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TOKYO, JAPAN

June 20, 2012

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-12167

Subject: Amended MHI's Responses to US-APWR DCD RAI No. 71-986, 459-3331 and 636-4732 (SRP 03.06.02)

Reference:

1) "Request for Additional Information No. 71-986 Revision 0, SRP Section: 03.06.02 – Determination of Rupture Locations and Dynamic Effects Associated with Postulated Rupture of Piping," dated September 9, 2008
2) "MHI's Responses to US-APWR DCD RAI No. 71-986," UAP-HF-08226, dated 10/7/2008.
3) "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.
4) "MHI's Responses to US-APWR DCD RAI No. 459-3331," UAP-HF-09488, dated 10/19/2009.
5) "Request for Additional Information No. 636-4732 Revision 0, 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 9/23/2010.
6) "MHI's Responses to US-APWR DCD RAI No. 636-4732," UAP-HF-10319, dated 11/24/2010.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document as listed in Enclosures.

In the enclosed documents, MHI provides amended responses to Questions 03.06.02-9, 10, 13, 14 and 15 contained in Reference 1, Questions 03.06.02-28, 29, 33, 34, and 35 in Reference 3, and Questions 03.06.02-40, 44, 45 and 46 in Reference 5. These amended responses were prepared to reflect discussions with the NRC staff through conference calls.

Please contact Mr. Joseph Tapia, General Manager of Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

D081
NRO

Sincerely,

Y. Ogata

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

Enclosures:

1. Amended Response to Request for Additional Information No.71-986, Revision 0
2. Amended Response to Request for Additional Information No. 459-3331, Revision 1
3. Amended Response to Request for Additional Information No. 636-4732, Revision 0

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-12167
Docket No.52-021

Amended Response to Request for Additional Information
No. 71-986, Revision 0

June 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 71-986 REVISION 0**

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: **9/9/2008**

QUESTION NO.: 03.06.02- 9:

SRP Section 3.6.2, Item III.2.A provides dynamic analysis criteria and discusses material capacity limitations for a crushable material type of whip restraint, while SRP Section 3.6.2, Item III.2.B discusses various methods of analyses. Also, ANSI/ANS-58.2-1988, Section 6.3 presents several different types of dynamic analysis methods. In US-APWR DCD Tier 2 (Rev. 0) Section 3.6.2.3, MHI provided details regarding assumptions in the piping dynamic analysis. The staff noted that some blowdown forces are computed using a steady jet force based on ANS 58.2, while others, such as those for the Reactor Coolant System (RCS) piping, are computed using an MHI transient analysis with the MULTIFLEX code. Provide answers to the following:

(a) SRP Section 3.6.2, Item III.2.A states that for piping pressurized during normal operation at power, the initial condition should be the greater of the contained energy at hot standby or at 102% power. The staff did not find this assumption in the APWR DCD. Clarify if this is applicable to all approaches used for the APWR. If not, then provide technical justification for the alternate initial conditions to be assumed in the analyses.

(b) Acceptable dynamic models suggested in the SRP include lumped parameter analysis models, energy balance analysis models, and static analysis models. Also, alternate analytical approaches are discussed in ANS standard Sections 6.3.1 through 6.3.5. US-APWR DCD Tier 2 (Rev. 0) Section 3.6.2.3 presents only two specific approaches: steady state method and dynamic time-history analysis. Clarify if any other analytical (nonlinear) methods and modeling techniques (discussed in the SRP and ANS standard) will be used for APWR plants.

(c) Discuss acceptable procedures and computer programs to be used to calculate the pipe whip dynamic responses.

(d) Discuss the validation and verification (V/V) of the computer programs which the NRC staff has not yet approved. In particular, include V/V of the MULTIFLEX code discussed in DCD Tier 2 (Rev. 0) Section 3.9.2.5.2.

(e) There does not appear to be any consideration of how potential feedback between the jet and any nearby reflecting surface(s), which can increase substantially the dynamic jet forces impinging on the nearby target component and the dynamic thrust blowdown forces on the ruptured pipe through resonance, is considered. Provide details (with example, if available) that describe the methods including a description of how feedback amplification of dynamic blowdown forces will be considered for calculating the

blowdown forcing functions at break locations and identify the computer program that will be used, if any.

ANSWER:

(Original Response dated October 7, 2008)

(a) Yes, the initial condition should be the greater of the contained energy at hot standby or at 102% power. This description will be added to the DCD.

(b) The following references summarize other methodologies to be used as described in the SRP:

- DCD Subsections 3.6.2.4.2.1 and 3.6.2.4.2.3 describe the Complete System Dynamic Analysis
- DCD Subsection 3.6.2.4.2.2 describes the Energy Balance Analysis
- DCD Subsection 3.6.2.4.1 describes the Static Analysis

(c) The response of whip restraints used in US-APWR is computed by energy balance method described in DCD Subsection 3.6.2.4.2.2. No computer program is used.

(d) The computer programs used in the postulated pipe rupture analysis are as follows:

- MULTIFLEX: This code is used for the Reactor Coolant System blowdown analysis in LOCA and calculates the behavior of break flow and pressure wave in the primary system. It has been approved by NRC in WCAP-8709 in the past (Ref. 1).
- RELAP-5: This code is used for the blowdown analysis in the secondary side pipe rupture. The verification report will be provided.
- GOTHIC: This code is used for the subcompartment pressure analysis in the pipe rupture. The verification of this code is provided as a part of the subcompartment pressure analysis technical report (Ref. 2) submitted in February 2008

(Revised Response)

(e) The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

(a) There is no impact on DCD Revision 3.

(b) There is no impact on DCD Revision 3.

(c) DCD Revision 3 Subsection 3.6.2.1.3.1 is revised as shown in Attachment 1 based on discussions with the NRC Staff.

(d) There is no impact on the DCD Revision 3.

(e) Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-44).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 71-986 REVISION 0**

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: **9/9/2008**

QUESTION NO.: 03.06.02-10:

In the event of a high pressure pipe rupture, the first significant fluid load on surrounding structures would be induced by a blast wave. A spherically expanding blast wave is reasonably approximated to be a short duration transient and analyzed independently of any subsequent jet formation. Since the blast wave is not considered in the ANS 58.2 or the APWR DCD for evaluating the dynamic effects associated with the postulated pipe rupture, omission of blast wave considerations is clearly non-conservative. Explain how the effects of blast loads on neighboring safety-related SSCs will be accounted for.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 2 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-40).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 71-986 REVISION 0**

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: **9/9/2008**

QUESTION NO.: 03.06.02-13:

On page 3.6-17 in DCD Section 3.6.2.4.1, the applicant stated that "structural integrity of safety-related SSCs against jet impingement load caused by pipe break is evaluated based on steady state jet force". Supersonic expanding jets, however, are unsteady, particularly those impinging on nearby structures. The applicant is requested to examine the following reference, "Knowledge Base for Emergency Core Cooling System Recirculation Reliability, February 1996, Issued by the NEA/CSNI," (http://www.nea.fr/html/nsd/docs/1995/csni-r1995-11.pdf), which states that tests in Germany's Heissdampfreactor (HDR) showed high dynamic (oscillating) loads in the immediate vicinity of breaks. The applicant also explained that the dynamic component of jet loading is considered independently from the static component, and that when static analysis methods are used to assess short term dynamic jet loads, the results are to be multiplied by a factor of two.

Free jets are notoriously unsteady and, in the case of supersonic jets, such strong unsteadiness will tend to propagate in the shear layer and induce unsteady (time-varying oscillatory) loads on obstacles in the flow path. Pressures and densities vary nonmonotonically with distance along the axis of a typical supersonic jet and this in turn feeds and interacts with shear layer unsteadiness. In addition, for a typical supersonic jet, interaction with obstructions will lead to backward-propagating transient shock and expansion waves that will cause further unsteadiness in downstream shear layers.

In some cases, synchronization of the transient waves with the shear layer vortices emanating from the jet break can lead to significant amplification of the jet pressures and forces (a form of resonance) that is not considered in the ANS 58.2 standard and DCD Tier 2. Should the dynamic response of the neighboring structure also synchronize with the jet loading time scales, further amplification of the loading can occur, including that at the source of the jet. These feedback phenomena are well-known to those in the aerospace industry who work with aircraft that use jets to lift off and land vertically [see, for example Ho, C.M., and Nosseir, N.S., "Dynamics of an impinging jet. Part 1. The feedback phenomenon," Journal of Fluid Mechanics, Vol. 105, pp. 119-142, 1981]. Some general observations by past investigators are that strong discrete frequency loads are observed when the impingement surface is within 10 diameters of the jet opening, and that when resonance within the jet occurs, significant amplification of impingement loads can result (Ho and Nosseir show a factor of 2-3 increase in pressure fluctuations at the frequency of the resonance). The applicant is requested to:

(a) Provide information that establishes that the applicant's interpretation of the jet impingement force as static is conservative.

(b) Explain whether any postulated pipe break locations are within 10 diameters of a neighboring SSC (or barrier/shield), and if so, how jet feedback/resonance and resulting dynamic load amplification are accounted for.

(c) Clarify whether dynamic jet loads are to be considered, and if so, using what methods. Also, should the dynamic loading include strong excitation at discrete frequencies corresponding to resonance frequencies of the SSC impinged upon, provide the basis for assuming a static analysis with a dynamic load factor of two is conservative.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-44).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 71-986 REVISION 0**

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: **9/9/2008**

QUESTION NO.: 03.06.02-14:

Explain quantitatively how reflections of jets by neighboring structures will be considered.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 4 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-45).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: **NO. 71-986 REVISION 0**

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: **9/9/2008**

QUESTION NO.: 03.06.02-15:

The applicant stated that in some cases, barriers or shields around essential equipment and instrumentation will be specified (DCD Section 3.6.2.4.4.2). If the barriers or shields are close to postulated jets, these nearby surfaces can induce feedback and resonance within the jets, potentially destroying the barrier or shield. Explain how the barriers or shields will be designed so that they will not be damaged or destroyed by dynamic jet resonant loading.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-46).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

Attachment 1 to RAI 71-986

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. For identifying potential targets resulting from the postulated pipe rupture, the direction of the fluid jet is based on the arrested position of the broken pipe end including variation of the broken pipe end movement during the blowdown. DCD_03.06.02-9 S01

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, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs may be taken into account, as applicable, in the reduction of jet discharge.

Piping movement is assumed to occur in the direction of the jet reaction unless limited by structural members, piping restraints, or pipe stiffness as demonstrated by inelastic limit analysis.

3.6.2.1.3.3 Leakage Cracks

Leakage cracks are postulated in high-energy fluid system piping at locations identified in Subsection 3.6.2.1.1.3. Leakage cracks are also postulated in moderate-energy fluid system piping at locations identified in Subsection 3.6.2.1.2.2, except where excluded by the criterion in Subsection 3.6.2.1.2.2.

Leakage cracks are not postulated in 1-inch nominal diameter and smaller piping.

Enclosure 2

UAP-HF-12167
Docket No.52-021

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

June 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

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:	**9/16/2009**

QUESTION NO.: 03.06.02-28:

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

In its response to RAI 03.06.02-9(e), MHI referred to its response to RAI 03.06.02-13. However, the staff found the response of RAI 03.06.02-13 not acceptable. Thus, it does not adequately address the concern of how potential feedback between the jet and nearby reflecting surface(s). The staff requests MHI to address the original RAI item (e). For your convenience, it is updated and restated below.

RAI 03.06.02-9(e)

SRP Section 3.6.2, Item III.2.A provides dynamic analysis criteria and discusses material capacity limitations for a crushable material type of whip restraint, while SRP Section 3.6.2, Item III.2.B discusses various methods of analyses. Also, ANSI/ANS-58.2-1988, Section 6.3 presents several different types of dynamic analysis methods. In US-APWR DCD Tier 2 Section 3.6.2.3, MHI provided details regarding assumptions in the piping dynamic analysis. The staff noted that some blowdown forces are computed using a steady jet force based on ANS 58.2, while others, such as those for the Reactor Coolant System (RCS) piping, are computed using an MHI transient analysis with the MULTIFLEX code. Provide answers to the following:

(a) – (d) Not shown here.

(e) There does not appear to be any consideration of how potential feedback between the jet and any nearby reflecting surface(s), which can increase substantially the dynamic jet forces impinging on the nearby target component and the dynamic thrust blowdown forces on the ruptured pipe through resonance, is considered. Provide details (with example, if available) that describe the methods including a description of how feedback amplification of dynamic blowdown forces will be considered for calculating the blowdown forcing functions at break locations and identify the computer program that will be used, if any.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-44).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

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:	**9/16/2009**

QUESTION NO.: 03.06.02-29:

This is the supplemental RAI S01 for RAI 71-986 (questions 10-15 were responded to by MHI Ref: UAP-HF-08258, dated 11/7/2008), 03.06.02-10.

In its response to RAI 03.06.02-10, MHI stated that the loading time duration of a blast wave on a structure neighboring a pipe break would be negligibly small (less than 1/400th of a second), so that the impulse load acting on the structure (computed by integrating the product of the force and application time) would be negligible compared with loads induced by a jet impingement. However, based on the information in the Knowledge Base for Emergency Core Cooling System Recirculation Reliability, February 1996, Issued by the NEA/CSNI, http://www.nea.fr/html/nsd/docs/1995/csnir1995-11.pdf, and ACRS concerns [Wallis - ADAMS ML050830344, Ransom – ADAMS ML 050830341], all high pressure and temperature pipes should be considered as sources of blast waves with initial energy and mass roughly equal to the exposed volume from a hypothesized break. The subsequent damage from such waves has been well documented and is not properly accounted for in ANS 58.2 by the isolated analysis of a pure spherically expanding wave. MHI should provide a rigorous and thorough explanation of their procedures for estimating the effects of blast waves on nearby SSCs. Also, the staff points out that blast wave load analyses should be based on three dimensional (or asymmetric) unsteady analysis of the flow field, with appropriate representation of the surrounding structures, subsequent to the initial blast. MHI is requested to document their blast wave assessment approach(es) in a revised version of the DCD.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 2 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-40).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

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:	**9/16/2009**

QUESTION NO.: 03.06.02-33:

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-13.

In its response to RAI 03.06.02-13(a), MHI maintained that the only dynamic portion of jet loading considered was the initial quasi-steady transient as the jet slowly evolved into a steady state phenomenon. To address the initial transient, MHI treated it as a sudden ramp up in loading, and applied the well known Dynamic Load Factor (DLF) of 2.0 to a static analysis of the structural response. MHI ignored the more rapid oscillations that occur within jets, however. These oscillations may occur hundreds (or even thousands) of times in a second. In their response to (b), MHI seemed to acknowledge that these oscillations occur, but discounted any possibility of the oscillations being magnified by the presence of nearby impinged-on structures. MHI's justification for ignoring feedback and resonance was that the fundamental structural resonances of neighboring objects were expected to be well below any jet oscillation frequencies. This justification ignored the feedback and amplification that occurs within a jet even for rigid neighboring structures. Finally, it is clear from MHI's response to (c) that high-frequency dynamic jet loads were not considered in their analyses.

MHI is advised that the ANS 58.2 standard is no longer universally acceptable, unless proven conservative, for modeling jet forces in nuclear power plants, and that dynamic effects beyond those due to the initial transient assumed in ANS 58.2 (0.1 millisecond ramp time) may need to be considered in the DCD. MHI is requested to consider the high-frequency oscillations within jet flows and how they are magnified by the presence of neighboring structures, along with the dynamic response of neighboring structures excited by these oscillations. In references 5 (Masuda, 1983, figures 6 and 9) and 6 (Isozaki, 1986, figure 7) of MHI's response to RAI 03-06-02-11, strong oscillations in the jet pressure fields were clearly visible. The amplitudes of these oscillations were comparable to the static levels. The staff's reference to Ho and Nosseir in the original RAI should also be consulted for evidence of the strong oscillations in jet pressure fields (note that the mean flows in Ho and Nosseir were subsonic, and that oscillatory pressures occurred in supersonic and subsonic jets). MHI is also advised that structural resonances beyond the fundamental are also of interest to the staff, particularly those that resonate at frequencies near the jet loading frequencies. In light of the above, MHI is requested to re-address the original RAI 03.06.02-13 (items a, b, and c). MHI should include any revisions to their jet loading modeling methodology in a revised version of the DCD.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Technical Report MUAP-10017, Revision 3, and Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-44).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

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:	**9/16/2009**

QUESTION NO.: 03.06.02-34:

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-14.

In its response to RAI 03.06.02-14, MHI stated that jets will not reflect from neighboring structures, and instead are converted into flow that remains on the surface of the structure impinged upon. However, if there is sufficient momentum, the impinging jet will be expected to separate from a target. To be more precise, although jets do not always separate from impinged-on surfaces and impinge on surrounding structures, it is expected that they generally do so, and reflections may need to be considered. MHI is therefore, requested to provide a conservative approach for assessing the effects of jet reflections. In addition, the approach should be documented in a revised version of the DCD.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 4 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-45).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

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:	**9/16/2009**

QUESTION NO.: 03.06.02-35:

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-15.

In its response to RAI 03.06.02-15, MHI stated that no feedback between any barrier or shield and the jets can occur since all fundamental natural frequencies of the barriers or shields are less than 50 Hz. MHI did not consider the potential for feedback and resonance within the jet itself, as documented within Ho and Nosseir, and by Powell (JASA, 83 (2), 515-533, February 2008). This feedback and resonance has nothing to do with the oscillations of the neighboring structure (although those oscillations can introduce further amplifications). MHI is advised that the ANS 58.2 standard is no longer universally acceptable, unless proven conservative, for specifying jet loads over barriers, shields, and enclosures in nuclear power plants, and that dynamic effects beyond those due to the initial transient assumed in ANS 58.2 may need to be considered. MHI should consider realistic jet loads which include dynamic effects and possible resonant amplification in their response to this RAI. MHI is advised to consult the Ho and Nossier reference cited in follow-up RAI 03.06.02-13, along with Powell (JASA, 83 (2), 515-533, February 2008) for guidance on the potential for feedback and resonance within a jet itself (irrespective of any structural resonance) prior to responding. MHI is also advised that structural resonances above the fundamental, when strongly excited, can also lead to the destruction of barriers or shields, and is asked again to explain how the barriers and shields will be designed so that they will not be damaged or destroyed by dynamic jet loading. The barrier and shield design approach should be included in a revised version of the DCD.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

Refer to the amended response to RAI 636-4732 (Question No. 03.06.02-46).

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

Enclosure 3

UAP-HF-12167
Docket No.52-021

Amended Response to Request for Additional Information
No. 636-4732, Revision 0

June 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 636-4732 REVISION 0**
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:	**9/23/2010**

QUESTION NO.: 03.06.02-40:

Follow-up RAI 03.06.02-10 S02

This is the supplemental RAI for RAI 71-986, 03.06.02-10 and RAI 459-3331, 03.06.02-29

In its response to the staff's RAI, the applicant continues to assert that the pressures induced by blast waves on surrounding structures in US-APWR plants will be negligible. In its justification, the applicant ignores the effects of surrounding structures and walls, and the pressure wave reflections they would cause. The applicant also assumed that the blast wave loading time history is a step function, rising from ambient pressure to a peak pressure and remaining at the peak pressure indefinitely. In actuality, blast wave pressure time histories will peak, and then decrease. More importantly, this is generally followed by shock reflections, pressure increases and subsequent expansions, often to pressures below ambient pressure. The applicant also considers only barrier structures, and resonance frequencies below 50 Hz, in their response. The applicant is advised that the staff is concerned about not only barrier structures, but other structures, and safety-related components and systems. The staff is also concerned about all structural resonances which could be strongly excited by blast waves, not only the fundamental modes. The applicant is requested again to provide a rigorous explanation of appropriate and conservative blast wave estimating procedures to be applied to the USAPWR design and to document those procedures in a revised version of the DCD.

References:

MHI's Response to US-APWR DCD RAI No. 71-986; MHI Ref: UAP-HF-08258; dated November 7, 2008; ML083180225.

MHI's Responses to US-APWR DCD RAI No. 439-3331; MHI Ref: UAP-HF-09542; dated December 1, 2009; ML093370091.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 2 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

DCD Revision 3 Subsection 3.6.2.4.1.1 and Subsection 3.6.5 References 3.6-25 and 3.6-32 are revised as shown in Attachment 1 based on discussions with the NRC Staff.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 636-4732 REVISION 0**
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:	**9/23/2010**

QUESTION NO.: 03.06.02-44:

Follow-up RAI 03.06.02-13 S02

This is the supplemental RAI for RAI 71-986, 03.06.02-13 and RAI 459-3331, 03.06.02-33

In its response to the staff's RAI, the applicant discounts the possibility of feedback amplification of dynamic jet loads on the grounds that the sound speed within the jet plumes of two-phase flows is much smaller than the sound speed outside the plumes. However, the acoustic waves which cause feedback and the amplification of shed vortices from the pipe break propagate outside the jet plume at the sound speed of the external, quiescent fluid (Ho and Nossier, 1981), and are not strongly affected by the sound speed within the jet plume. Thus, even supersonic jets have similar feedback mechanisms. The applicant is therefore requested to provide a conservative methodology for assessing jet impingement loading at resonant jet conditions. The applicant is also requested to provide a conservative methodology for assessing the effects of jet impingement loading oscillations at non-resonant conditions (without strong feedback amplification), and a methodology for assessing the effects of oscillating jet loads on impinged-upon structures. Furthermore, the applicant is requested to document these methodologies in a revision of the DCD.

References:

MHI's Response to US-APWR DCD RAI No. 71-986; MHI Ref: UAP-HF-08258; dated November 7, 2008; ML083180225.

MHI's Responses to US-APWR DCD RAI No. 459-3331; MHI Ref: UAP-HF-09542; dated December 1, 2009; ML093370091.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

DCD Revision 3 Subsection 3.6.2.4.1.2 is revised as shown in Attachment 1 based on discussions with the NRC Staff.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 636-4732 REVISION 0**
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:	**9/23/2010**

QUESTION NO.: 03.06.02-45:

Follow-up RAI 03.06.02-14 S02

This is the supplemental RAI for RAI 71-986, 03.06.02-14 and RAI 459-3331, 03.06.02-34

In its response to the staff's RAI, the applicant stated that jet reflection effects would be "assessed considering the changes in direction and expansion with decaying by distance." This response is vague, and does not constitute a substantiated, conservative approach for assessing the effects of jet reflections. Also, the applicant has not documented an approach for jet reflection assessment in a revision of the DCD. The applicant is therefore requested to provide a jet reflection assessment approach and to document it in a DCD revision.

References:

MHI's Response to US-APWR DCD RAI No. 71-986; MHI Ref: UAP-HF-08258; dated November 7, 2008; ML083180225.

MHI's Responses to US-APWR DCD RAI No. 459-3331; MHI Ref: UAP-HF-09542; dated December 1, 2009; ML093370091.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 4 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

DCD Revision 3 Subsection 3.6.2.4.1.3 is revised as shown in Attachment 1 based on discussions with the NRC Staff.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/20/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 636-4732 REVISION 0**
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:	**9/23/2010**

QUESTION NO.: 03.06.02-46:

Follow-up RAI 03.06.02-15 S02

This is the supplemental RAI for RAI 71-986, 03.06.02-15 and RAI 459-3331, 03.06.02-35

In its response to the staff's RAI, the applicant references the response to RAI 03.06.02-28. In that response, the applicant discounts the possibility of feedback amplification of dynamic jet loads on the grounds that the sound speed within the jet plumes of two-phase flows is much smaller than the sound speed outside the plumes. However, the acoustic waves which cause feedback and the amplification of shed vortices from the pipe break propagate outside the jet plume at the sound speed of the external, quiescent fluid (Ho and Nossier, 1981), and are not strongly affected by the sound speed within the jet plume. The applicant is therefore requested to provide a conservative methodology for assessing jet impingement loading on shields and barriers at resonant jet conditions and to document the methodology in a revision of the DCD.

References:

MHI's Response to US-APWR DCD RAI No. 71-986; MHI Ref: UAP-HF-08258; dated November 7, 2008; ML083180225.

MHI's Responses to US-APWR DCD RAI No. 459-3331; MHI Ref: UAP-HF-09542; dated December 1, 2009; ML093370091.

ANSWER:

The response to this RAI is revised based on discussion with the NRC Staff. For more information, refer to Section 3 of Technical Report MUAP-10022, Revision 2.

Impact on DCD

DCD Revision 3 Subsection 3.6.2.4.4.2 is revised as shown in Attachment 1 based on discussions with the NRC Staff.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Topical Report / Technical Report

There is no impact on the Topical Report / Technical Report.

Attachment 1 to RAI 636-4732

Blast wave is not considered to occur from a sub-cooled water pipe break. This is due to having a velocity of the two-phase flow at the break point that is slower than the speed of sound in atmospheric environments.

~~Therefore, the blast wave does not have an impact on the design. Refer to~~The details of the evaluation and the design procedure are contained in section 2 of Reference 3.6-32, Evaluation of Jet Impingement Issues Associated with Postulated Pipe Rupture, for details on assessing a blast wave from a steam pipe break. DCD_03.06.02-40

3.6.2.4.1.2 Jet Pressure Oscillation Assessing Procedure

Jet pressure oscillation from a steam pipe break is unlikely to occur in the US-APWR due to its high compression ratio. The jet flow expansion and Mach Disk is large. This leads to a stable flow downstream after the Mach Disk. The flow is so stable that disturbance at the impingement wall does not reach back to the Mach Disk.

When sub-cooled jet-flow impinges on the wall, pressure distributions on the wall are not of the concave type and a re-circulation vortex is not generated. This is due to having a flow velocity at the jet boundary that is lower than that of the core region.

However the jet pressure oscillation may occur, when the water flashes to steam in the later stages of a jet blowdown. Therefore, The load of jet pressure oscillation is evaluated in the later stage of blowdown process. ~~Therefore, jet pressure oscillation does not have an impact on the design. Refer to~~The details of the evaluation and the design procedure are contained in section 3 of Reference 3.6-32, Evaluation of Jet Impingement Issues Associated with Postulated Pipe Rupture, for details on assessing a jet pressure oscillation from a steam pipe break. DCD_03.06.02-44

3.6.2.4.1.3 Jet Reflection Assessing Procedure

When jet flow impinges on a perpendicular wall, impinged jet flow is redirected and runs along the surface of the wall. The zone of influence obtained by computational fluid dynamics is enveloped by the estimated zone of influence from MHI original methodologies (Reference 3.6-25). ~~Inside the zone of influence, impingement pressure includes effects of pressure due to flow parallel to an impingement wall. Loads due to jet impingement reflection outside of the zone of influence are considered so small that it is not necessary to be considered~~However, there may be a case that a jet impinges upon an oblique wall; the effect of jet reflection is considered outside of zone of influence. DCD_03.06.02-45

~~Therefore, jet reflection does not have an impact on the design. Refer to~~The details of the evaluation and the design procedure are contained in section 4 of Reference 3.6-32, Evaluation of Jet Impingement Issues Associated with Postulated Pipe Rupture, for details on assessing a jet reflection.

3.6.2.4.2 Dynamic Analysis for Piping Systems

3.6.2.4.2.1 RCL Piping

Appendix 3C provides analysis details for RCL piping. Loads generated by postulated breaks from branch lines are applied to determine structural response of RCL piping.

Attachment 1 to RAI 636-4732

C. Restraints generally must not impede the access required to carry out the ISI of pipe welds. If the position of any restraint impedes the access to the pipe welds, part of the restraint can be removed to assure the accessibility.

3.6.2.4.4.1.2 Analysis and Design of Pipe Whip Restraint

The analysis and design of the pipe whip restraints for the effects of postulated pipe rupture conform to the following criteria.

A. Pipe whip restraints are designed based on the principle of energy absorption by considering the behavior of material's elasticity/plasticity and strain hardening.

B. Coefficient of rebound 1.1 is applied to jet thrust forces.

C. Energy absorption by the broken pipe is assumed to be zero, except in the case of calculating to check the formation of a plastic hinge. The developed thrust force is assumed to be applied to move a broken pipe directly, and is not reduced by the forces required to bend the pipes.

D. In the elasticity/plasticity design, the kinetic energy of the pipe is absorbed by the restraint by yielding plastically. The strain in the restraint is limited as shown below.

$e = 0.5\varepsilon_u$

where

e = Allowable strain used in the design

ε_u= Ultimate homogeneous tensile strain.

3.6.2.4.4.2 Jet Impingement Barriers and Shields

Barriers or shields are provided to protect essential equipment, including instrumentation, from the effects of jet forces resulting from postulated pipe breaks. Generally, protection provided by walls, floors, and columns is sufficient to meet protection requirements. Loading combinations and design criteria for barriers and shields are described in Section 3.8. The design procedure for jet pressure oscillation is contained in section 4 of Reference 3.6-32, Evaluation of Jet Impingement Issues Associated with Postulated Pipe Rupture. DCD_03.06.02-46

3.6.2.4.4.3 Pipe Whip Impact on Structures

The evaluation of structures that are impacted by whipping pipes is described below.

Following a postulated pipe rupture, pipe whip into surrounding structures will occur, if the pipe is not sufficiently restrained. The level of energy in the whipping pipe may be determined by calculating work quantities using simplified methods. The external work is calculated by multiplying the break force acting on the whipping pipe by the distance

Attachment 1 to RAI 636-4732

3.6-25 US-APWR Methodology of Pipe Break Hazard Analysis, MUAP-10017, Rev. ~~1~~3, Mitsubishi Heavy Industries Ltd., ~~December, 2010~~May 2012. DCD_03.06.02-40

3.6-26 Kitade, K., Nakatogawa, T., Nishikawa, H., Kawanishi, K., and Tsuruto, C., Experimental Study of Pipe Reaction Force and Jet Impingement Load at the Pipe Break, Trans. 5th Int. Conf. on SMiRT, F6/2, 1979.

3.6-27 Kitade, K., Nakatogawa, T., Nishikawa, H., Kawanishi, K., and Tsuruto, C., Experimental Studies on Transient Water-Steam Impinging Jet, Vol. 22 No. 5, pp. 403-409, Journal of Atomic Energy Society of Japan, 1980 (in Japanese).

3.6-28 Kitade, K., Nakatogawa, T., Nishikawa, H., Kawanishi, K., and Tsuruto, C., Experimental Studies on Steam Free Jet and Impinging Jet, Vol. 22 No. 9, pp. 634-640, Journal of Atomic Energy Society of Japan, 1980 (in Japanese).

3.6-29 Masuda, F., Nakatogawa, T., Kawanishi, K. and Isono, M., Experimental Study on an Impingement High-Pressure Steam Jet, Nuclear Engineering and Design 67-2, pgs 273-285, 1982.

3.6-30 Masuda, F., Nakatogawa, T., Kawanishi, K. and Isono, M., Experimental Study on Jets Formed Under Discharges of High-Pressure Subcooled Water and Steam-Water Mixture, Trans. 7th Int. Conf. on SMiRT, F1/6, 1983.

3.6-31 Isozaki, T. and Miyazono, S., Experimental Study of Jet Discharging Test Results under BWR and PWR Loss of Coolant Accident Conditions, Nuclear Engineering and Design 96, 1986.

3.6-32 Evaluation on Jet Impingement Issues Associated with Postulated Pipe Rupture, MUAP-10022, Rev. ~~0~~2, Mitsubishi Heavy Industries Ltd., ~~January, 2011~~May 2012. DCD_03.06.02-40