piping system and the response from differential anchor