# REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**APR1400 Design Certification**

**Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD**

**Docket No. 52-046**

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| **RAI No.:** | **311-8278** |
| **SRP Section:** | **03.12 - ASME Code Class 1, 2, and 3 Piping Systems and Piping Components and Their Associated Supports** |
| **Application Section:** | **DCD Tier 2 Section 3.12** |
| **Date of RAI Issue:** | **11/16/2015** |

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## Question No. 03.12-8

ASME BPV Code Section III, as mandated by 50.55a, requires that piping be evaluated for seismic loads.

DCD Section 3.7.2.7 shows that the combination of modal responses is performed in accordance with the latest (2012) revision of RG 1.92, which is Revision 3. DCD Section 3.7.1.2 shows that damping values are based on the latest (2007) revision of RG 1.61, which is Revision 1. In contrast, DCD Section 3.12.3.2.4 states that RG 1.92 Revision 1 of 1976 and Revision 3 of 2012 are used for combination of modal responses. It also indicates that combination of modal responses with no closely spaced modes is obtained by the square root of the sum of the squares (SRSS). It further states that, for closely spaced modes within 10% of each other or less, the 1976 RG 1.92 Revision 1 NRC-Grouping method is used for combination of modal responses. Thus, the DCD implies that closely spaced modes are only those that are within 10% of each other. The design of APR1400 piping and supports includes loadings due to the safe shutdown earthquake (SSE) in their structural analysis and, because the OBE is set equal to 1/3 of the SSE, loads due to OBE are not required in the design analysis, as described in DCD Section 3.12.5.3.4. DCD Section 3.12.3.2.1 states that the response spectra analysis for piping will use damping values from the 2007 RG 1.61 Rev 1, which specifies 4% SSE damping for piping.

1. The paragraphs above show that guidance from more than one Regulatory Guide is utilized. In DCD Section 3.7, these guides are of comparable issue date, while an earlier version is used for one guide in DCD Section 3.12. The applicant is requested to provide a technical justification for the difference between DCD Sections 3.7.2.7 and DCD Section 3.12.3.2.4, and an explanation for the different combinations of revisions of RG 1.61 and RG 1.92.

2. According to RG 1.92 Revision 3, Section C.1.1.1(1) for critical damping ratios less than or equal to 2%, modes are considered closely spaced if their frequencies are

within 10% of each other. According to RG 1.92 Revision 3, Section C.1.1.1(2), for critical damping greater than 2%, modes are considered closely spaced if the frequencies are within five times the critical damping ratio (i.e. for damping of 4%, modes are considered closely spaced if the frequencies are within 4x5=20% of each other). From the above, it can be seen that the closely spaced modes definition of 10% is only applicable to 2% damping, which is reasonably consistent with the damping value for piping in the 1973 revision of RG 1.61. Also, for 4% damping (as specified for SSE piping damping in the 2007 revision of RG 1.61 and which APR1400 utilizes) closely spaced modes are considered those that are within 20% of each other. As shown above, in the APR1400 piping seismic analysis closely spaced modes are not grouped in accordance with the NRC regulatory guidance because for 4% damping, modes are considered closely spaced if the frequencies are only within 10% of each other instead of 20% that the NRC regulatory guidance specifies. Based on the justification provided in response to item 1, the applicant is requested to provide additional information to justify using a definition for closely spaced modes different from that provided in staff guidance, such that the requirements of 10 CFR 50.55a can be demonstrated to be met.

3. The Regulatory Positions section in RG 1.92 Revision 3 includes the following statement: "If applicants for new licenses choose to use RG 1.92 Revision 1 methods for combining modal responses, their analyses should address the residual rigid response of the missing mass modes discussed in Regulatory Positions C.1.4 and C.1.5 of RG 1.92-R3." Based on the justifications provided in response to items 1 and 2 above, the applicant is requested to provide additional information to describe how the piping analysis methodology described in the DCD is consistent with the regulatory positions C.1.4 and C.1.5 of RG 1.92 Revision 3, or to justify an alternative approach.

## Response – (Rev. 2)

KHNP applied RG 1.92 Revision 3 to the seismic analysis in the piping design. Previously, PIPESTRESS (Version 3.7.0) and APLPIPE (Version 3F10.1) computer programs were used for the analysis of piping systems in the APR1400. The programs did not implement the combination of modal responses in accordance with RG 1.92 Revision 3. The piping systems, with the exception of the surge line, are analyzed by PIPESTRESS. The surge line was analyzed by ADLPIPE. The PIPESTRESS (Version 3.9.0) computer program was issued in November 2016 and is an updated version that includes the method to combine the modal responses specified in RG 1.92 Revision 3. This PIPESTRESS version was subsequently used to analyze the APR1400 piping systems. Also, ANSYS (Version 14.0) has been substituted for ADLPIPE for the analysis of the surge line and implements RG 1.92 Rev. 3 methods for combining modal responses. The Seismic analysis of the piping design has been performed in accordance with RG 1.92 Revision 3 and the appropriate sections of DCD Tier 2 will be revised accordingly.

**Impact on DCD**

DCD Tier 2, ACRONYM AND ABBREVIATION LIST, Subsections 3.9.1.2.1.3, 3.9.10, 3.12.3.2.4, 3.12.3.2.5, 3.12.4.1, 3.12.4.3, 3.12.5.6, 3.12.5.10 and 3.12.8 will be revised as shown in the Attachment.

**Impact on PRA**

There is no impact on the PRA.

**Impact on Technical Specifications**

There is no impact on the Technical Specifications.

**Impact on Technical/Topical/Environmental Reports**

There is no impact on any Technical, Topical, or Environmental Report.

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| LWR | light water reactor |
| M&E | mass and energy |
| MAAP | modular accident analysis program |
| MBLOCA | medium break loss-of-coolant accident |
| MBV | mixed-bed ion exchanger vessel |
| MCA | multiple compartment analysis |
| MCC | motor control center |
| MCCI | molten corium concrete interaction |
| MCL | main coolant loop |
| MCR | main control room |
| MDNBR | minimum departure from the nucleate boiling ratio |
| MDS | makeup demineralizer system |
| MELB | moderate-energy line break |
| MF | membrane filter |
| MFIV | main feedwater isolation valve |
| MFLB | main feedwater line break |
| MFS | main feedwater system |
| MFW | main feedwater |
| MG | motor- generator |
| MG Set | motor-generator set |
| MI | minimum inventory |
| ML | manufacturing license |
| ~~MMC~~ | ~~missing mass correction~~ |
| MMI | modified Mercalli intensity |
| MOP | main oil pump |
| MORS | membrane oxygen removal subsystem |
| MOV | motor-operated valve |
| MRP | materials reliability program |
| MS | main steam |
| MSADV | main steam atmospheric dump valve |
| MSADVIV | MSADV isolation valve |

3.9.1.2.1.1 ABAQUS

The ABAQUS program is a general-purpose nonlinear finite element program with structural and heat transfer capabilities. ABAQUS is used for stress analysis of regions of vessels, piping, or supports that may deform plastically under prescribed loadings. It is also used for elastic analyses of complex geometries where the graphics capability enables a well-defined solution. The thermal capabilities of ABAQUS are used for complex geometries where simplification of input and graphical output are preferred.

ABAQUS is commercially available and has had sufficient use to justify its applicability and validity. See Reference 5 for information on ABAQUS.

3.9.1.2.1.2 PICEP

The PICEP program calculates the flow through a crack in a pipe. PICEP uses the simplified engineering approach for elastic-plastic fracture analysis for finding the crack opening displacement and area. Fluid calculation options include single and two-phase flow as well as allowance for friction. PICEP, commercial software, was developed by the Electric Power Research Institute (EPRI). See Reference 22 in Subsection 3.6.5 for information on PICEP.

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3.9.1.2.1.3 ~~ADLPIPE~~

~~ADLPIPE is a linear finite element program for the static and dynamic analysis of piping systems. These systems may include such components as bends, elbows, tees, reducers, socket or butt welds, flexible couplings, and flanges, with the appropriate flexibility factors and stress indices accounted for. Support types may include rigid, spring, constant-force, snubber, anchor, or user-specified types, and may have any desired orientation.~~

~~Analyses performed include thermal, deadweight, applied load, frequency and mode shape, and response spectrum. Following the static and dynamic analysis phase, the program performs the ASME Section III Class 1 analysis in any manner specified by the user to create the appropriate loading cases applicable for each of the ASME Code stress equations. See Reference 6 for information on ADLPIPE.~~

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3. NUREG/CR-5750 (INEEL/EXT-98-00401), "Rates of Initiating Event at U.S. Nuclear Power Plants: 1987 - 1995," U.S. Nuclear Regulatory Commission, February 1999.

4. NUREG/CR-6928 (INL/EXT-06-11119), "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," U.S. Nuclear Regulatory Commission, February 2007.

5. Computer code ABAQUS Version 6.10-1; Installed on DELL Workstation with Windows Server 2008; Verification Document No. 00000-SM-VV-038, Jan. 2011.

6. ~~Computer code, ADLPIPE Version 3F10.1; Computers with Windows XP O/S; Verification Document No. 00000-SM-VV-015, Rev. 04, April 2011.~~ Deleted

7. Computer code, CLEVER Version 1.0; Computers with Windows XP O/S; Verification Document No. 00000-SM-VV-037, Rev. 01, Oct. 2012.

8. Computer code, HeadPR Version 1; Computers with Windows XP, Windows 2000, Windows 7 O/S; Verification Document No. ND-G-CV-033, Rev. 2, October 2014.

9. Doherty, P. K., Software Verification and Validation Report of CEFLASH-4B, Version f4b.1.1, VV-FF-0178, Rev. 1, January 1995.

10. Computer code, ANSYS Version 12.1; Installed on IBM P6 570 24Core; Verification Document No. DAVM121, Rev. 0, December 2010.

11. Computer code, AFP2D Version 3; Installed on IBM P6 570 24Core; Verification Document No. ND-G-CV-019, Rev. 8, December 2014.

12. Computer code, TSPOST Version 0; Installed on IBM P6 570 24Core; Verification Document No. ND-G-CV-018, Rev. 4, October 2014.

13. Computer code, AFPOST Version 2; Installed on IBM P6 570 24Core; Verification Document No. ND-G-CV-027, Rev. 7, December 2014.

14. Computer code, ATHOS3 Mod-01; Installed on IBM P6 570 24Core; Verification Document No. ND-G-CV-017, Rev. 3, October 2014.

15. Computer code, PTXIG Version 1.0; Computers with Microsoft.Net 2.0 O/S; Verification Document No. 00000-RM-VV-002, Rev. 02, Sep, 2012.

16. DST Computer Services SA, "a nuclear and non-nuclear piping analysis program," PIPESTRESS Version 3.~~7~~.0, Geneva, Switzerland, 201~~2~~. 9 6

17. ASME Boiler and Pressure Vessel Code, Section III, Disivsion 1, "Rules for Construction of Nuclear Facility Components," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

18. ASME B31.1, "Code for Pressure Piping, Power Piping," The American Society of Mechanical Engineers, the 2012 Edition.

19. ASME B31.3, "Code for Pressure Piping, Power Piping," The American Society of Mechanical Engineers, the 2012 Edition.

20. REFORC-DEC User Manual, REF 03.7.483-1.0, Rev. 1, D.J. Pichurski, S&L, 21 January 1994.

21. RELAP5/MOD3.1, Transient Hydraulic Analysis Program, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho, USA.

22. NUREG/CR-5535, Rev. P3, "RELAP5/MOD3.3 Code Manual," U.S. Nuclear Regulatory Commission, March 2006.

23. Computer code, NOZPROG Version 1; Installed on IBM P6 570 24Core; Verification Document No. ND-G-CV-006, Rev. 10, October 2014.

24. ~~Computer code ANSYS Release 12.0, ANSYS, Inc., 2009.~~

25. "Dynamic Stress Analysis of Axisymmetric Structures under Arbitrary Loading," Ghosh, S. and Wilson, E., EERC 69-10, University of California, Berkeley, September 1969.

26. CENPD-42, "Topical Report on Dynamic Analysis of Reactor Vessel Internals Under Loss-of-Coolant Accident Conditions with Application of Analysis to C-E 800 MWe Class Reactors," Combustion Engineering, Inc., August 1972 (Proprietary).

27. Gabrielson, V. K., "SHOCK, A Computer Code to Solve the Dynamic Response of Lumped-Mass Systems," SCL-DR-69-98, November 1969.

Computer code ANSYS Release 10.0 (2005), 12.0 (2009), 13.0 (2010), 14.0 (2011), 14.5 (2012) and 15.0 (2013), ANSYS, Inc.

3.12.3.2.4 Modal Combination

The response of individual modes is calculated and combined with the other modal responses using the methods as described in NRC RG 1.92 (References 9 and 10).

For the piping system modes with no closely spaced (two consecutive modes are defined as closely spaced if their frequencies differ from each other by 10 percent or less of the lower frequency), the representative maximum responses are obtained by taking the square root of the sum of the squares (SRSS). This method may not produce conservative results for piping systems with closely spaced modes.

Therefore, to combine the modal responses of the piping system with closely spaced modes, the grouping method described in NRC RG 1.92 (Reference 9) is applied.

If some of the modes are closely spaced, the response of the individual modes is combined using the grouping method described in the computer program PIPESTRESS (Reference 15).

$$R = \sqrt{\sum_{k=1}^{N} R_k^{\,2} + \sum_{q=1}^{P}\sum_{l=i}^{j}\sum_{m=i}^{j}\left|R_{lq}\,R_{mq}\right|} \qquad l \neq m$$

Where

R = total undirectional response

$R_k$ = the peak value if the response due to the $K^{th}$ mode

$R_{lq}$, $R_{mq}$ = are the modal responses, $R_l$ and $R_m$ within the $q^{th}$ group

N = total number of modes considered

P = number of groups of closely spaced modes

i = lowest modal number associated with group j of closely spaced modes

j = highest modal number associated with group j of closely spaced modes

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The response of individual modes is calculated and combined with the other modal responses using the double sum equation as described in NRC RG 1.92 Revision 3 (References 10).

$$R_{pI} = \left[ \sum_{i=1}^{n} \sum_{j=1}^{n} \varepsilon_{ij} R_{pi} R_{pj} \right]^{1/2}$$

Where :

$R_{pI}$ = combined periodic response for the $I^{th}$ component of seismic input motion (I = 1, 2 and 3, for one vertical and two horizontal components),

$\varepsilon_{ij}$ = the modal correlation coefficient for mode i and j,

$R_{pi}$, $R_{pj}$ = periodic response or periodic components of a response of mode i and j respectively,

n = number of modes considered in the combination of modal responses.

For the piping system modes with no closely spaced, the representative maximum responses are obtained by taking the square root of the sum of the squares (SRSS). If modes with closely spaced frequencies exist, the SRSS method is not applicable. The definition of modes with closely spaced frequencies is a function of the critical damping ratio and is as follows:

a. For critical damping ratios ≤ 2%, modes are considered closely spaced if the frequencies are within 10% of each other (i.e., for $f_i < f_j$, $f_j \leq 1.1 f_i$)

b. For critical damping ratio > 2%, modes are considered closely spaced if the frequencies are within five times the critical damping ratio of each other (i.e., for $f_i < f_j$ and 5% damping, $f_j \leq 1.25\ f_i$, for $f_i < f_j$ and 10% damping, $f_j \leq 1.5 f_i$)

If modes with closely spaced frequencies exist, the double sum equation is used considering modal correlation coefficient defined in NRC RG 1.92 (References 10).

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The responses of low-frequency modes are obtained from all the low-frequency modes with frequencies up to the ZPA cutoff frequency.

Piping system modes greater than the ZPA cutoff frequency are considered as high-frequency or rigid range modes. The response from high frequency must be included in the response of the piping high-frequency rigid mode.

The PIPESTRESS program uses the left-out-force (LOF) method to calculate the effect of the high-frequency rigid modes. The LOF method is described in the PIPESTRESS Theory Manual (Reference 11).

PIPESTRESS generates a pseudo-load vector called a "left-out-force" vector. Generated left-out-force unit solutions are combined to approximate the contribution of the uncalculated modes to the piping system. Each left-out-force unit solution is multiplied by a scalar amplitude equal to the highest spectral acceleration for frequencies greater than the ZPA cutoff frequency. Combine the individual left-out-forces and combine the total left-out-force response with the combination of modal responses by absolute combination, as follows:

$$R = | R_{mod} | + | R_{lof} |$$

Where,

$R$ = combination of response in the periodic modes and residual rigid modes

$R_{mod}$ = response in the periodic modes

$R_{lof}$ = response in the rigid modes

The ANSYS computer program normally uses the SRSS method to combine the modal responses. In order to combine the modal response of the piping system with closely spaced modes, the double sum equation in NRC RG 1.92 Rev.3 (Reference 10) is used. The residual rigid responses of missing mass modes are accounted for by using the missing mass method in NRC RG 1.92 (Reference 10)

~~In the ADLPIPE program, to combine the modal response of the piping system with closely spaced modes, the grouping method described in NRC RG 1.92 (Reference 9) is applied. And the missing mass correction (MMC) method is used to include the effect of the high modes ($f \geq f_{zpa}$). The MMC method is described in the ADLPIPE manual (Reference 18) and implemented in the following steps.~~

~~Step 1: Make design response spectra analysis and cut off the analysis at the end of the resonant shock spectra bandwidth.~~

Step 2: Recalculate the response spectra analysis using a flat response spectrum equal to the ZPA. Make one analysis for each earthquake direction.

Step 3: Make three static analyses of the pipe system, one analysis for each principal axis.

Step 4: Take the absolute difference of the three static analyses (step 3) and the flat response analysis (Step 2) to form the missing mass correction for each axis.

Step 5: Take the SRSS of the results of step1 and step 4.

3.12.3.2.5 Directional Combination

The responses due to each of the three orthogonal spatial components of earthquake motion are combined by SRSS as described in Regulatory Position C.2.1 of NRC RG 1.92 (Reference 9 10).

3.12.3.2.6 Seismic Anchor Motion Analysis Method

Seismic anchor motion (SAM) analysis is a static analysis and includes the following effects acting on the piping system supported by either a single structure or more than one structure.

a. Building seismic movements

b. Equipment seismic movements as anchor motions on the piping system

c. Header piping seismic movements for decoupled branch lines

The effects of SAM on the piping system are considered for the safe shutdown earthquake (SSE).

In the SAM analysis, the relative displacements at the support are considered. The maximum relative support displacements are obtained from the structural response transient heat transfer and fluid flow. This program is described in Subsection 3.9.1.2.1.7.

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c. ~~ADLPIPE~~

~~ADLPIPE is a linear finite element program for the static and dynamic analysis of piping systems. The program performs ASME Class 1 analysis in any manner specified by the user to create the appropriate loading cases applicable for each of the ASME Code stress equations. This program is described in Subsection 3.9.1.2.1.3.~~

d. RELAP5/MOD3.3

RELAP5/MOD 3.3 is developed by the NRC is for best-estimate transient simulation of light water reactor (LWR) coolant systems during postulated accidents in the LWR. This program is also used for the analysis of a dynamic behavior, such as water hammer and safety/relief valve discharge, by modeling the fluid flow. This program is described in Subsection 3.9.1.2.1.16.

e. GTSTRUDL

GTSTRUDL is used for structural analysis of pipe supports in conformance with ASME Section III, Subsection NF, and ANSI/AISC 360-05 (Reference 14). This computer program is a general-purpose structural analysis program including the base plate flexibility, anchor bolts check, and the calculation of weld leg sizes.

f. RELAP5/MOD3.1

RELAP5/MOD3.1 is a best-estimate system code suitable for the analysis of all transients and postulated accidents in LWR systems. This code is used to analyze rapid transients such as pipe breaks and valve quick opening, by modeling the fluid flow. This program is described in Subsection 3.9.1.2.1.15.

In general, pipe supports are modeled as rigid with the rigidity verified by checking support deflection in the restrained direction, if springs with actual stiffness values for the restrained degrees of freedom. Pipe support hardware weight for snubbers, struts, and spring hangers supported by the piping system is considered in the piping analysis. The weight added by the component support is included in the piping analysis when it is greater than 10 percent of the total mass of the adjacent pipe span including pipes, contents, insulations, and in-line components.

In general, an entire piping system cannot be modeled and analyzed as a single model; the piping system is therefore conveniently divided into multiple, smaller piping subsystems that satisfy the analysis size limitations of the computer program used for the piping system analysis. Branch piping that does not have a significant effect on the run piping is decoupled from the run pipe analysis based on the branch decoupling criteria defined in Subsection 3.12.4.4. Intermediate pipe anchors such as wall or slab penetration sleeve anchors and structural anchor supports may also be used for subdividing the piping systems.

3.12.4.3 Piping Benchmark Program

The computer programs used for the piping system analysis are verified in accordance with NRC benchmark problems.

The piping benchmark problems prescribed in NUREG/CR-1677, Volumes 1 and 2 (Reference 16), are used to validate the PIPESTRESS and ~~ADLPIPE~~ ANSYS computer programs used in piping system analysis.

3.12.4.4 Decoupling Criteria

Small branch lines including instrument connections may be decoupled from the analysis model of the larger run pipe provided that either the ratio of the branch pipe mean diameter to the run pipe mean diameter ($D_b/D_r$) is less than or equal to 1/3 or the ratio of the moments of inertia of the two lines ($I_b/I_r$) is less than or equal to 1/25.

In the run pipe analysis, the applicable stress intensification factors (SIFs) and/or stress indices are incorporated. The mass effects of the branch line, where the mass of half the span of the branch pipe is greater than 10 percent of the mass of the pipe run span, are also

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3.12.5.4 Damping Values

Damping values in Table 3 of NRC RG 1.61 (Reference 7) are used for dynamic response spectra and time-history analyses.

Frequency-dependent damping values identified in Figure 1 of NRC RG 1.61 may also be used for USM response spectra analysis provided the five restrictions identified in C.2 of NRC RG 1.61 (Reference 7) are maintained.

3.12.5.5 Combination of Modal Responses

Seismic responses to each mode are calculated in accordance with the method described in NRC RG 1.92 (Reference 9) and combined with other responses. Seismic responses to periodic modal response with sufficiently separated frequencies are combined by SRSS. Closely spaced frequencies are combined by the 10 percent method.

3.12.5.6 High-Frequency Modes

PIPESTRESS ~~and ADLPIPE computer programs use~~ computer program uses left-out-force (LOF) ~~and missing mass correction (MMC) methods~~ method to calculate the effect of high-frequency rigid modes (~~References 11 and 18~~ Reference 11). The result obtained from this method is multiplied by scalar amplitude that is equivalent to the highest spectral acceleration for frequencies, which is greater than the last natural frequency being calculated by LOF ~~and MMC methods~~ method regarding the corresponding directional spectrum. ANSYS computer program accounts for the effects of high frequency modes in accordance with the missing mass method in NRC RG 1.92 (Reference 10).

3.12.5.7 Fatigue Evaluation of ASME Code Class 1 Piping

Fatigue evaluation of ASME Class 1 piping systems is performed for loadings caused by thermal and pressure transients, thermal stratification, and other cyclic events including earthquakes. Fatigue evaluation of ASME Class 1 piping greater than DN 25 (NPS 1) is performed per ASME Section III, Subsection NB-3653. The COL applicant is to perform fatigue evaluation of ASME Class 1 piping (COL 3.12(3)).

The fatigue evaluation considering the effects of the reactor coolant environment in ASME Class 1 piping follows the guidance in NRC RG 1.207 (Reference 19).

This condition induces a vertical thermal gradient, resulting in increased overall bending stresses and localized thermal gradient stresses. Stratified flow effects consist of (1) local stresses due to temperature gradients in the pipe wall, and (2) additional thermal pipe bending moments generated by the restraining effect of supports on the stratified-flow-induced curvature of the piping. The extent of stratification is reduced by sloping generally horizontal pipe runs and is mitigated by carefully selecting designs and operating procedures.

Structural evaluations are performed using elastic and/or simplified elastic-plastic analyses in accordance with the ASME Code, considering the applicable loadings in addition to the stratified flow loadings.

The stratified-flow-induced curvature of the piping and local stresses due to a temperature gradient are obtained from finite element analyses. These analyses provide the local effects and pipe rotations for an unsupported pipe segment. A stratified flow thermal-hydraulic model with the top half of the fluid at hotter temperature and the lower half of the fluid at colder temperature is used to determine the pipe wall temperature based on the thermal-hydraulic conditions. Heat transfer and structural thermal stress analyses are performed using the ANSYS computer program to determine the rotations and local stresses. Rotations are considered to act over all horizontal portions of the pipe. The resulting bending moments are calculated in the piping analysis with the ~~ADLPIPE~~ ANSYS computer program by allowing the pipe to thermally expand unconstrained and by then applying a set of equal and opposite displacements at the rigid support points. Local stress effects due to top-to-bottom thermal gradients are also considered to act over all horizontal sections of pipe. For ASME Class 1 piping, gross bending stresses due to stratification are considered as secondary stresses, while local stresses due to thermal gradients are considered as peak stresses.

3.12.5.11 <u>Safety Relief Valve Design, Installation, and Testing</u>

The design and installation of the safety valves and relief valves for overpressure protection are performed per the requirements in Appendix O of the ASME Code (Reference 23).

A static method with a conservative dynamic loading factor is used to calculate the discharge forces of safety valves and relief valves that use open vent stacks for discharging fluid directly into the air. Dynamic transient loads of fluid discharged from safety/relief

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4. ASME Section III "Code Cases: Nuclear Components, Boiler and Pressure Vessel Code," The American Society of Mechanical Engineers, the 2007 Edition.

5. Regulatory Guide 1.84, "Design, Fabrication, and Materials Code Case Acceptability," Rev. 36, U.S. Nuclear Regulatory Commission, August 2014.

6. EPRI NP-5639, "Guidelines for Piping System Reconciliation," Electric Power Research Institute, May 1988.

7. Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Rev. 1, U.S. Nuclear Regulatory Commission, March 2007.

8. Regulatory Guide 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components," Rev. 1, U.S. Nuclear Regulatory Commission, February 1978.

9. ~~Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Rev. 1, U.S. Nuclear Regulatory Commission, February 1976.~~ Deleted

10. Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Rev. 3, U.S. Nuclear Regulatory Commission, October 2012.

11. DST Computer Services. S.A., PIPESTRESS Theory Manual, Geneva, Switzerland.

12. NUREG-1061, "Evaluation of Other Loads and Load Combinations," Volume 4, U.S. Nuclear Regulatory Commission, December 1984.

13. K. Gordis, "Outline of Dynamic Analysis for Piping Systems," Nuclear Engineering and Design, Volume 52, No. 1, March 1979.

14. ANSI/AISC 360-05, "Specification for Structural Steel Buildings," American Institute of Steel Construction, 2005.

15. DST Computer Services. S.A., PIPESTRESS User's Manual, version 3.~~7~~9.0, Geneva, Switzerland, 201~~2~~6.

16. NUREG/CR-1677, "Piping Benchmark Problems. Vol. 1 and Vol. 2," U.S. Nuclear Regulatory Commission, August 1980.

17. NUREG-0484, "Methodology for Combining Dynamic Responses," Rev. 1, U.S. Nuclear Regulatory Commission, May 1980.

18. ~~ADLPIPE, Inc., ADLPIPE Static and Dynamic Pipe Design and Stress Analysis, Input Preparation Manual, March 1987.~~ Deleted

19. Regulatory Guide 1.207, "Guidelines for Evaluating Fatigue Analyses incorporating the Life Reduction of Metal Components Due to the Effects of the Light Water Reactor Environment for New Reactors," Rev. 0, U.S. Nuclear Regulatory Commission, March 2007.

20. Bulletin 88-08, "Thermal Stresses in Piping Connected to Reactor Coolant System," U.S. Nuclear Regulatory Commission, June 22, 1988.

21. Bulletin 79-13, "Cracking in Feedwater System Piping," U.S. Nuclear Regulatory Commission, June 25, 1979.

22. Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification,", U.S. Nuclear Regulatory Commission, December 20, 1988.

23. ASME Section III, Division 1, Appendix O, "Rules for Design of Safety Valve Installation," The American Society of Mechanical Engineers, the 2007 Edition.

24. NUREG-1367, "Functional Capability of Piping Systems," U.S. Nuclear Regulatory Commission, November 1992.

25. ACI-349-97, Appendix B, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute, February 2001.

26. Regulatory Guide 1.199, "Anchoring Components and Structural Supports in Concrete," U.S. nuclear Regulatory Commission, November 2003.

27. Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Rev. 2, U.S. Nuclear Regulatory Commission , March 1979.