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TOKYO, JAPAN

November 24, 2011

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

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-11408

Subject: MHI's Response to US-APWR DCD RAI No. 857-6110 Revision 3 (SRP 06.02.02)

Reference: (1) "Request for Additional Information No. 857-6110 Revision 3, SRP Section: 06.02.02 – Containment Heat Removal System –Application Section: 6.2.2, 6.3" dated October 25, 2011.]

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Response to Request for Additional Information No. 857-6110 Revision 3". In addition to this answer, MHI received additional question by the NRC staff informally by email. The additional question and the answer are enclosed only in proprietary version (enclosure 2) because both the question and the answer include proprietary information. Non-proprietary version (enclosure 3) contains only formal RAI question (RAI 06.02.02-86) and the answer.

Enclosed is the response to Question 06.02.02-86 that is contained within Reference 1.

As indicated in the enclosed materials, this submittal contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential. A non-proprietary version of the document is also being submitted with the information identified as proprietary redacted and replaced by the designation "[ ]".

This letter includes a copy of the proprietary version (Enclosure 2), a copy of the non-proprietary version (Enclosure 3), and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all materials designated as "Proprietary" in Enclosure 2 be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

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

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NRO

Sincerely,

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

Enclosures:

1. Affidavit of Yoshiki Ogata
2. Response to Request for Additional Information No. 857-6110 Revision 3 (Proprietary Version)
3. Response to Request for Additional Information No. 857-6110 Revision 3 (Non-Proprietary Version)

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

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ENCLOSURE 1

Docket No. 52-021

MHI Ref: UAP-HF-11408

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Yoshiki Ogata, being duly sworn according to law, depose and state as follows:

1. I am General Manager, APWR Promoting Department, of Mitsubishi Heavy Industries, Ltd. ("MHI"), and have been delegated the function of reviewing MHI's US-APWR documentation to determine whether it contains information that should be withheld from disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "MHI's Response to US-APWR DCD RAI No. 857-6110 Revision 3 (SRP 06.02.02)", dated October 25, 2011, and have determined that the document contains proprietary information that should be withheld from public disclosure. Those pages containing proprietary information are identified with the label "Proprietary" on the top of the page and the proprietary information has been bracketed with an open and closed bracket as shown here "[ ]". The first page of the document indicates that information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The basis for holding the referenced information confidential is that it describes the unique design of the safety analysis, developed by MHI (the "MHI Information").

4. The MHI Information is not used in the exact form by any of MHI's competitors. This information was developed at significant cost to MHI, since it required the performance of research and development and detailed design for its software and hardware extending over several years. Therefore public disclosure of the materials would adversely affect MHI's competitive position.

5. The referenced information has in the past been, and will continue to be, held in confidence by MHI and is always subject to suitable measures to protect it from unauthorized use or disclosure.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information.

7. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of supporting the NRC staff's review of MHI's application for certification of its US-APWR Standard Plant Design.

8. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without the costs or risks associated with the design and testing of new systems and components. Disclosure of the information

identified as proprietary would therefore have negative impacts on the competitive position of MHI in the U.S. nuclear plant market.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 24th day of November, 2011.

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

Enclosure 3

UAP-HF-11408
Docket No. 52-021

Response to Request for Additional Information
No. 857-6110 Revision 3

November 2011
(Non-Proprietary)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

11/24/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: 857-6110 REVISION 3

SRP SECTION: 06.02.02 – Containment Heat Removal Systems

APPLICATION SECTION: 6.2.2, 6.3

DATE OF RAI ISSUE: 10/25/2011

QUESTION NO.: 06.02.02-86

MUAP-08001-P Revision 5 was issued, in part, to provide revised design basis strainer qualification information. Technical report MUAP-08001, Table 3-6, "Debris Head Loss" provides head loss values for measured strainer head loss (at a given temperature) and predicts strainer head loss and debris head loss at various temperatures.

The March 2008 staff guidance regarding closure in the area of strainer head loss and vortexing, in Appendix A, Section 8.1, discusses temperature scaling of test results because head loss testing is typically performed at relatively low temperatures when compared to plant sump temperatures following a postulated LOCA. The methods for temperature scaling have ranged from simply applying the ratio of water viscosities to applying a head loss correlation both of which are based on debris bed uniformity. The staff requests that MHI provide the scaling method used to predict strainer head loss and debris head loss values at temperatures different from the measured temperature and a justification for the scaling method applied.

ANSWER:

The US-APWR strainer head loss and debris bed head loss values are calculated and temperature corrected where appropriate as described below.

A. Calculation Methodology - US-APWR Strainer Head Loss and Debris Head Loss

The PCI Technical Document No. SFSS-TD-2007-002, *Sure-Flow® Suction Strainer – Suction Flow Control Device (SFCD) Principles and Clean Strainer Head Loss Design Procedures* provides the basis for and the design principles associated with the patented suction flow control device (SFCD) -- also referred to as the core tube. The SFCD has, as its primary design function, the ability to achieve a uniform and very low approach velocity to the entire surface of the Sure-Flow® Suction (SFS) Strainer. The uniform and very low approach velocity serve to ensure that debris reaching the strainer is not affected by high velocity flow that could significantly deposit and pack the post-LOCA debris on the strainer surface areas. Due to the uniform and very low approach velocity associated with the strainer design, issues such as bore holes, vortex formation, unequal debris loading that invalidates the use of temperature correction, and the 'zipper effect' of debris deposit, among others are not issues for the SFS Strainer. NOTE: The subject PCI document is a 'proprietary and confidential' document that was previously submitted to the staff in accordance with 10 CFR § 2.390.

The PCI Technical Document No. SFSS-TD-2007-003, *Sure-Flow® Suction Strainer – Vortex Issues* provides further discussion and concludes that the SFS Strainer design does not support bore holes, vortex formation, and/or unequal debris loading. Therefore, it is appropriate to temperature correct the debris laden head loss for the US-APWR based on the method of water viscosity ratios. NOTE: The subject PCI document is a 'proprietary and confidential' document that was previously submitted to the staff in accordance with 10 CFR § 2.390.

In order to fully address each of the staff's concerns and questions in a logical and concise manner, an explanation of the methodology utilized to calculate the Clean Strainer Head Loss (CSHL), Clean Test Strainer Head Loss (CTSHL), and Total Strainer Head Loss (TSHL), and the application of temperature correction to each, if applicable, is provided as background information.

The CSHL normally consists of two (2) separate portions: (1) the SFS Strainer head loss, and (2) the fluid flow path components from the SFS Strainer discharge to the final component discharge into the US-APWR sump or pipe. Once the CSHL of the SFS Strainer arrangement is calculated, it is added to the debris laden head loss based on US-APWR specific testing performed at the Alden Research Laboratory (Alden) to establish the TSHL for the US-APWR. The TSHL is composed of the SFS Strainer head loss, the fluid flow path components, and the Alden test debris laden head loss. Each portion of the TSHL is temperature corrected as applicable and appropriate to the various US-APWR Design Basis temperatures.

The SFS Strainer head loss (the CSHL for the SFS Strainer module) is determined by application of the PCI 'Regression Formula' that is described in the proprietary Technical Document No. SFSS-TD-2007-002, Revision 1, December 11, 2008, *Sure-Flow® Suction Strainer – Suction Flow Control Device (SFCD) Principles and Clean Strainer Head Loss Design Procedures*. NOTE: The subject document is a 'proprietary and confidential' document that was previously submitted to the Staff in accordance with 10 CFR § 2.390.

The 'Regression Formula' calculates the CSHL of the strainer core tube. The specific strainer disk configuration, including strainer overall length (i.e., module length and number of modules), disk support wires, disk wire flow path, and perforated plate opening size, is separately addressed via conventional hydraulic and fluid mechanic calculations that are included as a part of the Total CSHL calculation. The formula incorporates the ability to perform temperature corrections for the US-APWR Design Basis temperature through the application of associated water kinematic viscosity values. The remaining portions of the SFS Strainer, other than the core tube which is addressed by the formula, are analyzed by conventional hydraulic calculation applications and methodology to determine their portion of the SFS Strainer CSHL. A 6% level of uncertainty is applied to the SFS Strainer CSHL.

Conventional hydraulic calculation applications and methodology are utilized to determine the CSHL of the SFS Strainer . Each of the fluid flow path components from the SFS Strainer discharge to the final component discharge into the US-APWR sump are individually analyzed in order to determine the Total CSHL. A 10% level of uncertainty is applied to the individual head loss components as appropriate. The individual head loss components are then added to the SFS Strainer CSHL to obtain the US-APWR Total CSHL. Recognized hydraulic calculation references such as Crane Technical Paper No 410, *Flow of Fluids Through Valves, Fittings, and Pipe,* I.E. Idelchik's *Handbook of Hydraulic Resistance, Marks' Standard Handbook for Mechanical Engineers*, and the *Moody Diagram,* among others, are utilized as applicable and appropriate. The use of Crane Technical Paper No 410 is based on 60 °F water temperature and no temperature adjustment is made for the Design Basis temperature. Computer based specific software such as Engineered Software's *Pipe-Flo* or other such software are not employed to calculate the US-APWR Total CSHL.

The debris laden head loss for the US-APWR utilizing the SFS Strainer is based on US-APWR plant specific testing at the Alden Research Laboratory (Alden). The US-APWR plant specific CSHL is first established based on testing at Alden. This is done in order to establish the 'base' CSHL of the actual plant specific strainer module. The US-APWR plant specific design basis debris allocation (i.e., fibrous, particulate, miscellaneous, and chemical precipitate debris) is then added to the Alden test flume. The Alden test CSHL is subtracted from the debris laden head loss determined at Alden for the US-APWR plant specific design basis debris allocation in order to determine the debris only head loss portion for the US-APWR.

The CSHL, previously calculated for the US-APWR, is then added to the US-APWR Alden debris laden head loss to determine the US-APWR TSHL for the US-APWR strainer configuration. The strainer module head loss is temperature corrected through the use of the 'Regression Formula'. The US-APWR strainer module discharge to the sump CSHL was determined by conventional hydraulic calculation applications and methodology, including use of the Moody Diagram as appropriate. The US-APWR debris laden only head loss portion is temperature corrected utilizing water dynamic (absolute) viscosity values. MHI can scale the debris laden only head loss portion since all US-APWR testing of the SFS Strainer in conjunction with design basis debris allocation has shown that the formation of vortices or boreholes have not been observed during actual testing at Alden.

The following table summarizes the calculation and temperature correction methodology utilized by MHI to calculate the CSHL and TSHL.

US-APWR Sure-Flow® Suction Strainer Head Loss & Temperature Correction Methodology

Calculated or Tested Head Loss	Sure-Flow® Suction Strainer Head Loss Component	Head Loss Determination Methodology	Temperature Correction Methodology	Comment
Calculated Head Loss Values	SFS Module CSHL	PCI 'Regression Formula'	Kinematic viscosity used within formula for temperature correction	Establishes CSHL of Sure-Flow® Suction Strainer modules based on calculation
	SFS Module Discharge Flow to Sump	Conventional hydraulic calculation applications and methodology	Moody Diagram as appropriate - not temperature corrected	Establishes CSHL of Sure-Flow® Suction Strainer Module Discharge Flow to Sump based on calculation
Tested Head Loss Values	Alden SFS Module CSHL	Actual Sure-Flow® Suction Strainer module test results	Kinematic viscosity of water used for correction from test to Design Basis temperature	Establishes CSHL of Sure-Flow® Suction Strainer modules based on actual testing
	Alden SFS Debris Laden Head Loss	Actual Sure-Flow® Suction Strainer module debris laden test results	Dynamic (absolute) viscosity of water used for correction from test to Design Basis temperature	Establishes TSHL of Sure-Flow® Suction Strainer modules based on actual testing

The following summary describes how the various strainer head loss components discussed in the previous table are utilized to determine the US-APWR SFS Strainer Arrangement Total Strainer Head Loss:

	Sure-Flow® Suction Strainer Arrangement Head Loss Component	**Head Loss Component Source**
	SFS Module CSHL	Calculated by PCI 'Regression Formula'
+	SFS Module Discharge Flow to Sump	Calculated by ConventionalHydraulic Methods
+	Alden SFS Total Debris Laden Head Loss	Alden Test Result Value
-	Alden SFS Module CSHL	Alden Test Result Value
=	SFS Strainer Arrangement TSHL	N/A

MHI applied the aforementioned methodology and philosophy for the US-APWR CSHL and TSHL calculations.

B. Justification - US-APWR Strainer Head Loss and Debris Head Loss Temperature Correction

MHI utilizes the methodology of applying the ratio of water viscosities at strainer test temperatures to correlate the head loss to various US-APWR Design Basis temperatures. This methodology has been previously reviewed by the NRR staff for current PWR licensees regarding the closure of GSI-191 issues and GL 2004-02.

The staff document, NRC Staff Review Guidance Regarding Generic Letter 2004-02 Closure in the Area of Strainer Head Loss and Vortexing March 2008 (ML080230038) specifically Section 8.1 Temperature Scaling states ... *Vendor head loss testing is typically performed with water that is at relatively low temperatures when compared to the plant sump temperatures following a postulated LOCA. The methods for temperature scaling have ranged from simply applying the ratio of the water viscosities to applying a head loss correlation such as the NUREG/CR-6224 correlation. However, if the test debris bed incurred pressure-gradient driven mechanical disruptions, such as bore holes, then the scaling of these head losses cannot be based on either viscosity or the standard head loss correlations that are based on debris bed uniformity. Because bore holes and channeling may not be easily observed or detected, it is recommended that flow sweeps be conducted at the end of the test to verify that the head loss varies relatively linearly with flow. Increasing flow is more likely to create disruptions to the bed by increasing head loss, so decreasing flow at the end of the test would likely be the preferred method to verify bed uniformity (flow and head loss change linearly). The primary temperature-affected* *parameter is the water viscosity, which increases at colder temperatures. Therefore, the test head losses are typically substantially reduced when applied to the plant condition at higher temperature.*

The staff position stated in the subject document is based on the results and conclusions found in NUREG/CR-6224. In Section *E.4.3 Results and Discussions* of NUREG/CR-6224 it is stated in part in section E.4.3 on page E-32 ... *Comparison of the correlation predictions with the experimental data, shown in Table E-5, also demonstrates* ***that the effect of temperature on the head loss can be accounted for by the viscosity term used in the correlation****. This is an important finding and can be effectively used to extend the correlation to other temperatures as needed by the analyst.* (emphasis added). Simply put, the change in head loss associated with change in temperature is directly related to the dynamic (absolute) viscosity of the water.

In addition, the Nuclear Energy Institute (NEI) document NEI 04-07 *Pressurized Water Reactor Sump Performance Evaluation Methodology*, Section 4.2.5.2.2 *Head Loss Correlations*, subsection *U.S. NRC NUREG/CR-6224 Head Loss Model* states in part with reference to the NUREG/CR-6224 *Correlation* that ... *This correlation has the following salient features:*

- ***Head loss dependence on water temperature can be handled explicitly through the use of flow viscosity in the equation***. (emphasis added)

The position taken in NEI 04-07 with regard to Section 4.2.5.2.2 is supported by the staff position documented in *Volume 2 – Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02***,** Revision 0, December 6, 2004. Specifically, Section 4.2.5 Head Loss states in part ... *The GR states that no head-loss refinements are offered other than those given in Section 3.7.2.3.2.3. (See SE Section 3.7.2.3.2.3, "Thin Fibrous Beds," for the staff evaluation of this section of the GR.) The supporting Appendix E repeats the text found in Section 4.2.5, and provides tables that summarize available domestic and international head-loss testing and results.* The Staff Evaluation of GR Section 4.2.5 goes on to further state ... *The staff did not identify any specific analytical refinements offered in Section 4.2.5 or appendix E. Therefore, no evaluation is provided for analytical refinements to the head-loss analysis.*

Finally, due to concerns raised by the ACRS Chairman in September 2004, the staff was charged with investigating and resolving the Chairman's issues with regard to the applicability of the NUREG/CR-6224 *Correlation* and its use for addressing strainer debris bed head loss. The staff issued NUREG-1862, *Development of a Pressure Drop Calculation Method for Debris-Covered Sump Screens in Support of Generic Safety Issue 191*, published February 2007. Even though the subject NUREG disputed portions of and conclusions reached in NUREG/CR-6224, it did conclude the following in Section 7 *Conclusions*:

> ... *In addition, it can generally be concluded that the pressure drop across a debris bed depends on water temperature as well as on the flows and temperatures to which the debris bed has been exposed. The developed calculational method generally predicts higher pressure drops at lower liquid temperatures, a result that follows classical theory expectations.*

Impact on DCD

There is no impact on the DCD

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 Technical Report/ Topical Report

There is no impact on the Technical Report/ Topical Report