Revised Response to Request for Additional Information – ANP-10264NP "U.S. EPR Piping Analysis and Pipe Support Design Topical Report" (TAC No. MD3128)

RAI EPR-2: *ASME B31.1 and Section XI Codes*

B. Confirm that ASME Code Section XI requirements will be used in the piping and pipe support design for EPR.

Response 2:

B. The U.S. EPR adheres to the requirements of the ASME Code Section XI requirements.

RAI EPR-3: *10CFR50.55a(b) Limitations and Modifications*

Section 2.1 of the TR states that for the dynamic loads, including seismic loads, the pipe stress analyses will be performed in accordance with the Sub-articles NB/NC/ND-3650 of the 1993 Addenda of the ASME Code as required by 10CFR50.55a(b)(1)(iii). However, AREVA did not address other limitations and modifications (related to Section III materials, weld leg dimensions, etc.) applicable to piping system design as included in 10CFR50.55a(b)(1). Explain how all limitations and modifications specified in 10CFR50.55a(b) will be satisfied.

Response 3:

The limitations of 10CFR50.55a(b)(1) are considered in the U.S. EPR design as follows:

- (b)(1)(i) Section III "Materials" – This is not considered for the U.S. EPR because it addresses the application of 1992 Edition of ASME. The U.S. EPR uses a later version of the code.
- (b)(1)(ii), "Weld leg dimensions" is incorporated into the U.S. EPR design.
- (b)(1)(iv) "Quality Assurance" – U.S. EPR Quality Assurance program is developed for a later edition of the code. This restriction does not apply to the U.S. EPR.
- (b)(1)(v) – Independence of Inspection – The inspection program for the U.S. EPR will not apply NCA-4134.10(a).
- (b)(1)(vi) Subsection NH – The U.S. EPR will not use Type 316 stainless pressurizer heater sleeves above a service temperature of 900°F.

For clarity, Section 2.1 of the TR will be revised to include the following text:

> "Piping analysis and pipe support design for the U.S. EPR addressed in this Topical Report use the 2001 ASME Code, Section III, Division 1, 2003 addenda as the base code with limitations identified in the Code of Federal Regulations, 10 CFR 50.55a(b)(1).

<u>RAI EPR-4:</u> *Mathematical Modeling*

TR Section 4.2 states that the seismic analysis methods for seismic Category I systems to withstand the effects of a safe shutdown earthquake (SSE) and to maintain the capability of performing their safety function will use the methods in accordance with SRP 3.7.3.

D. Discuss the analysis methods that will be used in the design of non-seismic Category I (or seismic Category II) piping systems.

Response 4:

D. Non-seismic piping that interacts with seismic systems and seismic Category II piping will be analyzed by response spectra (RS) or equivalent static methods

<u>RAI EPR-5:</u> *Piping Analysis Methods*

After constructing a mathematical model to reflect the static or dynamic characteristics of the piping system, describe the step by step computations (e.g., static analysis, modal analysis, modal participation factors) that may be performed to obtain the piping system response for each of the three methods of analysis (i.e., response spectrum, time history, and equivalent static load methods).

Response 5:

Section 4.2.2 will be revised to include the step by step computations for response spectra analysis. Section 4.2.2 will be revised as provided in Attachment A to this document.

Section 4.2.3 will be revised as follows to address the computations when Time History Analysis is employed:

> "The modal superposition method of time history analysis is used for seismic piping analyses with acceleration time history seismic input. This method is based on decoupling of the differential equations of motion, considering a linear elastic system, using the same method as that described in Section 4.2.2."
>
> "The Direct Integration Time History Analysis method may be used as an alternative to the modal superposition time history analysis. In this method the differential equation of motion, as provided in Section 4.2.2, is solved directly on the uncoupled equations without transformation. Rayleigh damping, or mass and stiffness damping, is used when direct integration time history analysis is performed."

Section 4.2.4 will be revised to include the following:

> "For cases where a piping configuration can be demonstrated to respond as a single degree of freedom system with a known fundamental frequency or rigid system with a fundamental frequency beyond the cutoff frequency, a factor of 1.0 may be used with the highest spectral acceleration at that frequency or any higher frequency (as may be the case for multiple peak input spectra).
>
> Mathematically the seismic force F_1 on a mass point in one (1) direction is represented as:
>
> $$F_1 = kmS_a$$
>
> Where:
>
> k = 1.0 for single degree of freedom or rigid system
> 1.5 for multiple degree of freedom system
> m = mass in direction 1
> S_a = value of acceleration from response spectrum
>
> The forces from each of the three orthogonal directions of earthquake are applied to calculate seismic stresses and then combined by SRSS to calculate overall seismic stresses."

(Note: the above revision to 4.2.4 is also addressed in RAI EPR-12).

<u>RAI EPR-6:</u> *Piping Analysis Criteria*

B. The cutoff frequency for modal responses is defined as the frequency at which the spectral acceleration approximately returns to the zero period acceleration (ZPA) of the input response spectrum. Define this cutoff frequency qualitatively or quantitatively for seismic and other building dynamic loads (if any) applicable to the piping analysis for the EPR.

Response 6:

B. Revised analysis and evaluation by AREVA NP has determined that since the ground motion cutoff frequency is 40 Hz, this same cutoff frequency is applicable to response spectra that have been developed using this ground motion.

TR Section 4.2.2.3 will be revised as follows:

> "For the U.S. EPR the cutoff frequency is 40 Hz or as defined by Figure 2 and 3 in RG 1.92, Rev 2".

<u>RAI EPR-7:</u> *Branch Pipe Inputs*

When a small seismic Category I or non-seismic Category I piping is directly attached to seismic Category I piping, it can be decoupled from seismic Category I piping if it satisfies the *decoupling criteria. However, the TR did not describe how the inputs for the small branch piping will be determined for both inertial and seismic anchor motion (SAM) response analyses when the piping system is decoupled from a large pipe run or connected to flexible equipment connections. The staff notes that computer code RESPECT (TR Section 5.1.8) generates seismic amplified response spectra at the branch nozzle locations in a model of a piping system. Describe the seismic analysis methods and procedures, including the input response spectra and input SAM displacements, that apply to the small branch piping design when decoupled from a large run pipe or connected to flexible equipment. The description should also discuss how any amplification effects and SAM effects, from the main run pipe at the attachment to the small branch pipe, are considered.*

Response 7:

The model of a decoupled Class 1 branch line includes an anchor where the branch line connects to the RCL. The seismic inertial analysis of the RCL yields time histories at branch connections and equipment nozzles. The inertial seismic analysis results then become input into the Class 1 branch line seismic analysis in the form of time histories or response spectra which are generated from the time histories using classical response spectra generation techniques. If response spectra are used, they are peak broadened by ±15% in accordance with RG 1.122 R1 before application to the Class 1 branch line model. The analysis of the Class 1 branch line also considers seismic movements generated from the RCL (seismic anchor motions), which are applied as static displacements at the branch-to-RCL anchor. This analysis captures the effects of run pipe amplification on the branch pipe.

For the remaining decoupled branch lines (not connected to the RCL), the model of a decoupled branch line includes an anchor at the run to branch intersection. The analysis of the branch line includes all anchor movements greater than 1/16" from the run pipe applied at the run to branch anchor for all load cases. The inertial seismic input for the branch line comes from the appropriately applied building spectra for branch lines connected to rigid run pipes or equipment and/or amplified response spectra for branch lines connected to flexible run piping or equipment (fundamental frequency below the ZPA cutoff frequency), based on support configurations. As an alternative to a decoupled analysis, the branch pipe analysis may include a portion of the run pipe meeting one of the model isolation methods described in TR Section 5.4.3 in order to capture the possible amplification of inertial input from the run pipe.

The last paragraph of Section 5.4.2 will be changed to the following:

> "The branch pipe analysis must include more consideration for the effects of the run piping. The branch point is considered as an anchor in the analysis of the branch pipe with the appropriate SIF and/or stress indices for the branch connection. The movements (displacements and rotations) of the run pipe at the branch intersection due to statically applied loads in the run pipe analysis (such as thermal and seismic anchor movement (SAM)) shall be applied as anchor movements with their respective load cases in the branch line analysis. Additionally, in the branch analysis, the applied SAMs at the decoupled location shall include the run pipe movements from both the run pipe SAM analysis and the run pipe SSE inertia analysis. The inertial effects of the run pipe on the branch line are considered in one of the following methods:
>
> - For branch lines decoupled from the RCL, the inertial input to the branch line is generated from the analysis of the RCL. The analysis of the RCL yields time

history responses at the branch connections and equipment nozzles. This time history response of the RCL, or a response spectrum generated from the time history response, is then applied as the input inertial excitation at the branch-to-RCL intersection. This method may also be used for decoupling pipe from flexible equipment if the response of the equipment is known.

- For other decoupled lines, branch piping analysis will include one of the following:
  - The fundamental frequency of the run pipe at the branch location will determined. If this frequency is at or above the ZPA cutoff frequency, the run pipe is considered as rigid and there will be no amplification of the building response spectra. Therefore, the applied inertial excitation at the branch-to-run pipe anchor shall include the envelope of building excitations for the nearest supports on both the branch and run pipes.
  - If the fundamental frequency of the run pipe at the branch location is below the ZPA cutoff frequency, the run pipe at this location is considered to be flexible and therefore may amplify the input inertial effects. Where practical, in these cases, amplified response spectra will be developed from the run pipe analysis and applied at the branch-to-run pipe anchor in the branch pipe analysis.
  - As an alternative to a decoupled analysis, for branch lines connected to flexible run piping where amplified response spectra are not generated, the branch line analysis may include a portion of the run pipe meeting one of the model isolation methods described in Section 5.4.3 in order to capture the possible amplification of inertial input from the run pipe. Therefore, the applied inertial excitation shall include the envelope of building excitations for the nearest supports on both the branch and run pipes. In these cases, the run pipe analysis remains qualified by the decoupled analysis.

RAI EPR-8: *Independent Support Motion Method*

The current staff position for the Independent Support Motion (ISM) method of analysis is presented in Volume 4, Section 2 of NUREG-1061, "Report of the US NRC Piping Review Committee. "Some differences (e.g., modal combinations per RG 1.92 for uniform support motion (USM) only) were noted between the ISM method of response combinations (both methods and their sequence) presented in the TR Section 4.2.2.2.2, and the method given in NUREG-1061. Indicate whether all of the provisions (for groups, modes, spatial and inertial and SAM combination methods) contained in NUREG-1061 for the ISM method of analysis will be followed or provide the technical justification for any alternatives or methods described in the TR.

Response 8:

All of the provisions of NUREG-1061, Volume 4, for using the ISM method of analysis will be followed. The following revisions to the TR will be made for clarification:

Section 4.2.2.2.1, the 2nd paragraph will be revised as follows:

"The combinations of modal responses and spatial components for systems analyzed using USM are performed consistent with the guidance provided in RG 1.92. The modal and directional responses are combined as discussed in Sections ...."

Section 4.2.2.2.2 will be revised to include a reference to NUREG-1061, Volume 4 as follows:

"The combinations of modal responses and spatial components for systems analyzed using ISM are performed consistent with the recommendations in NUREG-1061, Volume 4. Additionally, when using independent support motion, the seismic response of each mode is calculated by combining the responses of all support groups into one by using absolute summation method per the recommendations of NUREG-1061."

Section 4.2.2.3.1, first sentence, will be revised as follows:

"RG 1.92 provides guidance on combining the individual modal results due to each response spectrum in a dynamic analysis performed using USM."

and the following text will be added to the end of this section:

"For piping systems analyzed using ISM methods, modal results are combined without the consideration of closely spaced modes, per NUREG-1061. Therefore, for these systems, modal results are combined by the SRSS method presented above."

Section 4.2.2.3.2, the second sentence of the second paragraph which referred to RG 1.92, will be revised to read as follows:

"Guidance for including the missing mass effects is provided in RG 1.92[16] for USM and NUREG-1061 for ISM."

and the last paragraph will be revised to read:

"For systems analyzed using USM, the rigid range (missing mass) results will be combined with the low frequency modal results in accordance with Regulatory Position C.1.5.1 of RG 1.92. For systems analyzed using ISM, the missing mass results will be combined with the low frequency modal results by SRSS, per NUREG-1061."

See RAI EPR-28(D) for additional discussion on the combination of high frequency modes with low frequency modes.

Section 4.2.2.5 will be revised to read as follows:

"The analysis of these seismic anchor motions (SAM) will be performed as a static analysis with all dynamic supports active. The results of this analysis shall be combined with the piping system seismic inertia analysis results by absolute summation when an enveloped uniform support motion is used for the dynamic analysis, per SRP 3.7.3. When independent support motion is used in the inertial analysis, the responses due to the relative displacements and those due to inertia are combined by the SRSS method, per NUREG-1061."

<u>RAI EPR-9:</u> *Time History Analysis Using Modal Superposition Method*

Since many of the dynamic loads specified in the TR, using the time history method of analysis, may have a short duration and contain very high frequency content, the use of the modal superposition method must consider all modes up to the appropriate cutoff frequency as well as the missing mass contribution. Discuss how the proposed modal superposition method will address these considerations in accordance with RG 1.92, Rev.2.

Response 9:

Missing mass will be accounted for in time history modal superposition analyses in accordance with Appendix A of RG 1.92, Rev. 2.

The TR Section 4.2.3 will be revised to address this RAI as follows:

> "The mode shapes and frequencies are determined as they are in response spectrum analysis. The cutoff frequency for the determination of modal properties is 40 Hz or as defined by figure 2 and 3 in RG 1.92, Rev 2 as this is expected to encompass all of the important response frequencies of the system. Missing mass effects of the high frequency modes beyond the cutoff frequency are included via the Missing Mass Method described in Regulatory Position C.1.4.1 and Appendix A of RG 1.92, Rev. 2."

Also see the revised response to RAI EPR-6.

<u>RAI EPR-10:</u> *Time Step for Time History Analysis*

In a time history analysis, the numerical integration time step, Δt, must be sufficiently small to accurately define the dynamic excitation and to ensure stability and convergence of the solution up to the highest frequency of significance. In TR Section 4.2.3, AREVA indicates that for the most commonly used numerical integration methods, the maximum time step is limited to one-tenth of the shortest period of significance. However, this is typically selected for choosing an initial time step which is later checked against analysis results and their stability and convergence. An <u>acceptable</u> approach for selecting the time step, Δt, is that the Δt used shall be small enough such that the use of ½ of Δt does not change the response by more than 10%. Indicate whether this is part of the analysis requirements for time history method of analysis or provide a technical justification for not considering this criterion along with the criterion for initially choosing the time step described for seismic and other dynamic loading analyses.

Response 10:

AREVA has performed a time step study for the direct integration time history analysis of the RPV isolated model considering seismic loading. This model contains a representation of the RCS piping, components and supports, including the pressurizer and surge line, as well as a representation of the reactor building internal structure. In this study, a representative seismic case was analyzed using two integration time steps: 0.0005 seconds and 0.0025 seconds. Comparison of results (accelerations, displacements and forces) at several locations within the RPV and its internals indicates that the solution has converged (the maximum difference in response was identified as 5.5%). Based on this study, AREVA is confident that a 0.0001 second integration time step would be more than sufficient to achieve convergence. However, recognizing that there are inherent differences between the dynamic characteristics of the RPV isolated model and models of pure piping systems, AREVA will perform time step studies for three of the Class 1 attached piping problems for the U.S. EPR. This represents a sample of greater than 10% of the Class 1 piping problems that AREVA will analyze. The smallest integration time step required for convergence in these sample analyses will be used for all of the Class 1 piping analyses. It is currently not anticipated that time history analysis will be used for Class 2\3 piping, but if it is, the integration time step will be established in the same manner, i.e. through time step studies on a representative sample of Class 2\3 piping problems. The intent of these time step studies is to identify a practical lower bound integration time step that provides adequate assurance of convergence. Convergence will be determined by halving the integration time step until it can be shown that halving it further will not increase the response of the system by more than 10%.

The TR Section 4.2.3 will be revised to replace, “The time step to be used is to be no larger than one tenth (1/10) of the period of the cutoff frequency” with:

> “Time step studies will be performed for three of the Class 1 attached piping problems for the U.S. EPR. The smallest integration time step required for convergence in these sample analyses will be used for all of the Class 1 piping analyses. Convergence will be determined by halving the integration time step until it can be shown that halving it further will not increase the response of the system by more than 10%. If time history analysis of Class 2\3 piping problems is performed, the integration time step will be established in a similar manner, that is, through time step studies on a representative sample of Class 2\3 piping problems.”

RAI EPR-11: *Time History Analysis Uncertainties*

TR Section 4.2.3 states that to account for uncertainties in the structural analysis using the time history method, similar to peak shifting in the response spectrum method of analysis, three separate input time histories with modified time steps will be analyzed. Alternatively, the time histories at the attachment points may be derived considering variations in the concrete stiffness.

A. Describe the detailed procedure for using the peak shifting method that will be used in the time history method of analysis with modified time steps for seismic and other dynamic loadings.

Response 11:

A. The method of accounting for uncertainties in time history analysis will be further described in the TR, as indicated below.

The fifth paragraph of TR Section 4.2.3 will be revised to incorporate the responses to this RAI as follows:

> “To account for uncertainties in the structural analysis for seismic loading, a peak

shifting approach, similar to that described in Section 4.2.2.1.2 for response spectrum analysis, is used. This is accomplished by first converting the seismic time history excitations into response spectra, and then proceeding through the methodology outlined in Section 4.2.2.1.2. Note that shifting of the input excitation peaks is accomplished by adjusting the time step of the time histories which represent the excitations."

Further supporting information for the above revision to the TR is provided below:

(1) The seismic design basis of the U.S. EPR includes twelve different seismic analysis cases (twelve different combinations of soil conditions and seismic control motion); all twelve cases are anchored to a PGA of 0.3g). Therefore, there will be three translational time histories (one in each of the three orthogonal directions) at each anchor point and at each support\restraint in the piping system. AREVA NP intends to analyze each of the twelve seismic cases individually, though enveloping them is a conservative option.

(2) There will be sets of three translational time histories at each terminal point\support\restraint in the piping systems being analyzed. There are two options available regarding how to treat these different sets of time histories that are applicable to the various terminal points\supports\restraints in the piping systems:

i. The time histories at terminal points\supports\restraints can be enveloped by: a) turning them into response spectra, b) developing the enveloping terminal point\support\restraint response spectra, and then c) generating an artificial time history (and resulting response spectra) which envelopes the enveloping terminal point\support\restraint response spectra within the guidance of SRP 3.7.1.

ii. For Class 1 piping systems, the piping system in question can be coupled to the model used to perform reactor coolant loop (RCL) analysis, which has a representation of the reactor building interior structure (RBIS) in it and a representation of the containment building can be added (if necessary because one or more of the supports\restraints are attached to the containment building). The resulting model has one point of excitation (the nuclear island basemat) and therefore only one set of earthquake time histories per seismic case.

(3) Once the peak shifting factors are determined by the procedure described in Section 4.2.2.1.2 of the TR, the time steps of the translational time histories (either the enveloping time histories described in 2(i) above, or the basemat time histories described in 2(ii) above) are reduced, or increased, in order to move the peak input accelerations to the desired frequencies. Note that each orthogonal direction is treated separately. The piping model is then analyzed separately for the resulting time histories (N+3 for each orthogonal direction, see Section 4.2.2.1.2 of the TR). The maximum piping system response (accelerations, displacements and loads in the x, y and z directions) among the global X direction excitations, among the global Y direction excitations, and among the global Z direction excitations are combined at each time point.

RAI EPR-12: *Equivalent Static Load Analysis*

Confirm that the equivalent static load is always determined by multiplying 1.5 to the peak acceleration for all cases including a single degree of freedom system with known fundamental frequency or a rigid system with the fundamental frequency beyond the cutoff frequency. If not, then provide the criterion that will be used for these special cases.

Response 12:

See the revised response to RAI EPR-5.

RAI EPR-13: *Small Bore Piping*

The TR did neither define nor address the design of small bore piping to be used in the EPR piping design. Define the small bore piping to be used in the EPR piping design and discuss, with technical bases, the methods of analysis (handbook or a system flexibility analysis) that will be used in the small bore piping design for ASME Class 1, 2, 3 and QG D piping.

Response 13:

Section 4.5 of the TR will be added to include the following text:

> "Small bore piping (including instrumentation lines) for the U.S. EPR is defined as ASME Class 1 piping that is 1" NPS and smaller and Class 2, 3 and QG D that is 2" NPS and smaller. This piping may be analyzed using response spectrum methods described in 4.2.2 of the Topical Report or the equivalent static method described in 4.2.3."

RAI EPR-14: *Non-Seismic/Seismic Interaction*

B. TR Section 4.4.2 states that following the failure of the non-seismic pipe, (i) if the non-seismic piping is supported by seismic restraints within the ASME B31.1 Code-suggested pipe support spacing shown in TR Table 4-1, it is considered to lose its pressure boundary integrity, but not fall onto a safety-related piping or equipment. Provide the technical basis for this assumption. (ii) the side motion of a failed moderate energy piping is assumed to be ±6 inches (centerline to centerline) from the original position. Provide the technical basis for this assumption of ±6 inches side motion for all pipe sizes. (iii) safety-related piping with NPS and thickness equal to or greater than that of the non-seismic piping may be assumed to stop the downward motion of the non-seismic piping without failure of the safety-related piping. Provide the technical basis for this assumption.

Response 14:

B. (i) The second sentence in the third bullet in Section 4.4.2, Item 1, of the TR will be deleted.

(ii) The first bullet in Section 4.4.2, Item 2, of the TR will be removed.

(iii) The second bullet in Section 4.4.2, Item 2, of the TR will be removed (see attached mark-up).

RAI EPR-15: *Buried Piping*

TR Section 3.10 did not give details on the analysis method and how the criteria are to be applied in the design of buried piping.

A. Based on the criteria presented in the TR, describe the analysis method and design requirements that will be used for buried piping design (including buried pipe tunnel if used in the design). Explain how these methods compare to the analytical methods referenced in the recently published NRC Standard Review Plan 3.7.3, Rev. 3, (i.e., ASCE Standard 4-98, ASCE Report - Seismic Response of Buried Pipes and Structural Components, and NUREG/CR-1161).

B. Why doesn't TR Section 3.10 include consideration of ground-water effects and soil arching effects which could increase or decrease the stresses in the pipe due to the overlying soil plus the ground surface loads?

D. TR Table 3-4 provides the design conditions, load combinations and acceptance criteria for Class 2/3 buried piping. Explain clearly the term non-repeated anchor movement, Equation 9U (vs 9), and Equation 9E (vs 9). While the intent may be interpreted, it is important that these terms be clearly defined in the TR. For Equations 10M and 11M, which are identified as "modified to include axial friction forces," provide the equations to show how they are modified.

F. Confirm that Note 5 in the TR Table is applicable to all cases cited in TR Table 3-4 since it is not referenced in the Table like the other notes are. Also, explain how the criteria of NC/ND-3133 of the ASME Code (Note 5 in the Table) will be implemented in conjunction with meeting the loads and loading conditions specified in Table 3-4.

Response 15:

A. Section 3.10 of the TR will be revised to include analysis methods and design requirements for buried piping, as shown in Attachment B to this response.

The methods developed for the U.S. EPR buried piping meet requirements in SRP 3.7.3, Rev. 3, ASCE Standard 4-98 and ASCE Report-Seismic Response of Buried Pipes and Structural Components.

The last equation given in Section 3.10.1.3 of the TR will be revised as shown in Attachment B. Additionally, Section 3.10.1.1 of the TR will be revised as shown in Attachment B to delete the following sentence:

"The external pressure counteracts the internal pressure, this external pressure is significantly less than the internal pressure and its impact on design is not significant."

Section 3.10.1.1 of the TR will be revised as shown in Attachment B to indicate that, for conservatism, P will be defined as the sum of internal pressure and the absolute sum of P_V and P_P.

The revised Attachment B also includes Tables 3-5 and 3-6 that are referred to in Section 3.10.1.4 of the TR.

Thermal induced stresses, as defined in Reference 13 of the TR includes a term for hoop stress due to internal pressure. Hoop stress acts to reduce the stress due to restrained longitudinal expansion or contraction. Since this term is usually considered small, equations 10M and 11M for thermal expansion and contraction will be revised to remove this term. The allowable stress for 10M is S_a.

Section 3.10.3.1 of the TR was revised as shown in Attachment B to reflect some of the changes made in the more recent ASCE 4-98 standard (e.g., E is the secant modulus, equations given in axial and bending strains include the wave velocity coefficients, etc.).

Equation for S_{OL} in the TR will be revised as shown in Attachment B to include $E_{sct}\varepsilon_a$ and $E_{sct}\varepsilon_{b.}$ Seismic stresses in buried piping are considered secondary stresses. Therefore, the pressure stress (primary) is not included in this equation.

B. Section 3.10 of the TR will be revised as shown in Attachment B to include buoyancy forces from ground-water, overburden, and surface traffic from trucks, rail and construction equipment, as shown in Attachment B to this response.

D. Non-repeated anchor movements, in the case of buried pipe, refers to building settlement at the point where the buried pipe enters the building. Equations 9U and 9E refer to upset and emergency respectively. These designations are used to distinguish the differences in plant events that occur during the upset or emergency plant conditions and must be combined per Equation 9 and meet the allowable stresses as noted in the various section of NC/ND 3650.

The TR will be revised as shown in Attachment B to show equations 10M and 11M and to define the terms in all equations associated with buried pipe.

F. Note 5 will be added to Table 3-4 as appropriate. As shown in Attachment B, the external pressure of the soil overburden defined in NC/ND-3133 will be added to the discussion in 3.10. Note 5 applies to the equations that include a pressure term. The TR will be revised to include this term.

RAI EPR-20: *Piping Benchmark Program*

Final piping and pipe support stress analyses cannot be completed before design certification because their completion is dependent on as-built or as-procured information. Under a piping *benchmark program, the combined operating license (COL) applicant applies his computer program to construct a series of selected piping system mathematical models that are representative of the standard plant piping designs. Please confirm if AREVA has established such a piping benchmark program to be used by the COL applicants and whether its own piping analysis computer code described in Section 5.1 was verified using models representative of the U.S. EPR.*

Response 20:

AREVA will identify three (3) representative calculations from the analyses currently being completed for the U.S. EPR design certification to be used in the benchmark program. These calculations will utilize the piping analysis codes identified in 5.1 of the TR.

The COL applicant will implement this benchmarking program if he chooses to use programs other than those stated in TR 5.1. This requirement is Item 6 of Table 1-1.

Additionally, TR Section 5.3 and item 6 of TR Table 1-1 will be revised to change the term “NRC benchmark program” to “U.S. EPR benchmark program.”

RAI EPR-21: *Model Decoupling Criteria*

TR Section 5.4.2 states that adequate flexibility in the branch line is provided by maintaining a minimum length from the run pipe to the first restraint of ½ of the pipe span in TR Table 4-1 for the branch line. The mass to be considered at the branch connection of the run pipe is the mass of ½ of the first span of the branch pipe, including concentrated weights, in each direction. However, AREVA did not discuss other effects (e.g., moment or torsional load at the branch connection) of the eccentric concentrated masses, such as valves, in the first one-half span length from the main run pipe. Provide technical justification on how to account for the effect of a large concentrated mass near the branch connection in the decoupling criteria discussed in the TR.

Response 21:

TR Section 5.4.2 will be revised to include the following information:

> "Large concentrated masses should not be located within the first span of the branch pipe. If a large valve or other large concentrated mass is located within the first span of the branch piping, the torsional effects of the eccentric mass must be considered. In these cases, the branch piping will be modeled and analyzed with the run pipe, or a portion of the branch line shall be included in the run pipe analysis to adequately include the torsional effects of the eccentric mass."

RAI EPR-22: *Dynamic Analysis of Branch Lines*

TR Section 5.4.2 states that for the SSE inertia load case, each individual run pipe movement shall be analyzed as a separate anchor movement load case on the branch line and combined with its respective load case by absolute summation. Provide additional clarification to explain this procedure.

Response 22:

See the revised response to RAI EPR-7 for changes to TR section 5.4.2.

RAI EPR-25: *Piping Load Combinations*

The staff needs clarification of several items associated with TR Section 3.3 and Tables 3-1 and 3-2.

B. Note 3 to TR Table 3-1 states that dynamic loads are to be combined considering timing and causal relationships. SSE and Design Basis Pipe Break (including loss-of-coolant accident (LOCA)) shall be combined using the square root of the sum of the squares (SRSS) method. This is acceptable in accordance to NUREG-0484, Rev. 1. However, for dynamic responses resulting from the same initiating events (other than SSE), when time-phase relationship between the responses cannot be established, the absolute summation of these dynamic responses should be used. Confirm if this is true for the EPR piping design. If not, discuss with technical justification the combination method to be used when multiple LOCA or other dynamic load events are required to be combined. This combination criterion is also applicable to note 5 of the TR Table 3-2, which states that dynamic loads are combined by the SRSS.

C. Note 8 to TR Table 3-1 states that the earthquake inertial load used in the Level D Primary Stress (Equation 9F) calculations shall be taken as the peak SSE inertial load. The earthquake anchor motion load used in the Level D Primary Stress (Equation 9F) calculations shall be taken as the peak SSE anchor motion load. The staff position on the use of a single-earthquake design in SECY-93-087 states that the effects of anchor displacements in the piping caused by an SSE be considered with the Service Level D limits. For simplified elastic-plastic discontinuity analysis, if Eq. 10 cannot be satisfied for all pairs of load sets, then the alternative analysis per NB-3653.6 for Service Level D should be followed. In addition, the combined moment range for either the resultant thermal expansion and thermal anchor movements plus ½ the SSE seismic anchor motion or the resultant moment due to the full SSE anchor motion alone, whichever is greater must satisfy the equation (known as Eq. 12a) given in NB-3656(b)(4). Clarify if this is applicable to EPR piping design. Also, justify why this anchor motion stress is categorized as a primary stress in the TR Table 3-1 for the faulted condition.

D. Identify the applicability of notes 3 and 5 in the TR Table 3-2.

Response 25:

B. AREVA expects to be able to establish the timing and causal relationships between dynamic events such as pipe rupture and valve actuation. When the causal relationship between two dynamic events can be established, the results from the two events will be combined by SRSS, provided it is demonstrated that the non-exceedance criteria provided in NUREG-0484 is met, or by absolute summation. However, if this relationship cannot be established between two dynamic events, the responses from these events will be combined by absolute sum. Table 3-1 will be revised to clarify this point as shown in Attachment C to this response.

Note 11 of Table 3-1 will be revised as follows:

> "Loads due to dynamic events, other than High Energy Line Break (i.e. Loss-of-Coolant Accident and Secondary Side Pipe Rupture) and SSE, are combined considering the time phasing of the events (i.e. whether the loads are coincident in time). When the time phasing relationship can be established, dynamic loads may be combined by the Square-Root-Sum-of-the-Squares (SRSS) method, provided it is demonstrated that the non-exceedance criteria given in NUREG-0484 is met. When the time phasing relationship cannot be established, or when the non-exceedance criteria given in NUREG-0484 are not met, dynamic loads must be combined by absolute sum. SSE and High Energy Line Break loads are always combined using the SRSS method."

Note 5 of Table 3-2 will be revised to include:

> "When causal relationships can be established, dynamic loads may be combined by the Square-Root-Sum-of-the-Squares (SRSS), provided it is demonstrated that the non-exceedance criteria given in NUREG-0484 is met. When the causal relationship cannot be established , or when the non-exceedance criteria given in NUREG-0484 are not met, dynamic loads must be combined by absolute sum. SSE and High Energy Line Break loads are always combined using the SRSS method."

C. At the time that the Topical Report was written, portions of Section III NB-3600 in the 2004 Edition of the ASME Boiler and Pressure Code were not endorsed by the NRC, per the version of 10CFR50.55a in effect at that time. The proposed draft of 10CFR50.55a which was published in spring of 2007 indicates that restrictions on the use of the rules involving seismic loading have been removed. AREVA will therefore reference the equations from NB-3656(b)(4) for the treatment of SSE anchor motions. Table 3-1 has been revised for this reason and to provide further clarification of the Class 1 load combinations.

Table 3-1 will also be revised to include the following:

- In the upset loading condition for primary plus secondary stress intensity range (equations 10 and 11), the loads will include the SSE.
- If equation 10 cannot be satisfied for all pairs of load sets, then the alternative analysis as described in NB-3653.6 will be followed. In addition, the following condition shall be satisfied:

$S_{sam} = (C_2 D_o/2I)(M_{AM}) \leq 6S_m$

Where M_{AM} is the combined moment range for either the resultant thermal expansion and thermal anchor movements plus ½ the SSE seismic anchor motion or the resultant moment due to the full SSE anchor motion alone, whichever is greater.

D. Note 3 applies to the "Design" loading condition and Equation 8. Note 5 applies to Equations 9E and 9F. The TR will be revised to clearly identify the applicability of these notes.

<u>RAI EPR-26:</u> *Piping Damping Values*

In TR Section 4.2.5, it is identified that Rev. 0 of the RG 1.61 values of damping will be used in the seismic analysis of structures, systems, and components (SSCs) using ISM response spectrum analysis or time history analysis. However, for piping systems analyzed using USM response spectrum analysis, 5% damping will be used provided that the system is not susceptible to stress corrosion cracking. Five percent damping will not be used for analyzing the dynamic response of piping systems using supports designed to dissipate energy by yielding.

A. Since staff has issued the Rev.1 of RG 1.61 in March 2007, indicate if the design of EPR piping systems will use Rev. 1 of the RG-recommended damping values.

B. For piping systems analyzed using uniform support motion response spectrum analysis and 5% damping, verify that all of the limitations specified in RG 1.84 for ASME Code Case N-411 (or RG 1.61, Rev.1) will be met.

Response 26:

A. TR Section 4.2.5 will be revised to state:

> "RG 1.61, Rev. 1 damping values will be used for Independent Support Motion response spectra and Time-History analysis. RG 1.61, Rev. 1 will also be used for piping systems analyzed using uniform support motion response spectra which do not meet all of the limitations specified in RG 1.84 for ASME Code Case N-411."

B. TR Section 4.2.5 will be revised to state:

> "5 percent damping is used for piping that is analyzed using the uniform support motion response spectrum method. Piping that is analyzed using this method meets the limitations specified in RG 1.84 for ASME Code Case N-411."

AREVA NP recognizes that the damping value for piping in RG 1.61, Rev. 1 is limited to 4 percent. Accordingly, in the U.S. EPR design certification application, AREVA NP will identify the use of 5 percent damping for piping analyzed using the uniform support motion response spectrum method as an exception to RG 1.61, Rev. 1. The basis for this exception is provided below.

Regulatory precedent exists for using 5 percent damping for piping for advanced light-water reactors (ALWRs). Specifically, NRC has approved the use of 5 percent damping for System 80+, AP600, and AP1000. Further justification for the use of 5 percent damping for piping analyzed using the uniform support motion response spectrum method is provided below.

In AP1000 RAI No. 210.040 dated September 30, 2002, NRC requested the following information:

> "Section 3.7.3.15: Westinghouse should verify that all limitations specified in RG 1.84 for Code Case N-411 apply to the use of 5 percent damping."

The above RAI is almost identical to RAI EPR-26, item B above. In response to AP1000 RAI No.210.040[1], Westinghouse agreed to apply the limitations specified in RG 1.84 for Code Case N-411 for piping where the use of 5 percent damping is utilized. Subsequently, in the AP1000 Final Safety Evaluation Report (FSER)[2], NRC states:

> "The staff had reviewed and accepted for the AP600 the use of 5-percent damping for piping systems for ALWR plants on the basis that ALWR plants must be designed to a minimum 0.3 ZPA for the SSE. This high seismic acceleration provides assurance that piping systems will experience higher damping valves. Its acceptance was also subject to certain limitations specified in RG 1.84 for ASME Code Case N-411-1. The limitations applicable to design include (1) limiting the building filtered responses to 33 Hz and below, (2) using damping values only in those analyses in which current seismic spectra are used, (3) not allowing the use of damping values when using supports to dissipate energy by yielding, and (4) not allowing their use where stress-corrosion cracking is a concern. In RAI 210.040, the staff requested the applicant to verify that these limitations will apply to AP1000 piping. The applicant's response confirmed the staff's assumptions. The applicant stated that the 5-percent damping value will be used consistently for all piping system seismic analyses utilizing enveloped response spectrum methods. The enveloped response spectra are developed in accordance with RG 1.122, as described in the DCD. The design of the AP1000 piping systems does not include supports designed to dissipate energy by yielding, and the piping systems analyzed are not susceptible to stress-corrosion cracking. The staff concurs that these limitations conform to the RG 1.84 limitations."

Similarly, in the System 80+ FSER[3], NRC states:

> "ABB-CE proposed revisions to DCD Section 3.7.1.3, Figure 3.7-32, Table 3.7-1,

---

1 See Westinghouse letter AW-021557 dated October 2, 2002 (accession numbers ML022810020 and ML022810434).

2 See NUREG-1793 dated September 2004.

3 See NUREG-1462 Supplement 1, Section 3.12.5.4, dated May 1997.

and Appendix 3.9A. These revisions changed the maximum allowable damping value for piping analyzed using the uniform envelope response spectrum method from the ASME Code Case N-411-1 values to a 5% value for all modes of vibration. The revised Table 3.7-I contains a footnote stating that when the 5% value is used for such piping, the conditions in RG 1.84 for using CC N-411-1 will apply even though Code Case N-411-1 is not being used. Piping analyzed using either the time history or independent support method will use the appropriate values in Table 3.7-1."

"In section 3.12.5.4 of the FSER, the NRC staff reported that as an alternative to the RG 1.61 damping values, which are in Table 3.7-1, variable damping values in accordance with the requirements and limitations of the ASME Code Case N-411-1 may be used, subject to the conditions given in RG 1.84 relative to the use of Code Case N-411-1. In its evaluation of the above changes, the NRC staff considered the following inherent conservatisms implicit in the overall DCD criteria:

1. Implementation of the conditions specified in RG 1.84 will generally result in a conservative design.
2. The use of the uniform 5% value could result in a small under-prediction of support loads and piping deflection at higher frequencies. However, because the DCD (and other ALWR) seismic criteria are (1) based on ground response spectra as defined in RG 1.60 that are enhanced in the high frequency range (approximately 8-40 Hz), and (2) anchored at a relatively high peak ground acceleration value of 0.3g, the NRC staff finds that the use of the uniform 5% damping is acceptable only for use on ALWRs."

"On the basis of the above evaluation, the staff has concluded that use of the uniform 5% damping value when implemented with the seismic and piping design Criteria in the DCD will provide piping designs with margins which are consistent with those of designs using Code Case N-411-1, as limited by RG 1.84, and is therefore acceptable."

Reg. 1.84, Table 4, "Annulled Conditionally Acceptable Section III Code Cases," contains the Code Cases "that the NRC determined to be acceptable provided that they were used with the identified limitations or modifications, but that the ASME subsequently annulled." Table 4 indicates that Code Case N-411 was annulled on May 5, 2000. However, as noted in the quoted RAI and FSER for AP1000 (both of which were issued after Code Case N-411 was annulled), NRC has determined that the limitations specified in RG 1.84 for Code Case N-411 are still acceptable for the use of 5 percent damping.

During a conference call between AREVA NP and the NRC on October 4, 2007, representatives from Brookhaven National Laboratory (BNL) stated that: 1) the approval for 5 percent damping for AP1000 was case specific; and 2) AREVA NP needed to provide technical justification to utilize the 5 percent damping value. AREVA NP's response to these statements is provided below:

1) BNL's statement that the 5 percent damping was a case specific approval is based on a similar statement in NUREG/CR-6919 (BNL-NUREG-77174-2006), "Recommendations for Revision of Seismic Damping Values in Regulatory Guide 1.61," dated November 2006, prepared by BNL. Specifically, Section 4.2 of NUREG/CR-6919 states:

> "The NRC previously accepted ASME Code Case N411-1 damping (Ref. 9), with qualifications in accordance with Regulatory Guide 1.84 (Ref. 10). At the time the qualifications were initially specified, the NRC had intended to conduct studies aimed at evaluating the validity of these qualifications, and as appropriate, remove some of the restrictions on N411 damping. However, the required studies were not conducted.
>
> ASME has annulled Code Case N411-1, because Non-Mandatory Appendix N to Section III currently recommends 5% damping at all frequencies, for both OBE and SSE (Ref. 4). The staff had previously accepted 5% SSE damping for AP1000, for uniform support motion, response spectrum analysis of piping systems (Ref. 16). The staff invoked restrictions on its use, consistent with the qualifications formerly in Regulatory Guide 1.84 for Code Case N411-1.
>
> The staff continues to accept former Code Case N411-1 damping subject to the restrictions identified in Regulatory Guide 1.84. The staff considers acceptance of 5% damping for AP1000 to be a case-specific determination."

AREVA NP contends that the NRC acceptance for damping is not a "case-specific determination." As previously noted, NRC has approved the use of 5 percent damping for other ALWRs besides AP1000 (i.e., System 80+ and AP600). The stated basis for these determinations was the high seismic demand level required for ALWRs. As quoted in the NRC FSER for AP1000, NRC approved the "use of 5-percent damping for piping systems for ALWR plants on the basis that ALWR plants must be designed to a minimum 0.3 ZPA for the SSE." Similarly, as quoted in the System 80+ FSER, "because the DCD (and other ALWR) seismic criteria are (1) based on ground response spectra as defined in RG 1.60 . . . the NRC staff finds that the use of the uniform 5% damping is acceptable only for use on ALWRs." The seismic demand for the U.S. EPR piping meets or exceeds the seismic demand that NRC considered for AP600 and AP1000 in making this determination. If NRC still believes that use of 5 percent damping is a case specific determination, then AREVA NP requests that a similar determination be made for the U.S. EPR based on the same justification that NRC approved for the other ALWRs.

2) AREVA NP contends that no further technical justification is needed to support the 5 percent damping for piping analyzed using the uniform support motion response spectrum method. As previously noted, RAI EPR-26 is almost identical to AP1000 RAI No. 210.040. Similar to the AP1000 RAI response, which NRC accepted, AREVA NP has agreed to revise the TR to meet the limitations specified in RG 1.84 for ASME Code Case N-411. This justification was also

accepted by the NRC for the System 80+ and AP600. Also, Regulatory Position 2 in Section C of RG 1.61, Rev.1 provides the piping damping values that resulted from the NRC experience with ASME Code Case N–411 and application reviews of new reactor designs. Therefore, no further justification is required for the utilization of the 5 percent damping for piping analyzed using the uniform support motion response spectrum method.

RAI EPR-27: *Modal Combinations*

In TR Section 4.2.2.3.1, it is stated that for the response spectrum method of analysis, the modal contributions to the inertial responses are normally combined by the SRSS method. If some or all of the modes are closely spaced, any one of the methods (Grouping method, 10% method, and Double Sum method, as well as the less conservative methods in revision 2 of the RG 1.92) is applicable for the combination of modal responses. This combination method is applicable to both USM and ISM methods of analysis.

A. If guidance given in Revision 2 of the RG 1.92 is used for the EPR piping design, then Revision 2 of the RG no longer recognizes the Grouping method, 10% method and Double Sum method for closely spaced modes. These methods are renamed and AREVA should identify them as noted in the RG.

B. TR states that for closely spaced modes AREVA may use less conservative methods discussed in the RG. Please identify which methods are less conservative methods and explain why they are less conservative with respect to the other method(s).

Response 27:

A. In the Background discussion of Section B as well as in the Regulatory Position in Section C of RG 1.92 Revision 2, the methods of Revision 1 are included by reference as remaining acceptable for use. AREVA will add Revision 1 of RG 1.92 to the references since the detail for these methods are not provided in Revision 2.

During a conference call between AREVA NP and the NRC on October 4, 2007, NRC stated that the use of the RG 1.92 Rev. 1 methods for modal combination require that the lower damping values from RG 1.61 Rev. 0 also be used. This would limit the damping to 2 percent or 3 percent, depending on pipe size. NRC further stated that the methods described in these RGs are complementary (i.e., they are to be considered as a set in that one cannot choose to use previously approved methods in one and newer methods in another).

AREVA NP is not aware of any documented basis or indication that the increased damping values presented in Regulatory Guide 1.61 Revision 1 may only be used with the modal combination methods presented in Revision 2 of Regulatory Guide 1.92, or that revisions to these Regulatory Guides must be used as a set. In presenting the damping values to be used in the seismic design of nuclear power plant SSCs, RG 1.61 Revision 1 does not state any limitation of use based on the combination of modal responses. Furthermore, neither of the revised RGs makes reference to the other to indicate any relationship in the use of the methods in one being based on the use of the other.

Revised RGs 1.92 and 1.61 provide more accurate and realistic response in the dynamic analysis of nuclear power plant structures, systems, and components (SSCs) while reducing unnecessary conservatism included in the previous revisions.

RG 1.92, Rev. 2, was issued July 2006 and provides new methods for the combination of modal results when performing response spectrum analyses. These new methods introduce refined methods for the combination of out-of-phase responses of closely spaced modes. In the Rev. 2 methods, the combination of these responses includes a definition for closely spaced modes and a phase correlation coefficient which are dependent on the damping ratio. While this revision specifically states the allowance of the Revision 1 methods, it does not impose any damping value limits.

Revision 1 of RG 1.61 was issued in March 2007 and provides increased damping values for piping analysis. Additionally, Rev. 1 incorporates the acceptance of frequency-dependent damping which had previously been accepted as ASME Code Case N-411, along with the conditional restrictions on its use from RG 1.84. At the time of issuance of this revision to the Regulatory Guide, all methods of modal combination from Revisions 1 and 2 of RG 1.92 were considered acceptable and there is no mention of the use of the damping values being restricted to the Revision 2 modal combination methods.

NRC also referred to NUREG/CR-6645 to support their position that when the more conservative modal combination methods approved in Revision 1 of RG 1.92 are used in the pipe stress analysis, the more conservative damping values presented in Revision 0 of RG 1.61 must also be used. This NUREG/CR was prepared by BNL to re-evaluate the regulatory guidance for combining modal responses in response spectrum analysis and recommend revisions to RG 1.92.

NUREG/CR-6645 presents a comparison of results of numerous response spectra analysis (RSA) techniques versus a time history analysis which is considered to represent the most accurate analytical response. Review of the results presented show that the methods included in Revision 2 of RG 1.92 (Rosenblueth Double Sum Combination (DSC) and Der Kiureghian Complete Quadratic Combination (CQC)) produce overall more accurate results (a smaller standard deviation) than the methods in Revision 1 of RG 1.92 (the NRC Grouping, NRC Ten Percent and NRC Double-Sum methods). However, NUREG/CR-6645 shows that the methods from Revision 1 of RG 1.92 are more conservative even when considering 5% damping (Tables 3-16 and 3-17). Additionally, when looking only at the Revision 1 methods, more conservatism is noticed in the 5% damping solutions compared to the applicable time history results than in the same analyses considering 1% damping (Tables 3-14 and 3-15). On page 27 of NUREG/CR-6645, BNL makes the following statement: "The overall level of conservatism for RSA methods is higher at 5% damping than at 1%; however, the scatter is also significantly larger. The NRC methods and SRSS exhibit the largest increases in conservatism and scatter."

In conclusion, AREVA NP contends that there is no documented or technical basis or precedence to treat the revisions to RG 1.61 and RG 1.92 as a set. A review of NUREG/CR-6645 affirms that the use of the increased damping values discussed within this document with the modal combination methods of RG 1.92 Revision 1 will produce an acceptable, conservative, result as compared to the use of the Revision 2 methods. Therefore, based on this review, the use of the methods of RG 1.92 Revision 1 remain acceptable for use, as stated in the regulatory position in Revision 2, without additional damping restrictions.

B. See the response to item A above.

<u>RAI EPR-28:</u> *Missing Mass*

TR Section 4.2.2.3.2 presents a procedure to account for high-frequency modes in the response spectrum methods for calculating seismic and other dynamic load responses.

A. Discuss the differences in the mathematical derivations of the high frequency modes presented in the TR versus the methods acceptable to the staff as given in RG 1.92, Rev. 2.

B. The TR states that the response from high frequency modes will be included in the response of the piping system if it results in an increase in the dynamic results of more than 10%. However, in accordance with RG 1.92, Rev.2, C.1.4.1, this criterion may yield non-conservative results and should not be used. Since this guideline does not consider the total mass that is missing, which, in the limit, could be 10%, provide technical justification for using this criteria as a screening requirement for including the effects of any missing mass.

D. Finally, the TR states that this missing mass mode is considered to have a modal frequency and acceleration equal to the cut-off frequency used in the modal analysis. These modal results are combined with the low frequency modal results using the methods described in TR Section 4.2.2.3.1 for the low frequency modes (per RG 1.92). Please explain the combination method for the results to be used from both low and high frequency modes.

Response 28:

A. The method detailed in the TR is based on the Left-Out-Force method. This method is performed by the SUPERPIPE piping analysis code which has been accepted for use at many operating plants. Although this method is different than that shown in RG 1.92, it produces the same result. The basic difference in the presentations of the missing mass calculation as shown in RG 1.92 and as shown in the TR is that the RG equations are written for each modal degree-of-freedom while the TR equations are written in vector form. Re-writing the SRP equations in vector form shows that the formulations are equivalent.

BWSPAN uses the missing mass method given in Appendix A of RG 1.92, R2. TR Section 2.2.3.2 will be revised to state that BWSPAN uses the missing mass method outlined in Appendix A of RG 1.92 Revision 2.

B. The residual rigid response of the missing mass modes will be included in all seismic analyses of safety related piping systems. Section 4.2.2.3.2 will be revised to remove the option of using the 10% criteria. Additionally, references to Appendix A of SRP 3.7.2 with regards to the calculation of missing mass were removed when the 10% criteria mentioned above was removed.

D. The TR will be revised to state that, for USM, the rigid range (missing mass) results will be combined with the low frequency modal results in accordance with Regulatory Position C.1.5.1 of RG 1.92, Rev. 2. For systems analyzed using ISM, the missing mass results will be combined with the low frequency modal results by SRSS, per NUREG-1061. See RAI EPR-8 for revised text for TR Section 4.2.2.3.2.

When using the modal combination methods of Rev. 1 of RG 1.92, Combination Method A provided in Rev. 2 of RG 1.92 Section C.1.5.1 is applied. In these cases, the rigid modal response component of the low frequency modes is equal to zero, and the method reduces to the SRSS combination of the low frequency modal results and the high frequency missing mass results.

RAI EPR-29: *Nonlinear Vibrations Due to Support Gaps*

The TR does not provide an analytical method to account for nonlinear effects of excessively large gaps (for frame type supports) between the pipe and supports subject to high frequency vibration loads. Should such large gaps exist, provide the piping analysis method to be used to address the nonlinearity when subjected to vibratory loads with significant high-frequency caused by the gaps between the pipe and its supports.

Response 29:

As stated in TR Section 6.5, and further discussed in Section 6.11, the U.S. EPR design does not intend to utilize gapped supports. For the U.S. EPR, the normal design practice for frame structure guide supports is to utilize a nominal 1/16“ gap between the surface of the pipe and the edge of the support member for both sides of the pipe in the restrained direction.

Section 6.5 will be revised to add the following text:

> ” Although the use of gapped supports is not anticipated for the U.S. EPR, should the need for such supports arise, the non-linear piping analysis problem will be solved using direct integration time history methods.”

RAI EPR-30: *Thermal Stratification*

A. *TR Section 3.7.1 states that the main feedwater nozzle is located in the conical section of the steam generator which aids in reducing thermal stratification. Please explain how this reduces thermal stratification.*

B. *TR Section 3.7.2 states that the surge line may not be subjected to significant stratification/striping effects due to design features that mitigate these effects. Describe these design features and explain how they mitigate the effects of thermal stratification in the surge line.*

Response 30:

A. Since the main feedwater nozzle is attached to the sloped conical section of the steam generator, it too is inclined: ~18 degrees from the horizontal. This incline promotes mixing of the colder and hotter fluid layers in the line which in turn retards stratification. The inclined design also prevents permanent thermal stratification at low flow rates and ensures run-full conditions in the nozzle. Additional information on thermal stratification is provided in Section 3.12 of the design certification application.

B. There are three major features of the surge line which minimize the amount of stratification in the line: 1) The take-off from the hot leg is vertical upward and of sufficient length that turbulent penetration from hot leg flow does not spill over into the surge line beyond the take-off, and thus causing stratification; 2) the surge line is sloped ~5 degrees between the vertical take-off at the hot leg and the vertical leg at the pressurizer, which promotes contributes to mixing of the colder and hotter fluid layers in the line; and 3) during normal operation, a continuous bypass spray flow of sufficient magnitude is maintained to further suppress turbulent penetration from the hot leg flow. Additional information on the evaluation of unisolable piping for thermal stratification due to a leaking valve (NRC Bulletin 88-08) is provided in TR Section 3.7.3 and will be provided in Section 3.12 of the design certification application.

RAI EPR-33: *Codes for Support Design*

B. *AREVA also states that seismic Category II pipe supports are designed to ANSI/AISC N690, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities." These standards are used to design the structures or structural elements of a support for nuclear facilities, not the standard component supports (e.g., clamps, snubbers). ASME Code Subsection NF is typically used for seismic Category II pipe supports. Identify the standard that will be used to design, manufacture, install and test seismic Category II pipe supports.*

Response 33:

B. For all Seismic Category II pipe supports other than standard component supports, the design, manufacturing, installation and testing will meet the requirements of ANSI/AISC N690. Standard component supports will be designed, manufactured, installed and tested to Subsection NF of the ASME Code. Any structural members used as part of a pipe support also containing standard components will be designed, manufactured, installed and tested to ANSI/AISC N690. The reference to ANSI/AISC N690 in the TR will be revised to include Supplement 2 (2004), in accordance with SRP Sections 3.8.3 and 3.8.4.

RAI EPR-34: *Load Combination for Supports*

While reviewing TR Section 6.3, the staff needs clarification of the following items.

A. TR Section 6.3.11 provided a minimum design load criteria that will be used for all supports so that uniformity is obtained in the load carrying capability of the supports. All supports will be designed for the largest of the following three loads: 100% of the Level A condition load, the weight of a standard ASME B31.1 span of water filled, schedule 80 pipe, and minimum value of 150 pounds. Provide the technical basis for this criteria.

B. TR Table 6-1 provides the specific load combinations that will be used in the design of pipe supports. The acceptance criteria associated with the Service Levels will be per ASME Code, Subsection NF, ANSI/AISC N690 or the AISC Manual of Steel Construction, as appropriate. Note 1 to the Table states that operating basis earthquake (OBE) inertia and SAM loads are not included in the design of Class 2/3 piping. Explain how the seismic inertia and SAM loads are accounted for in the design of Class 2/3 pipe supports. Also, clarify how the same table is applicable to snubbers, struts, and anchors/guides.

C. AREVA discusses wind/tornado loads in TR Sections 6.3.5 and 6.3.6 for pipe supports. However, for the piping in TR Section 3.3.1.6, AREVA identified these loads to be COL-Action Item 3. Clarify AREVA's position on this.

Additionally, in Reference 4, NRC also requested the following information:

1. *Explain why the friction load F is not included in the load combinations that contain wind or tornado since these two loads may not always act as dynamic type loadings.*

2. *For piping design and pipe support design why isn't RSOT considered in other load combinations (i.e., in combination with RDBPB, RMS/FWPB, LOCA, RDBPB+SSE, RMS/FWPB+SSE, and LOCA+SSE)?*

Response 34:

A. The Minimum Design Load criteria given in this section is based on criteria given in Welding Research Council (WRC) Bulletin 353, Section 2.4.7. The bulletin recommends 125% of the Level A condition load, as the only difference from the topical's criteria. Presently, for the analyses being performed as part of the design certification process, the guidance is to apply a 25 percent increase to all pipe support loads to allow for possible future increases in support loads beyond the initial design. TR section 6.3.11 will be revised to change the criteria to use 125% of Level A loading, versus 100%. This is consistent with WRC Bulletin 353.

B. Table 6-1 includes three Faulted load combinations which contain SSE loads. In addition, Note 3 of the table states that SSE includes inertia and SAM loads combined by absolute sum. These would all apply to Class 1, 2 &3 pipe supports. In addition, struts and anchors/guides will be analyzed to all load combinations shown in the table. Snubbers will be designed to all but the Normal Level load combinations shown in the table.

Note that Class 1 was inadvertently not included in Note 1 of Table 6-1. This will be corrected in the next revision of the TR. Note 1 will be revised to state, “OBE inertia and SAM loads are not included in the design of Class 1, 2 & 3 piping.”

The terms in Table 6-1 are defined in 6.3.1 through 6.3.10, as discussed in 6.3. TR sections 6.3.5 and 6.3.6 will be revised to indicate that snubbers are active in the dynamic case noted, and inactive in the static case.

C. Section 3.3.1.6 states that for design certification, no Class 1, 2 and 3 piping is exposed to wind and tornado loads, and further states that if a COL Applicant creates such an exposed piping condition, it will be addressed at that time. Sections 6.3.5 and 6.3.6 discuss the inclusion of such wind related loads for pipe supports.

AREVA’s position on wind loadings for both piping and supports is as stated in Section 3.3.1.6. Clarification will be added to Sections 6.3.5 and 6.3.6 to cross reference this section, and state that these sections show how such loads would be treated if the need arises.

Responses to the additional information for this RAI in Reference 4 is provided below:

C.1 Per WRC Bulletin 353, “Forces due to friction of the piping on the support shall be considered under combined deadweight and thermal loading only.” Therefore, friction will not be considered with even the static analysis cases of wind and tornado.

C.2 Table 6-1 of the TR will be revised to include the effects of system operating transients (R_{SOT}) with pipe break, LOCA, and SSE loads, both in the Level C and the Level D cases. In addition, the following note will be added to the table:

"Loads due to dynamic events are combined considering the time phasing of the events (i.e. whether the loads are coincident in time). When the time phasing relationship can be established, dynamic loads may be combined by the Square-Root-Sum-of-the-Squares (SRSS) method, provided it is demonstrated that the non-exceedance criteria given in NUREG-0484 is met. When the time phasing relationship cannot be established, or when the non-exceedance criteria in NUREG-0484 is not met, dynamic loads are combined by absolute sum. SSE and High Energy Line Break (i.e. Loss-Of-Coolant-Accident and Secondary Side Pipe Rupture) loads are always combined using the SRSS method."

Note that any steady state effects from the system operating transients will be added to the combinations. Note also that the piping load combination tables 3-1 and 3-2 already have these loadings combined.

RAI EPR-36: *Support Stiffness*

AREVA does not adequately describe in TR Section 6.7 how the representative stiffness values are developed for all supports other than snubbers. Describe:

1. *the approach used to develop the representative stiffness values,*

2. *the procedure that will be imposed to ensure that the final designed supports match the stiffness values assumed in the piping analysis,*

3. *the procedure used to consider the mass (along with the support stiffness) if the pipe support is not dynamically rigid, and*

4. *the same information [(1), (2), and (3) above] for the building steel/structure (i.e., beyond the NF jurisdictional boundary) and for equipment to which the piping may be connected to.*

Response 36:

The initial piping analyses will assume all supports rigid (except for the few cases where the actual support structures are included in the piping model), and therefore utilize the default rigid support stiffness values contained in the analysis program. In addition, the initial pipe support designs will be developed to create a rigid support, based on the deflection check criteria given in Section 6.7 of the topical. If for some reason, a rigid support cannot be achieved, an actual support stiffness will need to be developed for the support noted, as well as for the other supports in the model. WRC Bulletin 353 discusses the use of deflection checks to determine stiffness of supports. It discusses the use of a 1/16 inch deflection for Level B checks, with no more than a maximum of 1/4 inch, for typical piping systems in the range of 3 to 9 Hz frequency. The deflection check criteria used in the TR has been used in other plants and falls within the bounds of the criteria of this document.

Typically, unless the support is a very simple structure, a frame support will be modeled using an analysis program such as GT STRUDL. This model will include the self-weight of the support, and will also be used to establish the deflections needed for the stiffness checks. Note that this model will include any flexible building steel, as applicable. If the deflection checks do not show rigidity, the model can be used to determine the actual stiffness of the support structure using the self-weight load case. In addition, the support mass can be determined from the model. This would be created for the supports in the model and provided to the piping analyst. At this point, the supports would need to be rechecked for the loads from the revised piping analysis. If any support changes were required, an iteration of the process would be required to assure that the stiffnesses and masses are consistent for both the support qualifications and the piping analysis. Information on GT STRUDL will be added to TR Section 5.1.

RAI EPR-37: *Inclusion of Support Self-Weight Excitation*

In TR Section 6.8, AREVA did not indicate if the criteria presented is also applicable to other dynamic loads and did not discuss how the damping value will be used in the response spectrum analysis.

A. Clarify whether the criterion presented in the TR is also applicable to other dynamic loads. If not, provide technical justification.

B. Since the piping and support structure damping value may be different per RG 1.61, discuss what damping value will be used in the response spectrum analysis when the support structure is also modeled as part of the piping analysis. See also RAI EPR-32.

Response 37:

A. The support structure itself will be excited by SSE dynamic inputs, as the SSE event is applicable to the whole site in the form of ground motion. As such, the excitation for the support's attachment to the building will be applied to the self-weight of the structure in the form of response spectra g values. For other fluid dynamic transient events within the piping system, forces from the fluid moving along the pipe are included in the pipe support loads for that event, but any subsequent excitation of the support structure itself for the fluid dynamic event will not be evaluated, as the forcing function at each support beyond applied piping loads will be minimal, and not usually defined. This is standard practice in pipe support design. The supports are typically not modeled with the piping. Per the revised response to comment B below, Section 6.8 of the TR will be revised to reference Rev. 1 of RG 1.61.

B. In most cases, Revision 1 of RG 1.61 calls for 4 percent damping for the piping analysis. Similarly, the RG allows for 4 percent damping for welded steel or bolted steel with friction connections and 7 percent for bolted steel with bearing connections, which would be applicable for the supports. If frequency dependent damping values are used in the piping analysis, the support structure will still utilize the 4 percent or 7 percent damping values.

In those analyses where the support\restraint stiffnesses are explicitly represented in the analysis model and where the support damping is judged to be different than the piping damping, one of two approaches may be taken: 1) the lower of the support\restraint and piping damping may be applied to both support\restraints and piping, or 2) composite modal damping (as described in AREVA response to RAI EPR-32) may be used.

3.10 *Seismic Category I Buried Pipe*

Class 2 and 3 Seismic Category I buried piping systems in the U.S. EPR will be analyzed for pressure, weight, thermal expansion and seismic loads using dynamic or equivalent static load methods. The acceptance criteria for buried piping systems are described in Table 3-4.

3.10.1 *Static Loads and Load Combinations for Buried Pipe*

Loads and Loading Conditions are similar to those outlined in 3.3 but are modified for additional considerations of strains and stresses induced by the motion of the pipe in the surrounding soil mass. Thermal loads are impacted by the friction between the pipe and soil due to expansion and contraction of the pipe.

3.10.1.1 *Pressure*

Internal design pressure, P, is calculated as described in 3.3.1.1. However, there is an external pressure, P_V, for buried pipe associated with the overburden of soil and P_P for loads from surface loads. The allowable external pressure is calculated using the methods and formula in NC/ND-3133.

3.10.1.2 *Deadweight*

For buried pipe, deadweight loads must include the weight of the soil overburden. It must also include live loads from surface traffic such as trucks, rail and construction equipment.

3.10.1.3 *Soil Overburden*

Soil overburden pressure is dependent on the diameter of buried pipe as well as the burial depth relative to the ground water table. Buried pipes are designed for soil load corresponding to weight of the overlying soil prism.

$P_v = \gamma H$. This equation applies to pipes buried above the groundwater table.

Where P_v = overburden pressure on pipe due to soil

γ = unit weight of backfill material

H = burial depth

In the case where the pipe is located below ground water table or where seasonal change in ground water table is significant, the effect of buoyancy and increased weight of water should be considered. For such condition, soil pressure should be computed as follows:

$$P_v = \gamma H - 0.33\gamma h + \gamma_w h$$

Where h = depth of groundwater above pipe

γ_w = unit weight of water

3.10.1.4 *Surface Loads*

Live loads such as those imposed by trucks, rail, and construction equipment or other construction conditions should be considered in the analysis and design. The pressure transmitted to the buried pipe under these loads may be computed as follows:

$$P_p = 0.48 \frac{P_s}{H^2\left[1+\left(\frac{d}{H}\right)^2\right]^{2.5}}$$

Where P_p = surface load transmitted to the buried pipe

d = offset distance from the surface load to buried pipe

H = thickness of soil cover above the pipe

P_s = concentrated surface load

The magnitude of P_p above is multiplied by an impact factor which is dependent on the soil cover and type of surface load. Table 3-5 [13] shows some recommended values of impact factors.

The magnitude of P_p may be taken from Table 3-6 which is based on AASHTO HS-20 Truck and Copper E-80 railroad loads [13]. The values reported in Table 3-6 include an impact factor of 1.50.

COL applicants should perform detailed geotechnical engineering analysis to determine if the surface load will cause lateral and/or vertical displacement of bearing soil for the piping. Consideration should also be given to the effect of wide and extra heavy loads when evaluating the buried utility.

3.10.1.5 *Bouyancy Force*

For utilities buried below groundwater table, vertical force due to buoyancy should be considered and may be evaluated as follows:

$$F_b = W_w - W_p - P_v D + \gamma_w h_w D$$

The above equation conservatively assumes that the pipe is empty.

Where F_b = buoyancy force per unit length of pipe

D = external diameter of the pipe

P_v = γH = overburden pressure due to soil

W_w = weight of water displaced by pipe per unit length

W_p = self weight of pipe per unit length

The corresponding buoyancy stress on the utility may be computed as follows:

$$\sigma_b = \frac{F_b L^2}{10Z}$$

Where L = length of the utility in the buoyancy zone

Z = section modulus of the utility

The effects of pressure (P, P_P, P_V), dead and live loads must meet the requirements of Table 3-4 as follows for Equation 8:

$$S_{SL} = \frac{B_1 P D_O}{2t_n} + \frac{B_2 M_A}{Z} + \frac{F_b L^2}{10Z} \le 1.5 S_h$$

Where S_{SL} = Stress from sustained loads

P = Internal pressure + ABS Sum (P_P +P_V)

B_1, B_2 = Stress indices

D_O = Pipe outside diameter

t_n = Pipe nominal wall thickness

M_A = Moment due to weight

S_h = Allowable stress (hot)

3.10.2 *Thermal Expansion and Contraction*

Depending on the relative temperature of the soil in which the pipe is buried and the temperature of the fluid contained in the pipe, a pipe that is fully restrained by the surrounding soil may experience contraction or expansion. This thermal-induced stress (due to friction between the pipe and soil) should be considered and may be evaluated as follows:

$$\sigma_A = E\alpha(T_2 - T_1)$$

Where σ_A = axial compressive stress in fully restrained pipe due to difference in temperature between soil and pipe content.

E = modulus of elasticity of the pipe material

α = coefficient of thermal expansion of the pipe

T_2 = maximum operating temperature of fluid in the pipe

T_1 = burial installation temperature

The effects of restrained thermal expansion/contraction forces in buried pipe are evaluated against the requirements of NC/ND-3653.2(a) by using a modified Equation 10 or NC/ND-3653.2(c) by using a modified Equation 11. From Reference 2, the equations are as follows:

$$S_E = \frac{iM_C}{Z} + E\alpha(T_2 - T_1) \le S_a \qquad \text{Equation 10M}$$

Where S_a = Allowable thermal expansion stress

M_C = Bending moment due to restrained thermal expansion

or

$$S_{TE} = \frac{PD_O}{4t_n} + 0.75i\frac{M_A}{Z} + i\frac{M_C}{Z} + E\alpha(T_2 - T_1) \le (S_h + S_a) \qquad \text{Equation 11M}$$

Where S_E = Stress from restrained thermal expansion

S_{TE} = Stress from pressure, weight and thermal expansion

3.10.3 *Seismic Loads*

Seismic-induced damage to buried piping is largely due to wave propagation or permanent ground deformation resulting from fault movement, landslide, and liquefaction-induced lateral spread. Where buried piping enters a structure, the seismic anchor movements of the structure must be accounted for in the design of the piping. Other forms of damage related to ground movement such as elastic and consolidation settlement (total and differential), freeze-thaw induced settlement, and seismic-induced settlement due to soil compaction and rearrangement should be considered on a case-by-case basis. For the case of piping anchored to an adjacent building, strain development in the utility due to settlement of the building should be evaluated. The seismic effects on buried piping are self limiting in that strains are limited by the surrounding soil. Therefore the stresses due to these strains are secondary in nature.

COL applicants shall carry out site investigation to assess the best route for the underground piping. During this field investigation, sites that are vulnerable to fault movement and liquefaction-induced landslide and lateral spread should be avoided. If a pipe must be buried in loose saturated cohesionless soil susceptible to liquefaction, rigorous linear and non-linear pipe-soil interaction analysis should be carried out to evaluate the integrity of the pipe under settlement and lateral spread conditions that may be caused by the liquefiable soil. If the result of the soil-pipe interaction is not acceptable, any of the following options recommended in Reference [14] may be adopted:

(1) Re-route the pipe to avoid areas of liquefiable loose saturated cohesionless soils;

(2) Modify the strength of the soil by using appropriate stabilizing agent;

(3) Excavate liquefiable soil and replace with competent structural fill materials; or

(4) Support the pipe in soil that is not susceptible to failure.

3.10.3.1 *Axial and Bending Strains Due to Propagation of Seismic Waves*

Typically, the magnitude of axial and bending strains on buried piping due to propagation of seismic wave is dependent on several factors such as the buried material and soil properties and pipe-soil interfacial properties. Conservatively, axial and bending strains on the buried piping are taken to be the same as those of the seismic wave if there is no site specific field instrumentation to measure the strain level experienced by the buried piping. Based on the axial and bending strains developed in the buried piping assuming long, linear runs remote from anchors or bends, the corresponding axial load and bending stress can be computed as follows:

$$F_a = \varepsilon_a AE$$

$$M_b = \sigma_b Z$$

Where $\sigma_b = \varepsilon_b E_{sct}$

In above equations,

E_{sct} = Secant modulus of the buried piping

ε_a = Axial strain in the buried piping due to wave propagation

ε_b = Bending strain in the buried piping due to wave propagation

Z = Section modulus of the buried piping.

For the computation of loads developed at elbows, the simplified procedures outlined in reference [14] are recommended for flexible and rigid conditions. At site locations where the differential settlement is significant, flexible anchors may be used in lieu of rigid anchors. All support structures (anchors) should be designed to resist the resulting axial loads and bending stresses.

The general axial and bending strains due to seismic wave propagation may be found as follows:

$$\varepsilon_a = \pm \frac{v}{\alpha c}$$

$$\varepsilon_b = \pm \frac{Ra}{\alpha c^2}$$

Where v = velocity of the soil layer (particle) in which the piping is embedded

a = acceleration of the soil layer (particle) in which the piping is embedded

c = apparent velocity relative to ground surface

R = radius of the pipe

ε_b = bending strain

ε_a = axial strain

α = wave velocity coefficient (compression=1.0, shear=2.0, Rayleigh=1.0)

In reference [14], it is noted that axial and bending strains are a result of three types of seismic waves, (1) compression, (2) shear and (3) surface or Rayleigh. The strain for each wave is calculated using the general form for axial and bending noted above.

The effects of seismic loads on above ground piping must meet the requirements of NC/ND-3655 as noted in Table 3-2. However, since seismic loads on buried piping are treated as secondary loads, the following equation must be met:

$$S_{OL} = \frac{iM_C}{Z} + \frac{iM_{SSE}}{Z} + \varepsilon_b E_{sct} + \varepsilon_a E_{sct} + E\alpha(T_2 - T_1) \leq 3.0S_h \text{ but not greater than } 2.0S_y$$

Where S_{OL} = stress from occasional loads

M_{SSE} = moment from seismic anchor movements

S_Y = yield stress

---

13. Guideline for the Design of Buried Steel Pipe; Report by American Lifelines Alliance, 2001.

14. Seismic Response of Buried Pipes and Structural Components; ASCE Committee on Seismic Analysis of Nuclear Structures and Materials, New York, 1983.

Table 3-4: Design Conditions, Load Combination and Stress Criteria for ASME Class 2&3 Buried Piping

Loading Condition	Service Levels	Loads	Stress Criteria
Design	-	Primary Stress Loads: Pressure[1], Weight Loads, Other Sustained Mechanical Loads	Equation 8[5] NC/ND-3652
Normal/ Upset	A/B	Occasional: Pressure[1], Weight Loads, Other Sustained Mechanical Loads, DFL	Equation 9U[5] NC/ND-3653.1 (Level B Only)
		Secondary Stress: Thermal Expansion, TAM, Thermal Friction Forces	Equation 10M[2] [4] NC/ND-3653.2(a)
		Non-Repeated Anchor Movement	Equation 10a NC/ND-3653.2(b)
		Sustained Plus Secondary Stress: Pressure[1], Weight Loads, Other Sustained Mechanical Loads, Thermal Expansion, TAM, Thermal Friction Forces	Equation 11M[3] [4][5] NC/ND- 3653.2(c)
Emergency	C	Occasional Stress: Pressure[1], Weight Loads, DFL	Equation 9E[5] NC/ND-3654.2(a)
Faulted	D	Secondary Stress: SSE Inertia & SAM(M_{SSE}), Thermal Expansion and TAM (M_C), Friction Axial Forces from Thermal Expansion	See note 6

Notes:

1. Pressure for buried pipe includes internal pressure and the soil overburden loads and loads due to motor vehicles and train cars.
2. Equation 10 modified to include stress due to axial friction forces caused by thermal expansion and soil interaction.
3. Equation 11 modified to include stress due to axial friction forces caused by thermal expansion and soil interaction.
4. Stresses must meet Equation 10M or 11M, not both.
5. Buried piping systems must be designed to meet the external pressure load criteria of NC/ND-3133 of the ASME Code.
6. Faulted D Equation is: $\frac{i(M_{SSE}+M_{C})}{Z}+\varepsilon_a E_{sct}+\varepsilon_b E_{sct}+E\alpha(T_2-T_1)\leq 3.0S_h$ but not greater than 2.0 S_Y

Table 3-5: Impact Factor for Surface Load Effect on Buried Pipes

Cover thickness (ft)	Surface Load Condition	
	Highways	Railways
0 - 1	1.50	1.75
1 - 2	1.35	1.50
2 - 3	1.15	1.50
> 3.0	1.00	1.35

Table 3-6: Recommended Surface Load for Buried Pipe

Cover thickness, ft	Surface load transmitted to pipe (lb/in^2)		Cover thickness, ft	Surface load transmitted to pipe (lb/in^2)	
	Highway H20	Railway E80		Highway H20	Railway E80
1	12.50	-	16	Negl.	3.47
2	5.56	26.39	18	Negl.	2.78
3	4.17	23.61	20	Negl.	2.08
4	2.78	18.40	22	Negl.	1.91
5	1.74	16.67	24	Negl.	1.74
6	1.39	15.63	26	Negl.	1.39
7	1.22	12.15	28	Negl.	1.04
8	0.69	11.11	30	Negl.	0.69
10	Negl.	7.64	35	Negl.	Negl.
12	Negl.	5.56	40	Negl.	Negl.
14	Negl.	4.17			

Table 3-1: Load Combinations and Acceptance Criteria for ASME Class 1 Piping

Service Condition	Service Level	Category	Loading or Stress Component	Acceptance Criteria[1]
Design	-	Primary Stress	Design Pressure, Deadweight, Steady State Flow Load and Dynamic Fluid Load[2] specified as Level A	Eq 9N NB-3652
Normal	A	Primary plus Second-ary Stress Intensity Range (S.I.R.)	Range of Level A: Service Pressure, Steady State Flow Load, Dynamic Fluid Load[2], Thermal Expansion Load[3], Thermal Expansion Anchor Motion Load[3], Cyclic Thermal Load[4], Material Discontinuity Stress	Eq 10N NB-3653.1
		Peak S.I.R.	Same as for Level A Primary plus Secondary S.I.R. plus Range of Level A Thermal Radial Gradient Stress (linear and non-linear)	Eq 11N NB-3653.2
		Thermal S.I.R.[5]	Range of Level A: Thermal Expansion Load[3], Thermal Expansion Anchor Motion Load[3], Cyclic Thermal Load[4]	Eq 12N NB-3653.6(a)
		Primary plus Second-ary Membrane plus Bending S.I.R.[5]	Same as for Level A Primary plus Secondary S.I.R. except Range of Level A Thermal Expansion Load[3], Thermal Expansion Anchor Motion Load[3] and Cyclic Thermal Load[4] is not considered	Eq 13N NB-3653.6(b)
		Alternating Stress Intensity (S.I.) (Fatigue Usage)[6]	Same as for Level A Peak S.I.R.	Eq 14N NB-3653.6(c)
		Thermal Stress Ratchet	Range of Level A Linear Thermal Radial Gradient	NB-3653.7

Table 3-1: Load Combinations and Acceptance Criteria for ASME Class 1 Piping

Service Condition	Service Level	Category	Loading or Stress Component	Acceptance Criteria[1]
Upset	B	Permissible Pressure	Maximum Level B Service Pressure	NB-3654.1
		Primary Stress	Coincident Level B Service Pressure, Deadweight, Steady State Flow Load, Dynamic Fluid Load[2]	Eq 9U NB-3654.2(a)
		Primary plus Secondary S.I.R.	Same as for Level A Primary plus Secondary S.I.R. (except Level B Load and Stress Ranges are used) plus Earthquake Inertial Load[7]	Eq 10U NB-3654.2(b)
		Peak S.I.R.[8]	Same as for Level B Primary plus Secondary S.I.R. plus Range of Level B Thermal Radial Gradient Stress (linear and non-linear)	Eq 11U NB-3654.2(b)
		Thermal S.I.R.[5]	Range of Level B: Thermal Expansion Load[3], Thermal Expansion Anchor Motion Load[3], and Cyclic Thermal Load[4]	Eq 12U NB-3654.2(b)
		Primary plus Second-ary Membrane plus Bending S.I.R.[5]	Same as for Level B Primary plus Secondary S.I.R. except Range of Level B Thermal Expansion Load[3], Thermal Expansion Anchor Motion Load[3] and Cyclic Thermal Load[4] is not Considered	Eq 13U NB-3654.2(b)
		Alternating S.I. (Fatigue Usage)[6]	Same as for Level B Peak S.I.R.	Eq 14U NB-3654.2(b)
		Thermal Stress Ratchet	Range of Level B Linear Thermal Radial Gradient	NB-3654.2(b)
		Deformation Limits	As Set Forth in the Design Specification	NB-3654.2(b)

Table 3-1: Load Combinations and Acceptance Criteria for ASME Class 1 Piping

Service Condition	Service Level	Category	Loading or Stress Component	Acceptance Criteria[1]
Emergency[9]	C	Permissible Pressure	Maximum Level C Service Pressure	NB-3655.1
		Primary Stress	Coincident Level C Service Pressure, Deadweight, Steady State Flow Load, Dynamic Fluid Load[2]	Eq 9E NB-3655.2(a)
		Deformation Limits	As Set Forth in the Design Specification	NB-3655.3
Faulted	D	Permissible Pressure	Maximum Level D Service Pressure	NB-3656(a)(1)
		Primary Stress[10]	Coincident Level D Service Pressure, Deadweight, Steady State Flow Load, Dynamic Fluid Load[2,11], Earthquake Inertial Load[11], High Energy Line Break Load[11] (Loss-of-Coolant Accident or Secondary Side Pipe Rupture)	Eq 9F NB-3656(a)(2)
		Secondary Stress[12]	MAX[Range of (Bending Moment due to Thermal Expansion Load[3] plus Thermal Expansion Anchor Motion Load[3] plus ½ Earthquake Anchor Motion Load) OR Range of Earthquake Anchor Motion Load]	6Sm[13]
Pressure Testing[14]	-	Primary Membrane S.I.	Test Pressure, Deadweight	NB-3657 NB-3226(b)
		Primary Membrane plus Bending S.I.	Test Pressure, Deadweight	NB-3657 NB-3226(c)

Table 3-1: Load Combinations and Acceptance Criteria for ASME Class 1 Piping (Continued)

Notes:

1. Acceptance Criteria are taken from the referenced section in Section III of the ASME Boiler and Pressure Vessel Code, or are as noted.
2. Dynamic Fluid Loads are occasional loads associated with hydraulic transients caused by events such as valve actuation (safety or relief valve discharge, rapid valve opening/closing), water hammer or steam hammer.
3. Thermal Expansion and Thermal Expansion Anchor Motion Loads are not calculated for those operating conditions where the piping system does not exceed 150F.
4. Cyclic Thermal Load includes loads due to thermal stratification, and stresses due to high cycle thermal striping and thermal penetration (i.e. thermal mixing).
5. The Thermal Bending and Primary plus Secondary Membrane plus Bending Stress Intensity Ranges (Equations 12 and 13) are only calculated for those load sets that do not meet the Primary plus Secondary Stress Intensity Range (Equation 10) allowable.
6. The cumulative fatigue usage factor is calculated by summing the Level A and Level B fatigue usage. If applicable, fatigue usage from Level C and Pressure Testing conditions is also included in the calculation of the cumulative usage factor (see Notes 9 and14).
7. The Earthquake Inertial Load considered in the Level B Primay plus Secondary Stress Intensity Range, Peak Stress Intensity Range and Alternating Stress Intensity calculations (Equations 10, 11 and 14) is taken as 1/3 of the peak SSE inertial load or as the peak SSE inertial load. If the earthquake inertial load is taken as the peak SSE inertial load then 20 cycles of earthquake loading is considered. If the earthquake inertial load is taken as 1/3 of the peak SSE inertial load then the number of cycles to be considered for earthquake loading is 300 (the equivalent number of 20 full SSE cycles as derived in accordance with Appendix D of IEEE Standard 344-1987).
8. The resultant moment calculated is the maximum of the resultant moment due to the full range of Earthquake Inertial Load or the resultant moment due to the consideration of half of the range of Earthquake Inertial Load with all other applicable loads.
9. If a piping system is subjected to more than 25 Emergency Condition transient cycles which result in an alternating stress intensity (S_a) value greater than that for 10^6 cycles, as determined from the applicable fatigue design curves of Figures I-9.0 in Section III of the ASME Boiler and Pressure Vessel Code, then those cycles in excess of 25 are included in the fatigue calculation that determines the cumulative usage factor. See Section NB-3113(b) in Section III of the ASME Boiler and Pressure Vessel Code.
10. The rules given in Appendix F of the ASME Boiler and Pressure Vessel Code may be used in lieu of those given in NB-3656(a) and NB-3656(b) when evaluating Level D primary stress.
11. Loads due to dynamic events other than High Energy Line Break (i.e. Loss-of-Coolant Accident and Secondary Side Pipe Rupture) and SSE are combined considering the time phasing of the events (i.e. whether the loads are coincident in time). When the time phasing relationship can be established, dynamic loads may be combined by the Square-Root-Sum-of-the-Squares (SRSS) method, provided it is demonstrated that the non-excedance criteria given in NUREG-0484 is met. When the time phasing relationship cannot be established, or when the non-excedance criteria in NUREG-0484 is not met, dynamic loads are combined by absolute sum. SSE and High Energy Line Break loads are always combined using the SRSS method.

12. This secondary stress check is only necessary if the stresses (including those due to Earthquake Inertial Load) exceed the Equation 10U (primary plus secondary stress intensity range for the Upset service condition) allowable stress. See Section NB-3656(b)(4) in Section III of the ASME Boiler and Pressure Vessel Code.

13. Sm = Allowable Design Stress Intensity value from Part D of Section II of the ASME Boiler and Pressure Vessel Code.

14. If a piping system is subjected to more than 10 Pressure Test cycles which result in an alternating stress intensity (S_a) value greater than that for 10^6 cycles, as determined from the applicable fatigue design curves of Figures I-9.0 in Section III of the ASME Boiler and Pressure Vessel Code, then those cycles in excess of 10 are included in the fatigue calculation that determines the cumulative usage factor. See Sections NB-3657 and NB-3226(e) in Section III of the ASME Boiler and Pressure Vessel Code.

Additional Revisions to ANP-10264NP
"U.S. EPR Piping Analysis and Pipe Support Design Topical Report"
(TAC No. MD3128)

The following change will be provided in the approved version of ANP-10264NP:

Page Number	Section	Description of Change	Reason
1-3 and 2-2	Table 1-1 (item 1) and 2.2	Deleted the Combined License (COL) action item for the COL applicant to identify any additional code cases that are not listed in the topical report for piping not included in the scope of the U.S. EPR design certification.	The COL applicant is permitted to use other code cases as long as they are listed in RG 1.84 as a conditionally or unconditionally accepted code case.