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July 16, 2013

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-13186

Subject: MHI's Response to US-APWR DCD RAI No. 1036-7069 (SRP 06.02.02)

Reference: 1) "Request for Additional Information No. 1036-7079, SRP Section 06.02.02 – Containment Heat Removal Systems, Application Section: 6.2.2 Containment Heat Removal Systems", dated May 20, 2013.

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. 1036-7079."

Enclosed is the response to question contained within Reference 1.

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

Sincerely,

Joseph Tapia for

Yoshiki Ogata,
Executive Vice President
Mitsubishi Nuclear Energy Systems, Inc.
On behalf of Mitsubishi Heavy Industries, Ltd.

Enclosure:

1. Response to Request for Additional Information No. 1036-7079

D081
NRD

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-13186
Docket No. 52-021

Response to Request for Additional Information No. 1036-7079

July 2013

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/16/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1036-7079**
SRP SECTION:	**06.02.02–Containment Heat Removal Systems**
APPLICATION SECTION:	**6.2.2**
DATE OF RAI ISSUE:	**05/20/2013**

QUESTION NO.06.02.02-94:

Tube-side and Shell-side Fouling Factors for US-APWR CS/RHR Heat Exchanger
This is a follow-up of RAI 947-6540, Question 06.02.01-24, being issued as a result of the public meeting with the applicant held on Mach 18, 2013. In response to RAI 947-6540, Question 06.02.01-24, the applicant has included the tube-side and shell-side fouling factors of 0.0005 hr-ft2-oF/Btu in the US-APWR DCD Table 5.4.7-2, for the CS/RHR heat exchanger design. In response to an earlier RAI 623-4942, Question 06.02.01-20, the applicant had argued the 0.0005 hr-ft2-oF/Btu fouling factor to be conservative in accordance with TEMA (Tubular Exchanger Manufacturers Association) standards.

The staff's concern is that 0.0005 hr-ft2-oF/Btu is the least conservative fouling factor available in the TEMA tables and other references for very clean water (distilled/condensate) under most favorable water velocity and temperature conditions. Besides, the "Standards for Power Plant Heat Exchangers," from Heat Exchanger Institute, identify the lowest fouling factor range of 0.0005-0.001 hr-ft2-oF/Btu applicable to demineralized water. Due to the sensitivity of the heat duty of the CS/RHR heat exchanger to the fouling factors, a higher fouling factor, e.g., 0.001 hr-ft2-oF/Btu (the upper limit of the lowest fouling factor range and the next higher value in the TEMA tables) may significantly reduce the heat removal capacity of the safety-related CS/RHR heat exchanger that would be relied on for containment spray and residual heat removal under the DBA conditions. In this backdrop, specifying the overall heat transfer coefficient (UA) in the DCD Table 5.4.7-2 is not sufficient, and the DCD must also provide a conservative fouling factor guidance to the CS/RHR heat exchanger vendor. The staff suggests the following in this regard.

- The applicant should justify using 0.0005 hr-ft2-oF/Btu as a conservative fouling factor for the primary and secondary sides of the CS/RHR heat exchanger for the expected water quality, velocity, and temperature conditions, over the life of the plant. Otherwise, update the DCD with conservative tube-side and shell-side fouling factors and demonstrate that the resulting peak pressure and temperature margins and the containment pressure reduction rate in the DBA safety analyses are still conservative.

- The US-APWR DCD does not include any discussion on the justification of the specified fouling factors or the evaluation of the impact of the surface fouling on the heat removal capacity of the CS/RHR heat exchangers over the life of the plant to satisfy GDC 38, either in DCD Chapter 5 or Chapter 6. The staff requests such a discussion be included in the US-APWR DCD, which would be in accordance with SRP Section 6.2.2, Acceptance Criteria #5, which states that the application should discuss the results of such a fouling analysis.

ANSWER:

As stated in the RAI question, as well as the response given to Question 06.02.01-20 in RAI 623-4942 (UAP-HF-10261), the shell and tube side fouling factors for the CS/RHR heat exchanger listed in DCD Table 5.4.7-2 are chosen based on Tubular Exchanger Manufacturers Association (TEMA) standards for demineralized water. It is MHI's position that the current fouling factor 0.0005 h ft^2°F/Btu is already a conservative and realistic value based on the fact that both the shell and tube side fluids of the heat exchanger will be tightly controlled by administrative measures. The tube side will contain RCS water while the shell side will contain demineralized CCWS water.

The listed UA value in Table 5.4.7-2 is the overall design basis value for the CS/RHR heat exchanger in which the listed fouling factors of 0.0005 h ft^2°F/Btu (tube and shell sides) are already taken into account (in other words, the UA value will be higher in the clean heat exchanger since this fouling would not exist in the new unit). The exact U and A values will be determined during the detail design phase in consideration of the assumed fouling factors and design bases.

Despite MHI's position that the existing fouling factors are believed to be conservative, it will be demonstrated that, even if the fouling factors for both the tube and shell sides of the heat exchanger exhibit an abnormal increase in fouling and the fouling becomes double the design basis values, the resultant decrease in the design basis UA listed in Table 5.4.7-2 will still allow a sufficient rate of heat removal during containment spray operation in a post-LOCA environment to meet or exceed the required safety criteria.

If the shell and tube side fouling factors double from the values tabulated in Table 5.4.7-2 to 0.001 h ft^2°F/Btu, it is calculated that the design basis UA value will decrease by approximately 30%.

Based on Attachment-1, it is demonstrated that the containment peak pressure during a LOCA still does not exceed the maximum design basis containment pressure (68 psig) with margin in the case of a decreased UA. The same calculations and figures demonstrate that the containment pressure is reduced to half of the peak pressure within 24 hours after the initial accident.

As demonstrated by the analysis in Attachment-1, sufficient margin is built into the design basis UA specification of the CS/RHR heat exchanger to account for any uncertainties associated with the fouling factor.

In accordance with GDC 38 and SRP Section 6.2.2 Acceptance Criteria 5, a discussion justifying the chosen fouling factor value of 0.0005 h ft^2°F / Btu will be added to DCD Section 5.4.7 in accordance with the attached mark-ups. Additionally, DCD Section 6.2.2.2.2 is revised to refer to DCD Section 5.4.7 for the discussion of CS/RHR heat exchanger fouling. It is not expected that the fouling factor will exceed the design basis value during the design life of the plant. Since this fouling is already considered in the design basis UA, additional fouling impact analyses are not required to be added to the DCD.

Impact on DCD

Refer to attached mark-ups for DCD Sections 5.4.7 and 6.2.2.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on Technical/Topical Reports.

Sensitivity Analysis Result with CS/RHR Heat Exchanger Fouling Factor Variation

As discussed in the response to the RAI, this sensitivity analysis assumes that the total increase of the fouling factor during the long-term operation of the plant is approximately 0.001 h ft^2°F/Btu for the CS/RHR heat exchanger. This is twice the value that is accounted for in the present design basis assumption. The increase in fouling factor beyond 0.0005 h ft^2°F/Btu can be converted to degradation of the UA, that is, overall heat transfer performance. Table 6.2.1-5 of US-APWR DCD Revision 3 lists the UA value for the CS/RHR heat exchanger under accident conditions.

A sensitivity study to quantify the effect of a change in UA on the maximum containment pressure and temperature analysis was performed. In correspondence with the fouling factor increase, the degradation of the UA value was calculated as a reduction to 70% of its original value (i.e. a 30% decrease) in Table 6.2.1-5. This result was incorporated into the GOTHIC input for the containment analyses. The resultant limiting peak LOCA pressure corresponds to the following accident condition: a double-ended guillotine break at the pump suction of the cold leg with a critical flow discharge coefficient (C_D) of 1.0. This case is shown in DCD Tables 6.2.1-6 and 6.2.1-7 with the calculated peak value for the containment pressure and vapor temperature.

The sensitivity case results are shown in Table A-1. Peak containment pressure increased to 74.9 psia (60.2 psig) from 74.2 psia (59.5 psig). Pressure 24 hours after the incident is 28.0 psia (13.3 psig). Peak vapor temperature and RWSP liquid temperature in the containment increased to 285°F from 284°F and 253°F from 249°F, respectively. Comparisons between the sensitivity and DCD case are provided in the Figures A-1 through A-3.

Although the assumption of UA degradation was added to the original value that included the fouling factor effect, the calculated peak pressure is still under the design value, 82.7 psia (68 psig) with 10% margin to the design pressure. Containment pressure at 24 hours after the accident is within half of the calculated peak value. Therefore, the sensitivity case satisfies the NUREG-0800 SRP Acceptance Criteria 6.2.1.1A. In conclusion, even when overestimating the fouling factor of CS-RHR heat exchanger, there is no adverse effect to the design adequacy of the US-APWR containment system.

Table A-1 Sensitivity of CS/RHR Hx UA Degradation for Pressure Limiting Condition (LOCA)

	Original Value in DCD Revision 3	Sensitivity
UA (Overall Heat Transfer Performance) of CS/RHR Hx, Btu/hr-°F/unit *1	1.85×10^6	1.295×10^6
Peak Pressure, psia (psig)	74.2 (59.5)	74.9 (60.2)
Peak Vapor Temperature, °F	284	285
Peak RWSP Water Temperature, °F	249	253
24 hours Pressure, psia (psig)	25.8 (11.1)	28.0 (13.3)

*1. Two units are accounted in the calculation.

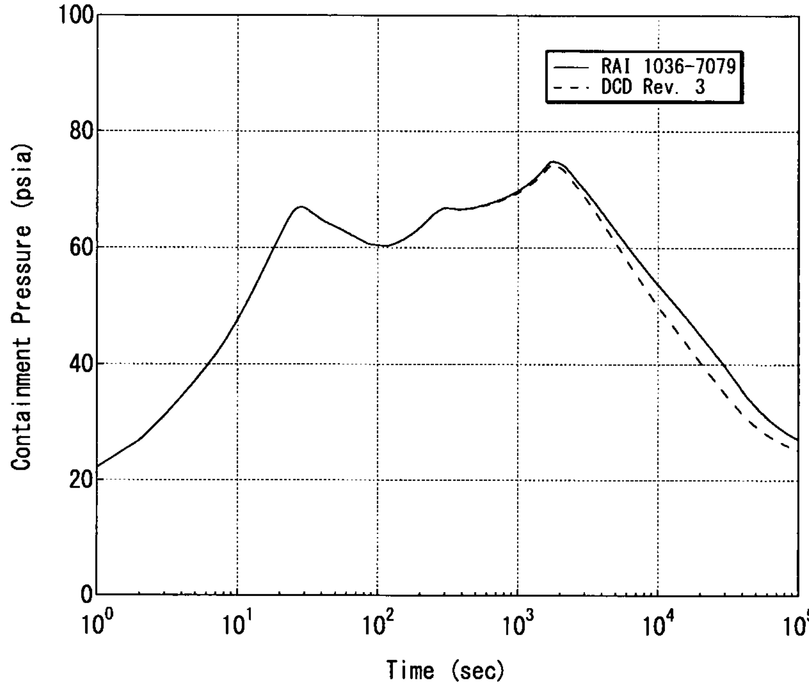

Figure A-1 Containment Pressure

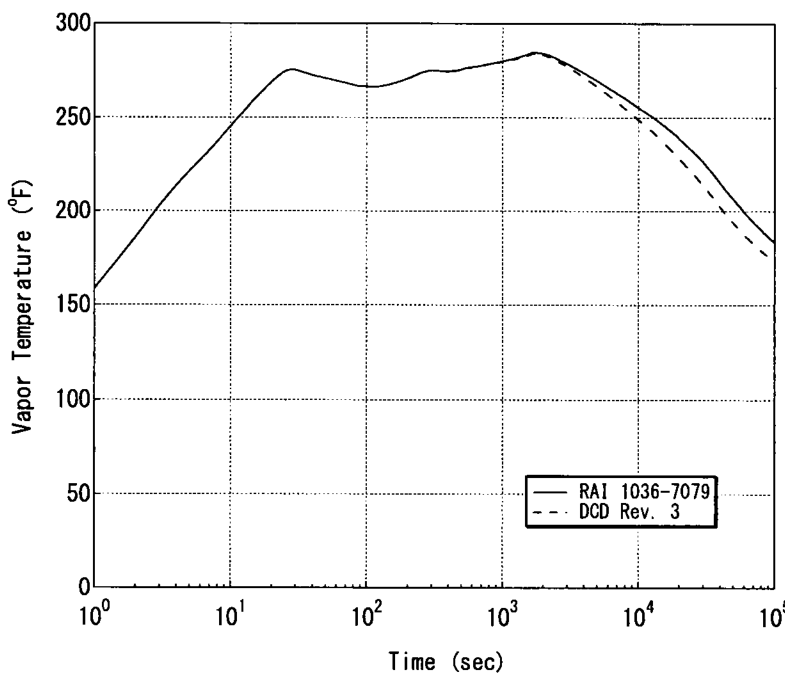

Figure A-2 Containment Vapor Temperature

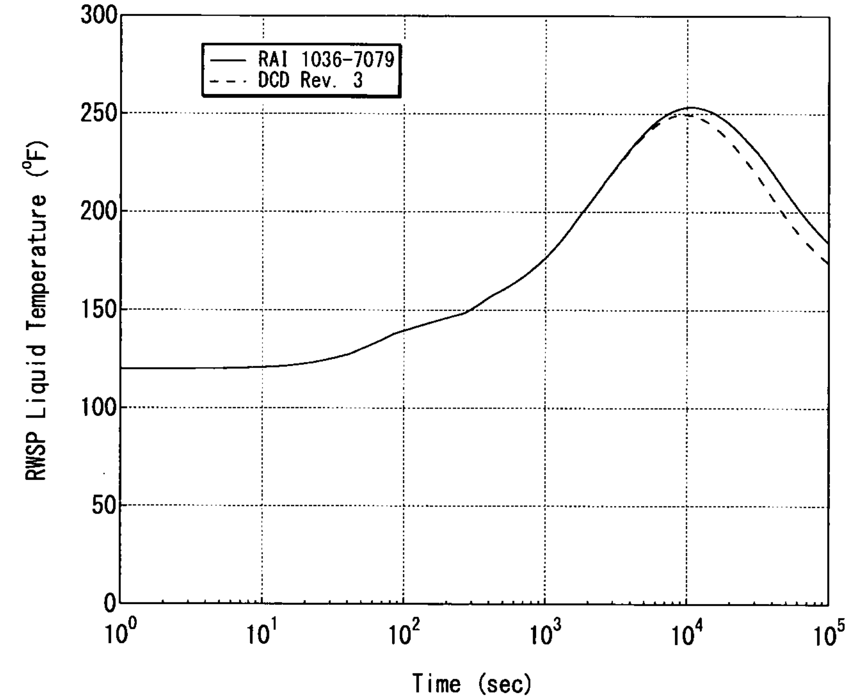

Figure A-3 RWSP Liquid Temperature

Guide 1.82 (Ref. 5.4-26). This test data will be used to support pre-operational CS/RHR pump testing. DCD_05.04.07-16

5.4.7.2.2.2 CS/RHR Heat Exchanger

The CS/RHR heat exchangers are provided to cool the reactor coolant during an RHR operation. The CS/RHR heat exchangers are also provided to remove the residual heat during normal shutdown, during shutdown in case of loss of external power sources and during safe shutdown. The CS/RHR heat exchangers are of the shell and U-type heat transfer tubes and are able to accommodate the difference in rates of heat expansion between the tube and the shell. A single unit is provided in each of the four trains and installed in a separate room so that one of the four heat exchangers may be repaired while the others are in operation.

The reactor coolant discharged from the CS/RHR pump is circulated through the tube side of the CS/RHR heat exchanger, while cooling is provided by circulating CCW through the shell side. The tubes are welded to the tube sheet to prevent leakage of the reactor coolant.

The CS/RHR heat exchanger design is based on heat loads and temperature difference between reactor coolant and CCW during normal and safe shutdown.

The overall design-basis heat transfer performance (UA) is given in Table 5.4.7-2. The exact values of U and A will be determined during detailed design once a heat exchanger vendor is selected. DCD_06.02.02-94

The listed tube and shell side fouling factors are accounted for in the design-basis UA specification in Table 5.4.7-2. The fouling factor values are selected based on Tubular Exchanger Manufacturer Association (TEMA) standards for demineralized water since strict administrative chemistry controls are employed for both the reactor coolant water and CCW.

5.4.7.2.2.3 Valves

A. CS/RHR pump hot leg isolation valves

Two normally closed motor-operated gate valves are aligned in the suction line in series in each of four RHR trains with power lockout capability between the high-pressure RCS and the low pressure RHRS. These valves isolate the RCS from the low pressure RHR piping.

These valves compose part of the RCPB. The second valve is a containment isolation valve. The first and the second valves in each train are interlocked so that they cannot be opened when the RCS pressure is above 400 psig and when the corresponding spray header isolation valves are not closed to prevent spraying the reactor coolant through the CS nozzle. These valves have a control room alarm, which alerts the operators if one or both the valves are not fully closed and the RCS pressure exceeds 400psig.

B. RHR discharge line containment isolation valve

6.2.2.2.2 CS/RHR Heat Exchangers

These components are included in the RHRS. Four CS/RHR heat exchangers are provided. They are horizontal tube and shell heat exchangers. The CS/RHR system water flows through the tubes, and the component cooling water flows through the shell. CS/RHR Heat exchanger fouling is discussed in Subsection 5.4.7.2.2.2. DCD_06.02.02-94

6.2.2.2.3 Containment Spray Piping

Each of the RWSP suction valves is normally open to ensure that suction piping remains full and aligned to provide a ready flow path to the CS/RHR pumps. Each CSS train's discharge line to the containment spray rings is provided with a normally closed, motor-operated containment isolation gate valve.

The system piping is normally filled and vented to the containment isolation valves (CSS-MOV-004A, B, C, and D) at elevation 36.75 ft. (typical for all four 50% containment spray trains) prior to plant startup. The minimum piping "keep full" level corresponds to the RWSP 100% water level at elevation ~~19.5 ft.~~20 ft. - 2 in. A conservative value of 100 seconds time delay is assumed between the system initiation and the spray ring flow for purposes of LOCA and the containment response analyses. The delay time associated with accidents is provided in Subsection 6.2.1.1.3.4 and Table 6.2.1-5. MIC-03-06-00070

6.2.2.2.4 Containment Spray Nozzles

The containment spray nozzles are of the type and manufacture commonly used in United States commercial nuclear applications. The nozzles are fabricated from 304 stainless steel, and each is fitted with a 0.375 in. orifice. As shown in Figure 6.2.2-2, the one-piece construction provides a large, unobstructed flow passage that resists clogging by particles, while producing a hollow cone spray pattern. Figure 6.2.2-3 shows each nozzle's orientation on a spray ring. The nozzle orientation is identified as vertical down (No. 1 nozzle, R-5605); 45° from vertical down (No. 3 nozzle, R-5604); and horizontal (No. 2, and No. 4 nozzles, R-5603). Figure 6.2.2-4 presents the spray pattern and typical spray coverage of each nozzle type.

Figure 6.2.2-5 is a sectional view of containment showing the elevation of the spray rings (A, B, C, and D) and the typical spray pattern from the nozzle to the containment operating floor level (elevation 76 ft. - 5 in). Figure 6.2.2-6 presents a plan view showing the location of each nozzle on each spray ring and the predicted spray coverage on the operating floor of the containment. Figure 6.2.2-6 also tabulates the number and orientation of the nozzles on each spray ring. Of the 348 containment spray nozzles distributed among the four containment spray rings, there are only four vertical up No. 4 nozzles (R-5603)—one on each spray ring. In addition to their spray function, these nozzles also serve as the high point vent on each spray ring.

6.2.2.2.5 Refueling Water Storage Pit

The RWSP is the protected, reliable, and safety-related source of boric acid water for the containment spray and SI. (Section 6.3 describes the SI function for the US-APWR ECCS.) The RWSP also is used to fill the refueling cavity in support of refueling operations. The RWSP is located on the lowest floor inside the containment, with a