REQUEST FOR ADDITIONAL INFORMATION 459-3331 REVISION 1

9/16/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.06.02 - Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping
Application Section: 3.6.2

QUESTIONS for Engineering Mechanics Branch 2 (ESBWR/ABWR Projects) (EMB2)

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).

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.

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.

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.

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.

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.

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.

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.

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.

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/csni-r1995-11.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.

03.06.02-30

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-11(a).

In its response to RAI 03.06.02-11(a), MHI cited both ANS 58.2 and their own methodologies (some of which were provided in Attachment 1, and were based on measurements cited in references 1-6 in their response to RAI 03.06.02-11). It is not clear exactly which procedures were being applied. MHI provided a similar response to RAI 03.06.02-12(a). The references showed measurements which clearly contradicted the methodologies in ANS 58.2. MHI is therefore requested to clarify which procedures are used for their design calculations. If different procedures are used for different portions of the plant, MHI should clearly state this. MHI is advised that the methodologies in the ANS 58.2 standard, unless proven conservative, are no longer considered universally acceptable for modeling jet forces in nuclear power plants. Alternative analysis approaches are acceptable, provided they are substantiated by valid benchmarks (such as the measurements in the citations). MHI is requested to document any revisions to their jet loading analysis approach in a revised version of the DCD.

03.06.02-31

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-12(a).

In its response to RAI 03.06.02-12(a), MHI cited both ANS 58.2 and their own approach for computing jet loads. Their approach, based on references 1-6 in their response to RAI 03.06.02-11, was described in Attachment 1. It appears that MHI's approach overrided most (if not all) of ANS 58.2. While this may be acceptable (provided the new approach is substantiated by appropriate benchmarks, such as the measurements in MHI's citations), it is unclear what, if any, sections of ANS 58.2 were actually applied. While MHI allowed for varying jet expansion angles (a departure from ANS 58.2), they maintained the assumption that the pressure is uniform over the jet (section 4.3 of Attachment 1 to their RAI response). This assumption was directly contradicted by the measurements presented in their citations. The references cited by MHI in their RAI response (1-6) clearly showed strongly nonuniform pressure distributions which varied with distance from the pipe break. MHI is requested to justify assuming a uniform pressure distribution in light of the existing measurements. Should MHI revise their approach to modeling pressure distributions, the revision should be documented in a revised version of the DCD.

03.06.02-32

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-12(b).

In its response to RAI 03.06.02-12(b), MHI provided a new table of postulated pipe break locations to which Leak Before Break (LBB) criteria are to be applied. MHI is requested to expand the table to include all postulated pipe breaks, along with the properties of the fluids inside and outside the pipes.

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.

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.

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.

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.

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.

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.

03.06.02-39

This is the supplemental RAI S01 for RAI 71-986, 03.06.02-18.

In the original RAI 03.06.02-18, MHI was requested to identify a list of information that will be included in the pipe break analysis report along with its (as-design aspect) completion schedule. In its response to the RAI, MHI stated that COL Item in Subsection 3.6.4 is modified in Revision 1 of the DCD. The revised COL Item states that the COL applicant is to implement the criteria for defining break and crack locations and configurations for the site-specific high-energy and moderate-energy piping systems. In addition, 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. Furthermore, the COL applicant is responsible for the as-built reconciliation of these site-specific high-energy and moderate-energy piping systems.

In its RAI response, MHI also referred to UAP-HF-08123 which describes MHI's design completion plan for piping systems and components. Specifically, it states that for ASME Class 1 piping, the dynamic effect evaluation for risk significant piping will be issued in December 2010 and the evaluation for other piping will be issued prior to material procurement. For ASME Class 2 and 3 piping, the dynamic effect evaluation for main steam piping will be issued in December 2010, the evaluation for risk significant piping will be issued in June 2012, and the evaluation for other piping will be issued prior to material procurement. Based on its review of the above information, the staff found that MHI did not address the original RAI adequately.

MHI should note that there are three areas involved in the pipe break analysis. These three areas are the methodology or the criteria for evaluating the effects of postulated pipe failures, the design aspect of the pipe break analysis report performed in according to the methodology, and then the as-built reconciliation to ensure the plant is built in according to the design and meets the applicable regulation. Since MHI indicates that the design aspect of the pipe break analysis will be performed by MHI and the COL applicant (for the site-specific piping), MHI should include a description in DCD Tier 2 Section 3.6.2 that clearly outlines the information that will be included in the as-designed pipe break analysis report. This is to ensure that the design aspect of the pipe break analysis report will contain sufficient information for the staff's review to ensure that the design is performed in according to the DCD methodology and meets the applicable regulation.

In addition, the staff noted that MHI includes only ASME Class 1, 2, and 3 piping but not non-safety class piping that is within the scope of SRP 3.6.2. Furthermore, MHI did not adequately address the closure milestone of the as-designed pipe break analysis report for all the piping systems that are within the scope of SRP 3.6.2. The DCD should include a description to address the point that the process will allow the coordination with staff's review, such that it will make the final as-designed pipe break analysis report available for NRC review. It should be noted that if the final as-designed pipe break analysis will not be completed within the design certification review phase, MHI is requested to propose an ITAAC to address the as-designed (in addition to the as-built) pipe break analysis including a description pertaining to the closure schedule of the report or an acceptable alternative. MHI is requested to address the above concerns.