REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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

Docket No. 52-046

RAI No.:	**334-8373**
SRP Section:	**03.12 – ASME Code Class 1, 2, and 3 Piping Systems and Piping Components and Their Associated Supports**
Application Section:	**3.12**
Date of RAI Issue:	**12/14/2015**

Question No. 03.12-10

ASME BPV Code Section III, as mandated by 50.55a, requires that piping be evaluated for dynamic loads. DCD Tier 2, Section 3.12.3.4, "Time-History Method," states that for the dynamic response of piping systems, the time-history analysis may be performed using the modal superposition method.

1. The applicant is requested to identify which piping systems are evaluated using time history analysis. In addition, the applicant is requested to indicate whether the analyses are linear or non-linear and specify the time-history analysis technique used (modal superposition method, direct integration method in the time domain, or the complex frequency response method in the frequency domain).

2. CD Tier 2, Section 3.7.2.1.2, "Time-History Methods," for the modal superposition method refers to ASCE Standard 4-98. ASCE 4-98 discusses an alternate method for considering the number of modes in a modal superposition analysis and states that the number of modes included should be sufficient to ensure that inclusion of all remaining modes does not result in more than a 10 percent increase in the total response of interest. The current NRC technical position, as described in RG 1.92, Revision 2 and Revision 3, is that this approach is "non-conservative and should not be used." The applicant is requested to verify that when modal superposition time history analysis is used, its use conforms to the guidance described in RG 1.92, Revision 2 or 3, or justify an alternative approach.

Response – (Rev. 3)

1. The specific time history analysis techniques and the dynamic load evaluated using time history analysis are as follows:

Piping System	Time-history analysis techniques	Dynamic load evaluated using time history analysis
Main Steam	Linear modal superposition method	Operation of the main steam atmospheric dump valve due to upset condition from 100% load
		Sudden closure of the turbine stop valve due to upset condition from 100% load
		Operation of the main steam safety valves due to upset condition from 100% load
		Pipe break transient due to postulated pipe break in the MS system inside and outside reactor containment
		RCS branch line break load
Feedwater	Linear modal superposition method	Transient due to trip of three (3) main feedwater pumps on a Valves Wide Open (VWO) condition
		Transient due to postulated line break in the FW System on a Valves Wide Open (VWO) condition (outside reactor containment)
		Transient due to trip of a startup feedwater pump
		RCS branch line break load
Safety Injection/Shutdown Cooling	Linear modal superposition method	Branch line pipe break loads
		Relief valve discharge loads
Reactor Coolant Loop (RCL) Piping	Linear complex frequency response method	Seismic loads
	Linear direct integration method	IRWST discharge loads
	Non-linear direct integration method	Branch line pipe break loads
Surge Line	Linear direct integration method	Branch line pipe break loads

As described in DCD Section 3.12, RELAP5/MOD3.3 is used to determine the transient blowdown thrust load from pipe breaks and transient loads from other dynamic effects mentioned in the above table (valve closures, pump trip water hammers, valve discharge, IRWST discharge, etc.). ANSYS is used to analyze the Reactor Coolant Loop (RCL) and surge line piping.

The APR1400 RCL piping is designed with no support gaps. The non-linear analysis of the (RCL) piping for branch line pipe break (BLPB) loads is to model the geometric non-linearities of the Reactor Coolant System (RCS) component support gaps, (i.e., the material is considered as linear elastic using the material properties of ASME Code Section II). The non-linear analysis of the RCL piping for BLPB loads is to consider any possible sudden movement of the RCS components due to the high frequency content of BLPB excitations and impact on the gaps. The gaps are modeled using the gap size and the stiffness of the support structure and the corresponding containment internal structure. The gaps in the component supports in the RCL analysis model are applied to the RPV, SG and PZR supports. The gaps are considered to be hot gaps that are required to be met at normal operating conditions. The gaps and clearances of the RPV, SG and PZR support are checked, recorded and adjusted by machining shims during the RCS hot functional test. The information related to the RPV, SG and PZR support gaps are described in DCD Tier 2 Section 5.4.15.2. This section and DCD Tier 2 Section 14.2.12.1.51, Pre-Core Reactor Coolant System Expansion Measurements, will be revised to address the control and verification of the component support design gaps. There is no critical design gaps in any other piping or component supports. DCD Tier 2 Subsection 3.12.3.4 will be revised to clarify the time history method used for the piping systems.

2. The linear modal superposition time history analysis used for the piping systems, (except the RCL piping and surge line), are performed with the PIPESTRESS program in the APR1400. The program uses the left-out-force (LOF) method to calculate the effects of the high frequency rigid modes. The linear modal superposition method to evaluate the piping systems is used in accordance with RG 1.92, Rev. 3 and is sufficient to ensure that inclusion of all remaining modes do not result in more than a 10 percent increase in the total response of interest.

Impact on DCD

Tier 2, Section 3.12.3.4, 5.4.15.2 and 14.2.12.1.51 will be revised as indicated in the attached markup.

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.

Analyses performed using the ISM method are used for damping values identified in Table 3 of NRC RG 1.61 (Reference 7).

3.12.3.4 Time-History Method

The time-history method may be used for other types of dynamic analyses such as hydraulic transient loads caused by water or steam hammer, safety and relief valve discharge actuation loads, jet force loads, postulated pipe breaks, or any other dynamic loading associated with fluid flow transients. ~~The analysis for the reactor coolant loop (RCL) piping is described in Appendix 3.9B.~~

~~For the dynamic response of the piping system, the time-history analysis may be performed using the modal superposition method (Reference 13).~~

When the modal superposition method is used, the cutoff frequency for the determination of modal properties is selected to account for the principal vibration modes of the piping system based upon mass and stiffness properties, modal participation factors, and the frequency content of the input forcing function. As required on a case-by-case basis, the analysis is repeated with more modes to verify the cutoff frequency for the determination of modal properties.

The missing mass effects of high-frequency modes are included based on the same principles described in Subsection 3.12.3.2.4.

Alternatively, the cutoff frequency is determined so that the calculated number of modes produces dynamic analysis results within 10 percent of the results of the dynamic analysis, including the next higher mode.

Damping values are described in Subsection 3.12.5.4.

3.12.3.5 Inelastic Analysis Method

For the APR1400, inelastic analysis methods are not used for the design of the piping system and its supports.

The dynamic analysis methods used for the reactor coolant loop (RCL) piping are the direct integration method and the complex frequency response method as described in Appendix 3.9B. The surge line is evaluated using the direct integration method. For the dynamic response of the other piping systems, the time-history analysis is performed using the modal superposition method (Reference 13).

RAI 334-8373 - Question 03.12-10_Rev.3

5.4.15 Component Supports

5.4.15.1 Design Basis

The criteria applied in the design of the RCS supports are that the specific function of the supported equipment be achieved during the conditions of normal, earthquake, POSRV actuation, IRWST discharge, and branch line pipe break (BLPB) conditions. BLPB includes feedwater line breaks, main steam line breaks and all LOCA conditions resulting from breaks not eliminated by leak-before-break analysis in piping to branch nozzles of the RCS. Specifically, the supports are designed to support the RCS components and to restrain the components in accordance with the stress and deflection limits of ASME Section III under the combined SSE, IRWST discharge and BLPB loadings.

5.4.15.2 Description

Figure 5.4.15-1 illustrates the RCS support points. A description of the supports for each supported component is as follows:

a. Reactor vessel supports

   The RV is supported by four vertical columns located under the vessel inlet nozzles. These columns are designed to be flexible to the horizontal direction to allow horizontal thermal expansion during heatup and cooldown. They also support the RV in the vertical direction.

   Horizontal keyways along the upper portion of the column guide the RV during thermal expansion and contraction of the RCS and maintain the vessel centerline.

   Four horizontal keys welded to the vessel bottom head and keyways of the column base plates allow free thermal expansion and contraction of the RV. The column base plate acts as a keyway to restrain the bottom of the RV for dynamic load conditions.

The clearance between the key and the supporting structure is shimmed and verified during hot functional testing.

RAI 334-8373 - Question 03.12-10_Rev.3

14.2.12.1.51 Pre-Core Reactor Coolant System Expansion Measurements

1.0 ~~OBJECTIVE~~OBJECTIVES

1.1 To demonstrate that the reactor coolant system (RCS) components are free to expand thermally as designed during initial plant heatup and return to their baseline cold position after the initial cooldown to ambient temperatures

2.0 PREREQUISITES

2.1 All construction activities have been completed on the RCS components.

2.2 Initial ambient dimensions have been set on the steam generator and reactor coolant pump (RCP) hydraulic snubbers, upper and lower steam generator and reactor vessels keys, ~~and~~ pressurizer keys, RCP columns and surge line supports.

2.3 Initial ambient dimensions for the steam generator, reactor vessel, pressurizer, RCP and ~~RCP~~ surge line supports have been recorded.

2.4 The instruments for the real-time measurements of the surge line pipe displacements at several major locations are installed.

2.5 The potential component support shimming is required to achieve proper gaps.

3.0 TEST METHOD

3.1 Check clearances at hydraulic snubber joints, keys, and column clevises during heatup and record at 37.8 °C (100 °F) increments during heatup.

3.2 At stabilized conditions, record all steam generator, reactor vessel, pressurizer and RCP clearances.

3.3 Record the real-time surge line displacements and the plant data such as hot leg and pressurizer temperatures, pressurizer pressure and level,

RAI 334-8373 - Question 03.12-10_Rev.3

charging and letdown flows, as well as the status RCPs, pressurizer heaters and spray valves.

4.0 DATA REQUIRED

4.1 Plant conditions

4.2 Clearances at the steam generator sliding base keys, hydraulic snubber joints, upper keys, and piston setting ~~at~~for hydraulic snubbers

4.3 ~~Clearance~~Clearances between the reactor vessel upper and lower supports and expansion plates

4.4 Reactor vessel support temperature

4.5 Clearances at pressurizer keys

4.6 Clearances at the RCP snubbers, column joints, and piston setting for the hydraulic snubbers

4.~~6~~7 Clearances at all test points after cooldown~~–~~

4.8 Surge line displacement time-history

4.9 Time-history plant data such as hot leg and pressurizer temperatures, pressurizer pressure and level, charging and letdown flows, as well as the status of RCPs, pressurizer heaters, and spray valves

5.0 ACCEPTANCE CRITERIA

5.1 Unrestricted expansion for selected points on components as described in Subsection 3.9.2

5.2 Verification that components return to their baseline ambient position as described in Subsection 3.9.2

RAI 334-8373 - Question 03.12-10_Rev.3

5.3 Verification that proper gaps exist for selected points on components as described in ~~Subsection 3.9.2~~

DCD Subsections 3.9.2 and 5.4.15

5.4 Verification that surge line moves within design limits

14.2.12.1.52 Pre-Core Reactor Coolant and Secondary Water Chemistry Data

1.0 ~~OBJECTIVE~~OBJECTIVES

1.1 To demonstrate that proper water chemistry for the RCS and ~~steam generator~~secondary system can be maintained

2.0 PREREQUISITES

2.1 ~~Primary~~The primary and secondary sampling systems are operable.

2.2 Chemicals and test equipment to support hot functional testing are available.

2.3 The primary and secondary chemical addition systems are operable.

2.4 Purification ion exchangers are charged with resin.

3.0 TEST METHOD

~~3.1 Minimum sampling frequency for the steam generator and RCS is specified by the chemistry manual.~~ 3.1 The sampling frequency is modified as required to provide reasonable assurance of the proper RCS and ~~steam generator~~secondary system water chemistry.

3.2 Perform RCS and ~~steam generator~~secondary system sampling and chemistry analysis after every significant change in plant conditions (i.e., heatup, cooldown, chemical additions).