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TOKYO, JAPAN

July 8, 2010

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-10194

Subject: MHI's Response to US-APWR DCD RAI No. 597-4590 Revision 2

Reference: 1) "Request for Additional Information No. 597-4590 Revision 2, SRP Section: 06.03 – Emergency Core Cooling System – Application Section: 6.3" dated June 8, 2010.

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. 597-4590 Revision 2."

Enclosed is the response to Question 06.03-84 through 86 that is contained within Reference 1.

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.

Sincerely,

Y. Ogata

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

Enclosure:

1. Response to Request for Additional Information No. 597-4590 Revision 2

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

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Docket No. 52-021
MHI Ref: UAP-HF-10194

Enclosure 1

UAP-HF-10194
Docket No. 52-021

Responses to Request for Additional Information No. 597-4590
Revision 2

July 2010

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/08/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 597-4590 REVISION 2**
SRP SECTION:	**06.03- EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**6/8/2010**

QUESTION NO.: 06.03-84

On March 8, 2010 at the MNES Arlington location, the NRC staff performed an audit of the NPSH calculations for the USAPWR. One of the areas of concern expressed during the audit was the determination of the end location for the NPSHa calculation.

Net positive suction head is the term that is usually used to describe the absolute pressure of a fluid at the inlet to a pump minus the vapor pressure of the liquid. The resultant value is known as the Net Positive Suction Head available (NPSHa).

Different pumps will have different NPSH requirements (NPSHr) dependent on the impeller design, impeller diameter, inlet type, flow rate, pump speed and other factors. A pump performance curve will usually include a NPSH requirement graph expressed in meters or feet head so that the NPSHr for the operating condition can be established. The fluid pressure at a pump inlet will be determined by the pressure on the fluid surface, the frictional losses in the suction piping and any pressure loses within the suction piping system associated with elbows, valves, orifices and any other obstructions to flow.

The CSS and SI pumps are estimated to be 6 feet tall and the midpoint of the pump is 3 feet below the inlet of the pump. The inlet and outlet of the pumps are on top of the pump. When the staff reviewed the diagram of the pump, it appeared that the flow of water goes through the pump suction inlet at the top of the pump and travels to the centerline before it enters the impeller. MHI assumes that the NPSH requirement should be applied at the center of the pump. The distance from the pump inlet to the centerline is 3 feet and applying MHI's assumption that the NPSHr is measured at the centerline adds 3 feet to the NPSHa calculated value. Based on staff experience, many NPSHa calculations are performed at the pump suction, which, for the case of the USAPWR CSS and SI pumps, is 3 feet above the centerline of the pump. If the NPSHr is measured at the pump inlet, MHI's NPSHa calculation could be in error.

The staff request that MHI's provide information from the vender of the pump that states specifically where the NPSHr is measured, i.e., at the pump suction or at the pump centerline.

ANSWER:

It is defined in ANSI/HI 1.2-2008 that NPSHa is the total suction head of liquid absolute, determined at the first-stage impeller datum minus the absolute vapor pressure of the liquid at a specific rate of flow. It is also defined that the datum is the horizontal plane through the center of the impeller described by the external points of the entrance edges of the impeller blade. Although ANSI/HI does not define the position to determine NPSHr, it is general knowledge among pump manufacturers to determine NPSHr at the centerline in order to compare it with NPSHa. Some vendor information explicitly states that NPSHr is measured at the centerline.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/08/2010

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DATE OF RAI ISSUE:	**6/8/2010**

QUESTION NO.: 06.03-85

The US-APWR design has four 50% safety injection (SI) pumps that will be required to mitigate a very large range of small and large break LOCAs. The FSAR states that the design flow of each pump is 1540 gpm and the minimum flow is 265 gpm through the pump minimum-flow loop. Therefore, the pumps will be required to operate at flows significantly less than their best efficiency flow condition. When the pumps automatically actuate following a LOCA occurrence, they will run at these lesser flow conditions for a significant period of time before system pressure drops sufficiently to allow flow closer to best efficiency operation. Even with only one pump running, the smallest break LOCAs would result in flows significantly less than best efficiency flow. The pumps are presumed to be "high suction energy" pumps, as defined by Hydraulic Institute standards ANSI/HI 9.6.1-1998 and ANSI/HI 9.6.3-1997, and would encounter recirculation cavitation at flows significantly less than the best efficiency flow. Recirculation cavitation is known to cause significant vibration and can damage pump impellers, wear rings, seals, shafts, and bearings within a short time period. The staff understands that the specific pump models have not been selected at this time. However, the staff requests that MHI provide (1) the range of possible values of suction energy (as defined by ANSI/HI 9.6.1-1998 and ANSI/HI 9.6.3-1997) for the SI pumps, (2) the required pump operating flows relative to the best efficiency flow conditions, and (3) the potential impact of recirculation cavitation on the pump internals that is predicted to occur for the range of small- and large-break LOCAs especially at low-flow conditions. Provide a description of the pump functional qualification and testing that will demonstrate the design-basis capability of the pumps for their required mission times under recirculation cavitation conditions that might occur for the range of small- and large-break LOCAs.

Similarly, the US-APWR design has four 50% residual heat removal/containment spray (RHR/CS) pumps. Each pump has a design flow of 3000 gpm and a minimum flow of 355 gpm through the pump minimum-flow loop. These pumps are required to operate at the minimum-flow condition until normally closed valves are opened to initiate CS flow following a LOCA. Similar to the SI pumps above, provide (1) the range of possible values of suction energy for the RHR/CS pumps, (2) the required pump operating flows relative to the best efficiency flow conditions, and (3) the impact of the resulting recirculation cavitation that is predicted to occur for the range of small- and large-break LOCAs especially at low-flow conditions. Provide a description of the pump functional qualification and testing that will demonstrate the design-basis capability of the pumps for their required mission times under recirculation cavitation conditions that might occur for the range of small- and large-break LOCAs.

ANSWER:

Regarding SI pump;

(1) For SI pumps proposed by vendors;

Suction Nozzle Size	: 8inch
Pump Speed	: 3600rpm
Suction Specific Speed	: above 12501

The predicted suction energy is about 5~6 x 10^8. However, all SI pumps proposed are multi-stage pumps and excluded from Figure 9.6.1.3 in ANSI/HI 9.6.1-1998.

(2) The required Safety Injection Pump operating flow rates depend on the conditions of accidents. In a small LOCA condition, the operating flow rate is smaller, but in a large LOCA condition, it is larger. Therefore, the pump operating flow rates have a range from 265 gpm, which is minimum flow rate, to 1540 gpm, which is the maximum flow rate.

(3) MHI will request time-proven pumps to vendors, which withstand significantly low-flow conditions that may encounter recirculation cavitation. MHI will request evaluations for integrity to pumps that do not have enough past records.

Regarding CS/RHR pump;

(1) For CS/RHR pumps proposed by vendors;

Suction Nozzle Size	: 12inch
Pump Speed	: 1800rpm
Suction Specific Speed	: 8501 to 12500

All RHR/CS pumps are high suction energy pumps in accordance with Figure 9.6.1.3 in ANSI/HI 9.6.1-1998. The predicted suction energy is about 2~3 x 10^8.

(2) The required Containment Spray / Residual Heat Removal (CS/RHR) Pump operating flow rates depend on operating pump number. CS/RHR pumps deliver borated water from Refueling Water Storage Pit (RWSP) to spray ring header. CS/RHR pumps and associated piping are independent but the spray ring header is common. So, the number of operating pumps is larger, the flow rate per one pump is smaller. Therefore, the pump operating flow rates have a range from 2800 gpm, which is in all (four) pumps operating condition, to 3400 gpm, which is in two pumps operating conditions.

(3) At the minimum flow condition which differs the most from the best efficiency condition, NPSHa increases due to the decrease of pressure loss. NPSH margin (NPSHa / NPSHr) is more than 4 or 5 and the recirculation cavitation is not predicted to occur.

Note: These information are based on a planned vendor information.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/05/2010

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

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SRP SECTION:	**06.03- EMERGENCY CORE COOLING SYSTEM**
APPLICATION SECTION:	**6.3**
DATE OF RAI ISSUE:	**6/8/2010**

QUESTION NO.: 06.03-86

Testing and operational experience for centrifugal pumps indicates that the greatest amount of cavitation-induced erosion of pump internal parts may occur with available net positive suction head (NPSH) significantly greater than that typically required for a 3% total head drop (approximately 1.1 to 1.6 times the NPSH values for a 3% total head drop). The staff understands that the specific SI and RHR/CS pump models have not been selected at this time. However, the staff requests that MHI provide (1) the expected range of available NPSH values and associated operating times relative to the NPSH required for a 3% total head drop and (2) the time periods where the pumps will be expected to operate with high-cavitation erosion. Provide a description of the pump functional qualification and testing that will demonstrate that the resulting cavitation induced erosion wear of the various pump parts occurring for the range of small- and large-break LOCAs will not result in unacceptable degradation of the SI and RHR/CS pump internal materials, structural integrity, or performance over the required pump mission times.

ANSWER:

(1) NPSH available for SI pump and CS/RHR pump were calculated based on the most conservative conditions such as minimum water level of RWSP. NPSH available/required for CS/RHR pump is 17.9 ft / 16.4 ft (Refer to DCD Subsection 5.4.7), and that for SI pump is 21.9 ft / 15.7 ft (Refer to DCD Section 6.3). These NPSH available are minimum, so realistic NPSH available at the operating times are greater than these values.

(2) MHI usually considers carefully the effects of cavitation for pump designs used in actual plants. MHI requests past records all over the operation ranges to pump vendors when deciding pumps to be used. In case of pumps not having enough past records, the pump vendors are to be required to provide an evaluation and a verification of the reliability at the flow rate and operation time shown in (1) by experimental and/or analytical methods.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.