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October 19, 2009

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-09488

Subject: MHI's Responses to US-APWR DCD RAI No. 459-3331

Reference: 1) "Request for Additional Information No. 459-3331 Revision 1, SRP Section: 03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping, Application Section: 3.6.2," dated 9/16/2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 459-3331, Revision 1."

Enclosed are the responses to 11 RAIs contained within Reference 1. Of the RAIs in Reference 1, 9 will not be answered within this package. They are;

RAI 03.06.02-28, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-29, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-30, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-31, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-32, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-33, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-34, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-35, which has a 60-day response time, as agreed to between the NRC and MHI, and will be issued at a later date by a separate transmittal.

RAI 03.06.02-39, which has a 30-day response time, however is not sufficiently complete at this time, and will be issued with other 60-day RAI responses at a later date by a separate transmittal.

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Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Responses to Request for Additional Information No. 459-3331, Revision 1

CC: J. A. Ciocco
C. K. Paulson

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Enclosure 1

UAP-HF-09488
Docket No. 52-021

Responses to Request for Additional Information No. 459-3331, Revision 1

October, 2009

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/16/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 459-3331 REVISION 1**
SRP SECTION:	**03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping**
APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-20

This is the supplemental RAI S01 for RAI 71-986 (questions 1-9 and 16-19 were responded to by MHI Ref: UAP-HF-08226, dated 10/7/2008), question 03.06.02-2(c).

In its response to RAI 03.06.02-2(c), MHI proposed changes to the DCD Subsection 3.6.2.1.1.1, items (2) and (3) to clarify the requirements for maximum stress ranges that should not be exceeded for Class 2 piping in the break exclusion area per BTP 3-4 Part B Items A(ii)(1)(d) and (e). Although these changes are consistent with some of the wording included in the BTP 3-4 Part B Items A(ii)(1)(c), (d), and (e), they seem to be confusing and difficult to determine how the suggested DCD changes would satisfy the requirements per BTP 3-4 Part B Items A(ii)(1)(d) and (e). MHI is requested to clarify clearly how the proposed changes to the DCD Subsection 3.6.2.1.1.1, items (2) and (3) would address the requirements per BTP 3-4 Part B Items A(ii)(1)(d) and (e).

ANSWER:

Items (2) and (3) of the 2nd paragraph in Subsection 3.6.2.1.1.1 will be modified in DCD Revision 2.

Impact on DCD

DCD Tier 2, Section 3.6, Revision 2 incorporates the following changes as impacted by RAI 71-986. No additional changes to the DCD are required as a result of this RAI answer.

- Replace Item (2) in the second paragraph of Subsection 3.6.2.1.1.1 with the following:

  "The maximum stress ranges as calculated by the sum of Equations 9 and 10 in Paragraph NC-3653 of ASME Code, Section III (Reference 3.6-9), considering those loads and conditions thereof for which Level A and Level B stress limits have been specified in the system's design specification, does not exceed 0.8(1.8 S_h + S_A). The S_h and S_A are allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III."

- Replace Item (3) in the second paragraph of Subsection 3.6.2.1.1.1 with the following:

  "The maximum stress in this piping as calculated by Equation 9, of paragraph NC 3653 of ASME Code, Section III (Reference 3.6-9) does not exceed the smaller of 2.25 S_h or 1.8 S_y, when subjected to the combined loading of internal pressure, dead weight and postulated pipe rupture beyond this portion of piping, except that following a failure outside containment, the pipe between the outboard isolation valve and the first restraint may be permitted higher stresses provided a plastic hinge is not formed, operability of the valves with such stresses is ensured in accordance with the criteria specified in SRP Section 3.9.3, the piping between the outboard isolation valve and the restraint is constructed in accordance with the Power Piping Code ANSI B31.1 and the piping should either be of seamless construction with full radiography of all circumferential welds or all longitudinal and circumferential welds should be fully radiographed.

  Primary loads include those which are deflection-limited by whip restraints."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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SRP SECTION:	**03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping**
APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-21

This is the supplemental RAI S01 for RAI 71-986, question 03.06.02-2(f).

In its response to RAI 03.06.02-2(f), MHI stated that the break exclusion zone requirements described in the DCD for the main steam room are not applicable to inside the PCCV, because there are no isolation valves inside of PCCV. However, in its response to item 2(b) and in Appendix A of this question response, MHI stated that the break exclusion zone is limited to those portions of piping from the PCCV penetration wall up to and including the inboard or outboard isolation valves as described in BTP 3-4. MHI is requested to clarify and define the break exclusion zone for piping (including all high energy piping – FW, MS, SGBD) that does not have any inboard isolation valves. In addition, MHI is requested to incorporate any changes in a revised version of the DCD.

ANSWER:

The Break Exclusion Region (PCCV penetration to 5-way restraint) in DCD Figure 3.6-1 is only applied to MS and FW piping. The break exclusion zone for other piping is limited to those portions of piping from the PCCV penetration wall up to and including the inboard or outboard isolation valves as described in BTP 3-4.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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SRP SECTION:	**03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping**
APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-22

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-4.

In its response to RAI 03.06.02-4, MHI stated that the US-APWR does not intend to utilize any high-energy fluid piping in complex systems, such as those containing arrangements of headers and parallel piping running between headers, in areas which contain safety-related components necessary to be protected from pipe breaks. MHI also stated that piping runs with headers and parallel piping running between headers, if they exist in complex systems, are inherently within the scope for consideration of the criterion BTP 3-4, Part B, Item A(iv) and therefore the designer is required by the reference to invoke the criterion. Based on this, MHI found that it was not necessary to state in the DCD special requirements for complex systems, if they exist. The staff noted that even if the US-APWR does not intend to utilize any high energy piping in complex systems at this certification phase, as indicated in MHI's response, there exists a potential that US-APWR may contain such a system in the future. Therefore, MHI is requested to include this specific criterion in the DCD as described in BTP 3-4 which requires the piping designer to identify and include all such piping within a designated run in order to postulate number of breaks.

ANSWER:

The criterion BTP 3-4, Part B, Item A(iv) will be added in the first paragraph in DCD Subsection 3.6.2.1.1, Revision 2.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- Add the following paragraph as the first paragraph in DCD Subsection 3.6.2.1.1:

  "The designer is to identify each piping run it considers in order to postulate the break locations pursuant to Subsection 3.6.2.1.1.2. In complex systems, such as those containing arrangements of headers and parallel piping running between headers, the designer is to identify and include all such piping within a designated run in order to postulate the number of breaks pursuant to these criteria."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-23

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-6(d).

In its response to RAI 03.06.02-6(d), MHI stated that DCD Subsection 3.6.2.1.2.2 describes that it is not necessary to postulate breaks of moderate-energy fluid system piping if the effect of the postulated break is less severe than those of the adjacent high energy fluid system piping. If the effects of breaks of moderate-energy fluid system piping is more severe than those of high-energy fluid system piping, then the criterion of BTP 3-4, Part B, Item B(iii) should be followed and the criterion of BTP 3-4, Part B, Item B(iv) is applicable. The staff found these criteria are consistent with BTP 3-4, Part B, Item B(iv). However, the staff noted that the criterion presented in DCD Subsection 3.6.2.1.2.2 does not include the second part of the criteria as described in the RAI response. MHI is requested to incorporate the second part of this criterion in a revised version of the DCD Subsection 3.6.2.1.2.2.

ANSWER:

The last paragraph in DCD Subsection 3.6.2.1.2.2 will be moved to the first paragraph in DCD Subsection 3.6.2.1.2 and will be modified.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- The last paragraph in DCD Subsection 3.6.2.1.2.2 will be moved to the first paragraph in DCD Subsection 3.6.2.1.2 and will be modified as follows:

  "Leakage cracks are not postulated in moderate-energy fluid system piping located in an area where a break in the high-energy fluid system is postulated, provided that such a crack does not result in environmental conditions more severe than the high-energy break. If the effects of breaks of moderate-energy fluid system piping are more severe than those of high-energy fluid system piping, then the provision of this Subsection 3.6.2.1.2.2 is applied."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-24

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-6(e).

In its response to RAI 03.06.02-6(e), MHI stated that the criterion related to through-wall leakage cracks in moderate-energy fluid system piping based on the 2 percent of the operating time rule is applicable to the APWR design. However, MHI did not incorporate this statement to the DCD. MHI is requested to incorporate this criterion in a revised version of the DCD.

ANSWER:

The criterion related to through-wall leakage cracks in moderate-energy fluid system piping will be added as the second paragraph of Subsection 3.6.2.1.2 in DCD Revision 2.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- Insert the following as the new second paragraph of Subsection 3.6.2.1.2:

  "Through-wall leakage cracks instead of breaks may be postulated in the piping of those fluid systems that qualify as high-energy fluid systems for about 2% of the operational period but qualify as moderate-energy fluid systems for the major operational period."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-25

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-7(b).

In its response to RAI 03.06.02-7(b), MHI stated that piping stiffness is used only when a plastic hinge is not developed in the piping. However, MHI did not incorporate this criterion to the DCD. MHI is requested to incorporate this criterion in a revised version of the DCD.

ANSWER:

The last paragraph of DCD Subsection 3.6.2.1.3.1 will be modified in DCD Revision 2 to incorporate this criterion.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- The last paragraph of DCD Subsection 3.6.2.1.3.1 will be modified as follows:

  "Following a circumferential break, the two ends of the broken pipe are assumed to move clear of each other unless physically limited by piping restraints, structural members, or pipe stiffness. Piping stiffness is used only when a plastic hinge is not developed in the piping. The effective cross sectional (inside diameter) flow area of the pipe is used in the jet discharge evaluation. Pipe whipping is assumed to occur in the plane defined by the piping geometry and configuration and to initiate pipe movement in the direction of the jet reaction."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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SRP SECTION:	**03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping**
APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-26

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-8.

In its response to RAI 03.06.02-8, MHI stated that since the PCCV penetrations are isolated in compartments made of concrete, guard pipes are not considered necessary around the PCCV penetrations. Therefore, it is not considered necessary to apply criteria of guard pipe, BTP 3-4 Part B Item A(ii)(3) and A(ii)(6) for this room. However, it appears to the staff that the guard pipe assembly is functionally similar to the piping penetration compartment (or sleeve) indicated in the DCD and MHI did not address the staff's concern described in the original RAI. Therefore, the applicant is requested to clarify whether conditions specified in BTP 3-4, Part B, Items A(ii)(3) and (6) are applicable to the design of piping penetrations shown in DCD Figure 3.8.1-8 or provide the design criteria for these piping penetrations.

ANSWER:

The annulus area is composed of several closed compartments surrounding the prestressed concrete containment vessel (PCCV). The high energy piping penetrating the PCCV is main steam, feedwater, steam generator blowdown, and chemical and volume control system (CVCS) piping. The high energy piping runs from the PCCV through the annulus to the piping area, which is isolated in a compartment made of concrete, is shown in Figure 1. The high energy piping has an isolation valve in the piping area. Therefore, the portion of the high energy piping passing through the annulus is not necessary to postulate pipe break due to satisfying pipe break exclusion criteria specified by BTP 3-4 Part B Item A(ii). Specifically, this portion passing through this area is designed with stress limitation, no weld attachment, minimization of welding, and 100% volumetric in-service examination is carried out for welding. Therefore guard pipes are not considered necessary for high energy piping penetrating the PCCV.

The moderate energy piping is also passing through the annulus. The postulated leakage crack of the moderate energy piping will not cause significant pressurization. Therefore, guard pipes are also not considered necessary for moderate energy piping penetrating PCCV.

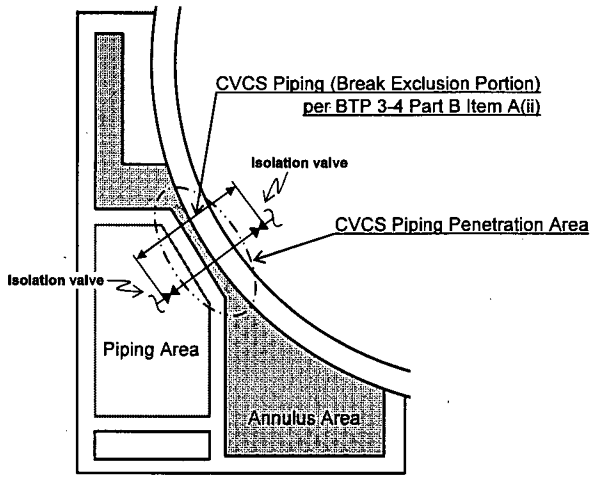

Figure 1 CVCS Piping Penetration Area

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-27

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-9(a).

In its response to RAI 03.06.02-9(a), MHI proposed some DCD changes which are consistent with the SRP Section 3.6.2. However, the staff noted that the proposed changes will be added at the end of DCD Subsection 3.6.3 and that DCD subsection addresses LBB evaluation. MHI is requested to incorporate this criterion in a revised version of the DCD subsection 3.6.2.

ANSWER:

"DCD Subsection 3.6.3" in the response to RAI 03.06.02-9(a) was typographical error, and will be corrected in the DCD.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- The following paragraph will be added at the end of DCD Subsection 3.6.2.3, opposed to the end of DCD Subsection 3.6.3:

  "The loading condition of a pipe run or branch, prior to the postulated rupture, in terms of internal pressure, temperature, and inertial effects are used in the evaluation for postulated breaks. For piping pressurized during operation at power, the initial condition is the greater of the contained energy at hot standby or at 102% power."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-36

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-16(b).

In its response to RAI 03.06.02-16(b), MHI stated that DCD Subsection 3.6.2.1.1.1 describes that a five-way restraint is installed for main steam piping and feedwater piping outside of the PCCV to prevent a load from being applied to the CV isolation valve due to a postulated pipe break outside of break exclusion zone. In other cases, the subject valve is installed sufficiently away from a postulated break location to prevent dynamic effects. Furthermore, the pipe stress in the vicinity of the valve is validated as very small by using a static force displacement methodology for the pipe displacement at the break location. However, just keeping the stress level low may not be adequate to ensure the operability of pipe mounted safety-related components. MHI is requested to clarify whether there are other safety-related components other than the CV isolation valve and provide criteria that would ensure their operability under pipe break conditions.

ANSWER:

The analysis of the broken pipe identifies the loading applied at the end of the pipe-mounted safety-related component, and will assure that the loading meets the loading specified in the specification of that safety-related component. Thus, the operability of the safety-related component is assured.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-37

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-16(c).

In the original RAI 03.06.02-16(c), MHI was requested to clarify a statement included in DCD Subsection 3.6.2.4.2.2 regarding the piping system and pipe whip restraint design. Specifically, that subsection of DCD states that when making a more detailed evaluation, the piping system and restraints are modeled and a time history analysis performed. In its RAI response, MHI proposed a DCD change to state that when making a more detailed evaluation, the piping system and pipe whip restraints are modeled without taking credit for the supports designed using operational loads and a time history analysis. It is still not clear as to which supports are not credited and how the piping system and pipe whip restraints are modeled for analysis and the design of pipe whip restraints. The applicant is requested to clarify the DCD per the staff's concerns.

ANSWER:

The seventh paragraph in DCD Subsection 3.6.2.4.2.2 will be modified in DCD Revision 2.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, changes to be incorporated:

- The seventh paragraph in DCD Subsection 3.6.2.4.2.2 will be modified to the following:

  "When making a more detailed evaluation to analyze the dynamic effects associated with pipe rupture events on the broken pipe, a non-linear elastic-plastic analysis is performed. In this model, restraints specifically designed to prevent pipe whip are included, i.e. pipe whip restraints. The normal supports that act during plant operational loads, including seismic events to maintain the integrity of the unbroken pipe, are not considered unless they are capable of withstanding pipe rupture loads based on a broken pipe analysis."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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APPLICATION SECTION:	**3.6.2**
DATE OF RAI ISSUE:	**09/16/2009**

QUESTION NO.: RAI 03.06.02-38

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-17.

In its response to RAI 03.06.02-17, MHI stated that since pipe whip restraints used to protect SSCs are designed as seismic Category I as described in DCD Subsection 3.6.2.4.4.1, the pipe whip restraint can resist a single application of SSE. MHI further stated that the evaluation to pipe break load is performed using the energy balance method, and the contribution due to random seismic load is not considered. The staff's concern is that if seismic load is not considered in the design, then how are the pipe whip restraints designed as seismic Category I structures. In addition, since whip restraints are not ASME Code supports, it is not clear what loads and load combinations are used in the design of pipe whip restraints for USAPWR. MHI is requested to address the staff's concerns as described.

ANSWER:

Loads to be evaluated in combination with pipe break forces are Level A or B service loads and are not combined with seismic loads as described in DCD Subsection 3.6.2.4.4.1. However, seismic loads are independently considered to confirm the structural integrity of the pipe whip restraint, in the event the restraint is in contact with the pipe during a seismic event. Subsection 3.6.2.4.4.1 will be clarified during Revision 2 of the DCD.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.6, Revision 2, changes to be incorporated:

- The last paragraph in DCD Subsection 3.6.2.4.4.1 will be modified to the following:

  "Loads to be evaluated in combination with pipe break forces are Level A or B service loads and are not combined with seismic loads. Seismic loads are independently considered to confirm the structural integrity of the pipe whip restraint if the restraint becomes in contact with the pipe during the seismic event. In the evaluation of structures, loads producing primary stresses are used."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

This completes MHI's responses to the NRC's questions.

(Reference 3.6-3). The general bases and assumptions of the analysis are per BTP 3-4 (Reference 3.6-5).

(1) The reconciliation of the as-built configuration as described by ITAAC Item 4 in Table 2.3-2 of Tier 1, Section 2.3, is provided in an as-built pipe break evaluation report prior to fuel load.

3.6.2.1 Criteria used to Define Break and Crack Location and Configuration

The following subsections establish the criteria used for selecting the locations and configuration of the postulated breaks and cracks, except for piping that satisfies the requirements for LBB described in Subsection 3.6.3.

The COL Applicant is to implement the criteria for defining break and crack locations and configurations for site-specific high-energy and moderate-energy piping systems. The COL Applicant is to identify the postulated rupture orientation of each postulated break location for site-specific high-energy and moderate-energy piping systems. The COL Applicant is to implement the appropriate methods to assure that as-built configuration of site-specific high-energy and moderate-energy piping systems is consistent with the design intent and provide as-built drawings showing component locations and support locations and types that confirms this consistency.

3.6.2.1.1 High-Energy Fluid Systems Piping

The designer is to identify each piping run it considers in order to postulate the break locations pursuant to Subsection 3.6.2.1.1.2. In complex systems such as those containing arrangements of headers and parallel piping running between headers, the designer is to identify and include all such piping within a designated run in order to postulate the number of breaks pursuant to these criteria.

3.6.2.1.1.1 High-Energy Fluid System Piping in PCCV Penetration Area

Breaks and cracks need not be postulated in the portions of piping from containment wall to and including the inboard or outboard isolation valves. This portion of piping meets the following criteria.

All piping in the PCCV penetration area defined above is ASME Code, Section III, Class 2 (Reference 3.6-9). For ASME Code, Section III, Class 2 piping the following design criteria are met.

(1) The design criteria of the ASME Code, Section III (Reference 3.6-10), Subarticle NE-1120, is satisfied for the PCCV penetration.

~~(2) Stresses do not exceed those specified within Subsection 3.6.2.1.1.2.~~

(2) The maximum stress ranges as calculated by the sum of Equations 9 and 10 in Paragraph NC-3653 of ASME Code, Section III (Reference 3.6-9), considering those loads and conditions thereof for which Level A and Level B stress limits have been specified in the system's design specification, does not exceed 0.8(1.8 S_h + S_A). The S_h and S_A are allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III.

(3) The maximum stress in this piping as calculated by Equation 9, of paragraph NC-3653 of ASME Code, Section III (Reference 3.6-9) does not exceed the smaller of 2.25 S_h or 1.8 S_y, when subjected to ~~the combined loading of internal pressure, dead weight and postulated pipe rupture beyond this portion of piping~~ primary loads, including those which are deflection-limited by whip restraints, and the combined loading of internal pressure, dead weight and postulated pipe rupture beyond this portion of piping, except that following a failure outside containment, the pipe between the outboard isolation valve and the first restraint may be permitted higher stresses provided a plastic hinge is not formed, operability of the valves with such stresses is ensured in accordance with the criteria specified in SRP Section 3.9.3, the piping between the outboard isolation valve and the restraint is constructed in accordance with the Power Piping Code ANSI B31.1 and the piping should either be of seamless construction with full radiography of all circumferential welds or all longitudinal and circumferential welds should be fully radiographed.

Primary loads include those which are deflection-limited by whip restraints.

(4) The number of circumferential and longitudinal piping welds and branch connections are minimized.

(5) Welded attachments, for pipe supports or other purposes, to this portion of piping are avoided. Where welded attachments are necessary, the welds are 100% volumetrically examinable and detailed stress analyses are performed to demonstrate compliance with the limits of Subsection 3.6.2.1.1.2.

(6) 100% volumetric examination in accordance with IWA-2400 of ASME Code, Section XI (Reference 3.6-11) of all piping welds is performed.

(7) Anchors or five way restraints do not prevent the access required to conduct inservice examination specified in ASME Code, Section XI (Reference 3.6-11). ISI completed during each inspection interval provides examination of circumferential and longitudinal welds within the boundary of this portion of piping.

(8) The length of these portions of piping is to be reduced to the minimum length practical.

Application to Main Steam Pipe Room

No breaks are postulated in the main steam supply system (MSS) and feedwater system (FWS) piping from the PCCV penetration outboard weld to the wall of main steam pipe room (Figure 3.6-1) provided the following actions are taken:

- The pipe is routed straight to lower the stresses.
- Five–way restraint (free only in axial direction) is installed in the main steam pipe room wall penetration.
- Essential equipment is protected from the environmental, flooding, and subcompartment pressurization effects of an assumed non-mechanistic longitudinal break. Each assumed non-mechanistic break has a cross sectional area of one square foot and postulated to occur at a location that has the greatest effect on essential equipment.

3.6.2.1.2 Moderate-Energy Fluid System Piping Break Locations

Leakage cracks are not postulated in moderate-energy fluid system piping located in an area where a break in the high-energy fluid system is postulated, provided that such a crack does not result in environmental conditions more severe than the high-energy break. If the effects of breaks of moderate-energy fluid system piping are more severe than those of high-energy fluid system piping, then the provision of this Subsection 3.6.2.1.2.2 is applied.

Through-wall leakage cracks instead of breaks may be postulated in the piping of those fluid systems that qualify as high-energy fluid systems for about 2% of the operational period but qualify as moderate-energy fluid systems for the major operational period.

3.6.2.1.2.1 Moderate-Energy Fluid System Piping in PCCV Penetration Areas

Leakage cracks are not postulated in those portion of the piping from PCCV wall to and including the inboard and outboard isolation valves provided that the PCCV penetration meets the requirements of ASME Code, Section III (Reference 3.6-10), Subarticle NE-1120 and the piping is designed so that the maximum stress range based on the sum of Equations (9) and (10) in Subarticle NC/ND-3653 of the ASME Code, Section III (Reference 3.6-9) does not exceed 0.4 times the sum of the stress limits given in NC/ND-3653.

3.6.2.1.2.2 Moderate-Energy Fluid System Piping in Areas Other than PCCV Penetrations

Leakage cracks are postulated in the following piping systems located adjacent to SSCs important to safety.

- For ASME Code, Section III, Class 1 piping, where the stress range calculated by Eq. (10) in NB-3653 is less than 1.2 S(m)
- For ASME Code, Section III (Reference 3.6-9), Class 2 and 3 and non-safety class piping, at axial locations where calculated stress by the sum of Equations 9 and 10 in NC/ND-3653 exceed 0.4 times the sum of the stress limits given in NC/ND-3653.
- For non-safety class piping, which has not been evaluated to obtain stress information, leakage cracks are postulated at axial locations that produce the most severe environmental effects.

~~Leakage cracks are not postulated in moderate-energy fluid system piping located in an area where a break in the high-energy fluid system is postulated, provided that such a crack does not result in environmental conditions more severe than the high-energy break.~~

3.6.2.1.3 Types of Break/Cracks Postulated

3.6.2.1.3.1 Circumferential Pipe Breaks

Circumferential breaks are postulated in high-energy fluid system piping and branch runs exceeding a nominal pipe size of 1 inch at locations identified by the criteria in Subsection 3.6.2.1.1.2.

No breaks are postulated in piping having a nominal diameter less than 1 inch, including instrument lines that are designed in accordance with RG 1.11 (Reference 3.6-13).

If the maximum stress range exceeds the limits specified in Subsection 3.6.2.1.1.2 and the circumferential stress range is greater than 1.5 times the axial stress range, no circumferential break is postulated; only a longitudinal break (Subsection 3.6.2.1.3.2) is postulated.

Where break locations are selected without the benefit of stress calculations, breaks are postulated at the piping welds to each fitting, valve, or welded attachment. The line restrictions, flow limiters, positive pump-controlled flow and the absence of energy reservoirs may be taken into account, as applicable.

Following a circumferential break, the two ends of the broken pipe are assumed to move clear of each other unless physically limited by piping restraints, structural members, or pipe stiffness. Piping stiffness is used only when a plastic hinge is not developed in the piping. The effective cross sectional (inside diameter) flow area of the pipe is used in the jet discharge evaluation. Pipe whipping is assumed to occur in the plane defined by the piping geometry and configuration and to initiate pipe movement in the direction of the jet reaction.

3.6.2.1.3.2 Longitudinal Pipe Breaks

Longitudinal breaks are postulated in high-energy fluid system piping and branch runs in nominal pipe sizes 4 inches and larger. Longitudinal breaks are postulated in high- energy fluid system piping at locations of circumferential breaks as described in Subsection 3.6.2.1.3.1.

If the maximum stress range exceeds the limits specified in Subsection 3.6.2.1.1.2 and the axial stress range is greater than 1.5 times the circumferential stress range, no longitudinal break is postulated, only a circumferential break (Subsection 3.6.2.1.3.1) is postulated.

Longitudinal breaks need not be postulated at terminal ends.

Longitudinal breaks in the form of axial split without pipe severance are postulated in the center of the piping at two diametrically opposed points (but not concurrently) located so that the reaction force is perpendicular to the plane of piping configuration and produces out-of-plane bending. Alternatively, a single split is assumed at the section of highest tensile stress as determined by detailed stress analysis (e.g., finite element analysis).

For longitudinal breaks, the dynamic force of the fluid jet discharge is based on a circular or elliptical (2D x 1/2D) break area equal to the effective cross-sectional flow area of the pipe at the break location and on a calculated fluid pressure modified by an analytically or experimentally determined thrust coefficient as determined for a circumferential break at the same location, where D is the effective inner diameter of the pipe. Line restrictions

The analytical methods used for the calculation of the jet thrust for the above described situations are based on SRP 3.6.2 (Reference 3.6-3) and ANSI/ANS 58.2-1988 (Reference 3.6-14).

The time dependent forcing function is effected by the thrust pulse resulting from the sudden pressure drop at the initial moment of pipe rupture, the thrust transient resulting from wave propagation and reflection, and the blowdown thrust resulting from the buildup of the discharge flow rate, which may reach a steady state if there is fluid energy reservoir having sufficient capacity to develop a steady jet for a significant interval.

Alternatively, a steady state jet thrust function may be used as outlined in Subsection 3.6.2.3.1.

A rise time of one millisecond is used for the initial pulse.

The loading condition of a pipe run or branch, prior to the postulated rupture, in terms of internal pressure, temperature, and inertial effects are used in the evaluation for postulated breaks. For piping pressurized during operation at power, the initial condition is the greater of the contained energy at hot standby or at 102% power.

3.6.2.3.1 Steady State Jet Force

The steady state jet force can be represented by:

$F_j = C_T P A$ (Reference 3.6-14)

where

F_j = Jet Force

C_T = Thrust Factor

P = Pipe Internal Pressure Before Break

A = Break Plane Area

The thrust factor C_T is established as a function of fluid state as follows:

(a) Sub-Cooled Water

$C_T = 2.0 - 0.861\, h^{*2}$ $(0 \le h^* \le 0.75)$

$= 3.22 - 3.0\, h^* + 0.97\, h^{*2}$ $(0.75 \le h^* \le 1.0)$

where

$h^* = (h_O - 180)/(h_{sat} - 180)$

h_O = Sub-Cooled water enthalpy (BTU/lbm))

h_{sat} = Saturated water enthalpy at pressure P (BTU/lbm)

C_T value varies based on the pressure and enthalpy. In case of saturated water, the minimum value of 1.26 comes closer to maximum value of 2.0 as enthalpy (temperature) based on Subsection 3.6.2.1 and the effects of pipe whipping are then evaluated based on Subsection 3.6.2.4.5.

If the above evaluation determines that no safety-related SSCs are damaged, then dynamic analysis is not necessary. If the above evaluation determines that the structural integrity of safety-related SSCs is impaired, pipe whip restraints are incorporated in the high-energy-fluid system piping of concern and dynamic analysis is conducted for the system including the piping and the pipe whip restraints.

In general, a gap is provided between a pipe whip restraint and pipe so as not to restrict thermal movement in the pipe. In the event of a pipe-break accident, the pipe accelerates in the gap due to the jet force and collides with the pipe whip restraint. The dynamic effects of this pipe and pipe whip restraint are usually evaluated by the energy balance method.

Conservatively assuming a fixed jet force at maximum load as described in Subsection 3.6.2.3, the maximum displacement of the pipe and pipe whip restraint can be given by the following equation based on the energy balance method.

$$\left[\text{work done on system}\right] = \left[\begin{array}{l}\text{energy absorbed by pipe +}\\ \qquad\text{energy absorbed by restraint}\end{array}\right] \qquad (1)$$

Generally, in Equation (1), energy absorbed by the system is conservatively ignored so that the maximum displacement of the pipe and pipe whip restraint is given by the following equation.

$$\text{work done on system} = \text{energy absorbed by restraint} \qquad (2)$$

See Subsection 3.6.2.4.4.1 for the design methodology for pipe whip restraints.

When making a more detailed evaluation to analyze the dynamic effects associated with pipe rupture events on the broken pipe, a non-linear elastic-plastic analysis is performed. In this model, restraints specifically designed to prevent pipe whip are included, i.e. pipe whip restraints. The normal supports that act during plant operational loads, including seismic events to maintain the integrity of the unbroken pipe, are not considered unless they are capable of withstanding pipe rupture loads based on a broken pipe analysis.

The five-way restraint is installed for main steam piping and feedwater piping outside of the PCCV to prevent a load from being applied to the CV isolation valve due to a postulated pipe break outside of break exclusion zone.

In other cases, the subject valve is installed sufficiently away from a postulated break location to prevent dynamic effects. Furthermore, the pipe stress in the vicinity of the valve is validated as very small by using a static force displacement methodology for the pipe displacement at the break location.

3.6.2.4.2.3 Closure of the Feedwater Check Valve

This loading has a short duration of approximately 0.5 seconds and arises from rapidly traveling pressure waves in piping systems connected to the broken piping system. The

- This is a U-shaped rod or flat plate, usually of carbon steel, looped around the pipe but not in contact with the pipe to allow unimpeded pipe movement during normal operation and a seismic event. At rupture, the pipe converges with the U-Bar(s), which absorbs the kinetic energy of the pipe by yielding plastically.

- Structural Steel (Two-Dimensional Restraint):
  - This is a structural steel frame assembly enveloping the pipe but not in contact with the pipe that allows unimpeded pipe motion during normal operation and a seismic event. At rupture, pipe converges with the structural steel frame and the frame, which deflects plastically, absorbing the kinetic energy of the pipe.

Pipe whip restraints used to protect SSCs are designed as seismic Category I.

Loads to be evaluated in combination with pipe break forces are Level A or B service loads and are not combined with seismic loads. Seismic loads are independently considered to confirm the structural integrity of the pipe whip restraint if the restraint becomes in contact with the pipe during the seismic event. In the evaluation of structures, loads producing primary stresses are used.

3.6.2.4.4.1.1 Location of Pipe Whip Restraints and Analytical Methods

A. To determine the pipe hinge location, the plastic moment of the pipe is determined in the following manner.

$$MP = 1.1\ ZP \times SY$$

where

ZP = Plastic section modulus of pipe

SY = Yield stress at pipe operating temperature

1.1 = 10% factor to account for strain hardening

Pipe whip restraints are located as close to the axis of the reaction thrust force break as practicable, but within the length of location of plastic hinge. When it is not possible to locate the whip restraint within the length of plastic hinge, the consequences of the whipping pipe and the jet impingement effect are further investigated.

B. Pipe whip restraints are installed with sufficient annular clearance between them and the process pipe. This provides sufficient clearance for insulation and thermal and seismic movement of the pipe during normal plant operation.

If restraint also functions as a seismic support, the restraint is included in the piping analysis.

3.6.3 LBB Evaluation Procedures

This subsection describes the design basis to eliminate the dynamic effects of pipe rupture (Subsection 3.6.2) for the selected high-energy piping systems of RCL piping, RCL branch piping, and main steam piping. GDC 4 of Appendix A to 10 CFR 50 (Reference 3.6-1) allows exclusion of dynamic effects associated with pipe rupture from the design basis, when analyses demonstrate that the probability of pipe rupture is extremely low for the applied loading resulting from normal conditions, anticipated transients and a postulated SSE. The LBB evaluation is performed in accordance with SRP 3.6.3 (Reference 3.6-4).

The LBB analysis combines normal and abnormal (including seismic) loads to determine a critical crack size for a postulated pipe break. The critical crack size is compared to the size of a leakage crack for which detection is certain. If the leakage crack size is sufficiently smaller than the critical crack size, the LBB requirements are satisfied.

The piping systems, for which the LBB criterion is not applied, are evaluated for dynamic effects of postulated pipe rupture at locations defined in Subsection 3.6.2. For piping systems for which LBB is demonstrated, the evaluation of environmental effects including spray wetting, and flooding is still performed for breaks or leakage cracks in accordance with Subsection 3.6.2.

The COL Applicant is to identify the types of as-built materials and material specification used for base metal welds, weldments, and safe ends for piping evaluated for LBB. Additionally, the COL Applicant is to provide information related to as-built material and material specifications for piping including toughness (J-R curves) and tensile strength (stress-strain curves), yield and ultimate strength, welding process/methods used, provide confirmation that the actual plant-specific stress analysis based on final as-built plant piping layout and material properties and welds satisfy the bounding LBB analysis, and provide confirmation that the final bounding LBB analysis addresses all plant-specific and generic degradation mechanisms in the as-built piping systems. This issue is to be resolved in ITAAC described in Table 2.3-2 of Tier 1 Chapter 2.3.

~~The loading condition of a pipe run or branch, prior to the postulated rupture, in terms of internal pressure, temperature, and inertial effects are used in the evaluation for postulated breaks. For piping pressurized during operation at power, the initial condition is the greater of the contained energy at hot standby or at 102% power.~~

3.6.3.1 Application of LBB Criteria

Piping systems to which LBB criteria are applied are high-energy systems with well defined loading combinations and conditions. LBB criteria are applied to the following high energy piping systems (see Appendix 3E).

- RCL Piping
- RCL branch piping with nominal diameter of 6 inches or larger, except for steam within the piping for the pressurizer safety valve and power operated relief valve
- Main Steam Pipe in PCCV