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March 19, 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-13067

Subject: MHI's Revised Response to US-APWR DCD RAI No. 707-5556 Revision 2 (SRP 19)

Reference: 1) "Request for Additional Information No. 707-5556 Revision 2, SRP Section: 19 – Probabilistic Risk Assessment and Severe Accident Evaluation, Application Section: 19.2," dated March 1, 2011.

2) Letter MHI Ref: UAP-HF-11084 from Y. Ogata to U.S. NRC, "MHI's Responses to US-APWR DCD RAI No. 707-5556 Revision 2 (SRP 19)", dated March 29, 2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Revised Response to Request for Additional Information No. 707-5556 Revision 2".

Enclosed is the revised response to one RAI contained within Reference 1. The original response to the RAI was submitted in Reference 2. This revision is submitted only to correct one minor typographical error as identified in the enclosed material. No other changes have been made to the response previously submitted in Reference 2.

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 below.

Sincerely,

Hiroki Nishio for

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

Enclosures:

1. Revised Response to Request for Additional Information No. 707-5556 Revision 2

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NRO

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-13067
Docket Number 52-021

Revised Response to Request for Additional Information
No. 707-5556 Revision 2

March 2013

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/19/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.: **NO. 707-5556 REVISION 2**

SRP SECTION: **19 – Probabilistic Risk Assessment and Severe Accident Evaluation**

APPLICATION SECTION: **19**

DATE OF RAI ISSUE: **3/1/2011**

QUESTION NO.: 19-499

The US-APWR PRA report includes an equipment survivability assessment that considers electrical and mechanical instruments and equipment required for severe accident management. The applicant classified the time frames for equipment survivability, selected the necessary equipment and instruments, analyzed severe accident environments, and finally assessed equipment survivability. The time frames for equipment survivability are classified in accordance with the characteristic stages of the severe accident progression. The time frames are as follows:

- T0: before the core has uncovered, the reactor core is intact and the environmental conditions in the containment are within the envelope of the DBA conditions.

- T1: from core uncovered to core damage, the reactor core is overheated and hydrogen generation starts due to cladding-water interaction. However, the environmental conditions in the containment are almost the same as in T0.

- T2: from core damage to reactor vessel failure, fission products are released from fuel to RCS and hydrogen is rapidly generated. The decay heat and oxidation heat promote the core degradation. Consequently core material relocates to the lower plenum if water is not properly injected into the reactor vessel. However, the environmental conditions in the containment are not harsh, i.e. the containment pressure at vessel failure is likely to be below the design pressure regardless of the containment cooling system condition. On the other hand, hydrogen release to the containment atmosphere is very likely in this time frame.

- T3: after reactor vessel failure, rapid hydrogen generation is expected to proceed immediately after the reactor vessel failure because un-oxidized metal in molten core reacts with water in the reactor cavity. After this transient oxidation event, hydrogen may be continuously generated due to MCCI, although further rapid hydrogen generation is unlikely. Hydrogen generation from MCCI occurs if reactor cavity is not flooded. The reactor cavity is flooded, and hence the possibility of MCCI is considered low. The environmental conditions in the containment for this time frame are maintained stable as long as containment heat removal is successful, regardless of hydrogen combustion by igniters. If containment heat removal is not achieved, harsh conditions for equipment are anticipated, mostly governed by pressurization and corresponding temperature rise. Influence by hydrogen combustion is considered insignificant.

The equipment survivability assessment only considered devices, systems or properties needed in time frames T2 or T3 that would be located either in the RCS or inside containment. The equipment and instruments necessary to function in each time frame are tabulated in Tables 15-23 and 15-24 of the US-APWR PRA. Thirteen countermeasures against severe accidents are also identified in the tables and described in the PRA.

This information is judged by the staff as important enough to be included in the DCD. Accordingly, please include in the DCD a description of the countermeasures and the time frames when they would be used. Also, please include the material in Tables 15-23 and 15-24, and discuss the relevant information regarding necessary devices, systems, and physical properties, and where each would be located.

ANSWER:

The original response to RAI 707-5556 Question 19-499, submitted by MHI letter UAP-HF-11084 dated March 29, 2011, contained a typographical error. The error was that MHI indicated that two new tables would be added to the DCD: Tables 19.2-10 and 19.2-11. However, instead of two tables, MHI actually added one table (Table 19.2-10) that has two sheets. Therefore, all references to Table 19.2-11 were incorrect and should be removed. This revised response is being submitted only to correct this typographical error in the markup. No other changes were made to the RAI response below. The DCD markup showing the changes from the original response as well as the correction of the typo is attached.

The Containment and Ventilation Branch 1 (AP1000/EPR Project) (SPCV) staff has issued several RAIs concerning the equipment survivability study in relation to the functionality of hydrogen igniters (including RAI 551-4356 and RAI 635-4954). In the answer for these RAIs, MHI has proposed revising the description of equipment survivability study in DCD Subsection 19.2.3.3.7, and this change proposal is incorporated in the DCD Revision 3. DCD Section 19.2.3.3.7 will be therefore further revised to be consistent with the answers for these RAIs as follows. Please note that the underlined portion is the modification to the RAI responses provided earlier and is not a modification to the DCD Revision 2.

19.2.3.3.7 Equipment Survivability

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<u>Analysis result</u>

During accident conditions, key systems and components are maintained with the most appropriate set of mitigation measures.

The key systems and components are selected by considering:

- The time frame of the severe accident progression, i.e. when the system or components are expected to be functional

- The location that equipment and instrumentation are arranged, i.e. at the inside or the outside of containment

- The significance of evaluations, i.e. if the system is backed up by an alternative measure, etc.

The time frames for equipment survivability are classified in accordance with the characteristic stages of the severe accident progression. Classification of the time frames enables limits to be placed on the equipment to be assessed for the survivability evaluation.

- T0: before core uncovered

  T0 is defined as the time frame that the reactor core is intact and the environmental conditions in the containment are within the envelope of the DBA conditions.

- T1: from core uncovered to core damage

  In this time frame, the reactor core is overheated and hydrogen generation starts due to cladding-water interaction. However, the environmental conditions in the containment are almost the same as in T0. The amount of hydrogen generation is limited and hence the impact of hydrogen burn to equipment functionality is not significant.

- T2: from core damage to reactor vessel failure

  In this time frame, fission products are released from the fuel to the RCS and hydrogen is rapidly generated. These physical phenomena are both caused by core damage. The decay heat and oxidation heat promote core degradation. Consequently, core material then relocates to the lower plenum if water is not injected into the reactor vessel. However, the environmental conditions in the containment are not harsh yet, i.e. the containment pressure at vessel failure is likely to be below the design pressure regardless of the containment cooling system condition. Hydrogen release to the containment atmosphere is very likely in this time frame. Therefore, the influence of containment temperature rise due to hydrogen burn must be evaluated.

- T3: after reactor vessel failure

  In this time frame, rapid hydrogen generation is expected immediately after reactor vessel failure because un-oxidized metal in the molten core reacts with water in the reactor cavity. After this transient oxidation event, hydrogen may be continuously generated due to molten core concrete interaction (MCCI) although at a much slower rate. Hydrogen generation from MCCI occurs if the reactor cavity is not flooded. When the reactor cavity is sufficiently flooded, the possibility of MCCI is considered low. The amount of hydrogen generated in this time frame is considered significant so that the impact of hydrogen burn must be evaluated.

The equipment survivability assessment is performed considering the following two criteria:

(1) The SSCs or parameters needed in the T2 and T3 time frames
(2) Equipped location is either in the RCS or inside the containment

Equipment and instruments are screened out from the survivability assessment in accordance with the following three criteria:

(1) The function of equipment and instruments are not directly related to the prevention of containment failure or fission product release.
(2) Alternative countermeasures are available
(3) Equipment is static and robust

The equipment and instruments necessary to function in each time frame are tabulated in Table 19.2-10.

The selected systems and components include containment penetrations, hydrogen igniters, depressurization valves used for severe accident mitigation, and a containment pressure sensor (wide range).

Systems / Components	Timeframe required to be functional
(1) Containment penetration	After core damage (T2 and T3)
(2) Hydrogen igniter	After core damage (T2 and T3)
(3) Depressurization valve	After core damage till reactor vessel failure (T2)
(4) Containment pressure sensor (wide range)	After core damage (T2 and T3)

An environmental condition associated with hydrogen burning via hydrogen ignition system operation has been evaluated using GOTHIC code. Detailed evaluation results are described in Section 15.7 of the PRA technical report "US-APWR Probabilistic Risk Assessment" (Reference 19.2-15). The environmental conditions which the above four systems/components must satisfy are the following.

(1) Containment penetration

Based on the following screening evaluation, the containment penetrations that are included in the equipment survivability study under the hydrogen burn condition can be limited to the electrical penetrations that provide power to the hydrogen igniters and the depressurization valves.

There are two major functions provided by containment penetrations; (1) provide the continuity of in-line, process flow paths between inside and outside containment across the containment boundary; and (2) maintain containment integrity at the location of the penetration. There are two basic types of containment penetrations; mechanical and electrical.

MHI has evaluated the environmental conditions in containment created by a local hydrogen burn. The results indicate that the pressure rise is not expected to be significant. The peak pressure has been determined to be below the containment design pressure of 68 psig. However, the local temperature rise is significant and in some locations the temperature rise could be as much as 1200°F. A high ambient temperature may not impact the containment integrity function at the penetration, but could impact the in-line process flow path function, especially for electrical penetrations.

Mechanical containment penetrations are robust by nature because they are made from heavy gauge metal, are firmly welded to the containment liner and can withstand excessive temperatures and pressures. Electrical containment penetrations are also robust in terms of containment integrity, but must be evaluated in terms of the severe accident (SA) survivability requirement for the in-line process flow path function, i.e., electrical current.

It is important to identify which electrical circuits that penetrate containment and that have functions that are fundamental to establish and maintain safe shutdown and containment structural integrity. Two circuits have been identified that serve components or systems with these functions; the circuits to the hydrogen igniters and the depressurization valves. As a result, these electrical penetrations which provide power to the hydrogen igniters and the depressurization valves are subject to the survivability study.

The highest temperature reached at the location of these electrical penetrations is evaluated to be less than 400°F, and the steady-state temperature is evaluated at about 200°F. The containment design temperature is 300°F. The highest pressure reached at the location of these electrical penetrations has been evaluated to be approximately 50 psig, which is lower than the containment design pressure of 68 psig. The amount of hydrogen burned in this analysis is conservatively assumed to be equivalent to that generated by oxidation of 100% of the active fuel length cladding. Hence, this analysis is conservative and brackets the various uncertainties involved in the hydrogen generation and burn calculation.

Based on the evaluation above, the environmental conditions that the electrical containment penetration must survive while maintaining containment integrity and supplying electricity to the circuits for the hydrogen igniters and depressurization valves are the containment design pressure of 68 psig and design temperature of 300°F for 24 hours, including consideration for an instantaneous temperature rise of 400°F due to a hydrogen burn.

(2) Hydrogen igniter

The hydrogen igniters can perform their function during and after exposure to the environmental conditions created by a hydrogen burn. Through the equipment survivability study, it has been evaluated that the peak temperature of containment atmosphere becomes as high as approximately 1200°F, and the temperature rise from 400°F and decline back to 400°F due to hydrogen burn takes approximately 10 minutes. The amount of hydrogen burned in this analysis is conservatively assumed to be equivalent to that generated by oxidation of 100% of the active fuel length cladding; hence this analysis bounds the uncertainties involved in the hydrogen generation and burn.

Therefore, in terms of the equipment survivability, it is required that the hydrogen ignition system keeps its function for at least 10 minutes at a containment atmosphere that is higher than 400°F with a peak temperature as high as 1200°F.

(3) Depressurization valve

Severe accident scenarios have been further evaluated in the equipment survivability study to determine when and under what conditions the functioning of the depressurization valve (DV) is considered necessary to establish and maintain safe shutdown and containment structural integrity. LOCA scenarios are eliminated because the initiating event depressurizes the RCS, and only transient scenarios resulting in high RCS pressure need be considered. Accordingly, it is concluded that the hydrogen burn condition does not directly affect the DV function, which is to depressurize the RCS after the core is significantly damaged. Potential hydrogen release paths from the RCS during transient events include a pathway via the pressurizer relief tank (PRT), the failure of the RCPB, or the opening of the DV. The hydrogen release from the PRT and the associated hydrogen burn has a negligible effect on the DV since the compartment where the PRT is located is apart from the location where the DV is located. Therefore, a hydrogen burn in the PRT compartment has very little influence on the functionality of the DV. Hydrogen release from a failure of the RCPB and the associated hydrogen burn may impact the functionality of the DV. However, the RCPB release simultaneously depressurizes the RCS, and hence the DV is not required for these accident scenarios. Hydrogen release via the opening of the DV and the associated hydrogen burn has the most significant impact on the functionality of the DV. Because a large amount of hydrogen is released via the opening of the DV, the atmosphere surrounding the DV becomes hydrogen-rich. This hydrogen is burned by the hydrogen igniters located near the DV. In such cases, the DV may encounter severe environmental conditions created by the hydrogen burn. However, after the DV is opened and hydrogen is released to the containment, the DV is not required to function. The DV is only operated under severe accident conditions in which the core has already been significantly damaged. Under such situations, the capability to close the DV is not required.

Considering the discussion above, the function of the DV to open is not adversely affected by hydrogen burns from the hydrogen released by the PRT or the RCPB. The function of the DV to open is not adversely affected by the hydrogen burn from the hydrogen released by the DV since the function to open has already been fulfilled and the DV is open.

(4) Containment pressure <u>sensor</u> (wide range)

The highest temperature where the containment pressure <u>sensor</u> (wide range) exists is evaluated slightly below 800°F. The temperature rise from 400°F and decline back to 400°F due to hydrogen burn takes approximately 2 minutes. The highest pressure evaluated from this study is approximately 50 psig, which is lower than the containment design pressure of 68 psig. The amount of hydrogen burned in this analysis is conservatively assumed to be equivalent to that generated by oxidation of 100% of the active fuel length cladding; hence this analysis bounds the uncertainties involved in the hydrogen generation and burn.

Considering the above findings, the environmental conditions under which the containment pressure <u>sensor</u> (wide range) must maintain its function include at least 2 minutes under 400°F atmosphere, and an instantaneous temperature rise due to hydrogen burn with peak temperatures as high as 800°F.

These specific environmental conditions obtained from the equipment survivability study are addressed for the type test or analyses of these systems and components. It will be confirmed through the type test or analyses that the systems and components in the US-APWR design are able to support achieving and maintaining safe shutdown, are able to maintain containment structural integrity with high confidence, and are able to keep their functions under the postulated severe accident environmental conditions created by hydrogen burning. These qualification requirements will be appropriately carried forward in procurement documents.

Existing experiments and associated literature (References 19.2-11, 19.2-12, and 19.2-13) are appropriately used to evaluate the US-APWR equipment survivability.

Table 19.2-10 Equipment and Instruments Used in Severe Accident Management (Sheet 1 of 2)

Function	Countermeasure	Required at (*1) T0	T1	T2	T3	Required Device, System or Parameter		Location	Judge (*2)	Note (*3)
Accident progression monitoring	Identification of core damage	X	X	-	-	parameter	Core exit temperature	in RCS	-	
							Containment radiation level	in-Cont	-	
	Monitoring of noble gas release path	X	X	X	X	parameter	Auxiliary building radiation level	ex-Cont	-	
							Main steam line radiation level	ex-Cont	-	
							Exhaust stack radiation level	ex-Cont	-	
							Environmental radiation level	ex-Cont	-	
Damaged core cooling	Water injection to primary system	X	X	X	-	system	Safety injection system	in-Cont	X	Screened out as it is normally open
							Alternate core injection	in-Cont	X	Screened out as insignificant for SA mitigation
							RV head vent	in-Cont	X	Screened out as insignificant for SA mitigation
		X	X	-	-	parameter	Core exit temperature	in RCS	-	
							RWSP water level	in-Cont	-	
							RV water level	in RCS	-	
	Water injection to reactor cavity	X	X	X	X	system	CSS	ex-Cont	-	
							Firewater injection to reactor cavity	ex-Cont	-	
							Firewater injection to spray header	ex-Cont	-	
		X	X	-	-	parameter	RWSP water level	in-Cont	-	
							Cavity water level	in-Cont	-	
							Cumulative firewater flow amount	ex-Cont	-	
Containment cooling	Containment depressurization	X	X	X	X	system	CSS	ex-Cont	-	
							Containment fan cooler unit	in-Cont	X	Screened out as it is static device
							CCW	ex-Cont	-	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							RWSP water level	in-Cont	X	Screened out as alternative device available
	Preparation for alternate containment cooling by containment fan cooler unit	X	X	X	X	system	CCW pressurization system	ex-Cont	-	
		X	X	X	X	parameter	CCW surge tank pressure	ex-Cont	-	
	Firewater injection to spray header	X	X	X	X	system	Firewater spray system	ex-Cont	-	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							Cumulative firewater flow amount	ex-Cont	-	

(*1) T0: Before core uncover, T1: After core uncover till core damage, T2: After core damage till RV failure, T3: After RV failure

(*2) Subject for study is judged considering the following criteria (1) the device, system or parameter is required at T2 and T3, and (2) location is either in RCS or in containment.

(*3) Judged as necessary to assess according to the above two criteria however screened out items are noted in this column with the reason screened out.

X: Included in the study, -: Excluded from the study

Table 19.2-10 Equipment and Instruments Used in Severe Accident Management (Sheet 2 of 2)

Function	Countermeasure	Required at (*1)				Required Device, System or Parameter		Location	Judge (*2)	Note (*3)
		T0	T1	T2	T3					
Prevention of Fission product release	Containment function	X	X	X	X	device	Containment body	in-Cont	X	Screened out due to its robustness
							Containment penetration	in-Cont	X	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							Containment temperature	in-Cont	X	Screened out due to less importance
	Containment isolation	X	X	X	X	device	Containment isolation valve	in and ex-Cont	-	
		X	X	X	X	parameter	Containment isolation valve position	in and ex-Cont	-	
	Reduction of radiation at containment atmosphere	X	X	X	X	system	CSS	ex-Cont	-	
							Firewater spray system	ex-Cont	-	
		X	X	X	X	parameter	Containment radiation level	in-Cont	X	Screened out as alternative device available
	Secondary system water supply	X	X	X	-	system	Emergency feedwater system	ex-Cont	-	
							Main feedwater system	ex-Cont	-	
		X	X	-	-	parameter	SG water level	in-Cont	-	
	Primary system depressurization	X	X	X	-	device	Depressurization valve	in-Cont	X	(Severe accident dedicated valve)
							Safety depressurization valve	in-Cont	X	Screened out as insignificant for SA mitigation
							Main steam relief valve	ex-Cont	-	
							Main steam turbine bypass valve	ex-Cont	-	
		X	X	-	-	parameter	RCS pressure	in RCS	-	
	Combustible gas control	X	X	X	X	device	Hydrogen igniter	in-Cont	X	
		X	X	X	X	parameter	Hydrogen concentration	ex-Cont	-	

(*1) T0: Before core uncover, T1: After core uncover till core damage, T2: After core damage till RV failure, T3: After RV failure

(*2) Subject for study is judged considering the following criteria (1) the device, system or parameter is required at T2 and T3, and (2) location is either in RCS or in containment.

(*3) Judged as necessary to assess according to the above two criteria however screened out items are noted in this column with the reason screened out.

X: Included in the study, -: Excluded from the study

Impact on DCD

The DCD will be revised as described above. (See attached Markups.)

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 Topical / Technical Report

There is no impact on topical and technical reports..

In order to satisfy the goals of analysis, the following analytical approaches are utilized:

- Determine the scope of analysis
  - Identify time frames necessary to consider in accordance with accident progression
  - Identify key systems and components to be examined during design certification stage
- Perform severe accident progression analysis
  - Employ MAAP to analyze representative accident scenarios to generate input conditions for GOTHIC analysis
  - Employ GOTHIC to analyze environmental conditions especially for hydrogen combustion
- Examine equipment survivability for design certification stage
  - Investigate availability of systems and components under calculated environmental conditions
  - Evaluate the effectiveness of systems and components

Analysis result

During accident conditions, key systems and components are maintained with the most appropriate set of mitigation measures.

The key systems and components are selected by considering:

- The time frame of the severe accident progression, i.e. when the system or components are expected to be functional,
- The location that equipment and instrumentation are arranged, i.e. at inside or outside of containment,
- The significance of evaluations, i.e. if the system is backed up by alternative measure, etc.

The time frames for equipment survivability are classified in accordance with the characteristic stages of the severe accident progression. Classification of the time frames enables limits to be placed on the equipment to be assessed for the survivability evaluation. DCD_19-499

- T0: before core uncovered

  T0 is defined as the time frame that the reactor core is intact and the environmental conditions in the containment are within the envelope of the DBA conditions.

- T1: from core uncovered to core damage DCD_19-499

  In this time frame, the reactor core is overheated and hydrogen generation starts due to cladding-water interaction. However, the environmental conditions in the containment are almost the same as in T0. The amount of hydrogen generation is limited and hence the impact of hydrogen burn to equipment functionality is not significant.

- T2: from core damage to reactor vessel failure

  In this time frame, fission products are released from the fuel to the RCS and hydrogen is rapidly generated. These physical phenomena are both caused by core damage. The decay heat and oxidation heat promote core degradation. Consequently, core material then relocates to the lower plenum if water is not injected into the reactor vessel. However, the environmental conditions in the containment are not harsh yet, i.e. the containment pressure at vessel failure is likely to be below the design pressure regardless of the containment cooling system condition. Hydrogen release to the containment atmosphere is very likely in this time frame. Therefore, the influence of containment temperature rise due to hydrogen burn must be evaluated.

- T3: after reactor vessel failure

  In this time frame, rapid hydrogen generation is expected immediately after reactor vessel failure because un-oxidized metal in the molten core reacts with water in the reactor cavity. After this transient oxidation event, hydrogen may be continuously generated due to molten core concrete interaction (MCCI) although at a much slower rate. Hydrogen generation from MCCI occurs if the reactor cavity is not flooded. When the reactor cavity is sufficiently flooded, the possibility of MCCI is considered low. The amount of hydrogen generated in this time frame is considered significant so that the impact of hydrogen burn must be evaluated.

The equipment survivability assessment is performed considering the following two criteria:

(1) The SSCs or parameters needed in the T2 and T3 time frames

(2) Equipped location is either in the RCS or inside the containment

Equipment and instruments are screened out from the survivability assessment in accordance with the following three criteria:

(1) The function of equipment and instruments are not directly related to the prevention of containment failure or fission product release.

(2) Alternative countermeasures are available

(3) Equipment is static and robust

The equipment and instruments necessary to function in each time frame are tabulated in Table~~s~~ 19.2-10~~ and 19.2-11~~. DCD_19-499 S01

The selected systems and components include containment penetrations, hydrogen igniters, depressurization valves used for severe accident mitigation, and containment pressure sensor (wide range). DCD_19-499

Systems / Components	Timeframe required to be functional
(1) Containment penetration	After core damage (T2 and T3)
(2) Hydrogen igniter	After core damage (T2 and T3)
(3) Depressurization valve	After core damage till reactor vessel failure (T2)
(4) Containment pressure sensor (wide range)	After core damage (T2 and T3)

DCD_19-499

An environmental condition under hydrogen burning by hydrogen ignition system operation has been evaluated using GOTHIC code. Detailed evaluation results are described in Section 15.7 of the PRA technical report "US-APWR Probabilistic Risk Assessment" (Reference 19.2-15). The environmental conditions above four systems/ components must satisfy are following.

(1) Containment penetration

Based on the following screening evaluation, the containment penetrations that are subject to the equipment survivability study under the hydrogen burn condition can be limited to the electrical penetrations that provide power to the hydrogen igniters and the depressurization valves.

There are two major functions provided by containment penetrations; (1) provide the continuity of in-line, process flow paths between inside and outside containment across the containment boundary; and (2) maintain containment integrity at the location of the penetration. There are two basic types of containment penetrations; one for mechanical processes and one for electrical processes.

MHI has evaluated the environmental conditions created by a local hydrogen burn. The results indicate that the pressure rise is not expected to be significant. In general, the peak pressure has been determined to top-out below the containment design pressure of 68 psig. On the other hand, the local temperature rise is significant and in some locations the temperature rise could be as much as 1~~0~~200°F. A high ambient temperature may not DCD_19-499 impact the containment integrity function at the penetration, but could impact the in-line process flow path function, especially for electrical penetrations.

Mechanical containment penetrations are robust by nature because they are made from heavy gauge metal, are firmly welded to the containment liner and can withstand excessive temperatures and pressures. Electrical containment penetrations are also robust in terms of containment integrity, but must be evaluated in terms of the SA survivability requirement for the in-line process flow path function, i.e., electrical current.

It is important to identify which electrical circuits that penetrate containment and have functions that are fundamental to establish and maintain safe shutdown and containment compartment has very little influence on the functionality of the DV. Hydrogen release from a failure of the RCPB and the associated hydrogen burn may impact the functionality of the DV. However, the RCPB release simultaneously depressurizes the RCS, and hence the DV is not required for these accident scenarios. Hydrogen release via the opening of the DV and the associated hydrogen burn has the most significant impact on the functionality of the DV. Because a large amount of hydrogen is released via the opening of the DV, the atmosphere surrounding the DV becomes hydrogen-rich. This hydrogen is burned by the hydrogen igniters located near the DV. In such cases, the DV may encounter severe environmental conditions created by the hydrogen burn. However, after the DV is opened and hydrogen is released to the containment, the DV is not required to function. The DV is only operated under severe accident conditions, in which the core has already been significantly damaged. Under such situations, the capability to close the DV is not required.

Considering the discussion above, the function of the DV to open is not adversely affected by hydrogen burns from the hydrogen released by the PRT or the RCPB. The function of the DV to open is not adversely affected by the hydrogen burn from the hydrogen released by the DV since the function to open has already been fulfilled and the DV is open.

(4) Containment pressure sensor (wide range) DCD_19-499

The highest temperature where the containment pressure sensor (wide range) exists is evaluated slightly below 800°F and the temperature rise from 400°F and reduced back to 400°F due to hydrogen burn takes approximately 2 minutes. The highest pressure evaluated from this study is approximately 50 psig, which is lower than the containment design pressure of 68 psig. The amount of hydrogen burnt in this analysis is conservatively assumed to be 100% active fuel length cladding reaction, hence this analysis widely covers various uncertainties involved in the hydrogen generation and burn.

Considering the above findings, the environmental condition required for the containment pressure sensor (wide range) is determined that it must maintain its functions for longer than 2minutes under 400°F atmosphere, with considering the instantaneous temperature rise due to hydrogen burn with its peak temperature to be as high as 800°F. DCD_19-499

The COL Applicant is responsible for providing a milestone for completing the equipment survivability assessment of the as-built equipment required to maintain safe shutdown and containment structural integrity to provide reasonable assurance that they will operate in the environmental conditions resulting from hydrogen burns associated with severe accidents for which they are intended and over the time span for which they are needed. This assessment is required only for equipment used for severe accident mitigation that has not been tested at severe accident conditions. The ability of the as-built equipment to perform during severe accident hydrogen burns will be assessed using the Environment Enveloping method or the Test Based Thermal Analysis method discussed in EPRI NP-4354 (Reference 19.2-11) DCD_06.02.05-45

~~These specific environmental conditions obtained from the equipment survivability study are addressed for the type test or analyses of these systems and components. It will be confirmed through the type test or analyses that the systems and components in the~~

DCD_19-499

Table 19.2-10 Equipment and Instruments Used in Severe Accident Management (Sheet 1 of 2)

Function	Countermeasure	Required at (*1) T0	T1	T2	T3	Required Device, System or Parameter		Location	Judge (*2)	Note (*3)
Accident progression monitoring	Identification of core damage	X	X	-	-	parameter	Core exit temperature	in RCS	-	
							Containment radiation level	in-Cont	-	
	Monitoring of noble gas release path	X	X	X	X	parameter	Auxiliary building radiation level	ex-Cont	-	
							Main steam line radiation level	ex-Cont	-	
							Exhaust stack radiation level	ex-Cont	-	
							Environmental radiation level	ex-Cont	-	
Damaged core cooling	Water injection to primary system	X	X	X	-	system	Safety injection system	in-Cont	X	Screened out as it is normally open
							Alternate core injection	in-Cont	X	Screened out as insignificant for SA mitigation
							RV head vent	in-Cont	X	Screened out as insignificant for SA mitigation
		X	X	-	-	parameter	Core exit temperature	in RCS	-	
							RWSP water level	in-Cont	-	
							RV water level	in RCS	-	
	Water injection to reactor cavity	X	X	X	X	system	CSS	ex-Cont	-	
							Firewater injection to reactor cavity	ex-Cont	-	
							Firewater injection to spray header	ex-Cont	-	
		X	X	-	-	parameter	RWSP water level	in-Cont	-	
							Cavity water level	in-Cont	-	
							Cumulative firewater flow amount	ex-Cont	-	
Containment cooling	Containment depressurization	X	X	X	X	system	CSS	ex-Cont	-	
							Containment fan cooler unit	in-Cont	X	Screened out as it is static device
							CCW	ex-Cont	-	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							RWSP water level	in-Cont	X	Screened out as alternative device available
	Preparation for alternate containment cooling by containment fan cooler unit	X	X	X	X	system	CCW pressurization system	ex-Cont	-	
		X	X	X	X	parameter	CCW surge tank pressure	ex-Cont	-	
	Firewater injection to spray header	X	X	X	X	system	Firewater spray system	ex-Cont	-	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							Cumulative firewater flow amount	ex-Cont	-	

(*1) T0: Before core uncover, T1: After core uncover till core damage, T2: After core damage till RV failure, T3: After RV failure

(*2) Subject for study is judged considering the following criteria (1) the device, system or parameter is required at T2 and T3, and (2) location is either in RCS or in containment.

(*3) Judged as necessary to assess according to the above two criteria however screened out items are noted in this column with the reason screened out.

X: Included in the study, -: Excluded from the study

DCD_19-499

Table 19.2-10 Equipment and Instruments Used in Severe Accident Management (Sheet 2 of 2)

Function	Countermeasure	Required at (*1)				Required Device, System or Parameter		Location	Judge (*2)	Note (*3)
		T0	T1	T2	T3					
Prevention of Fission product release	Containment function	X	X	X	X	device	Containment body	in-Cont	X	Screened out due to its robustness
							Containment penetration	in-Cont	X	
		X	X	X	X	parameter	Containment pressure	in-Cont	X	
							Containment temperature	in-Cont	X	Screened out due to less importance
	Containment isolation	X	X	X	X	device	Containment isolation valve	in and ex-Cont	-	
		X	X	X	X	parameter	Containment isolation valve position	in and ex-Cont	-	
	Reduction of radiation at containment atmosphere	X	X	X	X	system	CSS	ex-Cont	-	
							Firewater spray system	ex-Cont	-	
		X	X	X	X	parameter	Containment radiation level	in-Cont	X	Screened out as alternative device available
	Secondary system water supply	X	X	X	-	system	Emergency feedwater system	ex-Cont	-	
							Main feedwater system	ex-Cont	-	
		X	X	-	-	parameter	SG water level	in-Cont	-	
	Primary system depressurization	X	X	X	-	device	Depressurization valve	in-Cont	X	(Severe accident dedicated valve)
							Safety depressurization valve	in-Cont	X	Screened out as insignificant for SA mitigation
							Main steam relief valve	ex-Cont	-	
							Main steam turbine bypass valve	ex-Cont	-	
		X	X	-	-	parameter	RCS pressure	in RCS	-	
	Combustible gas control	X	X	X	X	device	Hydrogen igniter	in-Cont	X	
		X	X	X	X	parameter	Hydrogen concentration	ex-Cont	-	

(*1) T0: Before core uncover, T1: After core uncover till core damage, T2: After core damage till RV failure, T3: After RV failure

(*2) Subject for study is judged considering the following criteria (1) the device, system or parameter is required at T2 and T3, and (2) location is either in RCS or in containment.

(*3) Judged as necessary to assess according to the above two criteria however screened out items are noted in this column with the reason screened out.

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