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June 25, 2012

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-12172

Subject: MHI's Response to US-APWR DCD RAI No. 925-6413 Revision 3 (SRP Section 05.04.07)

Reference: 1) "Request for Additional Information No. 925-6413 Revision 3, SRP Section: 05.04.07 – Residual Heat Removal (RHR) System – Application Section: 5.4.7" dated April 25, 2012.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 925-6413 Revision 3".

Enclosed is the response to RAI 925-6413, Question 05.04.07-14 that is contained within Reference 1.

As indicated in the enclosed materials, this document 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 Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of the submittals. His contact information is below.

Sincerely,

Y. Ogata

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

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NRO

Enclosure:

1. Affidavit of Yoshiki Ogata

2. Responses to Request for Additional Information No. 925-6413 Revision 3 (proprietary version)

3. Responses to Request for Additional Information No. 925-6413 Revision 3 (non-proprietary version)

CC: J. A. Ciocco
J. Tapia

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Enclosure 1

Docket No. 52-021
MHI Ref: UAP-HF-12172

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Yoshiki Ogata, state as follows:

1. I am Director 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 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.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "Responses to Request for Additional Information No. 925-6413 Revision 3" dated April 25, 2012 and have determined that portions of the document contain 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 all information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The information identified as proprietary in the enclosed document has in the past been, and will continue to be, held in confidence by MHI and its disclosure outside the company is limited to regulatory bodies, customers and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and is always subject to suitable measures to protect it from unauthorized use or disclosure.

4. The basis for holding the referenced information confidential is that it describes the unique design information developed by MHI and 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.

5. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of information to the NRC staff.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information. Other than through the provisions in paragraph 3 above, MHI knows of no way the information could be lawfully acquired by organizations or individuals outside of MHI.

7. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without incurring the costs or risks associated with the design of the subject systems. Therefore, disclosure of the information contained in the referenced document would have the following negative impacts on the competitive position of MHI in the U.S. nuclear plant market:

A. Loss of competitive advantage due to the costs associated with development of the US-APWR Fluid System Engineering. Providing public access to such information permits competitors to duplicate or mimic the Fluid System Engineering information without incurring the associated costs.

B. Loss of competitive advantage of the US-APWR created by benefits of enhanced US-APWR Fluid System Engineering development costs associated with the pH Control System.

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 25th day of June, 2012.

Y. Ogata

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

Enclosure 3

UAP-HF-12172
Docket No. 52-021

Responses to Request for Additional Information No. 925-6413
Revision 3

June 2012
(Non Proprietary)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

6/25/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 925-6413 REVISION 3

SRP SECTION: 05.04.07 – RESIDUAL HEAT REMOVAL (RHR) SYSTEM

APPLICATION SECTION: 5.4.7

DATE OF RAI ISSUE: 4/25/2012

QUESTION NO.: 05.04.07-14

Follow-on to RAI 6280 responses.

1. In response to Question 1 of RAI 6280, the stated instrument uncertainty is 0.03 ft. What is the basis for the low-low level alarm 0.03 ft uncertainty? How is the 0.33 ft minimum analytical value supported by the CS/RHR pump testing level at 0.47 ft as indicated in footnote 4 of Figure 1? Does an ITAAC or pre-operational test exist which would test the pumps at an indicated level of 0.36 ft?

2. In response to Question 2 of RAI 6280, it is stated that letdown is automatically isolated on a low setpoint signal (0.47 ft per Figure 1) and it's operability is ensured by LCO 3.9.6. Does this imply the setpoint instrumentation and automatic valve isolation are safety related? If not, what is the basis for the automatic letdown isolation not being classified as safety related?

3. In response to Question 3 of RAI 6280, it is stated that MHI has confirmed, using existing Japanese plant data, that the RHR pumps can operate at 2645 gpm with no significant air ingestion. Provide the data which supports this conclusion and a detailed discussion (e.g., inlet geometry, flow rates, Reynolds numbers etc.) of how the existing Japanese plant data is applicable to the US-APWR design. The response also indicates that US-APWR scale data is available which confirms the minimal air ingestion occurs at 2645 gpm. Provide the data supporting that conclusion and discuss in detail why the scale test data is applicable to the USAPWR.

ANSWER:

The Low-Low level alarm uncertainty of 0.03 ft is based on the instrument uncertainty of the narrow range Reactor Coolant System (RCS) level sensor of the US-APWR. The narrow range RCS level sensor measures from the Main Coolant Pipe (MCP) centerline to the bottom of the Steam Generator (SG) nozzle. The instrument range and uncertainty components are listed in Table 1-1 below.

Table 1-1. RCS Level Uncertainty

Transmitter Equipment Uncertainty (% of Span)	[ ]
Transmitter Environmental Effect Uncertainty (% of Span)	[ ]
Control Board Input Uncertainty (% of Span)	[ ]
Total Uncertainty (% of Span)	[ ]
Narrow Range RCS Level Sensor Span	[ ]
Total Uncertainty (Absolute)	[ ]

The 0.33 ft minimum analytical value is supported by the scaled testing performed for APWR development, as described in the response to Question 3 below. Footnote 4 of Figure 1 in RAI 897-6280 (MHI Letter UAP-HF-12061) was unclear in referring to the pre-operational test for the Residual Heat Removal (RHR) System. The RHR pre-operational test will be performed over the full range of low water levels to verify that sufficient margins exist, from Low-Low alarm level of 0.36 ft and above Low alarm level of 0.47 ft.

The response to RAI 897-6280 will be amended to revise footnote 4 of Figure 1 as follows:

> 4. Pre-operational testing for the CS/RHR pump is performed both at Low-Low water level and above Low water level.

Question 2

Components associated with the automatic letdown isolation function were included in the Technical Specification (TS) LCOs considering the risk significance of their function, as described in response to RAI 577-4482 and 628-4866. The inclusion of the automatic isolation valve into the TS LCO is not based on credit for any safety-related functions, and it does not imply the associated setpoint instrumentation and automatic valve isolation should be classified as safety related.

The safety-related function of maintaining the reactor in a safe shutdown condition by providing decay heat removal is performed by the RHR system. The setpoint instrumentation and automatic letdown isolation are provided as a back-up for the manual operator action to isolate letdown in order to increase the likelihood that the RHR system remains within its design basis and, therefore, operable. The setpoint instrumentation and automatic letdown isolation function are not relied upon to remain functional to assure decay heat removal and therefore, are not classified as safety-related.

Question 3

Introduction

Japanese utilities have confirmed through testing that existing Japanese PWR plants can operate RHR pumps at a flow rate of 2,650 gpm and at the center level of the MCP with no significant air ingestion. Differences between existing Japanese PWRs and the US-APWR RHR operating parameters are summarized in Table 3-1. However, MHI cannot provide detailed test results, since the test data is proprietary to the utilities which performed the testing.

Table 3-1 RHR Configuration for Existing Japanese PWRs

Parameter	Japanese PWR Tests	US-APWR
Hot Leg Inner Diameter	Japanese PWR Tests	31-in
RHR Suction Nozzle	29-in	[ ]
RHR Flow Rate	12-in Sch 160	2650 gpm
Minimum Mid-Loop Water Level	2650 gpm	0.36 ft above MCP center

However, MHI performed scale testing to justify for the US-APWR that the RHR suction nozzle configuration and mid-loop water level were sufficient to prevent significant air ingestion during mid-loop operation. This testing was performed during development of the Japanese APWR and was not performed according to NQA-1 requirements. The full test report is documented in Japanese. A summary of the testing is given below.

<u>Test Setup</u>

The test setup is shown in Figures 3-1 and 3-2. Scaled testing was performed with [ ] models. The models consisted of a geometrically scaled RHR suction nozzle connected at a 45-degree angle to a section of scaled main coolant pipe with a free surface. The scaled main coolant pipe was based on a prototype inner diameter of 31-inches. The region of interest for the main coolant pipe and RHR suction nozzle was constructed from acrylic so that the vortex behavior could be visually observed. The scaled RHR suction nozzle connected to a storage tank for air separation. The test pump drew suction from the bottom of the air separation tank and returned flow to the scaled main coolant pipe. The air separation tank was constructed to allow entrained air to accumulate in a measurement pipe at the top of the tank so that the integrated void ratio could be measured.

<u>Governing Parameters</u>

RHR air ingestion is caused by the development of vortices at the RCS free surface during mid-loop operation. For flows with a free surface, gravity is a more dominant force than viscosity. The Froude number (ratio for gravity and inertia) was used as the basic similarity rule for testing to achieve dynamic similarity. The Froude number for scale testing was expressed through the following equation:

[ ]

It should be noted that all flow rates discussed herein are not model test flow rates, but equivalent prototypical flow rates for the full-scale plant equipment. To achieve dynamic similarity between the scale model and the prototypical plant equipment, the model velocities were scaled to maintain identical Froude numbers as follows:

Test Methodology

Prior to each test, the air separation tank and test lines were filled with water. After confirming that the air separation tank was full, the measuring pipe was flooded using a vacuum pump. Next, the RCS water level was set. The test pump was then actuated at a constant flow to observe whether any air ingestion vortex was generated, and the amount of ingested air accumulated in the measuring pipe was measured.

Testing was repeated for various RCS water levels, RHR pump flow rates, and nozzle dimensions. Testing was performed for equivalent prototype RHR suction flow rates ranging from [ ] and water levels ranging from [ ]. The following suction nozzles were evaluated, although only the [ ] nozzle is relevant for the US-APWR:

The test data was then analyzed to evaluate the relative water levels (h/d) and flow rates (Froude numbers) for a given air ingestion percentage. Relationships were developed for the various nozzle geometries to limit air ingestion to less than [ ]. A non-zero air ingestion limit was chosen for the acceptance criteria for practical considerations since small amounts of transient air ingestion due to random vortex formation caused by surface turbulence could not be eliminated. A [ ] air ingestion limit was chosen because this amount provides significant margin for challenges to pump integrity and is below the 2% amount which begins to result in performance degradation. The 2% air ingestion limit for performance degradation is consistent with general industry experience and recommendations, such as those in RG 1.82 Rev. 4 and NUREG/CR-2792.

Test Results

Testing for the [ ].

The relevant test data is shown in Figures 3-3 and 3-4. The [ ] suction nozzles demonstrated that the [ ] air ingestion limit could be expressed as follows (and shown in Figure 3-5):

Applicability to the US-APWR

The scale testing was performed with a [ ] suction nozzle, and the US-APWR is designed using an [ ] suction nozzle. Although test results demonstrated dependency on nozzle geometry, the US-APWR nozzle is considered to be sufficiently similar to the test nozzle such that Eq. 3 can be applied. This difference in nozzle diameter is considered acceptable given the large margin to air ingestion in the US-APWR during mid-loop water levels. The comparison in this margin for various nozzles is shown below in Figure 3-5.

The US-APWR design for mid-loop is based on a minimum RCS level of 100 mm (0.33 ft) above the RCS center line, which corresponds to [ ]. The rated mid-loop flow rate for the US-APWR is 600 m^3/hr (2650 gpm), which corresponds to a Froude number of [ ]. For nominal conditions, the US-APWR is designed for a minimum mid-loop water level above (0.46 ft), which corresponds to [ ] and a Froude number of [ ]. The minimum RCS level (0.33 ft) operating point is shown in Figure 3-5 along with the limiting air ingestion curve.

Tables 3-2 and 3-3 show application of Eq. 3 to the rated US-APWR conditions to illustrate the margin in both the RCS water level and RHR mid-loop flow rate to prevent [ ] air ingestion. Based on Tables 3-2 and 3-3, the US-APWR should not experience significant air ingestion unless RCS water level [ ] at rated flow (2650 gpm), RHR flow [ ] at Low-Low water level (0.33 ft above centerline), or RHR flow [ ] at Low water level (0.47 ft above centerline). This margin is sufficient to provide reasonable assurance that the US-APWR mid-loop operation can be performed without significant air ingestion. Furthermore, as discussed in the response to Question 1 above, operation without significant air ingestion during mid-loop will be confirmed as part of the RHR pre-operational test.

Table 3-2 Air Ingestion Limit at Various Mid-Loop Water Level Conditions

Table 3-3 Air Ingestion Limit at Low Mid-Loop Water Level

Figure 3-1 RHR Air Ingestion Scale Test Apparatus Schematic

Figure 3-2 RHR Air Ingestion Scale Test Apparatus Photo

Figure 3-3 [ ] Test Results

Figure 3-4 [ ] Test Results

Figure 3-5 Operating Region for [ ] Air Ingestion

Impact on Previous RAIs

The response to RAI 897-6280 will be amended to revise footnote 4 of Figure 1 as follows:

> 4. Pre-operational testing for the CS/RHR pump is performed both at Low-Low water level and above Low water level.

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/Topical Report

There is no impact on Technical/Topical Report.