May 19, 2008

Mr. Ronnie L. Gardner, Manager
AREVA NP
3315 Old Forrest Road
P.O. Box 10935
Lynchburg, VA 24506-0935

SUBJECT: DRAFT SAFETY EVALUATION REPORT REGARDING ANP-10264NP, "U.S. EPR PIPING ANALYSIS AND PIPE SUPPORT DESIGN TOPICAL REPORT" (TAC NO. MD3128)

Dear Mr. Gardner:

By letter dated September 29, 2006 (NRC's ADAMS Accession Number ML062770021), as supplemented by letters dated July 13, 2007 (ML071990264), November 20, 2007 (ML073300462), and April 18, 2008 (ML081140034), AREVA NP (AREVA) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review Topical Report (TR) ANP-10264NP, "U.S. EPR Piping analysis and Pipe Support Design Topical Report" (ML062770023). Enclosed for your review and comment is a copy of the staff's draft Safety Evaluation Report (SER) for the TR.

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 2.390, we have determined that the enclosed draft SER does not contain proprietary information. However, we will delay placing the draft SER in the public document room for a period of ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. After ten working days, the draft SER will be made publicly available, and an additional ten working days are provided for you to comment on any factual errors or clarity concerns contained in the SER. The final SER will be issued after making any necessary changes and will be made publicly available. The staff's disposition of your comments on the draft SER will be discussed in the final SER.

To facilitate the staff's review of your comments, please provide a marked-up copy of the draft SER showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact me at gxt2@nrc.gov or (301) 415-3361.

Sincerely,

/RA/

Getachew Tesfaye, Sr. Project Manager
EPR Projects Branch
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-020

Enclosure: Draft Safety Evaluation Report

cc w/encl: U.S. EPR Mailing List

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DRAFT

SAFETY EVALUATION BY THE OFFICE OF NEW REACTORS

TOPICAL REPORT ANP-1026NP, REVISION 0

"EPR PIPING ANALYSIS AND PIPE SUPPORT DESIGN TOPICAL REPORT"

AREVA NP, INC. (AREVA)

DOCKET NO. 52-020

1.0 Introduction and Background

This safety evaluation report (SER) provides the staff's evaluation of design methods and acceptance criteria for the U.S. EPR piping system design documented in the Topical Report (TR) ANP-10264NP (Revision 0), "U.S. EPR Piping Analysis and Pipe Support Design," submitted by AREVA NP Inc. (AREVA). AREVA plans to reference the approved version of this document in its EPR design certification application final safety analysis report (FSAR) [also referred to design control document (DCD)] for the U.S. EPR and will use these criteria to support detailed design activities. To evaluate the piping and pipe support design information given in this TR, the staff used the Nuclear Regulatory Commission (NRC) acceptance criteria and guidelines documented in the General Design Criteria (GDC), Standard Review Plan (SRP) Sections 3.7.3, 3.9, and 3.12, Regulatory Guides (RGs), and other NRC regulatory guidance documents (e.g., NUREG Reports, NRC Bulletins, etc.). The design criteria related to whip restraints (and pipe break analysis) for the U.S. EPR piping design are not within the scope of this review.

In TR Section 1.0, AREVA states that the reactor coolant loop (RCL) and the pressurizer surge line piping requirements, modeling techniques, analysis approaches and acceptance criteria are not specifically addressed in this document and will be included in the FSAR. In the Request for Additional Information (RAI) EPR-1, the staff requested AREVA to describe any significant differences in the requirements, techniques, approaches and criteria for the RCL and the pressurizer surge piping as against those presented in this TR. In response (dated July 13, 2007), AREVA stated that the RCL loop structural model includes representation of the nuclear island basemat and the interior concrete structure (ICS), to which the RCL supports are attached, as well as very detailed representations of the primary components and their internals. In addition, in most cases, the RCL supports are explicitly represented in the model. In case of typical Class 1 piping analysis, the models do not include representations of the supporting concrete structures or detailed representations of components, and the supports are not typically explicitly modeled. The method of seismic loading is also quite different, with the RCL loop structural model being loaded through application of basemat excitation to the base of the ICS, whereas Class 1 piping models are loaded through the application of attachment point response spectra (or time histories), floor response spectra (or time histories) and seismic anchor motions at the various support locations in the model. Other aspects of RCL structural analysis are the same as those described for Class 1 piping in the TR, such as damping requirements, load combinations, mass distribution requirements, cutoff frequency requirements, and applicable ASME stress and fatigue allowables. AREVA will include a thorough description of the approaches and methods employed in the structural, stress and fatigue analysis of the RCL and the pressurizer piping in Chapter 3 of the FSAR. Based on this, the staff concludes that the modeling and analysis of the RCL and the pressurizer surge line piping along with its supporting structures are performed based on the basic principles of the

structural analysis, and include all piping criteria presented in the subject TR. Therefore, the staff finds this acceptable and the **RAI EPR-1 is resolved.**

The staff evaluated the adequacy of the structural integrity and functional capability of safety-related piping systems associated with the design of the U.S. EPR standard plant. The review included not only the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BP&V) Code Class 1, 2, and 3 piping and pipe supports, but also buried piping, instrumentation lines, the interaction of non-seismic and/or seismic Category II piping with seismic Category I piping and any safety-related piping designed to industry standards other than the ASME Code. The following sections of this report provide the staff's evaluation of the adequacy of the U.S. EPR piping and pipe support analysis methods, design procedures, and acceptance criteria. The staff's evaluation includes:

2.0 Regulatory Evaluation
3.1 Codes and Standards
3.2 Piping Analysis Methods
3.3 Modeling of Piping Systems
3.4 Pipe Stress Analysis Criteria
3.5 Pipe Support Design Criteria

The staff must arrive at a final safety determination that, if the combined license (COL) applicant successfully completes the piping design and analyses, and complies with the Inspection, Tests, Analyses and Acceptance Criteria (ITAAC) as required by Part 52 of Title 10 of the *Code of Federal Regulations* (10 CFR), using the design methods and acceptance criteria discussed herein, there will be adequate assurance that the piping systems will perform their safety-related functions under all postulated combinations of normal operating conditions, system operating transients, and seismic and other dynamic events.

2.0 Regulatory Evaluation

The staff reviewed the TR in accordance with NUREG-0800, SRP Section 3.7.3, "Seismic Subsystem Analysis," Rev. 3, Section 3.9.1, "Special Topics for Mechanical Components," Rev. 3; Section 3.9.2, "Dynamic Testing and Analysis of Systems, Components, and Equipment," Rev. 3; Section 3.9.3, "ASME Code Class 1, 2, and 3 Components, Component Supports, and Core Support Structures," Rev. 2; and Section 3.12, "ASME Code Class 1, 2, and 3 Piping Systems, Piping Components and Their Associated Supports," Initial Issuance, March 2007. The applicant's piping and pipe support design criteria, including the analysis methods and modeling techniques, are acceptable if they meet codes and standards, and regulatory guidance documents commensurate with the safety function to be performed. This will ensure that the piping system design criteria meet the relevant requirements of 10 CFR 50.55a, "Codes and Standards," and the GDCs 1, 2, 4, 14, and 15 of Appendix A to 10 CFR Part 50.

The acceptance criteria are based on meeting the relevant requirements of the following regulations for piping system, piping components and their associated supports:

10 CFR 50.55a and GDC 1 as they relate to piping system, pipe supports, and components being designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

GDC 2 and 10 CFR Part 50, Appendix S with regard to design transients and resulting load combinations for piping and pipe supports to withstand the effects of earthquakes combined with the effects of normal or accident conditions.

GDC 4, with regard to piping systems and pipe supports important to safety being designed to accommodate the effects of, and to be compatible with, the environmental conditions of normal as well as postulated events such as loss-of-coolant accident (LOCA) and dynamic effects.

GDC 14, with regard to the reactor coolant pressure boundary (RCPB) of the primary piping systems being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

GDC 15, with regard to the reactor coolant systems and associated auxiliary, control, and protection systems being designed with sufficient margin to assure that the design condition of the RCPB are not exceeded during any condition of normal operation, including anticipated operational occurrences.

10 CFR 52.47(b)(1), as it relates to ITAAC (for design certification) sufficient to assure that the structures, systems, and components (SSCs) in this area of review will operate in accordance with the certification.

10 CFR 52.80(a), as it relates to ITAAC (for combined licenses) sufficient to assure that the SSCs in the area of review have been constructed and will be operated in conformity with the license the provisions of the Atomic Energy Act and the Commission's rules and regulations.

The NRC has established requirements in 10 CFR Part 50 to ensure the pressure boundary leakage integrity of the piping components and structural integrity of the pipe supports in the nuclear power plants. The staff evaluates the design, materials, fabrication, erection, inspection, testing, and inservice surveillance of piping and pipe supports based on the following industry codes and standards, materials specifications, and regulatory guides:

ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components," contains the material specifications, design criteria, fabrication and construction requirements, construction testing and examination techniques, and structural integrity testing of the piping and pipe supports.

ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," contains inservice inspection and testing requirements and repair and replacement criteria for piping and pipe supports.

RG 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," Revision 4, March 2007.

RG 1.29, "Seismic Design Classification," Revision 4, March 2007.

RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, March 2007.

RG 1.92, “Combining Modal Responses and Spatial Components in Seismic Response Analysis,” Rev. 2, July 2006.

RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components," Revision 1, February 1978. RG 1.199, “Anchoring Components and Structural Supports in Concrete,” November 2003.

RG 1.206, “Combined License Applications for Nuclear Power Plants,” June 2007.

NUREG - 0484, “Methodology for Combining Dynamic Responses,” Revision 1, May 1980

NUREG - 1061, “Report of the U.S. Nuclear Regulatory Commission Piping Review Committee - Evaluation of Other Loads and Load Combinations,” Volume 4, December 1984.

NUREG - 1367, “Functional Capability of Piping Systems,” November 1992.

3.0 Technical Evaluation

3.1 Codes and Standards

GDC 1 requires that SSCs important to safety should be designed, fabricated, erected, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they should be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. 10 CFR 50.55a requires that systems and components of boiling and pressurized water-cooled nuclear power reactors must meet the requirements of the ASME Code. It specifies the latest edition and addenda endorsed by the NRC and any limitations. RG 1.84 and RG 1.147 list ASME Code Cases that the NRC staff finds acceptable.

In TR Section 2.0, AREVA identifies all applicable codes and standards that will be used for the U.S. EPR design of ASME Code, Class 1, 2, and 3 pressure retaining components and their supports. Also, this section identifies ASME Code Cases that are applicable to the RCPB components, including piping and pipe supports.

3.1.1 ASME Boiler and Pressure Vessel Code

For the U.S. EPR piping and pipe support design, in TR Section 2.1, AREVA established that the 2001 ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, 2003 addenda will be used for the design of ASME Code Class 1, 2, and 3 pressure retaining components and their supports. Other TR sections (e.g., 5.1, 6.2) reference the use of ASME B31.1 Code for piping analysis; however, AREVA has not identified which category or group of piping systems that will be analyzed using the ASME B31.1 Code requirements. In addition, AREVA has not identified ASME Code Section XI for testing and inspection of installed pipe components (e.g., pressure testing, weld examinations) that may be used in the design of piping and pipe supports. Therefore, in RAI EPR-2 the staff requested AREVA to clarify if ASME B31.1 Code will be used for Quality Group (QG) D piping systems, as suggested in RG 1.26, and if the ASME Section XI Code requirements are part of this design review.

In response (dated July 13, 2007), AREVA stated that the U.S. EPR piping systems containing radioactive material (outside the RCPB) are classified as QG D and are designed to ASME B31.1, 2004 Edition. This QG D piping will be analyzed to ASME B31.1, 2004 Edition, no addenda. In addition, the U.S. EPR adheres to the requirements of the ASME Section XI, 2001 Edition, 2003 addenda and at this time of the certification stage no Section XI code cases are used for the U.S. EPR. The staff finds this acceptable, since both B31.1 Code (2004) for QG D piping design and Section XI along with Section III of the ASME Code (2001 edition with 2003 Addenda) for Class 1, 2, and 3 piping are consistent with 10CFR50.55a requirements. Therefore, **RAI EPR-2 is resolved, pending revision to TR Sections 1.0 and 2.1.**

The ASME Code involves a consensus process to reflect the evolving design and construction practices of the industry. Although the reference to a specific edition of the Code for the design of ASME Code class components and their supports is suitable to reach a safety finding during the design review stage, the construction practices and examination methods of an updated Code that would be effective at the COL application stage must be consistent with the design practices established at the design review stage.

The staff finds that the specific edition and addenda stated in the TR are appropriate because they would provide the means for the COL applicant to revise or supplement the referenced Code edition with portions of the later Code editions and addenda needed to ensure consistency between the design for the U.S. EPR pressure retaining components and their supports and construction practices. In this manner, the updated reference Code to be used at the time of the COL application is ensured to be consistent with the latest design, construction, and examination practices at that time. However, where the staff finds that there may be a need to specify certain design parameters from a specific Code edition or addenda during its design certification review, particularly when that information is of importance to establish a significant aspect of the design or is used by the staff to reach its final safety determination, such considerations, if necessary, are reflected in the various sections of this safety evaluation.

AREVA states in TR Section 2.1 that for the dynamic loads, including seismic loads, the pipe stress analyses will be performed in accordance with the Subsubarticles 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 applicable to piping system design as included in 10CFR50.55a(b)(1). Therefore, in RAI EPR-3 the staff requested AREVA to explain why all six limitations and modifications specified in 10CFR50.55a(b)(1) are not addressed in the TR. In its revised response (dated November 20, 2007), AREVA stated that piping analysis and pipe support design for the U.S. EPR addressed in this TR 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). The staff finds this acceptable, since the response included all six limitations listed in 10CFR50.55a(b)(1) and the U.S. EPR piping design meets the 2001 ASME Code, Section III, Division 1 through the 2003 Addenda with limitations in 10CFR50.55a(b)(1) (ii) Weld Leg, (iii) Seismic, (v) Independence of Inspection, and (vi) Inspection NH, and other limitations (i) Section III-Materials and (iv) Quality Assurance do not apply to U.S. EPR piping design. Therefore, **RAI EPR-3 is resolved, pending revision to TR Section 2.1.**

AREVA also states in TR Section 2.1 that Class 1 piping one-inch NPS and smaller and Class 1 piping meeting the requirements of Subsubarticle NB-3630(d)(2) may be analyzed to Subarticle NC-3600. The staff notes that this is acceptable for Class 1 piping provided the specified service loads for which Level A and B Service Limits are designated meet all the requirements stipulated in (a) through (e) of the Subsubarticle NB-3630(d)(2).

Based on the above, all ASME Code Class 1, 2, and 3 pressure retaining components and their supports must be designed in accordance with the requirements of ASME Code, Section III and Section XI using the 2001 Edition and 2003 Addenda as identified in the TR. The QG D piping are analyzed and designed to ASME B31.1, 2004 Edition, no addenda. However, the COL applicant should also ensure that the design is consistent with the construction practices (including inspection and examination methods) of the ASME Code edition and addenda as endorsed in 10 CFR 50.55a in effect at the time of COL application. The portions of the later Code editions and addenda must be identified to the NRC staff for review and approval with the COL application.

3.1.2 ASME Code Cases

The only acceptable ASME Code Cases that may be used for the design of ASME Code Class 1, 2, and 3 piping systems in the U.S. EPR standard plant are those either conditionally or unconditionally approved in RG 1.84 and RG 1.147 in effect at the time of design certification. This review is based on Revision 33 of RG 1.84, dated August 2005, since AREVA did not identify any code cases associated with Section XI of the ASME Code for RG 1.147 at this pre-certification stage. Both RGs include Code Cases listed up to Supplement 6 (or 2003 Addenda) to the 2001 Edition of the ASME B&PV Code. AREVA states in TR Table 1-1 that COL applicant will identify any additional Code Cases used that are not listed in this TR for piping and are, therefore, not included in the scope of the U.S. EPR Design Certification. This is identified as COL-Action Item 1. The staff finds the statement of the COL-Action Item to be acceptable as long as the additional Code Cases are listed in RG 1.84 and RG 1.147 as a conditionally or unconditionally accepted Code Cases at the time of their use.

All ASME Code Cases that are listed in TR Section 2.2 for the RCPB components, which are applicable to the U.S. EPR piping and pipe support design, are listed below.

- ASME Code Case N-122-2[1], “Procedure for Evaluation of the Design of Rectangular Cross Section Attachments on Class 1 Piping, Section III, Division 1." The staff endorses the use of this Code Case in RG 1.84.

- ASME Code Case N-318-5, "Procedure for Evaluation of the Design of Rectangular Cross Section Attachments on Class 2 or 3 Piping, Section III, Division 1.” The staff endorses the use of this Code Case in RG 1.84.

- ASME Code Case N-319-3, "Alternate Procedure for Evaluation of Stress in Butt Weld Elbows in Class 1 Piping, Section III, Division 1." The staff endorses the use of this Code Case in RG 1.84.

- ASME Code Case N-391-2, "Procedure for Evaluation of the Design of Hollow Circular Cross Section Welded Attachments on Class 1 Piping, Section III, Division 1." The staff endorses the use of this Code Case in RG 1.84

[1] Code Case N-122-2 is identified as the second revision of Code Case N-122.

- ASME Code Case N-392-3, "Procedure for Evaluation of the Design of Hollow Circular Cross Section Welded Attachments on Class 2 and 3 Piping, Section III, Division 1." The staff endorses the use of this Code Case in RG 1.84.

Based on the above evaluation of all code cases referenced in the TR for piping and pipe support design, the staff concludes that all of these code cases either meet the guidelines of RG 1.84, or have been reviewed and endorsed by the staff.

3.1.3 Design Specifications

ASME Code, Section III, Subsubarticle NCA-3250 requires that a design specification be prepared for Class 1, 2, and 3 components such as pumps, valves, and piping systems. The design specification is intended to become a principal document governing the design and construction of these components and should specify loadings and their combinations; design, service and test limits; and other design data inputs. Subsubarticle NCA-3260 of the Code also requires a design report for ASME Code, Class 1, 2, and 3 piping and components. In the TR, AREVA committed to construct all safety-related components, such as vessels, pumps, valves and piping systems, to applicable requirements of the ASME Code, Section III.

TR Section 2.3 states that COL applicants referencing the U.S. EPR design will make available to the staff design specifications and design reports demonstrating and documenting that as-designed[2] piping and pipe support configurations adhere to the requirements of the design specification as required by the ASME Code. This is identified as the COL-Action Item 2 in TR Table 1-1. This issue will be addressed during the design certification and RCOL application.

3.1.4 Conclusions

On the basis of the evaluation of TR Section 2.0, the staff concludes that the piping systems important to safety are designed to quality standards commensurate with their importance to safety. The staff's conclusion is based on the following:

(a) AREVA satisfies the requirements of GDC 1 and 10 CFR 50.55a by specifying appropriate codes and standards for the design and construction of safety-related piping and pipe supports, and

(b) AREVA identified ASME Codes and Code Cases that may be applied to ASME Code, Class 1, 2, and 3 piping and pipe supports.

3.2 Piping Analysis Methods

GDC 1 requires that SSCs important to safety should be designed, fabricated, erected, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized methods of analysis are used, they shall be identified and evaluated to determine their applicability, adequacy, and margin of safety to withstand the loadings as a result of normal operating, transients, and accident conditions.

[2] AREVA, in Attachment B of its second revised response to RAIs dated April 18, 2008, changed "as-built" to "as-designed" in TR Table 1-1, Item 2 and in TR Section 2.3. The staff finds this acceptable, since the design reports and design specifications are generally associated with as-designed piping and support configurations, prior to as-built reconciliation.

GDC 2 requires that the piping and pipe supports should withstand the effects of earthquakes combined with the effects of normal or accident conditions.

The staff reviewed the applicable information in TR Section 4.0 related to the methods of analysis to be used for all seismic Category I piping and pipe supports designated as ASME Code Class 1, 2, and 3 under ASME Code, Section III, as well as those not covered by the Code. TR Section 4.2 indicates that the analysis methods described in SRP Section 3.7.3 are applicable to piping systems for all seismic Category I subsystems. Analysis methods to be used for piping systems include the response spectrum (RS) method (both uniform support motion and independent support motion), the time history (TH) method (both modal superposition and direct integration) and the equivalent static load method. Experimental stress analysis methods (as stated in TR Section 4.1) and inelastic analysis methods (as stated in TR Section 4.3) are not planned to be used to design piping for the U.S. EPR standard plant at this design certification stage.

AREVA did not provide details of the seismic analysis methods discussed in TR Section 4.2, which indicate that the analysis methods described in SRP Section 3.7.3 are applicable to piping systems for all seismic Category I subsystems. Therefore, in RAI EPR-4 and RAI EPR-5 the staff requested AREVA to expand the mathematical derivations and associated assumptions to develop a mathematical model of a piping system and to discuss their application procedures and limits.

In response (dated July 13, 2007), AREVA stated that the seismic response of a piping system is determined by developing a mathematical model of the system suitable for calculating the response of the system to the seismic input. Dynamic equilibrium equations are formulated for the system using the direct stiffness method. In this method, the element stiffness matrices are formed according to virtual work principles and assembled to form a global stiffness matrix for the system relating external forces and moments to nodal displacements and rotations. Once the mathematical model has been established, dynamic equilibrium equations are solved to determine the seismic response of the system by performing a modal analysis using either the RS method or TH methods. Alternatively, the direct integration TH method and, where applicable, the equivalent static load method may be used.

AREVA also stated that factors considered when choosing the analysis method to be used for a given piping configuration include complexity of the system, type of loads to be included in the analysis, class of piping (ASME Class 1, 2, 3 or non-seismic) and analysis tools available. In general, for seismic load cases, RS and TH methods of analysis will produce similar results with TH producing acceptable results that are not as conservative as RS. Class 1 piping analysis which requires considerably more detail may be analyzed by TH methods although RS will yield acceptable results. The TH method is also used when transient loads due to pipe break, water hammer, or other dynamic events are anticipated and static analysis produces a high level of conservatism. Class 2 and 3 and non-seismic piping analysis is generally analyzed using the RS method. Equivalent static analysis can only be used on Class 2 and 3 and non-seismic piping 2 inches NPS[3] and smaller where the piping configuration can be reduced to simple models. In its revised response (dated November 20, 2007), AREVA stated that non-seismic piping that interacts with seismic systems and seismic Category II piping will be analyzed by the RS or the equivalent static load methods. In

[3] NPS – Nominal Pipe Size

Attachment A to the RAI response dated July 13, 2007, AREVA provided step by step computations for response spectra analysis to be included in the revised TR Section 4.2.2.

AREVA further, in its revised response (November 20, 2007), stated that 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 TR Section 4.2.2 (see Attachment A to the RAI response dated July 13, 2007). The direct integration TH analysis method may be used as an alternative to the modal superposition TH analysis. In this method, the differential equation of motion, as provided in Section 4.2.2 (see Attachment A to the RAI response dated July 13, 2007), is solved directly on the uncoupled equations without a coordinate transformation. Rayleigh damping, or mass and stiffness damping, is used when direct integration TH analysis is performed.

All of the above seismic analysis methods (including those described in TR Section 4.2 and Attachment A to the RAI response dated July 13, 2007) are consistent with the SRP 3.7.3, and therefore, the staff finds this acceptable. Thus, **RAI EPR-4 and RAI EPR-5 are resolved, pending revision to TR Section 4.2.**

3.2.1 Experimental Stress Analysis

In TR Section 4.1 AREVA states that U.S. EPR piping system design will not use the experimental stress analysis method. The staff finds this acceptable.

3.2.2 Response Spectrum Method with Uniform Support Motion

TR Section 4.2.2 describes the dynamic analysis procedure using the RS method with uniform support motion (USM) using enveloped floor response spectra or independent support motion (ISM) using multiple floor response spectra.

AREVA states that the effects of the ground motion during a safe shutdown earthquake (SSE) event are transmitted through structures to the piping system at support and equipment anchorage locations. The floor response spectra are developed which represent the maximum acceleration responses of idealized single-degree-of-freedom damped oscillators as a function of natural frequency to the vibratory input motion of the structure. These floor response spectra are applied to the piping system at locations of structural attachment, such as support or equipment locations in each of three (3) orthogonal directions. The total seismic response of the system is determined by combining the modal and spatial results.

In TR Section 4.2.2.2.1, AREVA also states that for a piping system supported at points with different dynamic excitations, an enveloped response spectrum of all attachment points is used in the USM method of analysis. Typically, from the mode shapes, participation factors and spectral accelerations of each mode, the modal responses are calculated. They include the modal forces, stresses and deflections. For a given direction, the modal responses are combined in accordance with the methods described in TR Section 4.2.2.3. Following the modal combinations, the responses due to each of the three orthogonal earthquake motion inputs (two horizontal and vertical) are combined using the SRSS method as stated in TR Section 4.2.2.4. AREVA did not provide a criterion for ensuring that adequate number of modes are included in a piping model nor define the cutoff frequency that will be used in piping dynamic analysis. Therefore, in RAI EPR-6 the staff requested AREVA to define the number of modes to be included in the dynamic range of the input spectra.

In response (dated July 13, 2007), AREVA stated that the criterion for the inclusion of sufficient number of modes in accordance with SRP 3.9.2, Item II.2.A(i)(3) is that the inclusion of additional modes does not result in more than a 10-percent increase in responses. For U.S. EPR piping analyses, all modes with frequencies below the zero period acceleration (ZPA) frequency (i.e., cutoff frequency) are included. Above this frequency, in the rigid range, the effects of all additional modes are also included by the application of the missing mass correction as discussed in TR Sections 4.2.2.3.2 and 4.2.3. The cutoff frequency for a given spectra is the frequency at which the response curves for all damping values converge to the same acceleration value ZPA and remain at this value for all frequencies above this cutoff frequency. In its revised response (dated November 20, 2007), AREVA stated that for the U.S. EPR the cutoff frequency is 40 Hertz or as defined by Figures 2 and 3 in RG 1.92, Rev 2. Since this approach is consistent with the industry practice and SRP 3.9.2, the staff finds this acceptable. Therefore, **RAI EPR-6 is resolved, pending revision to TR Section 4.2.**

The staff notes that for piping systems that are anchored and restrained to floors and walls of structures that have differential movements during a seismic event, additional forces and moments due to the differential supporting structure movements are induced in the system. Additional static analyses are performed to determine responses to these structure movements as described in TR Section 4.2.2.5. The support displacements are imposed in a conservative manner using the static analysis method for each orthogonal direction with all dynamic supports active. This is known as seismic anchor movement (SAM) analysis. For USM method of analysis, the results of the SAM analysis are combined with the results of the dynamic analysis by absolute sum method in accordance with SRP Section 3.9.2.

AREVA discusses in TR Section 4.2.2 how to determine the input spectra and input displacement when the piping system is attached to structures or at equipment connections, but did not discuss how the input response spectra and SAM displacements will be defined for a flexible equipment connection or branch piping of a smaller size when decoupled from a large pipe run. Therefore, in RAI EPR-7 the staff requested AREVA to describe the procedures to be used in defining the inputs for the analysis of a branch pipe when decoupled from a large pipe run or flexible equipment.

In its revised response (dated November 20, 2007), AREVA described the response for Class 1 branch lines from the reactor coolant loop (RCL) and for those decoupled from other large pipe runs. 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 THs 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 THs or response spectra which are generated from the THs using classical response spectra generation techniques. If response spectra are used, they are peak broadened by ±15 percent in accordance with RG 1.122, Rev. 1, 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 or equipment amplification on the branch pipe.

AREVA also stated that 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 inch from the run pipe applied at the run to branch anchor for all load cases. AREVA stated that the branch pipe analysis will include more consideration for the affect of the run piping. The branch point is considered as an anchor in the analysis of the branch pipe with the appropriate stress intensity factor (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 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 also include the run pipe movements from the run pipe SSE inertia analysis. The inertial effects of the run pipe (other than RCL) on the branch line are considered in one of the following methods:

- The fundamental frequency of the run pipe at the branch location will be 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.

Since the above methods of analysis to be used in the U.S. EPR piping design are consistent with the current industry practices and will account for the effects of run pipe or flexible equipment responses on the decoupled branch piping, the staff finds this acceptable. Therefore, **RAI EPR-7 is resolved, pending revision to TR Section 5.4.2.**

The staff reviewed the TR description of the RS method with USM and found that it is consistent with the applicable guidelines in SRP Section 3.9.2, Subsection II.2. Therefore, the staff finds this acceptable.

3.2.3 Response Spectrum Method with Independent Support Motion

As an alternative to the enveloped response spectrum method, the RS method with ISM may be used. The theory and development of the governing equations of motion for this method are basically the same as the USM RS method. Additional requirements associated with the application of this method are described in the TR Section 4.2.2.2.2. This section states that when the ISM method of analysis is used, the following conditions must be met. First, a support group is defined by supports which have the same time history input. This usually means all supports located on the same floor, or portions of a floor, of a structure. Second, the responses from motions of supports in two or more different groups are combined by the absolute sum procedure. The modal and directional responses are then combined similar to those discussed for the USM RS method and as discussed in TR Sections 4.2.2.3 and 4.2.2.4, respectively.

In addition to the inertial response, the effects of relative support displacements, similar to that discussed in the USM method above, are performed to obtain the SAM responses, as discussed in TR Section 4.2.2.5.

The current staff position for modal and group combinations in the ISM method of analysis is presented in Volume 4, Section 2 of NUREG-1061. For inertial or dynamic components, group responses are combined by the absolute sum method. Both modal and directional responses are combined by the square-root-of-the-sum-of-the-square (SRSS) method; the modal combination is performed without considering the effects of closely spaced frequencies. For SAM components, the maximum absolute responses from each directional input for each group are combined by the absolute sum method, and the directional responses are combined by the SRSS method. Finally, the dynamic and SAM responses are combined by the SRSS method, unlike the case for the USM method of analysis where the combination uses the absolute sum method as required by SRP Section 3.9.2.

The staff noted some differences between the ISM method of response combinations presented in TR Section 4.2.2.2.2 and the method given in NUREG-1061 (e.g., the modal combination methods). In RAI EPR-8, the staff requested AREVA to indicate whether all of the rules contained in NUREG-1061 for the ISM method of analysis will be followed or AREVA should provide the technical justification for the methods described in TR Section 4.2.2.2.2. In response (dated July 13, 2007), AREVA stated that all of the provisions of NUREG-1061, Volume 4, for using the ISM method of analysis will be followed for U.S. EPR piping design. AREVA will revise various subsections of TR Section 4.2.2 in order to include all provisions of NUREG-1061, including the combination of the missing mass effects with the low frequency model responses, as committed in its revised responses of November 20, 2007. Since this will satisfy the current staff position on ISM method of analysis, the staff finds this acceptable. Therefore, **RAI EPR-8 is resolved, pending revision to TR Sections 4.2.2.2.1, 4.2.2.2.2, 4.2.2.3.1, 4.2.2.3.2, and 4.2.2.5.**

3.2.4 Time History Method

Typically, a TH analysis may be performed using either the modal superposition method, direct integration method in the time domain, or the complex frequency response method in the frequency domain. AREVA described the modal superposition method in TR Section 4.2.3, which is the only method that will be used for the U.S. EPR plants. However, as discussed in Section 3.2 of this report, AREVA may use the direct integration TH analysis method as an alternative to the modal superposition TH analysis. The modal superposition method involves the calculation and utilization of the natural frequencies, mode shapes, and appropriate damping factors of the particular system toward the solution of the equations of dynamic equilibrium. The orthogonality of the mode shapes is used to effect a coordinate transformation of the displacements, velocities, and accelerations such that the response in each mode is independent of the response of the system in any other mode. Through this transformation, the problem becomes one of solving a set of "n" independent differential equations rather than simultaneous differential equations. As long as the system is linear, the principle of superposition holds and the total response of the system oscillating simultaneously in "n" modes may be determined by direct addition of the responses of the individual modes.

In TR Section 4.2.3 AREVA states that the cutoff frequency for the determination of modal properties is selected to account for the principal vibration modes of the system based upon mass and stiffness properties, modal participation factors and the frequency content of the input forcing function. The missing mass effects of high frequency modes are included based on the same principle for the response spectrum method described in TR Section 4.2.2.3.2. Alternatively, the cutoff frequency is determined such that the number of modes calculated will produce dynamic analysis results within 10 percent of the results of the dynamic analysis including the next higher mode. AREVA will use guidance for including the missing mass effects as provided in Appendix A of SRP Section 3.7.2, as well as RG 1.92, Rev.2, as stated in TR Section 4.2.2.3.2. However, Appendix A of the RG 1.92, Rev. 2 has some differences in the calculation of the missing mass contribution to total response in its Step 2 when compared to the Appendix A of the SRP Section 3.7.2. In addition, RG 1.92 Section 1.4.1 states that in recently-published literature it is shown that the missing mass contribution needs to be considered only if the fraction of the missing mass at any degrees of freedom exceeds 0.1 as stated in the SRP may produce non-conservative response and should not be used. Rather, the missing mass contribution should be calculated in all RS analyses because its potential effect on support reactions is difficult to judge based on the fraction of missing mass. This is discussed further in Section 3.4.6 (under high-frequency modes) of this report.

In addition to seismic analysis, the modal superposition TH method will be used for the dynamic analysis of water/steam hammer loads; relief/safety valve thrust loads; jet force loads or other hydraulic transient loadings. Since many of these loads are for a short duration and may contain very high frequency content, all modes up to the appropriate cutoff frequency must be considered. As in RS analysis, the modal superposition TH method must also consider the missing mass contribution. RG 1.92, Rev. 2, Section 1.4.1 describes an acceptable methodology in which the missing mass contribution is scaled to the instantaneous acceleration and then algebraically summed with the transient solution at the corresponding time to obtain the total solution. In RAI EPR-9 the staff requested AREVA to explain the methods to include the high frequency content including the missing mass contribution when applying the modal superposition TH method.

In its revised response (dated November 20, 2007), AREVA stated that missing mass will be accounted for in TH modal superposition analyses in accordance with Appendix A of RG 1.92, Rev. 2. The mode shapes and frequencies are determined as they are in the RS analysis. The cutoff frequency for the determination of modal properties is 40 Hz or as defined by Figures 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. Since by including the missing mass effects of the high frequency modes beyond the cutoff frequency would include the piping response to any high frequency transient loadings, the staff finds this acceptable. Therefore, **RAI EPR-9 is resolved, pending revision to TR Section 4.2.3.**

In TR Section 4.2.3 AREVA also states that the time step to be used in the TH analysis is no larger than one-tenth of the period of the cutoff frequency. Generally, the numerical integration time step, Δt, must be sufficiently small to accurately define the dynamic excitation and to render stability and convergence of the solution up to the highest frequency of significance. For most of the commonly used integration methods, the maximum time step is limited to one-tenth of the smallest period of interest selected initially, which is generally the reciprocal of the cutoff frequency. In accordance with industry practice and as described in Section 3.2.2.1(c) of ASCE 4-98, an acceptable approach for selecting the actual time step (Δt) is that the Δt used shall be small enough such that the use of one-half of Δt does not change the response by more than 10 percent. In RAI EPR-10, the staff requested AREVA to clarify whether this criterion is used as part of the piping analysis requirements using time history analysis method in addition to the 10 percent of the period of the cutoff frequency as the initial selection or AREVA should provide a technical justification for not considering this criterion for seismic and other dynamic loading analyses.

In its revised response (dated November 20, 2007), AREVA stated that a time step study has been performed for the direct integration TH analysis of the reactor pressure vessel (RPV) isolated model considering seismic loading. This model contains a representation of the reactor coolant system (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 percent). 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 percent 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 TH analysis will be used for Class 2 and 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 and 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 percent. Since this approach is consistent with the current industry practices and will ensure convergence of the solution, the staff finds this acceptable. Therefore, **RAI EPR-10 is resolved, pending revision to TR Section 4.2.3.**

In TR Section 4.2.3, AREVA states that the total seismic response is predicted by combining the responses from the three orthogonal components (two horizontal and one vertical) of the earthquake. The combined response is obtained by algebraically adding the codirectional responses from each analysis at each time step or the total response may be obtained directly by applying the three component motions simultaneously in one analysis. Whenever these methods are used, the three component input motions must be mutually statistically independent. As an alternative, when separate TH analyses are performed for each directional component, the combined response may be obtained by taking the SRSS of the maximum codirectional responses caused by each component.

To account for uncertainties in the structural analysis using the TH method, in TR Section 4.2.3 AREVA states that similar to peak shifting in the response spectrum method of analysis, three separate input TH with modified time steps may be analyzed. Alternatively, the THs at the attachment points may be derived considering variations in the concrete stiffness. An acceptable method to vary the frequency content of the in-structure acceleration TH to account for uncertainties in the analysis is either by expanding and shrinking the TH within 1/(1± 0.15) so as to change the frequency content of the TH within ±15 percent or by varying building stiffness (Note that for AP1000, NRC accepted building stiffness variation within ±30 percent). In RAI EPR-11, the staff requested AREVA to provide additional details on their procedure for accounting for these uncertainties in a TH analysis of piping systems when subjected to seismic and other dynamic loadings.

In its revised response (dated November 20, 2007), AREVA stated that to account for uncertainties in the structural analysis for seismic loading, a peak shifting approach, similar to that described in TR Section 4.2.2.1.2 for RS analysis, is used. This is accomplished by first converting the seismic TH 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 THs 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 THs (one in each of the three orthogonal directions) at each anchor point and at each support\restraint in the piping system. AREVA 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 THs 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 THs that are applicable to the various terminal points\supports\restraints in the piping systems:

i. The THs 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 TH (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 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 THs 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 THs (either the enveloping THs described in 2(i) above, or the basemat THs 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 THs (N+3 for each orthogonal direction, see Section 4.2.2.1.2 of the TR, where N is the number of piping modes within the broadened frequency range). 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.

AREVA also, in its response (July 13, 2007), stated that methods used to account for uncertainties will only be used in seismic analysis as the intent is to approximate the effect of the application of peak broadened spectra in a RS analysis. The time step compression/expansion approach to account for these uncertainties will be demonstrated by equating its results to the peak shifting method used in RS analysis as described in TR Section 4.2.2.1.2. As stated in TR Section 4.2.3, the approach of considering variations in concrete stiffness to account for uncertainties in seismic time history analysis will be removed from the TR.

Since these methods to account for uncertainties in the structural analysis are industry-accepted practices, the staff finds this acceptable. Therefore, **RAI EPR-11 is resolved, pending revision to TR Section 4.2.3.**

It should be noted that as an alternative to the spectral broadening procedure, the staff has accepted the peak shifting method for specific plant applications on a case-by-case basis pending revision of RG 1.122, as indicated in RG 1.84 for the Code Case N-397. Since the peak shifting method applicable to floor spectrum generation has now been included in the Appendix N (Section N-1226.3) of the ASME Code Section III, ASME has currently annulled this Code Case that was conditionally accepted by the staff. In addition, ASCE 4-98 Section 3.4.3.2(b) for TH analysis and Section 3.4.2.3(c) for RS method of analysis provide acceptable methods of peak shifting. The applicability of the peak shifting method for developing floor response spectra is also discussed in Section 3.4.1 of this report. Based on this, the staff finds the peak shifting method to account for analysis uncertainties is acceptable.

3.2.5 Equivalent Static Load Method

In TR Section 4.2.4, AREVA discusses an alternative method of analysis that allows a simpler technique but is known to yield more conservative results. The equivalent static load analysis method is used when a simplified analysis is considered with the mass of the piping and components as lumped masses at their center of gravity locations. The seismic response forces due to these masses are then statically determined by multiplying the contributing mass by an appropriate seismic acceleration coefficient at each location. This method does not require frequency calculation of the system and the loads are statically applied at each mass point by a multiplying a static coefficient equal to 1.5 times the maximum spectral acceleration at appropriate damping value of the input floor response spectrum. The static coefficient of 1.5 is intended to account for the effect of both multi-frequency excitation and multi-mode response for piping systems which have multiple degrees of freedom and have a number of significant modal frequencies in the amplified region of the RS curve (i.e., below the ZPA).

In accordance with SRP Section 3.9.2, II.2.A (ii), TR discusses the following conditions that should be met prior to using this method of analysis:

- Justification is provided that the system can be realistically represented by a simple model and the method produces conservative results in terms of responses.

- The design and associated simplified analysis account for the relative motion between all points of support.

- To obtain an equivalent static load of equipment or component which can be represented by a simple model, a factor of 1.5 is applied to the peak acceleration of the applicable floor response spectrum.

This analysis is performed for all three directions of the seismic input motion. The results of these three analyses are then combined using the SRSS method. The SAM analysis is performed similar to that for RS analysis methods as discussed in TR Section 4.2.2.5.

In general, if the system behaves essentially as a single degree of freedom system and the fundamental frequency of this system is known, a factor of 1.5 of the spectral acceleration at the highest spectral acceleration value at or beyond the fundamental frequency may be used. Also, when the system is rigid, the ZPA instead of the maximum spectral acceleration of the input spectra may be used. A component is considered to be rigid when its fundamental frequency is equal to or greater than the frequency at which the input RS returns to approximately the ZPA. In RAI EPR-12, the staff requested AREVA to confirm that as stated in the TR, the equivalent static load is determined by multiplying 1.5 to the peak acceleration for all cases including a single degree of freedom system and a rigid system.

In response (dated July 13, 2007), AREVA stated that for multiple degree of freedom systems, the peak acceleration of the appropriate floor response spectra will be multiplied by 1.5. However, in response to RAI EPR-5, AREVA stated that 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). Since these criteria typically provide conservative piping response, the staff finds this acceptable. Therefore, **RAI EPR-12 is resolved, pending revision to TR Section 4.2.4.**

3.2.6 Inelastic Analysis Method

In TR Section 4.3, AREVA states that inelastic analysis will not be used to qualify piping for the U.S. EPR design certification. The staff finds this acceptable.

3.2.7 Small Bore Piping Analysis Methods

Small bore piping is typically defined as piping 50 mm (2 inches) and less nominal pipe size. In many cases, small bore piping systems are field run and qualified based on in-house developed design criteria by architect engineering firms. The TR did not define the small bore piping for the U.S. EPR piping design. Also, the TR did not provide any design methods, analysis techniques or acceptance criteria for small bore piping. In RAI EPR-13, the staff requested AREVA to provide the design criteria applicable to small bore piping in the U.S. EPR piping design.

In its revised response (dated November 20, 2007), AREVA defined the small bore piping (including instrumentation lines) for the U.S. EPR as ASME Class 1 piping that is 1 inch NPS and smaller and Class 2, and 3 and QG D that is 2 inches NPS and smaller. AREVA suggested adding a new TR Section 4.5 on small bore piping and this piping may be analyzed using RS methods described in TR Section 4.2.2 or the equivalent static method described in TR Section 4.2.4. Since the classification and analysis of small bore piping are consistent with industry practices, the staff finds this acceptable. Therefore, **RAI EPR-13 is resolved, pending addition of a new TR Section 4.5 on small bore piping design for the U.S. EPR.**

3.2.8 Non-Seismic/Seismic Interaction (II/I)

All non-seismic Category I piping (or other systems and components) should be isolated from seismic Category I piping. This isolation may be achieved by designing a seismic constraint or barrier or by locating the two sufficiently apart to preclude any interaction. If it is impractical to isolate the seismic Category I piping system, the adjacent non-seismic Category I system should be evaluated to the same criteria as the seismic Category I system.

In TR Section 4.4, AREVA states that for non-seismic Category I piping systems attached to seismic Category I piping systems, the dynamic effects of the non-seismic Category I system are considered in the analysis of the seismic Category I piping. In addition, the non-seismic Category I piping from the attachment point to the first anchor is evaluated to ensure that, under all loading conditions, it will not cause a failure of the seismic Category I piping system (per RG 1.29, Regulatory Position C.3).

In TR Section 4.4, AREVA also states that the primary method of protection for seismic piping is isolation (by physical separation or physical barrier as discussed in TR Section 4.4.1) from all non-seismically analyzed piping. In cases where it is not possible, or practical, to isolate the seismic piping, In response to RAI EPR-14 for isolation criteria (dated July 13, 2007), AREVA clarified that isolation of a non-seismic piping is achieved when two piping systems in the same room (one seismic and one non-seismic) by physically locating away from each other as much as possible, such that there will be little chance of the non-seismic piping adversely interacting with the seismic piping, potentially causing damage to the seismic piping during a seismic event. Otherwise, the adjacent non-seismic piping is classified as seismic Category II and analyzed and supported such that an SSE event will not cause an unacceptable interaction with the seismic Category I piping. Alternatively, an interaction evaluation (as discussed in TR Section 4.4.2) may be performed to demonstrate that the interaction will not prevent the seismic Category I piping system from performing its safety-related function. Furthermore, in its revised response (dated November 2007), AREVA agreed to remove some of the interaction criteria given in TR Section 4.4.2 and these include dead weight support spacing ensures its structural integrity but losing pressure boundary integrity, and two other criteria on the failure of the non-seismic piping based on the pipe break analysis procedures. All other non-seismic/seismic interaction criteria discussed in TR Sections 4.4.1 and 4.4.2 are found reasonable and acceptable to the staff. Therefore, **RAI EPR-14 is resolved, pending revision to TR Section 4.4.2.**

3.2.9 Buried Piping

In TR Section 3.10, AREVA states that 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 are the same as those used for non-buried piping systems described in TR Table 3-2 with additional consideration of the following differences:

• Deformations imposed by either seismic waves traveling through the surrounding soil or by differential deformations between the soil and anchor points and lateral earth pressures acting on buried piping will be considered.

• The effects of static resistance of the surrounding soil on piping deformations or displacements, anchor movements and pipe geometry will be considered using the theory of structures on elastic foundations.

• The effects of local soil settling will be considered when applicable.

• It is also assumed that soil liquefaction and fault displacement will be avoided.

• Seismic loads experienced by buried piping are primarily generated by soil strains and therefore are self-limiting and considered secondary in nature.

Design conditions, load combinations and stress criteria to be used in the qualification of buried piping are addressed in TR Table 3-4.

AREVA also states that these criteria conform to the applicable guidelines in SRP Section 3.9.2. However, AREVA did not give any details on how these criteria are to be applied in the design of buried piping. Therefore, in RAI EPR-15, the staff requested AREVA to discuss the design criteria for buried pipes. In Attachment B to the RAI responses (July 13, 2007), AREVA provided a revised new TR Section 3.10 on seismic Category I Buried Piping. In this section, AREVA defined all applicable loads, methods of analysis, and acceptance criteria for various load combinations. However, the staff review of this new section found several errors and inconsistencies in the governing equations and definitions of various load parameters in loads and load combinations given in TR Table 3-4. In Attachment B to the RAI revised responses (November 20, 2007), AREVA provided a revised TR Section 3.10 addressing the buried piping design. The staff review of this revised section also found several errors and inconsistencies. Finally, on April 18, 2008 AREVA provided a new TR Section 3.10 in Attachment B of its second revised response to the RAIs, which the staff finds acceptable. **Therefore, the RAI EPR-15 is resolved, pending revision to TR Section 3.10.**

3.2.10 Conclusions

On the basis of the evaluations, the staff concludes that the analysis methods to be used for all seismic Category I piping systems as well as non-seismic Category I piping systems that are important to safety are acceptable. The analysis methods utilize piping design practices that are commonly used in the industry and provide an adequate margin of safety to withstand the loadings as a result of normal operating, transient, and accident conditions. The staff concludes that AREVA satisfies the requirements of GDC 2 by specifying appropriate analysis methods for designing piping and pipe supports against seismic loads.

3.3 Modeling of Piping Systems

GDC 2 requires that components important to safety should be designed to withstand effects of natural events including earthquakes. 10 CFR Part 50, Appendix B requires that design quality should be controlled for ensuring structural and functional integrity of seismic Category I components. For determining design adequacy, each piping system is idealized as a mathematical model and dynamic analysis is performed using computer programs. Modeling techniques should be in conformance with generally recognized engineering practices, and computer programs should be verified in accordance with one or more methods suggested in SRP Section 3.9.1.

TR Section 5.0 describes piping modeling techniques and discusses the computer programs and their applications in the U.S. EPR piping design.

3.3.1 Computer Codes

In TR Section 5.1 AREVA provides short descriptions of the major computer programs to be used in the analysis and design of safety-related piping systems. These computer programs include: SUPERPIPE, BWSPAN, BWHIST, BWSPEC, COMPAR2, CRAFT2, P91232, and RESPECT. AREVA states that SUPERPIPE has been thoroughly verified and validated to NRC standards. For all other computer codes, AREVA did not indicate whether these programs are verified for their application by appropriate methods, such as hand calculations, or comparison with results from similar programs, experimental tests, or published literature, including analytical results or numerical results to the benchmark problems and validated as the piping program SUPERPIPE. Moreover, AREVA did not mention how the quality of these programs and computer results is controlled.

AREVA did not specifically identify the computer programs associated with other than linear type of pipe support designs, welding of lugs or stanchions to pipe, or other piping analysis related calculations (e.g., nozzle load and analysis, broadening of spectra or time history). However, in TR Section 3.6, AREVA states that support and restraint designs using such welded attachments will adhere to industry practices and ASME Code Cases identified in TR Section 2.2. Based on the TR Section 5.1, the following are short descriptions of each of the computer codes addressed at this pre-certification stage:

SUPERPIPE - Analyzes piping for both static and dynamic loads, performs design checks for ASME Class 1, 2, and 3 and B31.1 piping. Dynamic analysis methods include both RS and TH analysis using either modal superposition or direct integration methods.

BWSPAN - Performs structural analysis of piping and structural systems. Also, performs pipe stress and fatigue calculations to a variety of design codes including B31.1, B31.7 and the ASME Code, and calculates stresses for linear type supports according to Subsection NF of the ASME Code.

BWHIST - Converts pressure THs generated by CRAFT2 or COMPAR2 into force THs by integrating the pressure over the area to which it is being applied.

BWSPEC - Tabulates displacements, pipe and structure loads, support loads and spring loads using output from a BWSPAN analysis.

COMPAR2 - Performs hydraulics analysis of fluid systems (generally containment cavities).

CRAFT2 - Performs hydraulics analysis of fluid systems (generally piping or components).

P91232 - Calculates through-wall gradient temperatures and stresses given pipe or nozzle geometry and thermal characteristics.

RESPECT - Generates amplified response spectra (ARS) given the frequency and mode characteristics of the system in question (from BWSPAN) and the acceleration TH applicable to the base of the structure. Also, generates seismic ARS at the branch nozzle locations in a model of a piping system.

Since AREVA did not provide any validation and verification of any of these computer codes, in RAI EPR-16 the staff requested AREVA to provide the status and quality control aspects of these computer programs. In response (dated July 13, 2007), AREVA stated that BWSPAN and SUPERPIPE are the only two computer codes currently in use during the pre-certification stage. BWSPAN is being used for analysis of the RCL piping during the design certification phase. While the other codes given in the initial version of the TR are also being used for RCL analysis in the design certification phase, they are not strictly piping analysis codes (they are general purpose hydraulic and post processing codes) and so their description will be removed from the TR. Also, SUPERPIPE is being used during design certification for the analysis of ASME Class 2 and 3 piping. It may be used for Class 1 piping. The following is the status of the two computer codes requiring design pre-certification:

BWSPAN: The use of BWSPAN for Class 1 RCL analysis has previously been approved by the NRC, see letter David E. LaBarge (NRC) to W.R. McCollum, Jr. (Duke Energy Corporation), Oconee Nuclear Station, Units 1, 2 and 3 Re: Reactor Coolant Loop Analysis Methodology for Steam Generator Replacement (TAC Nos. MA9886, MA9887, and MA9888), dated September 6, 2001. Earlier versions of BWSPAN have been successfully benchmarked to the piping problems given in NUREG/CR-1677. Later versions have been benchmarked to a prior version of BWSPAN by running selected sample problems which demonstrate that the changes made in moving from one version to the next have been correctly implemented. BWSPAN is controlled and maintained per AREVA NP, Inc. administrative procedures. The files which document the verification, validation, maintenance and control of BWSPAN are available. These files will provide the author, source, dated version, program description, the extent and limitation of the program application; and the computer solutions to the test problems described above.

SUPERPIPE: The use of SUPERPIPE, in previous versions, has been approved by the NRC for a number of previous license applications including the Catawba Nuclear Station (CNS UFSAR, Rev. 12, Table 3-68) and the System 80+ Design Certification (NUREG-1462, Section 3.12.3). Current versions of SUPERPIPE have been subsequently verified under the AREVA software QA program by comparison of results to the results of previously accepted versions. SUPERPIPE is controlled and maintained per AREVA NP Inc. administrative procedures. The files which document the verification, validation, maintenance and control of SUPERPIPE are available. These files will provide the author, source, dated version, program description, the extent and limitation of the program application; and the computer solutions to the test problems described above.

As discussed in Section 3.5.7 of this report, in response to RAI EPR-36 AREVA is also committed to add the computer code GT STRUDL at this phase of the design certification, since AREVA intends to use this program to calculate the pipe support stiffnesses in the pipe support design. This would require changes to the TR Section 5.1.

The information on the first two computer codes is available for NRC inspection. These files will provide the author, source, dated version, program description, the extent and limitation of the program application; and the computer solutions to the test problems described above. **However, in its revised response (dated November 20, 2007) to RAI EPR-36, AREVA is committed to include the computer code GT STRUDL for design pre-certification of pipe supports.** Since the BWSPAN and SUPERPIPE computer codes satisfy the requirements of SRP 3.9.1, the staff finds this acceptable. Therefore, **RAI EPR-16 is resolved, pending revision to TR Section 5.1 with GT STRUDL and other suggested changes.**

3.3.2 Dynamic Piping Model

In TR Section 5.2, AREVA describes the procedures used for analytical modeling of piping systems. For dynamic analysis, the piping system is idealized as a three dimensional model using finite element analysis programs. The analysis model consists of a sequence of nodes connected by pipe elements (both straight and bend elements) with stiffness properties representing the piping and other inline components. Nodes are typically modeled at points required to define the piping system geometry as well as lumped mass locations, support locations, locations of structural or load discontinuities and at other locations of interest along the piping. System supports are idealized as springs with appropriate stiffness values for the restrained direction.

In the dynamic mathematical model, AREVA also states that the distributed mass of the system, including pipe, contents (fluid or gas) and insulation weight, is represented either as a consistent (distributed) mass or as lumped masses placed at each node. For the latter case, in order to adequately determine the dynamic response of the system, elements may be subdivided and additional mass points added. The minimum number of degrees of freedom in the model is to be equal to twice the number of modes with frequencies below the ZPA frequency. Maximum mass point spacing may be no greater than one half of the span length of a simply supported beam with stiffness properties and distributed mass equal to that of the piping cross-section and the first fundamental frequency equal to the cutoff frequency.AREVA further states that concentrated weights of in-line components, such as valves, flanges and instrumentation, are also modeled as lumped masses. Torsional effects of eccentric masses are included in the analysis. For rigid components (those with natural frequencies greater than the ZPA cutoff frequency) the lumped mass is modeled at the center of gravity of the component with a rigid link to the pipe centerline. Flexible components (those with natural frequencies less than the ZPA cutoff frequency) are included in the model using beam elements and lumped mass locations to represent the dynamic response of the component.

Additionally, a portion of the weight of component type supports (such as snubbers, struts, spring hangers, etc.) is supported by the pipe and is considered in the piping analysis model. The mass contributed by the support is included in the analysis when it is greater than 10 percent of the total mass of the adjacent pipe span (including pipe, contents, insulation and concentrated masses). The adjacent span is defined as the piping including the applicable support and bounded by the adjacent restraint on each side of this support in each direction. AREVA also states that because the mass of a given support will not contribute to the piping response in the direction of the support, only the unsupported directions need to be considered. It is not clear why the mass of the support will not contribute to the piping response in the direction of a flexible support. Therefore, in RAI EPR-17, the staff requested AREVA to provide conditions under which this statement is applicable. In response (dated July 13, 2007), AREVA stated that the mass contributed by the support is included in the analysis when it is greater than 10 percent of the total mass of the adjacent pipe span (including pipe contents, insulation and concentrated masses). It is agreed that if the support is determined to be flexible in the direction of the restraint, the support mass should also be included in this direction, as well as for the unrestrained directions. Since this will simulate the actual response of the piping and its supports, the staff finds this acceptable. Therefore, **RAI EPR-17 is resolved, pending revision to TR Section 5.2.**

A review of the impact of contributing mass of supports on the piping analysis will need to be performed by the COL applicant(s) following the final support design to confirm that the mass of the support is no more than 10 percent of the mass of the adjacent pipe span. This is identified as the COL-Action Item 5 in TR Table 1-1.

In TR Section 5.4, AREVA discusses the model boundaries based on defining terminal points. Piping system analysis models are typically terminated by one of three techniques: structural boundaries, termination based on decoupling criteria, or termination by model isolation methods. Structural boundaries and the use of decoupling criteria are the preferred methods. However, after applying these first two methods, further division of the piping system may be desired to create more manageable models for analysis. This may be accomplished using the model isolation methods. The structural boundary and the model isolation methods are discussed here. The decoupling criteria are discussed later in Section 3.3.4 of this report.

AREVA states that structural model boundaries, such as equipment nozzles or penetrations, provide isolation of the effects of the piping on one side of the boundary to the piping on the opposite side. For large piping systems, AREVA also describes three different ways to create model boundaries for separating a large piping model into smaller models: an in-line physical anchor, restrained elbows, and restrained tees. The addition of an in-line anchor generally creates stiffer piping systems and may cause significant increases in stress and support loads on lines with high thermal movements. Additionally, the use of in-line anchors on high energy lines adds additional postulated terminal end pipe rupture locations. Therefore, additional in-line anchors are only added if they are determined to be practical.

In TR Sections 5.4.1.2 and 5.4.1.3, AREVA describes two other alternate approaches when a single full anchor support is not feasible. A pair of guide supports placed around an elbow or a tee may be used to separate analysis models. In this method, an elbow or a tee is restrained by a pair of guide supports in each leg at a certain distance apart from the pipe component. This creates a structurally rigid zone around the elbow or the tee in which the piping effects from one end of the restrained section are not transmitted beyond the other end. AREVA did not provide any technical justifications or references to any available literature for the restrained elbow or tee method of piping model terminations. Therefore, in RAI EPR-18, the staff requested AREVA to provide technical justifications with sample calculations to create a structurally rigid zone around an elbow or a tee.

In response (dated July 13, 2007), AREVA stated that the configurations shown in Figures 5-1 and 5-2 produce boundaries which, over a relatively short distance, provide effective restraint for the six degrees of freedom. The configuration creates a rigid zone of pipe with natural frequencies well above the ZPA and provides four restraints in the out-of-plane direction. The location of the two in-plane restraints on each side of the elbow or each segment of the tee provides a very short, stiff segment of piping from the intersect point and therefore create an effective axial restraint for the piping in the in plane direction. This configuration meets the recommendations for an overlap zone presented in NUREG/CR-1980.

In accordance with NUREG/CR-1980 recommendations, first the overlap region should have enough rigid restraints and include enough bends (or tees) in three directions to prevent the transmission of motion due to modal excitation from one end to the other and to reduce to a negligible level of the sensitivity of the structure to the direction of excitation. For this to achieve the NUREG/CR-1980 recommends four (4) rigid restraints in each of the mutually perpendicular directions in the overlap region (including the ends). For axial restraints only this requirement may be relaxed to a single restraint in any straight segment. The second condition to this rigidity in each of the three mutually perpendicular directions includes a demonstration of the fundamental frequency of the overlap region to be at least 25 percent higher than the highest significant forcing frequency. Since AREVA states that both the restrained elbows and/or restrained tees configuration meet the recommendations for an overlap zone presented in NUREG/CR-1980, the staff could not conclude from TR Figures 5-1 and 5-2 how these configurations meet the two conditions of NUREG/CR-1980 discussed above. However, on April 18, 2008, AREVA provided revised pages of the TR in Attachment B of its second revised response, where both Subsections 5.4.1.2 on Restrained Elbows and 5.4.1.3 on Restrained Tees (including their corresponding TR Figures 5-1 and 5-2) are deleted from the TR. **Since AREVA has deleted these TR Subsections, the staff finds that RAI EPR-18 is no longer needed. Thus, RAI EPR-18 is withdrawn.**

In TR Section 5.4.3, AREVA describes two model isolation methods, namely, overlap region method and influence zone method, to divide large seismic piping systems that cannot be separated by structural methods or decoupling criteria. Both these methods are similar in technique in that a section of the piping system is used as the boundary of the models. This section of the system is defined such that the effects of the piping beyond one end of the region do not significantly affect the piping beyond the opposite end of the region. In TR Section 5.4.3.1, AREVA suggests for the overlap region method that, as a minimum, an overlap region must contain at least four (4) seismic restraints in each of three perpendicular directions and at least one change in direction. The overlap region should be selected in a rigid area of the piping system and is modeled in two or more piping analyses. A dynamic analysis of the overlap region shall be made with pinned boundaries extended beyond the overlap region either to the next actual support or to a span length equal to the largest span length within the region. The fundamental frequency determined from this analysis shall be greater than the frequency corresponding to the ZPA.

In TR Section 5.4.3.2, AREVA states that the main difference between the influence zone and the overlap region is that in using the influence zone, all piping and supports are qualified by a single model. This is achieved by first determining the qualification boundary between models. Each model is then extended to a termination point such that the response of the piping at the termination of the model will not influence the response of the piping within the qualification boundary. The influence zone is then defined by the section of piping between the qualification boundary and the model termination point. However, when using this methodology versus the overlap region method, a significantly larger section of piping may be required to be included in two or more models.

AREVA did not provide any technical justifications or references to any available literature for these two methods of model isolation. Therefore, in RAI EPR-19, the staff requested AREVA to provide technical justifications with sample calculations to demonstrate the isolation of two piping problems using either the overlap region method or the influence zone method.

In response (dated July 13, 2007), AREVA stated that the overlap methodology provided in TR Section 5.4.3.1 is consistent with the recommendations of NUREG/CR 1980. The zone of influence (ZOI) method is provided as an option when the requirement for a rigid section of piping can not be met in order to use the overlap methodology. In this method, all piping must be modeled to a point where boundary conditions and loadings no longer impact the piping being qualified. This will typically be more piping than is required by the overlap method and the validity of the boundary is required to be demonstrated during the analysis. Since these methods use four (4) seismic restraints in each of three perpendicular directions and at least one change in direction consistent with the recommendations in NUREG/CR-1980, the staff finds this acceptable. **Therefore, RAI EPR-19 is resolved, pending revision to TR Section 5.4.3.**

3.3.3 Piping Benchmark Program

In TR Section 5.3, AREVA states that pipe stress and support analysis will be performed by the COL applicant. If the COL applicant chooses to use a piping analysis program other than those listed in TR Section 5.1, the applicant will implement the NRC benchmark program using models specifically selected for the U.S. EPR. This is identified as COL-Action Item 6 in TR Table 1-1.

The staff requires the COL applicants who will complete the piping analysis and finalize the piping designs to verify their computer programs in accordance with the NRC benchmark program specific to the standardized plant design. Under a piping benchmark program, the 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. The results of the analyses must be compared with the results of independent benchmark problem analyses developed by the staff. The COL applicant must document and submit any deviations from these values, as well as justification for such deviations, to the NRC staff for review and approval before initiating final piping analyses. The benchmark program provides assurance that the computer program used to complete the piping design and analyses produces results that are consistent with results considered acceptable to the staff.

In TR Section 5.3, AREVA indicated that if the COL applicant chooses to use a piping analysis program other than those listed in TR Section 5.1, the applicant will implement the NRC benchmark program using models specifically selected for the U.S. EPR. However, AREVA did not indicate if such a piping benchmark program for the EPR standardized plant exists for its own use or the use by the COL applicants. Furthermore, it did not indicate that its piping analysis computer code described in Section 5.1 was verified using models representative of the U.S. EPR. Therefore, in RAI EPR-20 the staff requested AREVA to provide the status of a piping benchmark program for the U.S. EPR piping design.

In its revised response (dated November 20, 2007), AREVA identified 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 Section 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 Section 5.1. This requirement is COL- Action Item 6 of Table 1-1.

Additionally, AREVA will revise TR Section 5.3 and Item 6 of TR Table 1-1 to change the term “NRC benchmark program” to “U.S. EPR benchmark program.” Since this is consistent with the current staff position on Advanced Light Water Reactor (ALWR) design certifications, the staff finds this acceptable. Therefore, **RAI EPR-20 is resolved, pending revision to TR Section 5.3 and Table 1-1.**

3.3.4 Decoupling Criteria

In TR Section 5.4.2, AREVA defines smaller branch lines as those lines that can be decoupled from the analytical model used for the analysis of the main run piping to which the branch lines are attached. Branch lines can be decoupled when the ratio of run to branch pipe diameter is 3 to 1, or greater, or moment of inertia is 25 to 1, or greater; and with sufficient flexibility to prevent restraint of movement of the main run pipe. The decoupling criteria may also be applied for in-line pipe size changes (such as at a reducer or reducing insert). In addition to the pipe diameter or the pipe moment of inertia criterion for acceptable decoupling, AREVA did not specify that these smaller branch lines shall be designed with no concentrated masses, such as valves, in the first one-half span length from the main run pipe. Therefore, in RAI EPR-21, the staff requested AREVA to technically justify how the effect of a large eccentric concentrated mass near the branch connection is considered in the decoupling criteria.

In its revised response (dated November 20, 2007), AREVA stated that 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. Since this is consistent with the industry practice associated with this situation, the staff finds this acceptable. Therefore, **RAI EPR-21 is resolved, pending revision to TR Section 5.4.2.**

AREVA also states that the small branch line is considered to have adequate flexibility if its first anchor or restraint to movement is at least one-half pipe span in a direction perpendicular to the direction of relative movement between the pipe run and the first anchor or restraint of the branch piping. A pipe span is defined as the length tabulated in Table NF-3611-1, Suggested Piping Support Spacing, ASME B&PV Code Section III, Subsection NF. For branches where the preceding criteria for sufficient flexibility cannot be met, the applicant will demonstrate acceptability by using an alternative criterion for sufficient flexibility, or by accounting for the effects of the branch piping in the analysis of the main run piping.

AREVA also stated that the branch pipe analysis includes 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 same stress intensity factor (SIF) and/or stress indices as the run pipe at this point. The movements (displacements and rotations) of run pipe from the thermal, seismic anchor movement (SAM) or pipe break analyses shall be applied as anchor movements with their respective load cases in the branch line analysis. 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. The meaning of this static analysis for the inertia load case was not clear. Therefore, in RAI EPR-22 the staff requested AREVA to provide further clarification of this procedure.

In its revised response (dated November 20, 2007), AREVA referred to the response of RAI EPR-7 and the suggested changes in TR Section 5.4.2 by this response. This is discussed in detail in Section 3.2.2 of this report and the criteria presented by AREVA are consistent with the industry practices. Therefore, the staff finds this acceptable. Thus, **RAI EPR-22 is resolved.**

In TR Section 5.5, AREVA provides the criteria for analyzing the decoupled seismic Category I piping from the non-seismic piping affecting the seismic Category I piping, which typically occurs at the seismic Category I transition valve(s). The model boundary at a non-seismic/seismic piping interface may consist of structural isolation, decoupling or model isolation methods similar to those discussed in TR Section 5.4. However, additional considerations are required to ensure that the dynamic effects of the non-seismic piping on the seismic Category I piping are considered.

AREVA states that the seismic Category I design requirements extend to the first seismic restraint beyond the seismic system boundary. The non-seismic piping and supports beyond this location that impact the dynamic analysis of the seismic Category I piping are reclassified as seismic Category II and included in the model. The extent of piping classified as seismic Category II may be bounded by the same three methods discussed in TR Section 5.4 and the staff evaluation of these sections is discussed in this section as well as in section 3.3.2 of this report. AREVA states that when structural boundaries are used to terminate the seismic Category II region, all piping and supports between the seismic Category I design boundary and the structural anchor, or the final restraint of a restrained elbow or tee, are classified as seismic Category II. When the decoupling criteria are used, all piping and restraints beyond the seismic Category I boundary up to the decoupled location are classified as seismic Category II. Finally, when the isolation method is used, isolation of dynamic effects is provided by three (3) seismic restraints in each of the three orthogonal directions beyond the seismic Category I design boundary. The staff notes that in TR Section 5.4.3.1 AREVA uses four (4) such restraints in each orthogonal direction for the isolation method in the overlap region. In RAI EPR-23A, the staff requested AREVA to explain this discrepancy. In response (dated July 13, 2007), AREVA corrected to use four (4) seismic restraints in each of the three orthogonal directions for separation criteria beyond the seismic Category I system boundary, consistent with NUREG/CR-1980 recommendations. Also, AREVA will revise the TR Section 5.5 to reflect this correction.

In all three cases cited in TR Section 5.5, the seismic Category II portion of the system is analyzed with the seismic Category I piping for the SSE load case as well as loads resulting from the potential failure of the non-seismic piping and pipe supports. This is accomplished by the application of a plastic moment in each of three orthogonal directions at the termination of the model. Each moment is applied and evaluated in a separate analysis and the results of the three analyses are enveloped. To clarify the method of applying a plastic moment at the termination point, the staff, in RAI EPR-23B, requested AREVA to describe the calculation of the loads resulting from the potential failure of the non-seismic piping and pipe supports and to discuss the step-by-step procedure for applying this load to the seismic Category I piping analysis.

In response (dated July 13, 2007), AREVA provided details for the plastic moment to be calculated as:

$$M_P = S_Y Z_P \quad \text{and} \quad Z_P = (D^3 - d^3) / 6$$

Where, M_P = Plastic moment to be applied
S_Y = Material Yield Strength at 70°F
Z_P = Plastic section modulus of the pipe
D = Outside diameter of the pipe
d = Inside diameter of the pipe

Each moment is applied and evaluated in a separate analysis and the results of each analysis are individually combined with the seismic inertia results by absolute summation methods. The results of these three analyses are then enveloped to obtain the design loads for the piping and supports. Since the criteria presented are consistent with the industry practices to include the worst effects of a failed non-seismic piping on a seismic Category I piping, the staff finds this acceptable. Therefore, **RAI EPR-23 is resolved, pending revision to TR Section 5.5.**

Since all methods described in the TR provide assurance that the seismic Category I piping is adequately designed to include the effects from the non-seismic piping during an earthquake, the staff finds them acceptable.

3.3.5 Conclusions

On the basis of the discussions in the above subsections and evaluation of TR Section 5.0, the staff concludes that design control measures are acceptable to ensure quality of computer programs and piping modeling methods. The staff's conclusion is based on the following:

(1) AREVA satisfies the requirements of GDC 2 by providing criteria for the seismic design and analysis of all seismic Category I piping and pipe supports using prescribed modeling techniques and design methods that are in conformance with generally recognized engineering practice.

(2) AREVA meets Appendix B to 10 CFR Part 50 by demonstrating the applicability and validity of the computer programs for performing piping seismic analysis.

(3) Computer programs to be used by the COL applicant to complete its analyses of the U.S. EPR piping systems will be verified and validated.

3.4 Pipe Stress Analysis Criteria

GDC 1 requires that the piping and pipe supports should be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. 10 CFR Part 50, Appendix B requires that design quality should be controlled for ensuring structural and functional integrity of seismic Category I components. GDC 2 requires that the piping and pipe supports should withstand the effects of earthquake loads. GDC 4 requires that the piping and pipe supports should withstand the dynamic effects of equipment failures including missiles and blowdown loads associated with the loss-of-coolant accident. The basis for design of ASME Code Class 1, 2, and 3 piping components sufficiently defines the design and service load combinations, including the system operating transients, and associated design and service stress limits considered for all normal, abnormal and accident conditions.

GDC 14 requires that the RCPB components should be designed, fabricated, erected, and tested to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross failure. GDC 15 requires that the reactor coolant system should be designed with sufficient margin to assure that the design conditions are not exceeded. In accordance with NUREG-1367, the Code rules assure that violation of the pressure boundary will not occur if the design specification satisfactorily addresses protection against catastrophic failure, and against initiation and propagation of a crack or propagation of a Section III acceptable flaw through the pressure boundary (i.e., fatigue failure).

3.4.1 Seismic Input

In TR Section 4.2.1, AREVA states that the response spectra curves for the U.S. EPR are being developed to cover an appropriate range of possible soil conditions with the ground motion anchored to peak ground acceleration (PGA) of 0.3g. The PGA in the vertical design ground motion is equal to the horizontal design ground motion PGA. Since the input design ground motion response spectra for the U.S. EPR standard plant is being developed, the review of this section cannot be performed at this design pre-certification stage. However, AREVA should develop these input spectra using the guidelines given in RG 1.60 and SRP Section 3.7.1 and include them in the FSAR.

The staff recognizes that the site enveloping response spectra for the U.S. EPR plant would contain conservatisms that may be excessive for certain specific site conditions. If amplified building response spectra are generated using site-dependent properties, then the approach and method used must be submitted to the staff for review and approval as part of the COL application. The staff notes that the method to generate the amplified building floor response spectra should be consistent with the methods accepted by the staff as given in RG. 1.122 and SRP Section 3.7.3.

In TR Section 4.2.2.1, AREVA describes the method of analysis to be used in developing the floor response spectra for the structures using the guidelines provided in RG 1.122, Rev. 1. In addition, AREVA states in TR Section 4.2.3 that to account for uncertainties in the structural analysis using the TH method, similar to peak shifting in the response spectrum method of analysis discussed in TR Section 4.2.2.1.2, three separate input time histories with modified time steps may be analyzed. Alternatively, the THs at the attachment points may be derived considering variations in the concrete stiffness, which is later withdrawn by AREVA in response to RAI EPR-11 as discussed in Section3.2.4 of this report. The issue pertaining to the validity of using the peak shifting method is also discussed in Section 3.2.4 of this report. This section also discusses the method of adjusting the peak responses in the time history method of analysis that will be used for generating floor response spectra applicable to U.S. EPR structures to account for variations in soil/structure and modeling techniques. The staff will assess the development of seismic input and floor response spectra when it is described in the FSAR. Therefore, the staff finds this acceptable.

3.4.2 Design Transients

TR Section 3.1 defines the classification of SSCs for seismic and non-seismic categories in accordance with RG 1.29. Piping required to be designed to withstand the effects of a SSE and remain functional during and after the event is classified as seismic Category I. These components must meet the requirements of Appendix B to 10 CFR Part 50. Piping that is not required to function during or after an SSE event, but its structural failure could reduce the functioning of seismic Category I SSCs is classified as seismic Category II piping by AREVA in TR Section 4.4. To prevent adverse impact to seismic Category I SSCs, seismic Category II piping will be designed to the same requirements as seismic Category I piping. Finally, piping that does not meet the criteria for seismic Category I or II is considered non-seismic. When it is not practical to route non-seismic pipe away from seismic Category I and II piping, the non-seismic piping will be upgraded to seismic Category II. Since the categorization of SSCs is consistent with the industry, the staff finds this acceptable.

In TR Section 3.2, AREVA defines the four service levels and test conditions used in the ASME Code. The plant operating conditions are:

(a) ASME Service Level A: normal condition - loading during plant startup, operation, refueling and shutdown
(b) ASME Service Level B: upset condition - incidents of moderate frequency - occasional, infrequent loadings without sustaining any damage or reduction in function

(c) ASME Service Level C: emergency condition - incidents of low frequency - infrequent loadings causing no significant loss of integrity
(d) ASME Service Level D: faulted condition - incidents of extremely low frequency - loadings associated with design basis accidents such as SSE, design basis pipe break and LOCA
(e) testing conditions

Based on the guidance in SRP 3.9.3, AREVA states that loading combinations of the various potential analysis load cases will be developed for the defined levels.

AREVA identifies in very general terms the load combinations of transients and other loads in TR Tables 3-1 through 3-4. However, the specific transients and number of events or cycles resulting from each of these design transients applicable to ASME Code Class piping system design are not yet developed for fatigue analysis at this pre-certification stage. In accordance with SRP Section 3.9.1, Item II.1, all transients to be used in the design and fatigue analysis of all Code Class 1 piping and pipe supports within the RCPB must be submitted for staff review. Therefore, in RAI EPR-24 the staff requested AREVA to list all applicable design transients and the number of events associated with each of these design transients that will be used in the design and fatigue analysis of all Code Class 1 piping and pipe supports within the reactor coolant pressure boundary. In response (dated July 13, 2007), AREVA states that the list of transients will be included in Chapter 3 of the FSAR. The staff finds this acceptable. Therefore, **RAI EPR-24 is resolved.**

3.4.3 Loadings and Load Combinations

In TR Section 3.3, AREVA identifies the loadings and load combinations that are applicable to the design of U.S. EPR piping system. Loadings applicable to the U.S. EPR piping design include:

- pressure
- deadweight
- thermal expansion (includes thermal anchor movements)
- seismic (includes seismic anchor movements)
- fluid transients (includes relief valve thrust, valve closure and water/steam hammer)
- wind/tornado (identified as the COL-Action Item 3 in TR Table 1-1)
- design basis pipe breaks (includes pipe whip, jet impingement, dynamic effects)
- thermal and pressure transients
- hydro tests

AREVA states that the zero thermal load temperature is 70 ^{o}F, and that piping systems with an operating temperature equal to or less than 150 ^{o}F do not require a thermal analysis. In addition, thermal anchor movements less than or equal to an industry acceptable 1/16th of an inch may be excluded from the analysis. Since these criteria are typically used by the industry, the staff finds this acceptable.

AREVA also states that the ground motion of the operating basis earthquake (OBE) for the U.S. EPR is equal to one-third of the ground motion of 0.3g for the SSE. In case of a seismic event greater than the OBE ground motion, in accordance with Appendix S to 10 CFR Part 50 plant shut down is required and seismic Category I piping and supports are required to be inspected to ensure no loss of function or physical damage has occurred. Both inertial and

SAM effects are considered as Service Level D loads, since U.S. EPR is not designed to an OBE loading. This is consistent with SECY 93-087 and therefore, acceptable to the staff.

AREVA states in TR Section 3.3.1.7 for piping and Section 6.3.7 for pipe supports that design basis pipe break loads must be evaluated for the appropriate service condition. However, pipe breaks in the RCL, main steam and pressurizer surge lines which meet the leak-before-break (LBB) size criteria are eliminated from consideration based on LBB analysis. The impact of smaller attached lines and other lines outside the LBB analyzed zone will be considered. Per SECY 93-087, the staff has approved the LBB approach on a case-by-case basis for austenitic stainless steel and carbon steel with stainless steel clad piping inside the primary containment and pipe size of at least 6-inch NPS. Based on this document, appropriate bounding limits are to be established using preliminary analysis results during the design certification phase and verified during the COL phase by performing the appropriate ITAAC discussed in it. In RAI EPR-25A, the staff requested AREVA to discuss the technical basis for exclusion of pipe break analysis for the above three lines, with the LBB criteria to be used for the U.S. EPR piping design. In response (dated July 13, 2007), AREVA stated that LBB criteria for the U.S. EPR will be addressed in Chapter 3 of the FSAR. It was not included in the TR because it was not addressed in SRP 3.12. The staff finds this acceptable. Therefore, **RAI EPR-25A is resolved.**

AREVA further stated in TR Section 3.3.2 that using the methodology and equations from the ASME Code, pipe stresses are calculated for various load combinations. The ASME Code includes design limits for design conditions, Service Levels A, B, C and D and testing. Design conditions, load combinations and stress criteria for ASME Class 1 piping are given in TR Table 3-1 and that for ASME Class 2 and 3 piping in TR Table 3-2. In reviewing the TR Section 3.3 and Tables 3-1 and 3-2, the staff identified a need for clarification of several items associated with this TR section and its tables. The staff requested AREVA for these clarifications in RAI EPR-25B through E.

The staff notes that SSE and design basis pipe break (including LOCA) shall be combined using the 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. On this subject area, AREVA responded to RAI EPR-25B in its revised response (November 20, 2007) that it expects to be able to establish the timing and causal relationships between dynamic events such as pipe rupture and valve actuation for U.S. EPR piping design. 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 summation. Since this is consistent with the recommendations in NUREG-0484, the staff finds this acceptable. Therefore, **RAI EPR-25B is resolved, pending revision to notes for TR Tables 3-1 and 3-2.**

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 of the ASME Code cannot be satisfied for all pairs of load sets, then the alternative analysis per ASME Subparagraph 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 one-half 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 Subsubparagraph NB-3656(b)(4). AREVA stated in its response to RAI EPR-25C (dated July 13, 2007) that at the time the TR 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. However, AREVA will now, therefore, reference the equations from Subsubparagraph NB-3656(b)(4) for the treatment of SSE anchor motions and revise Table 3-1 for this reason. The staff finds this not acceptable, since AREVA stated in its response that in the upset loading condition for primary plus secondary stress intensity range (equations 10 and 11), the loads will include the SSE. However, AREVA removed the SSE load from the equation 11U in Table 3-1 in its revised response in Attachment C (dated November 20, 2007). On April 18, 2008, AREVA provided in Attachment B of its second revised response a revision to the TR Table 3-1 for load combinations and acceptance criteria for ASME Class 1 piping with appropriate loads for the upset loading. Since this is consistent with equations 10 and 11 of the ASME Code, the staff finds this acceptable. **Therefore, RAI EPR-25C is resolved, pending revision to TR Table 3-1.**

AREVA also added explanations of notes for both TR Tables 3-1 and 3-2, and confirmed that there are no other dynamic loads on the building structure that would impact piping analysis and support design, when using Equation 11a of Subparagraph NC/ND 3653.2 for reversing loads. The seismic (reversing) inertia loads are included in Equation 9 and the secondary effects of these loads are included in Equation 10 as in the 1993 Code Addenda. The staff finds this acceptable. Therefore, **RAI EPR-25D & E are acceptable and therefore, are resolved.**

From its review, the staff concludes that appropriate combinations of normal, operating transients and accident loadings are specified to provide a conservative design envelope for the design of piping systems. The load combinations are consistent with the guidelines provided in SRP Section 3.9.3 and the staff position associated with the SECY 93-087 for elimination of an OBE. Therefore, the staff finds the load combination for the U.S. EPR piping design acceptable.

3.4.4 Damping Values

In TR Section 4.2.5, AREVA identified RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 0, for recommended values of damping (i.e., 2 percent for piping with 12-inch NPS or less, and 3 percent for piping larger than 12-inch NPS) to be used in the seismic analysis of SSCs using ISM RS analysis or TH analysis. However, for piping systems analyzed using USM RS analysis, 5 percent damping may be used provided that the system is not susceptible to stress corrosion cracking (SSC). Five percent damping will not be used for analyzing the dynamic response of piping systems using supports designed to dissipate energy by yielding.

The staff notes that Rev. 1 of the RG 1.61, issued in March 2007, recommends damping values for piping (i.e., 4 percent independent of pipe size and frequency) which are different from its Rev. 0 values. Therefore, in RAI EPR-26 the staff requested AREVA to clarify whether they will use the Rev. 0 or the Rev. 1 damping values. The use of 5 percent damping in USM analysis has been previously reviewed and accepted by the staff for ALWR plants on the basis that ALWR plants must be designed to a minimum 0.3g ZPA for the SSE. This high seismic acceleration provides assurance that piping systems will experience higher damping values. Its acceptance, however, was also subject to the limitations specified in RG 1.84 for ASME Code Case N-411-1 as well as several additional ALWR design-specific conditions. In RAI-EPR-26 the staff requested AREVA to clarify its position on various damping values that apply to U.S. EPR piping.

In its revised response (dated November 20, 2007), AREVA stated that the U.S. EPR will use 4 percent damping for systems susceptible to SCC and when supports that dissipate energy are used. AREVA also stated that this is consistent with RG 1.61, Rev. 1 damping values and will be used for ISM response spectra and TH methods of analysis. RG 1.61, Rev. 1 will also be used for piping systems analyzed using USM response spectra which do not meet all of the limitations specified in RG 1.84 for ASME Code Case N-411-1. Since this is consistent with RG 1.61, Rev.1, **the staff finds this acceptable, pending revision to TR Section 4.2.5.**

The staff notes that AREVA, however, suggests 5 percent damping for piping systems analyzed using USM response spectra which meets all of the limitations specified in RG 1.84 for ASME Code Case N-411-1. RG 1.61, Rev. 1 recommends frequency-dependent 5 percent damping for 0-10 Hz, 2 percent damping for greater than 20 Hz, and a linear transition from 5 percent to 2 percent for 10-20 Hz. The RG does not allow 5 percent damping, independent of frequency.

AREVA, in its response, justified that the seismic design criteria for U.S. EPR piping is at least as stringent as for CE System 80+, AP600, and AP1000, where the staff accepts the use of 5 percent damping only for USM RS analyses, subject to the same restrictions the staff previously imposed on former Code Case N-411-1. However, the staff notes that in addition to the restrictions outlined in Regulatory Position C.2 of RG 1.61, Rev.1 for frequency-dependent damping for USM method of analysis, the SERs for these design certifications also include the following additional restrictions (as stated in the FSERs for System 80+, AP600, and AP1000):

- For the primary coolant loop, a damping value of 4 percent must be used. For coupled piping-structure systems, an equivalent modal damping matrix or composite damping matrix is acceptable when using 5 percent damping for structures and 4 percent damping for the RCS components.
- Applicable to piping systems with rigid valves analyzed by the USM method.
- Not applicable to ISM and TH methods of analysis.
- Piping design must limit the building filtered responses to 33 Hz and below.
- Plants must be designed to a minimum 0.3g ZPA for the SSE.
- Limited to current seismic spectra applications only.

Even if one satisfies all these additional conditions, the current staff position does not allow 5 percent damping for all frequency range. Prior to this issuance of RG 1.61, Rev. 1, in March 2007, all other ALWR design certifications (System 80+, AP600, and AP1000) have been committed to RG 1.61, Rev.0 damping values of 2 and 3 percent, depending on the pipe size, which are much less than 4 percent allowed in RG 1.61, Rev.1. Based on this, the staff finds it unacceptable for using 5 percent damping for USM RS analysis, regardless of whether the Code Case N-411-1 limitations are satisfied, until AREVA provides additional technical justifications.

However, on April 18, 2008, AREVA provided its second revised response, in which AREVA is now committed to use damping values given in RG 1.61, Rev. 1 for both uniform support motion and independent support motion response spectrum analysis, and time history analysis. In Attachment B to this response, AREVA provided revised pages of the TR Section 4.2.5 on damping values. This is consistent with the current staff position on damping values to be used in piping systems for the EPR standard plant and therefore, the staff finds this acceptable. **RAI EPR-26 is resolved, pending revision to TR Section 4.2.5.**

3.4.5 Combination of Modal Responses

The inertial response of a piping system in a seismic response spectrum analysis is considered in two parts. First, the modal analysis calculates the peak response of the piping system for all low frequency (or non-rigid) modes with seismic excitation frequencies up to the frequency (known as the cutoff frequency) at which spectral accelerations return to the ZPA. Modal combinations associated with this part are evaluated in this section. Second, at modal frequencies above the cutoff frequency, pipe members are considered rigid. The acceleration associated with these rigid modes is usually small. However, in certain situations the response to high frequency modes can significantly affect support loads, particularly axial restraints on long piping runs. To account for these effects, AREVA presented a method of calculating the missing mass correction in TR Section 4.2.2.3.2.

In TR Section 4.2.2.3, specifically in Section 4.2.2.3.1 for low frequency modes, AREVA states that for the RS method of analysis, the modal contributions to the inertial responses (i.e., low frequency modes) 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 percent method, and double sum method, as well as the less conservative methods in Revision 2 of RG 1.92) is applicable for the combination of modal responses. The staff notes that the modal combination methods presented in RG 1.92 are applicable only to the USM response spectrum method of analysis. Specific guidance on the combination methods for groups, modes and directions to be used for the ISM method of analysis is given in NUREG-1061, V.4, and is discussed in Section 3.2.3 of this report. However, AREVA has not indicated any such differences in modal combinations between the ISM and USM methods of analysis (see RAI EPR-8). In RAI EPR-27 the staff requested AREVA to justify the use of modal combination methods in accordance with RG 1.92, Rev. 1, rather than RG 1.92, Rev. 2.

In its revised response (dated November 20, 2007), AREVA stated that in the background discussion of Section B as well as in the Regulatory Position in Section C of RG 1.92, Rev. 2, the methods of Revision 1 are included by reference as acceptable for use. In this regard, the staff's concern is that the definition of closely spaced modes has been shown to be damping dependent. See the discussion provided in Section 2.1.4 and Appendix D of NUREG/CR-6645, as this is also noted in Regulatory Position C.1.1.1 of RG 1.92, Rev. 2. The 10 percent (i.e., five times the critical damping ratio) definition of closely spaced modes is only appropriate up to around 2 percent damping.

The staff previously accepted Code Case N-411-1 damping for use with the RG 1.92, Rev. 1, modal combination methods. Since the strong dependency on damping is now better understood, the staff's position is that the modal combination methods recommended in RG 1.92, Rev. 2, are more compatible with damping of 4 percent to 5 percent. The staff acknowledges that there is no explicit referencing between RG 1.92, Rev. 2 and RG 1.61, Rev. 1. However, Recommendation (3) in Section 5.2 of NUREG/CR-6645 provides a concise summary of this issue, and the appropriate use of the grouping method.

For the specific piping problem used as the basis for the comparisons in NUREG/CR-6645, the numerical results using RG 1.92, Rev. 1, modal combination methods show a comparable level of conservatism for both 1 percent damping and 5 percent damping. However, a generic conclusion cannot be drawn from this single outcome. Based on the numerical values presented in Appendix D of NUREG/CR-6645, it is feasible that the level of conservatism could diminish with increasing damping. Of real concern is the trend toward significantly greater data scattering, as evidenced by the large increase in the standard deviation between 1 percent and 5 percent damping. Comparing the results on pages 42 and 44 of the NUREG report, the standard deviation for the recommended methods in RG 1.92, Rev. 2, increased from 0.35 and 0.37, to 0.45 and 0.47, respectively, between 1 percent and 5 percent damping. For the RG 1.92, Rev. 1 methods, the standard deviation increased from 0.48, 0.67, and 0.49, to 1.21, 1.65, and 1.67, respectively, between 1 percent and 5 percent damping. This is indicative of the fact that at higher damping, these methods give increasingly unrealistic results.

As noted in NUREG/CR-6645, Section 2.1, there is no logical technical basis for any of the RG 1.92, Rev. 1, methods to account for closely spaced modes. They were intended to be conservative corrections for cases where the interaction of closely spaced modes might compromise the conservatism of the SRSS rule. The 10 percent definition for closely spaced modes is consistent with low damping (less than or equal to 2 percent). In the interest of obtaining more accurate results using the RS analysis method, for damping of 4 percent to 5 percent, the applicant is strongly advised to completely adopt the methods recommended in RG 1.92, Rev. 2, for obtaining the complete RS solution. This also includes the methods for separation of out-of-phase (periodic) and in-phase (rigid) response components. Based on this, the staff finds the AREVA response not acceptable until AREVA provides additional technical justification for using RG 1.92, Rev. 1 modal combination methods for higher damping values (in accordance with RG 1.61, Rev. 1) for the U.S. EPR piping design.

On April 18, 2008, AREVA provided its second revised response, in which AREVA is now committed to use the modal combination methods given in RG 1.92, Rev. 2 for uniform support motion response spectrum analysis. In Attachment B to this response, AREVA provided revised pages of the TR Section 4.2.2.3 on modal combinations. This is consistent with the current staff position on modal combination methods to be used in piping systems for the EPR standard plant and therefore, the staff finds this acceptable. **RAI EPR-27 is resolved, pending revision to TR Section 4.2.2.3.1.**

3.4.6 High-Frequency Modes

In TR Section 4.2.2.3.2, AREVA presents a procedure to account for high-frequency modes in the RS methods of analysis to be used for seismic or other dynamic loads. This procedure requires the computation of individual modal responses only for lower-frequency modes (below the ZPA). For flexible piping systems, the high frequency response may not be significant since a significant portion of the system mass is excited at frequencies below the ZPA. However, for piping systems, or portions of piping systems, which are more rigidly restrained or have lumped masses near rigid restraints, a significant portion of the system mass may not be accounted for in the low frequency modal analysis. This mass which is not excited at the lower frequencies is termed the "missing mass" of the system. While high frequency modes usually involve small displacement amplitudes and small pipe stresses, they can have a significant impact on determining the support loads.

AREVA 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 percent. The peak modal responses of the system at frequencies above the ZPA are considered to be in phase. Thus, the responses of all high frequency modes are combined by absolute summation.

AREVA also states that the missing inertia forces are calculated independently for all input components of earthquake motion (i.e., in each direction for each support group). The mode displacements, member end action, and support force corresponding to each missing mass mode is determined. These results are treated as an additional modal result in the response spectrum analysis. This missing mass mode is considered to have a modal frequency and acceleration equal to the cutoff 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, Rev. 1).

AREVA further states that the modal combination for the high frequency modes above the cutoff frequency for vibratory loads is performed in accordance with the Appendix A of SRP 3.7.2, Rev 2, as well as Rev. 2 of the RG 1.92 (since the Rev. 1 of the RG does not address the missing mass contribution). However, the staff notes that there are some differences between the methods of calculating the effects of missing mass presented in the SRP and the RG. In RG 1.92, Rev. 2, Regulatory Position C.1.4.1 states that for calculating the residual rigid response of the missing mass modes the criteria presented in the Appendix A of SRP 3.7.2, Rev. 2, would yield non-conservative results and Appendix A of RG 1.92, Rev. 2 now provides the updated criteria for the missing mass contribution to the total response. Since AREVA is committed to RG 1.92, Rev. 2, piping methodology for missing mass contribution presented in TR Section 4.2.2.3.2 is not consistent with the RG. Also, the staff needs clarification on the mathematical derivations presented in the TR and how the missing mass contribution is combined with the modal responses. In RAI EPR-28, the staff requested AREVA to describe the technical differences between the method presented in the TR and the method acceptable to the staff as given in the RG, and also clarify the combination method to be used for the missing mass results with the modal responses.

In its revised response (dated November 20, 2007), AREVA stated that 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, Rev. 2, it produces the same result. The basic difference in the presentations of the missing mass calculation as shown in RG 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 RG equations in vector form shows that the formulations are equivalent. However, BWSPAN uses the missing mass method given in Appendix A of RG 1.92, Rev. 2, and U. S. EPR piping design will use BWSPAN for calculating the missing mass. The staff finds this acceptable.

AREVA also stated that the residual rigid response of the missing mass modes will be included in all seismic analyses of safety related piping systems. For cases where responses at frequencies above the ZPA are in phase, the responses of all high frequency modes will be combined by algebraic summation. Also 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, Vol. 4. The staff finds this acceptable.

AREVA further stated that 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 actually 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. It should be noted that the staff has not accepted the AREVA-suggested modal combination methods of RG 1.92, Rev. 1 (per RAI EPR-27). With regards to combination of the missing mass results in the rigid range with low frequency modal results, the staff finds the Combination Method A given in Section C.1.5.1 of Rev. 2 of RG 1.92 acceptable. Therefore, **RAI EPR-28 is resolved, pending revision to TR Section 4.2.2.3.**

The staff also notes that another consideration involves high frequency responses of the piping system when the nonlinear analyses are used to account for gaps between the pipe and its supports and subjected to vibratory loads (other than seismic) with significant high-frequency. The description of and justification for such analyses (which may require a nonlinear analysis) must be submitted to the staff for review and approval before use. Therefore, in RAI EPR-29 the staff requested AREVA to provide the piping analysis method to be used when subjected to vibratory loads with significant high-frequency content caused by gaps between the pipe and its supports.

In its revised response (dated November 20, 2007), AREVA stated that 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 one-sixteenth inch gap between the surface of the pipe and the edge of the support member for both sides of the pipe in the restrained direction. Although the use of gapped supports is not anticipated for the U.S. EPR, should the need for such supports arise, the nonlinear piping analysis problem will be solved using direct integration time history methods. This is acceptable to the staff, provided the nonlinear modeling and method of analysis are accepted by the staff prior to its use. Therefore, **RAI EPR-29 is resolved, pending revision to TR Section 6.5, and subject to a condition that any nonlinear analysis used in the U.S. EPR piping design must be reviewed and approved by the staff prior to its use.**

3.4.7 Fatigue Evaluation for ASME Code Class 1 Piping

ASME Code, Section III requires that the cumulative damage from fatigue be evaluated for all ASME Code Class 1 piping. The fatigue cumulative usage factor (CUF) should take into consideration all cyclic effects caused by the plant operating transients for a 60-year design life. However, recent test data indicates that the effects of the reactor environment could reduce the fatigue resistance of certain materials. A comparison of the test data with the Code requirements indicates that the margins in the ASME Code fatigue design curves might be less than originally intended.

In TR Section 3.4.1 AREVA states that Class 1 piping will be evaluated for the effects of fatigue as a result of pressure and thermal transients and other cyclic events including earthquakes. The environmental effects of the reactor coolant on fatigue will be accounted for in the Class 1 piping fatigue analyses using methods acceptable to the NRC at the time of performance. The staff notes that AREVA must include in the FSAR regarding how the environmental effects will be accounted for in the Class 1 piping fatigue analysis for the design certification. The staff finds this acceptable.

In TR Section 3.4.1, AREVA also states that since the OBE is not considered for the U.S. EPR, the fatigue analysis of Class 1 piping greater than 1 inch NPS is performed using the ASME Code requirements with 2 SSE events with 10 maximum stress-cycles each for a total of 20 full cycles of SSE stress range (which is considered equivalent to one SSE and 5 OBE events with 10 maximum stress cycles per event as defined in SRP Section 3.7.3). Alternatively, per NRC memo SECY-93-087, AREVA may use the methods of Appendix D of IEEE Standard 344-1987 to determine a number of fractional vibratory cycles equivalent to 20 full SSE cycles. Thus, for a case with one-third of the SSE amplitude, 300 fractional SSE cycles will be considered. This is consistent with the requirements of SRP Section 3.7.3 and therefore, is acceptable.

3.4.8 Fatigue Evaluation of ASME Code Class 2 and 3 Piping

In TR Section 3.4.2, AREVA states that Class 2 and 3 piping is evaluated for fatigue due to thermal cycles by following the requirements of the ASME Code, which involve the reduction of Code allowables for the thermal expansion stresses calculated as determined in Table NC/ND-3611.2(e)-1, "Stress Range Reduction Factors." The environmental effects on fatigue of Class 2 and 3 piping will follow guidelines established by the NRC at the time of analysis. The staff notes that AREVA must include in the FSAR regarding how the environmental effects will be accounted for in the Class 2 and 3 piping for the design certification. Therefore, the staff finds this acceptable.

3.4.9 Thermal Oscillations in Piping Connected to the Reactor Coolant System

In accordance with NRC Bulletin 88-08, the staff requires that licensees and applicants review systems connected to the RCS (including the RPV) to determine whether any sections of this piping, that cannot be isolated, can be subjected to temperature oscillations that could be induced by leaking valves. In TR Section 3.7.3, AREVA states that unisolable sections of piping connected to the RCL will be evaluated to determine if thermal stratification and striping (i.e., temperature oscillations) caused by a leaking valve are plausible, as discussed in NRC Bulletin 88-08. In addition, contributions to fatigue from thermal stratification and striping will be considered where it is determined that these phenomena are occurring. The staff notes that AREVA must identify all sections of piping that will be subject to thermal oscillation and connected to the RCS and include it in the FSAR for the design certification review. Therefore, the staff finds this acceptable.

3.4.10 Thermal Stratification

Thermal stratification is a phenomenon that can occur in long runs of horizontal piping when two streams of fluid at different temperatures flow in separate layers without appreciable mixing. Under these stratified flow conditions, the top of the pipe may be at a much higher temperature than the bottom. This thermal gradient produces pipe deflections, support loads, pipe bending stresses, and local stresses that may not have been accounted for in the original piping design. The effects of thermal stratification have been observed in PWR piping as discussed in NRC Bulletins 79-13 (on feedwater lines) and 88-11 (on pressurizer surge lines).

NRC Bulletin 79-13 was issued as a result of a feedwater line cracking incident at D.C. Cook Nuclear Plant Unit 2 which led to the discovery of cracks in numerous other plants. The primary cause of the cracking was determined to be thermal fatigue loading due to thermal stratification and high-cycle thermal striping during low flow emergency feedwater injection. In TR Section 3.7.1, AREVA states that the steam generators and main feedwater lines in the

U.S. EPR are designed to minimize thermal stratification. Separate nozzles are designed on the steam generator for the main feedwater and emergency feedwater connections and pipe runs are relatively short. The main feedwater nozzle is located in the conical section of the steam generator which aids in reducing thermal stratification. In addition, the effects of thermal stratification and striping will be evaluated during the evaluation of the main feedwater system and the evaluation will confirm that all load cases meet the ASME Code allowables.

NRC Bulletin 88-11 requires consideration of the effects of thermal stratification on the pressurizer surge line. In TR Section 3.7.2, AREVA states that the surge line on the U.S. EPR will be analyzed with the RCL piping and supports. The effects of thermal stratification and striping will be considered as part of this analysis or it will be demonstrated that the surge line is not subjected to significant stratification/striping effects due to design features that mitigate these effects.

AREVA also states that the COL applicant will confirm that thermal deflections do not create adverse conditions during hot functional testing. This is identified as the COL-Action Item 4 in TR Table 1-1.

In RAI EPR-30, the staff requested AREVA to clarify some of the suggested design features that will minimize the effects of thermal stratification in the feedwater line and the surge line. In its revised response (dated November 20, 2007), AREVA stated that since the main feedwater nozzle is attached to the sloped conical section of the steam generator, it too is inclined approximately 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 will be provided in Section 3.12 of the FSAR. With regard to the pressurizer surge line, there are three major features which minimize the amount of stratification in this line: 1) The take-off from the hot leg is vertical upward and of sufficient length that turbulent penetration from hot leg flow will not spill over into the surge line beyond the take-off and cause stratification; 2) the surge line is sloped approximately 5 degrees between the vertical take-off at the hot leg and the vertical leg at the pressurizer, which will promote 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 also be provided in Section 3.12 of the FSAR. The staff finds this acceptable at this pre-certification stage and the thermal stratification issue will be further assessed when additional information is available during the design certification. Therefore, **RAI EPR-30 is resolved.**

3.4.11 Safety Relief Valve Design, Installation, and Testing

In TR Section 3.8.1, AREVA states that the design and installation of safety and relief valves for overpressure protection are performed to the criteria specified in Appendix O of the ASME Code, “Rules for the Design of Safety Valve Installations,” 2001 Edition, 2003 Addenda. In addition, the design and installation requirements will include the additional criteria in SRP Section 3.9.3, Paragraph II.2. In TR Section 3.8.2, AREVA describes analysis requirements for pressure relieving devices when the discharge is directly to the atmosphere (open discharge) and to headers or tanks (closed discharge).

In accordance with TMI Action Item II.D.1 of NUREG-0737, both PWR and BWR licensees and applicants are required to conduct testing to qualify the RCS relief and safety valves and associated piping and supports under expected operating conditions for design-basis transients and accidents. AREVA did not discuss the testing and qualification aspects of the safety and relief valves and also did not define the design parameters or criteria that need to be specified for the piping and support design. Therefore, in RAI EPR-31 the staff requested AREVA to describe the relevant design parameters in designing pressure relief devices and automatic depressurization valves connected to the pressurizer, the safety valves, power operated relief valves on the steam lines, and the relief valve on the containment isolation lines. In response (dated July 13, 2007), AREVA stated that discussion of SRV design parameters and criteria will be addressed in the FSAR at the time of design certification. This is acceptable to the staff and therefore, **RAI EPR-31 is resolved.**

3.4.12 Functional Capability

All ASME Code Class 1, 2, and 3 piping systems that are essential for safe shutdown must retain their functional capability for all Service Level D loading conditions as required by GDC 2. Designs meeting the recommendations in NUREG-1367, "Functional Capability of Piping Systems," are accepted by the staff as satisfying the functional capability requirements.

In TR Section 3.5, AREVA states that all ASME Code Class 1, 2, and 3 piping systems that are essential for safe shutdown under the postulated events listed in the TR Table 3-3 are designed to meet the recommendations in NUREG-1367. In no case shall the piping stress exceed the limits designated for Service Level D in the ASME Code, Section III. The Service Level D limits are 3.0 S_m (not to exceed 2.0 S_y) for ASME Code Class 1 piping and 3.0 S_h (not to exceed 2.0 S_y) for Class 2 and 3 piping. In addition, the criteria also include: (1) the ratio of pipe NPS and the wall thickness (D_o/t) not to exceed 50; (2) dynamic responses for reversing dynamic loads (e.g., earthquake, building hydrodynamic loads) based on an elastic response spectrum with 15 percent peak broadening with not more than 5 percent damping; (3) the external pressure not to exceed the internal pressure; and finally, (4) steady state stresses from dead weight loads not to exceed 0.25 S_y. For piping analyzed by TH methods, uncertainties in the applied THs must be accounted for. Since AREVA is committed to satisfy all requirements of NUREG-1367, the staff finds this acceptable.

3.4.13 Combination of Inertial and Seismic Anchor Motion Effects

Piping analyses must include the effects caused by the relative building movements at supports and anchors (seismic anchor motion) as well as the seismic inertial loads. This is necessary when piping is supported at multiple locations within a single structure or is attached to two separate structures or buildings.

The effects of relative displacements at support points must be evaluated by imposing the maximum support displacements in the most unfavorable combination. This can be performed, using a static analysis procedure. Relative displacements of equipment supports (e.g., pumps or tanks) must be included in the analysis along with the building support movements.

When required for certain evaluations, such as support design, the responses that are due to the inertia effect and relative displacement effect should be combined by the absolute sum method per SRP Section 3.9.2 for the USM method of analysis, and the SRSS method per NUREG-1061 for the ISM method of analysis (assuming that the group, modal, and directional combinations follow the recommended methods in NUREG-1061, V.4). In lieu of this method, THs of support excitations may be used, in which case both inertial and relative displacement effects are already included.

In TR Section 4.2.2.5, AREVA states that the results of the SAM analysis will be combined with the results of the seismic inertia analysis using the absolute sum method. AREVA did not distinguish any differences between the USM and ISM methods of RS analysis for the inertial responses. In RAI EPR-8, the staff requested that AREVA clarify its position for the ISM method of RS analysis. AREVA is committed to use the absolute sum method for the USM method of analysis consistent with SRP 3.9.2, and the SRSS method for the ISM method of analysis consistent with NUREG-1061, Volume 4. The staff finds this acceptable.

3.4.14 OBE as a Design Load

In SECY-93-087, the staff recommended eliminating the OBE from the design for ALWRs. The Commission approved the staff recommendations in its Staff Requirements Memorandum (SRM) dated July 21, 1993. The SECY document includes specific supplemental criteria for fatigue, seismic anchor motion, and piping stress limits that should be applied when the OBE is eliminated. The staff position on the use of a single-earthquake design for SSCs is discussed in Section 3.4.3 for load combinations and Section 3.4.7 for fatigue evaluation. The effects of SAM due to the SSE should be considered in combination with the effects of other normal operational loadings that might occur concurrently. For fatigue evaluation, two SSE events with 10 maximum stress cycles per event (or an equivalent number of fractional cycles) should be considered.

For Class 1 primary stress evaluation, seismic loads need not be evaluated for consideration of Level B Service Limits for Eq. (9). However, for satisfaction of primary plus secondary stress range limits in Eq. (10), the full SSE stress range or a reduced range corresponding to an equivalent number of fractional cycles must be included for Level B Service limits. These load sets should also be used for evaluating fatigue effects. In addition, the stress that is due to the larger of the full range of SSE anchor motion or the resultant range of thermal expansion plus half the SSE anchor motion range, must not exceed 6.0 S_m. For Class 2 and 3 piping, seismic loads are not required for consideration of occasional loads in satisfying the Level B Service Limits for Eq. (9). Seismic anchor motion stresses are not required for consideration of secondary stresses in Eq. (10). However, stresses that are due to the combination of range of moments caused by thermal expansion and SSE anchor motions must not exceed 3.0 S_h. TR Table 3-2 appropriately addresses the load combinations and stress criteria for Class 2 and 3 piping design. In RAI EPR-25C, the staff requested AREVA to clarify similar criteria for Class 1 piping and AREVA has added this consideration in TR Table 3-1. This is discussed in Section 3.4.3 of this report.

In TR Section 3.4.1, AREVA states that the fatigue evaluation of ASME components will take into consideration 2 SSE events with 10 peak stress cycles per event. Alternately, an equivalent number of fractional vibratory cycles (i.e., 300 cycles) may be used (but with an amplitude not less than one-third of the maximum SSE amplitude) when derived in accordance with Appendix D of IEEE Standard 344-1987. The staff finds this acceptable, since the commitment is consistent with the NRC guidance document previously discussed above and the Commission-approved staff recommendations on the issue of OBE elimination.

3.4.15 Welded Attachments

For the analysis of local stresses at welded attachments to piping (e.g., lugs, trunnions, or stanchions), in TR Section 3.6 AREVA states that the support and restraint designs that require welded attachments to the pipe for transfer of the pipe loads to the supporting structure will adhere to industry practices and ASME Code Cases identified in TR Section 2.2. Since this will ensure the quality of these welded attachments, the staff finds this acceptable.

3.4.16 Composite Modal Damping

For subsystems that are composed of different material types (e.g., welded steel pipe and pipe supports), either a mass or stiffness weighted method can be used to determine the composite modal damping value. Composite modal damping for coupled building and piping systems can be used for piping systems that are coupled to the primary coolant loop system and the interior concrete building.

The composite modal damping ratio can be used when the modal superposition method of analysis (either TH or RS) is used, as required by SRP Section 3.7.2, II.13. AREVA has not described any methods of calculating the composite damping that may be used in the dynamic analysis of piping and supports. In RAI EPR-32, the staff requested AREVA to provide the method(s) for determining the composite modal damping to be used in the U.S. EPR piping design.

In response (dated July 13, 2007), AREVA stated that composite modal damping may be applied when the modal superposition method of analysis is used. The methods used will meet the requirements of SRP 3.7.2. The staff finds this acceptable and therefore, **RAI EPR-32 is resolved.**

3.4.17 Minimum Temperature for Thermal Analyses

In TR Section 3.3, AREVA states that the zero thermal load temperature is 70 ^{o}F and for piping systems with an operating temperature equal to or less than 150 ^{o}F, a thermal analysis is not required. Since these criteria are typically used by the industry, the staff finds this acceptable.

3.4.18 Intersystem LOCA

In SECY 90-016, dated January 12, 1990, the staff discussed the resolution of the Intersystem LOCA (ISLOCA) issue for advanced light water reactor plants by requiring that low pressure piping systems that interface with the RCPB be designed to withstand full RCS pressure to the extent practicable. In its June 26, 1990, SRM, the Commission approved these staff recommendations provided that all elements of the low-pressure systems are considered.

In TR Section 3.9, AREVA states that low pressure piping systems that interface with the RCL and are thus subjected to the full RCL pressure will be designed for the full operating pressure of the RCL. The appropriate minimum wall thickness of the piping will then be calculated for each system using Equation 1 of Subsubarticle NB-3640 of the ASME Code for Class 1 piping or Equation 3 of Subsubarticle NC/ND-3640 for Class 2 and 3 piping. The piping will be analyzed to the requirements in Subsubarticle NB/NC/ND-3650. Since this satisfies the

ASME Code and ensures the low pressure piping to withstand a full RCL pressure, the staff finds this acceptable.

3.4.19 Conclusions

On the basis of the discussion in the above subsections and evaluation of TR Sections 3.0 and 4.0, the staff concludes that the stress analysis methods for the U. S. EPR piping design are acceptable for ensuring its structural integrity when subject to ASME Code-defined service loads. The staff's conclusion is based on the following:

(1) AREVA meets GDC 1 and 10 CFR Part 50, Appendix B with regard to piping systems being designed, fabricated, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed, and with appropriate quality control.

(2) AREVA meets GDC 2 and 10 CFR Part 50, Appendix S with regard to design transients and resulting load combinations for piping and pipe supports to withstand the effects of earthquakes combined with the effects of normal or accident conditions.

(3) AREVA meets GDC 4 with regard to piping systems important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions of normal and accident conditions.

(4) AREVA meets GDC 14 with regard to the reactor coolant pressure boundary of the primary piping systems being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapid propagating failure, and of gross rupture.

(5) AREVA meets GDC 15 with regard to the reactor coolant piping systems being designed with specific design and service limits to assure sufficient margin that the design conditions are not exceeded.

3.5 Pipe Support Design Criteria

GDC 1 requires that the piping and pipe supports should be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. 10 CFR Part 50, Appendix B requires that design quality should be controlled for ensuring structural and functional integrity of seismic Category I components. GDC 2 requires that the piping and pipe supports should withstand the effects of earthquake loads. The supporting elements should be capable of carrying the sum of all concurrently acting loads and designed to provide the required support to the piping system and allow pipe movement with thermal changes without causing overstress. All parts of the supporting equipment or structure should be fabricated and assembled so that they would not be disengaged by movement of the supported piping.

In TR Section 6.0, AREVA states that the pipe support elements will be designed to meet the requirements of the appropriate design codes and be consistent with the code requirements of the overall piping system. Pipe supports typically include structural elements, which sometimes are coupled with standard manufactured catalog items developed specifically for pipe supports. The piping analysis usually makes assumptions for the support mass and stiffness as required by the specific analysis conditions. Typically, supports are designed separately from the piping analysis, with design methods to match the assumed analysis constraints. As such, the supports should be designed to minimize their effects on the piping analysis and not invalidate the piping analysis assumptions. There are situations where AREVA did not provide criteria to address cases where assumptions made in the piping analysis deviate from those of the support design. In such cases, either the support should be redesigned in accordance with the assumptions made in the piping analysis, or the piping system should be reanalyzed using the actual parameters used in the design of the pipe supports. The staff requested AREVA to address the verification criteria of the as-built support parameters with the assumptions made during piping analysis. AREVA's responses to these RAIs are discussed here.

3.5.1 Applicable Codes

Pipe supports include hangers, snubbers, struts, spring hangers, frames, energy absorbers and limit stops and can be plate and shell type supports, linear type supports or commercially available standard piping supports. In TR Section 6.1, AREVA states that for Service Levels A, B and C, the seismic Category I pipe supports will be designed, manufactured, installed and tested in accordance with Subsection NF of the ASME Code and for Service Level D, Appendix F of Section III of the ASME Code will be utilized. In addition, the welding requirements for A500, Grade B tube steel from AWS D1.1 will be utilized.

AREVA also states that plate and shell type supports such as skirts or saddles are fabricated from plate elements and loaded to create a biaxial stress field. Linear type supports (i.e., beams, columns, frames and rings) are essentially subjected to a single component of direct stress, but may also be subjected to shear stresses. Standard supports are made from typical support catalog items such as springs, rigid struts and snubbers and are typically load rated items, but may be also qualified by plate and shell or linear analysis methods.

Further, AREVA 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." Non-seismic category pipe supports are designed using guidance from the AISC Manual of Steel Construction. In addition to the pipe support design codes mentioned above, expansion anchors and other steel embedments in concrete shall be designed for concrete strength in accordance with ACI-349, "Code Requirements for Nuclear Safety Related Concrete Structures."

AREVA further states that typically the stress limits for pipe supports are in accordance with ASME III, Subsection NF and Appendix F. The design of all supports for the non-nuclear piping satisfies the requirements of ASME/ANSI B31.1 Power Piping Code, Paragraph 120 for loads on pipe supporting elements and Paragraph 121 for design of pipe supporting elements. The staff reviewed the applicable codes in TR Section 6.1 and in RAI EPR-33 requested AREVA to clarify the applicability of some codes and standards suggested in the TR.

In response (dated July 13, 2007), AREVA stated that seismic Category I pipe supports will be designed to ASME Subsection NF loadings for Service Levels A, B, C and D, while using the acceptance limits of Subsection NF for Levels A, B and C, and the acceptance limits of Appendix F for Level D. Subsection NF of the ASME Code will be used for the manufacturing, installation and testing of all seismic Category I pipe supports.

AREVA also stated that 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.

AREVA further stated that for non-seismic pipe supports supporting piping analyzed to B31.1, the requirements of B31.1 for supports (Paragraphs 120 and 121) will be met, where applicable. In addition, the structural elements will meet the requirements of the AISC Manual. For standard components used in such supports, vendors catalog requirements will be utilized, which also meet B31.1 requirements. For non-seismic pipe supports supporting unanalyzed piping, the structural elements will meet the requirements of the AISC Manual, and standard components will meet vendors catalog requirements.

The staff finds that the ASME Code Section III, Subsection NF and Appendix F, along with the other associated design documents for seismic Category II and non-seismic pipe supports are quality industry standards and are acceptable. Therefore, RAI **EPR-33 is resolved, pending revision to TR Section 6.1.**

3.5.2 Jurisdictional Boundaries

In TR Section 6.2, AREVA states that all piping supports are designed in accordance with the rules of Subsection NF of the ASME Code up to the building structure interface as defined by the jurisdictional boundaries in Subsubarticles NF-1130 of the ASME Code. For attachments to building steel, the boundary is taken at the interface with the building steel, with the weld being designed to the rules of ASME Code, Subsection NF. For attachments to concrete building structures, the boundary is generally at the weld of the support member to a baseplate or embedded plate, with the weld again being designed to the rules of ASME Code, Subsection NF.

The jurisdictional boundary between the pipe and its support structure will follow the guidance of Paragraph NB-1132, NC-1132, or ND-1132, as appropriate for the ASME Class of piping involved. For piping analyzed to B31.1, the jurisdictional boundary guidance of Paragraph ND-1132 will be utilized.

The staff's review of the jurisdictional boundaries in the Code finds that they are sufficiently defined to ensure a clear division among the piping, pipe support and the building structure. Therefore, the staff finds this acceptable.

3.5.3 Loads and Load Combinations

TR Section 6.3 defines the support loads and their combination methods for the design of piping supports correspond to those used for design of the supported pipe. The loadings for the pipe support design include:

- deadweight (includes pipe and fittings, contents and support itself)
- thermal (for all four service levels: normal, upset, emergency and faulted)
- friction (due to thermal expansion movement)
- system operating transients (safety/relief valve thrust, fast valve closure, water/steam hammer)

- wind and tornado
- design basis pipe break (includes jet impingement or pipe whip)
- main steam/feedwater pipe break
- LOCA
- seismic (safe shutdown earthquake and seismic anchor movement)

In TR Section 6.3.11, AREVA 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 percent 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. 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.

AREVA states that since signed thermal loadings may cancel other signed loadings, the cold condition must also always be considered for support loads. In TR Section 6.3.2, AREVA states consideration for local, radial thermal expansion of the pipe cross section must be made. This effect is often addressed by having small gaps around the pipe for such thermal growth, while still maintaining relatively tight constraints for seismic loadings.

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 the COL-Action Item 3.

Based on the above, in RAI EPR-34 the staff requested AREVA to clarify several statements made in the TR Section 6.3. In its revised response (dated November 20, 2007), AREVA clarified that the minimum design load criteria of 100 percent of the Level A condition load given in this section is based on criteria given in Welding Research Council (WRC) Bulletin 353, Section 2.4.7. The bulletin recommends 125 percent of the Level A condition load and the TR will be revised to this in order to be consistent with WRC Bulletin 353. The staff finds this acceptable.

To clarify the load combinations for different types of supports, AREVA also clarified that 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 the absolute sum method. These would all apply to Class 1, 2 and 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.

With regards to wind/tornado loads, AREVA clarified the TR Section 3.3.1.6 that for design certification, no Class 1, 2 and 3 piping is exposed to wind and tornado loads, and further stated 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.

AREVA also stated in its response that 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. Table 6-1 of the TR will be revised to include the effects of system operating transients (RSOT) with pipe break, LOCA, and SSE loads, both in the Level C and the Level D cases.

AREVA further stated that 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 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 are not met, dynamic loads are combined by absolute summation. SSE and high energy line break (i.e. LOCA 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.

Since the load combinations presented in TR Table 6-1 are consistent with the industry practice using ASME Code, Subsection NF, ANSI/AISC N690 or AISC Manual for Steel Construction for Service Level A, B, C and D loads, and consistent with NUREG-0484 for dynamic load combinations, the staff finds this acceptable. Therefore, **RAI EPR-34 is resolved, pending revision to TR Sections 6.3.5, 6.3.6, and 6.3.11 and Table 6-1.**

3.5.4 Pipe Support Baseplate and Anchor Bolt Design

In TR Section 6.4, AREVA states that the use of baseplates with expansion anchors will be minimized in the U.S. EPR design. The concrete will be evaluated using ACI-349, Appendix B subject to the conditions and limitations of RG 1.199. This guidance accounts for the proper consideration of anchor bolt spacing and distance to a free edge of concrete. In addition, all aspects of the anchor bolt design, including baseplate flexibility and factors of safety will be utilized in the development of anchor bolt loads, as addressed in IE Bulletin 79-02, Revision 2. The staff finds that baseplate and anchor bolts will be adequately designed based on the above requirements and hence, are acceptable.

3.5.5 Use of Energy Absorbers and Limit Stops

In TR Section 6.5, AREVA states that energy absorbers and limit stops for pipe supports utilizing normal design loadings will not be used for the U.S. EPR piping design. However, AREVA may use energy absorbing material in the design of pipe whip restraints, which are out of scope for this assessment. The staff finds this acceptable.

3.5.6 Use of Snubbers

The operating loads on snubbers are the loads caused by dynamic events during various operating conditions. Snubbers restrain piping against response to dynamic excitation and to the associated differential movement of the piping system support anchor points. The loads calculated in the piping dynamic analysis cannot exceed the snubber load capacity for design, normal, upset, emergency and faulted conditions. Snubbers are generally used in situations where dynamic support is required because thermal growth of the piping prohibits the use of rigid supports. The snubber locations and support directions are first decided by estimation so that the stresses in the piping system have acceptable values.

In TR Section 6.6, AREVA states that typical snubber components are manufactured standard hardware, and may be either hydraulic or mechanical in operation. Other design/analysis considerations for snubbers are related to the ability of the snubbers to properly activate for their design loadings. For snubbers which might experience high thermal growth rates, the analysis should ensure that such growth rates do not exceed the snubber lock-up velocity. Also, for parallel snubbers utilized in the same support, care must be taken to ensure that total fitting clearances are not mismatched between the tandem snubbers such that one will activate before the other.

AREVA also states that design specifications provided to the snubber suppliers will include the codes and standards, functional requirements, operating environment (both normal and post accident), materials (construction and maintenance), functional testing and certification, and requirements for construction to meet ASME Code, Subsection NF. The proper installation and operation of snubbers will be verified by the COL applicant, utilizing visual inspections, hot and cold position measurements, and observance of thermal movements during plant startup. This is identified as the COL-Action Item 7 in TR Table 1-1.

In accordance with SRP Section 3.9.3, II.3B, AREVA should provide the criteria for acceptance for snubber operability assurance for safety-related systems. The criteria should include structural analysis and systems evaluation, characterization of mechanical properties, design specifications, installation and operability verification, and inspection and testing. In RAI EPR-35, the staff requested AREVA to provide this information. In response (dated July 13, 2007), AREVA stated that the design specifications will be the responsibility of the COL applicant (See item 2 of TR Table 1-1). The specification will be generated using the snubber specification requirements given in Chapter 3 of the FSAR. Therefore, the staff finds this acceptable, and **RAI EPR-35 is resolved.**

3.5.7 Pipe Support Stiffnesses

TR Section 6.7 provides limited information about modeling the stiffness of pipe supports by using representative stiffness values either as the actual stiffness or an arbitrary rigid stiffness. Also, AREVA discusses two deflection checks that will be performed for each support modeled as rigid in the piping analysis. The first check will compare the deflection in the restrained direction(s) to a maximum of one-sixteenth inch for SSE loadings or the minimum support design loadings of TR Section 6.3.11. The second check will compare the deflection in the restrained direction(s) to a maximum of one-eighth inch for the worst case deflection for any load case combination. Note that in the development of the support deflections, dynamically flexible building elements beyond the support jurisdictional boundaries will also be considered.

AREVA does not adequately describe how the representative stiffness values are developed for all supports other than snubbers. Therefore, in RAI EPR-36, the staff requested AREVA to 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 ASME Subsection NF jurisdictional boundary) and for equipment to which the piping may be connected to.

In its revised response (dated November 20, 2007), AREVA stated that 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 TR. If for some reason, a rigid support cannot be achieved, 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 one-sixteenth inch deflection for Level B checks, with no more than a maximum of one-quarter 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.

AREVA also stated that 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. Since the process described is consistent with the industry practices, the staff finds this acceptable. Therefore, **RAI EPR-36 is resolved, pending revision to TR Section 5.1.**

3.5.8 Seismic and Other Dynamic Load Self-Weight Excitation

In TR Section 6.8, AREVA states that the response of the support structure itself to SSE loadings is to be included in the pipe support analysis. In general, the inertial response of the support mass will be evaluated using a RS analysis similar to that performed for the piping. Damping values for welded and bolted structures are given in RG 1.61. This support self-weight SSE response, the piping inertial load SSE response and the SSE loads from SAM are to be combined by the absolute sum method. However, this criterion does not include other dynamic loads, specifically the system operating transients, and AREVA did not specifically discuss how the RG 1.61 damping will be used in the analysis since the support structure and piping damping may be different. Therefore, in RAI EPR-37 the staff requested AREVA to provide this information.

In its revised response (dated November 20, 2007), AREVA stated that 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. AREVA will revise TR Section 6.8 to reference Rev. 1 of RG 1.61. Since this is consistent with the industry practices, **the staff finds this part of RAI EPR-37 acceptable, pending revision to TR Section 6.8.**

AREVA also stated that 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.

However, in the original RAI the staff requested AREVA to explain the criterion applicable to other dynamic loads due to system operating transients. It is not clear what AREVA meant by stating that any subsequent excitation of the support structure itself for the fluid dynamic event will not be evaluated since its effect is minimal. The staff assumes that the loads from these subsequent self excitation caused by the fluid dynamics are bounded by the piping loads. If this is not true for any dynamic condition, then AREVA must provide technical justification for not including them in the pipe support design. AREVA should clarify how other dynamic loads, such as thermal and pressure transients, water hammer, etc., are included in the design of pipe supports, including the load combinations given in TR Table 6-1. On April 18, 2008, AREVA provided in Attachment B of its second revised response a discussion to be added to TR Section 6.8.2 addressing the effect of support self-weight excitation for other dynamic loads. The staff finds this acceptable, since the criteria presented in this subsection include the dynamic characteristics of supports that are not rigid while performing the piping analysis. **Therefore, RAI EPT-37 is resolved, pending revision to TR Section 6.8.**

3.5.9 Design of Supplementary Steel

Supplementary steel includes structural steel within the jurisdictional boundary of ASME Subsection NF (e.g., structural steel members connecting a snubber to the building structure). TR Section 6.9 provides design criteria for the design of pipe supports using supplementary steel. Supplementary steel for pipe supports are designed in accordance with ASME Code, Section III, Subsection NF (for seismic Category I supports), to ANSI/AISC N690 (for seismic Category II supports), or AISC Manual (for non-seismic supports). The use of Subsection NF or other standards is an industry practice acceptable to the staff since it was developed by a professional society and voluntary consensus standards organization and has proven to provide adequate design guidelines for the design of structural steel for use as pipe supports. The staff finds the use of these criteria for the design of U.S. EPR supplementary steel provides reasonable assurance of the structural integrity of the supports and is therefore, acceptable.

3.5.10 Consideration of Friction Forces

In TR Section 6.10, AREVA describes the criteria for considering the effect of friction forces due to thermal movements. The friction forces are calculated using the deadweight and thermal loads normal to the applicable support member. Specifically, to calculate the friction forces, a force will only need to be calculated if the thermal movement in the applicable unrestrained direction(s) is greater than one-sixteenth inch. If this threshold is met, the force will be calculated using C x N, where C is the appropriate coefficient of friction and N is the total force normal to the movement. The coefficient of friction will be taken as 0.3 for steel-to-steel conditions and 0.1 for low friction slide/bearing plates. If support stiffness information is readily available, this calculated force can be reduced by using the force of K x D (if less than C x N), where K is the support stiffness in the movement direction and D is the movement. This is acceptable to the staff.

3.5.11 Pipe Support Gaps and Clearances

In TR Section 6.11, AREVA states that for rigid guide pipe supports in the piping analysis, the typical industry design practice is to provide small gaps between the pipe and its surrounding structural members. These small gaps allow radial thermal expansion of the pipe, as well as allow rotation of the pipe at the support. The normal design practice for the U.S. EPR will be to use a nominal cold condition gap of one-sixteenth inch on each side of the pipe in the restrained direction. This will lead to a maximum total cold condition gap around the pipe for a particular direction of one-eighth inch. For gaps around the pipe in an unrestrained direction, the gap magnitudes should be specified large enough to accommodate the maximum movement of the pipe. The staff finds this acceptable.

3.5.12 Instrumentation Line Support Criteria

In TR Section 6.12, AREVA states that the design and analysis loadings, load combinations and acceptance criteria to be used for instrumentation line supports will be similar to those used for pipe supports. The applicable design loads will include deadweight, thermal expansion and seismic loadings (where appropriate). The applicable loading combinations will similarly follow those used for normal and faulted levels in TR Table 6-1, utilizing the design loadings mentioned above. The acceptance criteria will be from ASME Code, Subsection NF for seismic Category I instrumentation lines, ANSI/AISC N690 for Seismic Category II instrumentation lines and the AISC Manual of Steel Construction for non-seismic instrumentation lines. The staff notes that TR Table 6-1 covers all four service level (i.e., normal, upset, emergency and faulted) load combinations for pipe supports. In RAI EPR-38, the staff requested AREVA to clarify why only the load combinations for the normal and faulted conditions are used in the pipe support design.

In response (dated July 13, 2007), AREVA stated that based on the inclusion of only deadweight, thermal and SSE seismic loadings for analysis of the tubing, the vast majority of the support loads would fall into normal or faulted conditions. Since there may be thermal loads for other levels, this section of the topical will be modified to delete the reference to only normal and faulted loading conditions. Since this change in TR Table 6-1 will be consistent with the current industry practices, the staff finds this acceptable. Therefore, **RAI EPR-38 is resolved, pending revision to TR Section 6.12.**

3.5.13 Pipe Deflection Limits

In TR Section 6.13, AREVA states that for pipe supports utilizing standard manufactured hardware components, the manufacturer's recommendations for limitations in its hardware will be followed. Examples of these limitations are travel limits for spring hangers, stroke limits for snubbers, swing angles for rods, struts and snubbers, alignment angles between clamps or end brackets with their associated struts and snubbers, and the variability check for variable spring supports. In addition to the manufacturer's recommended limits, allowances will be made in the initial designs for tolerances on such limits. This is especially important for

snubber and spring design where the function of the support can be changed by an exceeded limit. AREVA did not specify any quantitative allowances for the pipe deflection limit. In RAI EPR-39, the staff requested AREVA to provide the deflection limits that will be used for different support types.
In response (dated July 13, 2007), AREVA stated that the first check mentioned is the travel range limitation for spring hangers. This check will utilize the “working range” given in the standard Load Table for Selection of Hanger Size typically given in the vendor catalogs. This working range already provides a deflection tolerance beyond each end limit of the range (with the magnitude dependent on the spring type), provided the hot and cold loads fall within the working range. The second check mentioned is the stroke limit checks for snubbers. The current project guidance is to allow at least one-half inch of stroke at each end for the initial design checks. The third check mentioned is the swing angle check for rods, struts and snubbers. For current analyses, ANVIL International[4] hardware is being used. ANVIL’s limit for these checks is 4 degrees. AREVA will apply a tolerance of 1 degree to this, thus checking to 3 degrees for initial design. The fourth check mentioned is for alignment angles of strut and snubber paddles and their associated clamps or end brackets. ANVIL’s limit is 5 degrees. AREVA will apply a tolerance of 1 degree to this, thus checking to 4 degrees for initial design. The fifth check mentioned is for the spring variability check. The recommended limit on this check by ANVIL is 25 percent. AREVA will apply a tolerance of 5 percent to this, thus checking to 20 percent for initial design. Since this is consistent with the industry practices, the staff finds these specifications and allowances acceptable. Therefore, **RAI EPR-39 is resolved.**

3.5.14 Conclusions

On the basis of these discussions and the evaluation of TR Section 6.0, the staff concludes that supports of piping systems important to safety are designed to quality standards commensurate with their importance to safety. The staff's conclusion is based on the following:

(1) AREVA satisfies the requirements of GDC 1 and 10 CFR 50.55a by specifying methods and procedures for the design and construction of safety related pipe supports in conformance with general engineering practice, and

(2) AREVA satisfies the requirements of GDC 2 and GDC 4 by designing and constructing safety-related pipe supports to withstand the effects of normal operation as well as postulated events such as LOCAs and dynamic effects resulting from the SSE.

4.0 Conclusions

The staff concludes that piping systems important to safety are designed to quality standards commensurate with their importance to safety. As committed, AREVA shall incorporate all the pertinent additional information in the next revision of the topical report. The staff also concludes the following:

- AREVA meets the requirements of GDC 1 and 10 CFR 50.55a by specifying methods and procedures for the design and construction of safety-related piping systems in conformance with general engineering practice.

[4] ANVIL International is a manufacturer of pipe fittings and pipe hangers and supports.

- AREVA meets the requirements of GDC 2 and GDC 4 by designing and constructing the safety-related piping systems to withstand the effects of normal operation as well as postulated events such as LOCAs and dynamic effects resulting from the SSE.

- AREVA meets 10 CFR Part 50 requirements by identifying applicable codes and standards, design and analysis methods, design transients and load combinations, and design limits and service conditions to ensure adequate design of all safety-related piping and pipe supports in the U.S. EPR for their safety functions.

- AREVA meets 10 CFR Part 52 requirements by providing reasonable assurance that the piping systems will be designed and built in accordance with the certified design. The implementation of these pre-approved methods and satisfaction of the acceptance criteria will be verified through the performance of the ITAAC by the COL holder to ensure that the as-constructed piping systems are in conformance with the certified design for their safety functions.

- AREVA meets 10 CFR Part 50, Appendix S, requirements by designing the safety-related piping systems, with a reasonable assurance to withstand the dynamic effects of earthquakes with an appropriate combination of other loads of normal operation and postulated events with an adequate margin for ensuring their safety functions.

- AREVA meets the requirements of GDC 14 by following the Code requirements with regard to the RCPB of the primary piping systems being designed, fabricated, constructed, and tested to have an extremely low probability of abnormal leakage, of rapid propagating failure, and of gross rupture.

- AREVA meets the requirements of GDC 15 by following the Code requirements with regard to the reactor coolant piping systems being designed with specific design and service limits to assure sufficient margin that the design conditions are not exceeded.

5.0 References

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21. U.S. NRC Regulatory Guide 1.29, “Seismic Design Classification,” Revision 3, September 1978.

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