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April 18, 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-11107

Subject: MHI's Response to US-APWR DCD RAI No. 715-5262 Revision 0 (SRP 06.05.02)

References: 1) Request for Additional Information No.715-5262 Revision 2, SRP Section: 06.05.02, Application Section: 6.5.2, dated 3/14/2011

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "MHI's Response to US-APWR DCD RAI No. 715-5262 Revision 0".

Enclosed is the response to one RAI 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 in this package (Enclosure 3). In the non-proprietary version, the proprietary information, bracketed in the proprietary version, is replaced by the designation "[ ]".

This letter includes a copy of the proprietary version of the RAI response (Enclosure 2), a copy of the non-proprietary version of the RAI response (Enclosure 3), and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all material designated as "Proprietary" in Enclosure 2 be withheld from 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 this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

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

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Enclosures:

1. Affidavit of Yoshiki Ogata
2. MHI's Response to US-APWR DCD RAI No. 715-5262 Revision 0 (proprietary)
3. MHI's Response to US-APWR DCD RAI No. 715-5262 Revision 0 (non-proprietary)

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

<u>Contact Information</u>

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ENCLOSURE 1

Docket No. 52-021

MHI Ref: UAP-HF-11107

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. 715-5262 Revision 0" dated April 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 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 of the safety analysis, developed by MHI (the "MHI Information").

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 MHI.

7. 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 of the subject system. 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 cost associated with unique design parameters.

B. Loss of competitive advantage of the US-APWR created by benefits of approach to justification for post accident pH control system design.

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 18th day of April, 2011.

Y. Ogata

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

ENCLOSURE 3

UAP-HF- 11107
Docket No. 52-021

MHI's Response to US-APWR DCD RAI No. 715-5262 Revision 0

April 2011

(Non-Proprietary)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

4/18/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 715-5262 REVISION 2

SRP SECTION: 06.05.02 – CONTAINMENT SPRAY AS A FISSION PRODUCT CLEANUP SYSTEM

APPLICATION SECTION: 6.5.2

DATE OF RAI ISSUE: 3/14/2011

QUESTION NO.: 06.05.02-9

The February 25, 2010 response to RAI question 06.05.02-8, referred to three license amendments for currently operating plants as precedents with respect to the design basis LOCA modeling of iodine behavior in the containment and potential for re-evolution from the pool for the time period that the pH of the sump fluid is less than 7. Provide a discussion of the iodine behavior and conditions in the US-APWR containment that justifies that the additional dose from potential re-evolution of iodine from the sump during the first 15 hours of the LOCA is not expected to be substantial and supports application of the cited precedents to the US-APWR design.
ADAMS accession numbers for cited Grand Gulf submittals: Grand Gulf: ML003679610 (original submittal package), ML003679582 (iodine re-evolution calculation), ML010300358 (response to RAI)

ANSWER:

This RAI response shows the impact to dose due to iodine re-evolution during the 15 hour duration after accident condition. The approach showing the impact consists of realistic pH analysis, realistic iodine re-evolution and realistic dose analysis.

Iodine re-evolution from a pool may occur when the pH is less than 7. Additionally, it is known that both lower pH and higher pool temperatures will cause higher release fractions of iodine. Depending on the inputs and analysis method, the effect of iodine re-evolution on dose can be shown to be greater than 1 rem. However, by selecting of a more realistic inputs and analysis method, the dose results due to iodine re-evolution are less significant.

1. Realistic pH analysis

The base analysis uses the alternative source term and parameters from the reference documents. In this analysis the following parameters have been modified.

- Boron Concentration: The recirculation water boron concentration is a combination of the RWSP of initial concentration of 4200 ppm plus the water from the reactor coolant of initial concentration of 1800 ppm and accumulators of initial concentration of 4200 ppm. Hence a value closer to the selected value of [ ] ppm is more reasonable.

- Cable in the containment: The design value for cable surface area is used rather than the overly conservative twice design value.

- NaTB addition timing: Using a realistic spray flow into the NaTB basket container, the time when the NaTB basket container will overflow is reduced. In addition, [ ] Figure 1 shows the fraction of NaTB available in the pool versus time for the 2 cases.

Fig.1 NaTB addition versus time for the US-APWR

- RWSP pool temperature: The RWSP pool temperature has a peak value of [ ] deg.C. As shown in Figure 2, the use of [ ] deg.C is excessive, and the use of [ ] deg.C for the modified case still allows a conservative margin.

Proprietary

Fig.2 RWSP pool temperature versus time for the US-APWR

The result of these more realistic inputs on pH analysis (MHI's Response to US-APWR DCD RAI No.517-4088 Rev.0, ADAMS Accession No. ML100600359) is shown in Fig.3. As expected, the variation in pH retains the same form and the only significant change is due to the earlier introduction of NaTB shifting the "modified" curve to the left.

Fig.3 Realistic recirculation water pH of US-APWR

Proprietary

1.1 <u>Input parameters used in the analysis</u>

Table 1:
US-APWR Major Input Parameters Used
in the RWSP water pH Analysis

Parameters	Value	
	Base Case	**Realistic iodine re-evolution**
Containment volume (ft^3)	2,800,000	
Recirculation water volume (m^3)	3,330	
Boron concentration of RWSP (ppm as B)	4,200	
Pool temperature (deg.C)	150	
Time of NaTB addition RWSP after LOCA (h)	3.5	
NaTB concentration in RWSP (ppm)	0.0158	
Iodine inventory (g-atoms)	336.96	
Cesium inventory (g-atoms)	3895.6	
Gamma rays absorption dose in liquid phase for 30 days (kGy)	571	
Beta rays absorption dose in liquid phase for 30 days (kGy)	172	
Gamma rays absorption dose for containment gas phase for 30 days (kGy)	1,076	
Beta rays absorption dose for containment gas phase for 30 days (kGy)	5,583	
Nitric acid production rate in water (molecules/100eV)	7.0E-3	
Hydrochloric acid production rate in Hypalon (molecules/100eV)	2.115	
Linear absorption coefficient for gamma ray in air (1/cm)	3.74E-5	
Linear absorption coefficient for beta ray in air (1/cm)	1.98E-2	
Linear absorption coefficient for gamma ray in Hypalon (1/cm)	9.9E-2	
Total normalized length of cables in containment (cm)	5.63E+6	

2. Iodine re-evolution fraction evaluation

Following the formulation in the Grand Gulf report (GGNS-98-0039 Rev 3 ADAMS Accession No. ML010300358) the equations in section 5 of that report were modified to account for the quantity of iodine removed from the pool due to re-volatilization of the iodine. Note, that this model only uses gm-atoms as opposed to the report that uses both gm-atoms and gm-moles.

$[I]_D$ Iodine deposited in the pool by sprays (gm-atoms)
$[I]_T$ Total iodine in the pool (gm-atoms)
I_{2aq} Aqueous iodine concentration in the pool (gm-atoms/l)
I_{2g} Gaseous iodine concentration in the pool and containment (gm-atoms/l)
V_c Volume of the containment (l)
V_P Volume of the pool (l)

Using the temporal average,

$$[I]_{T-avg} = \frac{[I]_T^{K+1} + [I]_T^K}{2}$$

$$[I]_{T-avg} = [I]_{D-avg} - I_{2g-avg} * V_C \qquad (1)$$

$$I_{2aq-avg} = \frac{[I]_{T-avg}}{V_P} + \frac{d + e * 10^{-pH}}{4 * 10^{-2pH}} - \frac{1}{4 * 10^{-pH}} \left[\frac{\left(d + e * 10^{-pH}\right)^2}{10^{-2pH}} + 8 * \frac{[I]_{T-avg}}{V_P} * \left(d + e * 10^{-pH}\right) \right]^{1/2}$$

This I_2_aqueous equation has been adjusted to use mass units as opposed to the iodine concentration units in section 5 of the report. It can then be recast more simply as

$$I_{2aq-avg} = \frac{[I]_{T-avg}}{V_P} + \frac{A}{4 * B^2} - \frac{1}{4 * B} \left[\left(\frac{A}{B}\right)^2 + 8 * \frac{[I]_{T-avg}}{V_P} * A \right]^{1/2} \qquad (2)$$

where

$A = d + e * 10^{-pH}$

$B = 10^{-pH}$

d and e are from the original report and represent the chemical equilibrium coefficients.

$$I_{2g-avg} = \frac{I_{2aq-avg}}{C} \qquad (3)$$

$$C = 10^{6.29 - 0.0149 * T(K)}$$

The three equations can be combined and solved iteratively using a spreadsheet.

Based on section 1 and the method of iodine re-evolution delineated above, the iodine re-evolution fraction for US-APWR was re-evaluated. In applying the model it was also assumed that iodine in the recirculation water was only the CsI particulates removed from containment atmosphere due to containment spray minus whatever was re-volatilized. The base case assumed that all the iodine that was released from the fuel instantly entered the pool while the modified case used a nominal spray removal coefficient. This delays the time until all the iodine enters into the pool. Approximately 86% of the released CsI has entered the pool when the NaTB is added a[ ] hours and by 4.5 hours 99% of CsI released from the fuel to the containment has entered the pool.

Re-evolution iodine fraction from the RWSP pool water is shown in Fig. 4 for the base case, i.e. no modifications from the design documentation. Also shown is the effect of using more realistic input values noted in Table 1 and discussed earlier. This modified case also used the design value for constant "d" based on NUREG/CR-5950 and the pH variation from those modifications. Note that the resulting re-volatilization fraction has dropped by almost a factor of [ ] ([ ] versus [ ]). The drop is due to the use of realistic input values rather than the overly conservative values used in the base case.

[ ]

Figure 4: Re-evolution fraction of recirculation water iodine for US-APWR

3. Realistic dose analysis input

A realistic dose analysis was performed using the results from the re-volatilization analysis. To account for the iodine re-volatilization dose, a separate case was run that only released iodine to the containment. The RADTRAD model for the cases was essentially that model described in the DCD. Except for parameters from RG 1.183 and the related SRP, only the following parameters were changed.

- Leak fraction to secondary containment (i.e., containment penetration area): from 50% to [ ]. The inner surface of containment includes a welded steel plate liner anchored to the concrete. All penetrations of the liner occur at the containment penetration area level, thus all leakage is expected to enter the annulus. For conservatism, [ ] of the leakage is released directly through the containment to the environment. Thus [ ] of containment leak goes to the annulus emergency exhaust system. It is exhausted from the annulus emergency exhaust system through the stack to the environment at very high flow, thus creating a conservative delay on the order of seconds.

- Containment leak rate during the first 24 hours (1 day) was changed from 0.15% to a time-dependent leak rate based on containment internal pressure analysis and is shown in Figure 5. The containment leak rate is based on containment pressure given in DCD Ch.6 (DCD Section 6.2.1 and Figure 6.2.1-1). Thus the containment leak during the accident is derived using the following equation.

[ ]

[ ]

Figure 5: Containment leak rate versus time

ESF leak rate: from twice of 4000cc/h to twice of [ ]. According to RG 1.183, twice the expected leak rate should be used in radiological consequences. The expected leak rate is set conservatively and based on the following assumptions. The safety injection system and containment spray system circulating outside containment leakage occurs under recirculation operation. The leak rate under recirculation operation is derived by integration of estimated leak rate from each component in these systems. Integrated value is [ ], however 4000cc/h was used in the Chapter 15 radiological consequences calculations.

Table 2 lists the input modifications and Table 3 shows the release fractions for the re-volatilized iodine, i.e. using the results from Figure 4 to determine this additional dose. Note that the fraction in Figure 4 is the fraction of iodine in the pool whereas the release fraction is the fraction of all iodine in the core, hence as only 40% of the iodine is released the two fractions should be different by a factor of 0.40.

Table 2:
US-APWR Major Input Parameters Used
in the LOCA Consequence Analysis

Parameters	Value		
	DCD Ch.15 Table 15.6.5-4	Realistic iodine re-evolution	
		Without Re-evolution	With Re-evolution
Core thermal power level (MWt)	4540 (2% above the design core thermal power)		
Reactor coolant radionuclide inventory			
Noble gas concentration	300 μCi/g DE Xe-133		
Iodine concentration	1.0 μCi/g DE I-131		
Particulate concentration	Based on 1% fuel defect (See DCD Table 11.1-2.)		
Reactor coolant mass (lb)	646,000		
Radionuclide release from damaged core			
Core activity at start of accident	See DCD Table 15.0 -14.		
Release fractions to containment	See Table 15.0-15.		
Release timing and durations	See Table 15.0-16.		
Iodine species distribution			
• Cesium iodide (%)	95		
• Elemental (%)	4.85		
• Organic (%)	0.15		
Containment purge release data			
Containment purge flow rate (cfm)	20,700		
Duration of purge from accident initiation until isolation valves fully close (s)	15		
Release characteristics	100% of reactor coolant inventory is released to the containment at the initiation of the LOCA		

Table 2 (continued):
US-APWR Major Input Parameters Used
in the LOCA Consequence Analysis

Parameters	Value		
	DCD Ch.15 Table 15.6.5-4	Realistic iodine re-evolution	
		Without Re-evolution	With Re-evolution
Containment leakage release data			
Containment volume (ft^3)	2,800,000		
Containment leak rate (%/d), 0-24 hr (Figure 5)	0-24h:0.15		
Containment leak rate (%/d), > 24 hr	0.075		
Leakage fraction to containment penetration areas (%)	50		
Leakage fraction to environment (%)	50		
Filter efficiency for particulates in annulus emergency exhaust system (%)	99		
Penetration areas negative pressure arrival time (min)	4		
Containment spray system initiation time (min)	5		
Containment spray flow rate (lb/h)	2,650,000		
Sprayed Containment Volume (ft^3)	1,680,000		
Mixing rate between the sprayed and unsprayed regions of containment (cfm)	37,300		
Elemental iodine deposition removal coefficient in sprayed and unsprayed regions (h^{-1})	0.376		
Powers model percentile for particulates deposition removal coefficient in unsprayed region only (%)	See Section 15A.1.2.10		
Particulates containment spray removal coefficient in sprayed region only (h^{-1})	7.32 (When DF for particulate reaches 50, this removal coefficient is reduced by a factor of 10.)		
DF limit for elemental iodine removal	200		
Elemental iodine removal end time	15.0 hr		
The time when the DF for particulate equals 50	3.23 hr		

Table 2 (continued):
US-APWR Major Input Parameters Used
in the LOCA Consequence Analysis

Parameters	Value		
	DCD Ch.15 Table 15.6.5-4	Realistic iodine re-evolution	
		Without Re-evolution	With Re-evolution
ESF system leakage release data			
Recirculation water mass (lb)	3,540,000		
Recirculation water leakage rate (lb/h)	17.6		
Start time of recirculation water leakage (min)	0		
Flash fraction (%)	10		
Iodine re-evolution release data			
Release fractions, timing and durations to containment	N/A		
Chemical form of Re-evolved iodine • Elemental (%) • Organic (%)	 N/A N/A		
Accident period (d)	30		
χ/Q	See DCD Tables 15.0-13 and 15A-23.		
Breathing rate	See DCD Table 15.0-13.		
Dose conversion factors	See DCD Table 15.0-14.		

Table 3: Release fraction, timing and duration of iodine re-evolution

Duration (h)				
Release fraction due to iodine re-evolution				

4. Dose result

Based on these margin changes and iodine re-evolution fraction analysis from section 2, a realistic dose with iodine re-evolution was determined. Note that in these analyses it was conservatively assumed that the re-evolved iodine would not go back into solution as indicated by the fall off in Figure 4 after[ ]hours, but only that the spray and pool would not release additional iodine. The atmospheric dispersion factors used are the same as the response to RAI No.562 (These atmospheric dispersion factors are shown in DCD rev.3 Table 15.0-13 and 15A-23.). Table 4 shows the dose results from the DCD base case and Table 5 shows the dose using both the margin changes and the re-evolution analysis.

Table 4 Radiological consequence for DCD Ch.15 Rev.3 (for Licensing analysis)

Source	EAB (rem)		LPZ (rem)		MCR (rem)			
	CV	stack	CV	stack	CV		stack	
					intake	inleak	intake	inleak
Reactor coolant	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
Damaged fuel	10.42	1.97	7.10	2.54	0.84	2.04	0.34	0.24
ESF leak	-	0.50	-	3.21	-	-	0.32	0.75
Total	13		13		4.6			
Criteria	25		25		5			

Table 4 delineates the dose calculation for the base licensing analysis. Note that the RADTRAD code is run several times so that the dose due to release from the containment (CV) to the environment is separate from the release that passes from the containment to the annulus and up through the HEPA filters and the stack to the environment. The table also indicates the effect from the release of radionuclides within the reactor coolant system, from release of radionuclides from the damaged fuel to the containment, and from release of radionuclides from the sump water due to ESF leakage.

Table 5 Radiological consequence for realistic condition with iodine re-evolution

Source	EAB (rem)		LPZ (rem)		MCR (rem)			
	CV	stack	CV	stack	CV		stack	
					intake	inleak	intake	inleak
Reactor coolant	[							]
Damaged fuel								
ESF leak								
Iodine re-evolution								
Total	[							]
Criteria	25		25		5			

Table 5 presents the same information as Table 4 for the modified case and also shows the dose due to the re-volatilized iodine. This dose assumes a release of elemental iodine from the fuel to the containment atmosphere based on the re-volatilized fraction of Figure 4, or about[ ]of the iodine in the fuel is available from[ ]hours onward.

As is shown, the more realistic leakage fraction to the annulus causes the damaged fuel dose to change significantly, for example the total EAB dose from fuel damage release changes from [.], as the iodine preferentially releases through the annulus emergency exhaust system with its particulate removal capability. Likewise the dose from the iodine re-evolution follows the same pattern of a larger release from the stack. The re-evolved iodine numbers are large due to the iodine being elemental in form and thus not filtered at the stack.

5. Conclusion

Tables 4 and 5 show that realistic dose analysis with iodine re-evolution would be bounded by dose analysis in DCD chapter 15 and has only a small impact. Therefore, it is not necessary yo include the iodine re-evolution iin the design basis.

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.