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September 9, 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-11304

Subject: MHI's Responses to US-APWR DCD RAI No. 803-5891 Revision 3 (SRP 06.02.05)

Reference: 1) "Request for Additional Information No. 803-5891 Revision 3, SRP Section: 06.02.05 – Combustible Gas Control in Containment, Application Section: 6.2.5," dated August 11, 2011.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document as listed in Enclosures.

Enclosed are the responses to two RAIs 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.

D081
NRO

Enclosures:

1. Responses to Request for Additional Information No. 803-5891 Revision 3

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

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Enclosure 1

UAP-HF-11304
Docket Number 52-021

Responses to Request for Additional Information
No. 803-5891 Revision 3

September, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/9/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.: **NO. 803-5891 REVISION 3**

SRP SECTION: **06.02.05 – Combustible Gas Control in Containment**

APPLICATION SECTION: **6.2.5**

DATE OF RAI ISSUE: **8/11/2011**

QUESTION NO. : 06.02.05-44

Clarify if the US-APWR Hydrogen igniters are needed for compliance with 10 CFR 50.44(c)(1); Clarify how accident sequences were selected to demonstrate compliance with 10 CFR 50.44.

In RAI Number 751-5709 Question 06.02.05-43, the staff requested you clarify how the structures, systems and components used to fill the RSWP act to be reliable, redundant, single-failure proof, able to be tested and inspected and remain operable with a loss of onsite or offsite power.

In your response you state the following:
"10CFR50.44(c)(1) and (c)(2) require that a mixed atmosphere be provided to prevent local elevated hydrogen levels and control hydrogen levels by limiting the overall (uniformly distributed) hydrogen concentration. The US-APWR design features to achieve these requirements are the containment spray system and the hydrogen igniters, as discussed in DCD Subsection 6.2.5 Rev.3"

In this RAI response you also propose the following change to DCD Subsection 6.2.5 to clarify how Containment Mixing is accomplished:
"The containment spray system, in conjunction with convective heat transfer and hydrogen diffusivity, performs atmospheric mixing to ensure uniform distribution of hydrogen and contact with the installed hydrogen igniters. Figure 6.2.5-2 presents the typical air-hydrogen flow patterns within the C/V. The containment spray system is a design-basis safety-related system which is reliable, redundant, single-failure-proof, able to be tested and inspected, and remains operable with a loss of onsite or offsite power per RG 1.7. Rev. 3. The technical report "US-APWR Probabilistic Risk Assessment" Section 15.3.3 (Ref. 6.2-37) demonstrates that the atmospheric mixing provided by the containment spray system as well as the combustible gas control provided by the hydrogen igniters ensures that combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause loss of containment integrity."

Based on the review of the RAI response, the response to RAI Number 627-4926 Question 19-449, and the proposed DCD text, the staff understands that the regulatory requirement for a mixed containment is accomplished with the following systems and design features:

- Large containment/open spaces (passive)
- Containment Spray (active; safety related)
- Components used to fill the RWSP(active)

Therefore the staff requests the following information:

1) Please clarify DCD Subsection 6.2.5 to clearly discuss those systems that are credited to satisfy 10 CFR 50.44(c)(1). I.e., discuss all systems used to provide the capability for ensuring a mixed atmosphere during design-basis and significant beyond design-basis accidents.

2) The staff notes that the above draft language omits the role of components used to fill the RWSP to satisfy 10 CFR 50.44(c)(1). In your response to RAI Number 627-4926 Question 19-449, you state that, although unlikely, there is the potential for buildup of hydrogen concentrations in the RWSP to combustible or detonable levels in a severe accident scenario, and you have proposed a severe accident mitigation strategy where the RWSP is filled by means of manual operator actions. Based on this proposed strategy, the staff would consider those SSCs use to eliminate this high hydrogen concentration potential (the components used to fill the RWSP with firewater) as those subject to design criteria stated in RG 1.7 Section C3.

    a. Please clarify the functions of the firewater system in Tier 2 and Tier 1 of the DCD to include this severe accident insight, and clarify the design basis of the US-APWR containment mixing system to include the role of the firewater system. Alternatively, propose an alternate method of ensuring a fully mixed containment using those systems you currently credit for this function, with respect to the RWSP compartment.

    b. Please clarify the design basis functions of the Containment Spray system to include the role of ensuring a mixed atmosphere in the containment in the Containment Spray System Section of the DCD Tier 1 and Tier 2.

3) With regard to the hydrogen control function and objectives 10 CFR 50.44(c)(2). The staff notes that in the above DCD draft language, you include the hydrogen igniter function in the discussion of how the US-APWR achieves both mixing and control. As discussed above, the staff requests you clarify if your intent is that that design utilizes the igniter function to achieve the requirements for a mixed containment (10 CFR 50.44(c)(1)) as well as hydrogen control (10 CFR 50.44(c)(2)), or is the igniter function not needed to meet the requirements for a mixed containment.

    a. The staff has reviewed the PRA, MUAP -07030 (R2) and notes that in paragraph 15.3.3.2, where you discussed the selection of PRA scenarios used as a basis for satisfying 10 CFR 50.44(c)(1) and (c)(2), the condition of the containment spray is important. You note that when spray is operable, (which is likely since this is a safety-related system), the hydrogen percentage by volume increases since the steam inventory in containment is suppressed by spray. You state that the operation of containment spray needs to be considered for a conservative estimation. The staff notes that for the station blackout scenario discussed in your response to RAI Number 627-4926 Question 19-449, both the spray system and the Igniters are not available for first several hours (AP102SNG and AP102S-IG).

       The staff reviewed accident sequence AP105, which is a scenario where spray is available and igniters are not available due to LOOP, and they are not powered by DC or alternate AC sources. In chapter 14 of the PRA page 14-75, hydrogen concentration appears to exceed 10 CFR 50.44 (c)(2) criteria.

The staff reviewed accident sequence AP205, which is a scenario where spray is available. In chapter 14 of the PRA page 14-99, hydrogen concentration exceed 10 CFR 50.44 (c)(2) criteria.

The staff reviewed accident sequence AM008, which is a scenario where Sprays come on late, and igniters are not available due to LOOP. In chapter 14 of the PRA page 14-135, hydrogen concentration appears to exceed 10 CFR 50.44 (c)(2) criteria.

In regard to these Severe accident sequences, please clarify how the US-APWR Combustible Gas Control system (igniters) satisfy 10 CFR 50.44 (c)(2) criteria, and why one of these scenarios were not chosen as the most conservative analysis with respect to conditions to demonstrate compliance with 10 CFR 50.44

As you discussed in your response to RAI 270-1898, Question 6.2.5-24, careful operator action is required to manage containment hydrogen concentration when steam-inerted conditions are no longer present. And these severe accident procedures will be the responsibility of the COL applicant in COL item 19.3(6). You provide a general description of accident management and the importance of hydrogen in section 19.2.5. This description indicates that high hydrogen concentrations are reached when CSS fails and the containment vessel pressure is high. The description does not seem to address PRA sequence AP 105 or AP 205, which are sequences where CSS does not fail, steam inerted conditions are not reached for any significant length of time, and the hydrogen concentration reaches above 10% by volume for sustained periods of time.

Please describe severe accident management for these cases. In your discussion, please also address the merits of any severe accident strategies that are needed to restore power to the hydrogen igniters in containment to provide confidence that igniters will have power and be available for severe accident management and to minimize the potential for the inability to manage the accumulation of combustible or detonable quantities of hydrogen in the containment. Revise DCD chapter 19 paragraph 19.2.5 as needed.

ANSWER:

As stated in the response to RAI Number 751-5709, Question 06.02.05-43, the US-APWR complies with 10 CFR 50.44 by following the guidance in Regulatory Guide (RG) 1.7, Rev. 3, which states:

> *This regulatory guide describes methods that are acceptable to the NRC staff for implementing the revised Section 50.44 for reactors, subject to the provisions of Sections 50.44(b) or 50.44(c).*

Per these methods, the US-APWR provides a Combustible Gas Control System (RG 1.7, Section C1) consisting of hydrogen igniters and an Atmosphere Mixing System (RG 1.7, Section C3) consisting of a large containment with open spaces and a containment spray system. These SSCs meet the guidance of RG 1.7 (as shown in Table 1 and discussed below) and, therefore, are acceptable to meet 10 CFR 50.44.

MHI proposed, in the responses to several RAIs including 627-4926 and 751-5709, employing the firewater system to fill the RWSP when hydrogen build-up in the RWSP is anticipated during specific severe accident events involving the failure of all igniters, all containment spray trains,

and all safety injection trains. The most likely cause for failure of all these systems would be a "complete" station blackout, when no AC power is available. The US-APWR design for station blackout meets RG 1.155. The US-APWR includes additional Alternate AC (AAC) Gas Turbine Generators, in addition to the back-up Class 1E Emergency Gas Turbine Generators, to prevent a "complete" loss of AC power, as discussed in Item 2a below.

That is, the specific severe accident events for which MHI proposed utilizing the firewater system to fill the RWSP are not necessary to be considered in the NRC guidance. Overall US-APWR compliance with NRC guidance is outlined in Table 1 below. Additional details for specific RAI items are given below.

1) DCD, Rev. 3, Subsections 6.2.5 and 6.2.5.1 state:

> *"Figure 6.2.5-2 presents the typical air-hydrogen flow patterns within C/V. Convective heat transfer and hydrogen diffusivity, in conjunction with containment spray discharges, ensure uniform mixing of hydrogen and contact with the installed hydrogen igniters."*
>
> *"The containment hydrogen monitoring and control system is designed in accordance with 10 CFR 50.34(f)(2)(ix), "Additional TMI-related requirements;" 10 CFR 50.44, "Combustible Gas Control for Nuclear Power Reactors;" and GDC 41, "Containment Atmosphere Cleanup." The systems also address the recommendations of RG 1.7, "Control of Combustible Gas Concentrations in Containment;" and NUREGs 0737 and 0660, as presented in Section 1.9."*

These descriptions clarify that atmospheric mixing is a design-basis function of the containment spray system and that the containment spray system meets the requirements of RG 1.7, Rev. 3. The descriptions also state that the containment structure will be designed with large open spaces to facilitate atmospheric mixing in conjunction with the containment spray.

To further clarify, DCD Section 6.2.2.2 System Design (of the containment spray) will be revised to describe the function of atmosphere mixing in containment. DCD Section 6.2.5.3 will be revised to include a reference to PRA report Attachment 15A, which provides support information for hydrogen mixing analyses by employing the GOTHIC code. DCD markups are attached to this RAI response.

2a) It is not necessary to credit the firewater system for RWSP flooding in the US-APWR design to meet NRC guidance in RG 1.7 Section C3. Instead, the US-APWR design credits that the igniters are designed to meet the requirements of RG 1.155 (invoked by RG 1.7).

MHI proposed applying the firewater system to fill RWSP when hydrogen build-up in the RWSP is anticipated during specific severe accident events involving the failure of all igniters (as well as all containment spray and safety injection trains). The most likely cause for this failure would be a "complete" station blackout, when no AC power is available. Even in this case, the firewater system is likely to be available because a diesel-driven firewater pump is provided, which does not need AC power to operate. Although filling of the RWSP is not necessary with the Combustible Gas Control and Atmosphere Mixing System of RG 1.7, application of the firewater system could therefore be considered as a potential mitigation method to prevent RWSP hydrogen build-up.

The regulatory guidance does not require that failure of these components be considered or that back-up systems be provided which meet the same requirements. RG 1.7 does require that the igniters meet RG 1.155 for station blackout, which the US-APWR design satisfies as outlined in Table 1. The US-APWR includes four Class 1E Emergency Gas Turbine Generators to provide onsite AC power in the case of a Loss of Offsite Power. RG 1.155 requires design features to ensure AC power in the event that these Class 1E generators fail. The US-APWR provides two Alternate AC (AAC) Gas Turbine Generators (GTGs) to ensure onsite AC power for this scenario and satisfy the station blackout guidance in RG 1.155. The accident sequences outlined above,

which result in a "complete" station blackout with no AC power available, include failure of these AACs. The guidance does not require that this scenario be considered for compliance with 10 CFR 50.44.

Therefore, MHI would like to withdraw the proposal to apply the firewater system for prevention of RWSP hydrogen build-up during these specific severe accident scenarios, which are not required to be considered in the RG 1.7 guidance. DCD Subsections 19.2.3.3.2 and 19.2.5 will be amended to withdraw the application of the firewater system for RWSP flooding via reactor cavity injection. The DCD will be revised to reflect this discussion, as indicated in the attached mark-up.

The importance of the firewater system for severe accidents is injection into the reactor cavity to prevent concrete erosion and additional hydrogen generation due to molten core concrete interaction, and this function will remain in the DCD.

2b) DCD Tier 2, Subsection 6.2.2.2, System Design (of Containment Spray System) will be revised to include the role of ensuring a mixed atmosphere as discussed in Item 1 above and indicated in the attached mark-ups.

3) The hydrogen igniters are provided as the Combustible Gas Control system described in RG 1.7. The containment spray and containment design are provided as the Atmosphere Mixing System described in RG 1.7.

The analysis results reported in the PRA Technical Report (MUAP-07030) Chapter 14 do not include igniters in the model. PRA Section 14.2.1, second bullet, states:

> Hydrogen burn in containment is not considered in the accident progression analyses by MAAP. Instead, it is separately evaluated by GOTHIC code, which is described in Chapter 15 of this report. Igniter model is not included in the development MAAP analysis model.

The intention of the accident progression analysis for hydrogen concentration in PRA Chapter 14 is to determine the containment failure fraction due to hydrogen burn in case of failure of all igniters. These evaluations are not applicable to review for compliance with 10 CFR 50.44(c)(2) because igniters are not modeled in the analysis. Functionality of igniters and compliance to the 10 CFR 50.44(c)(2) requirement is evaluated by utilizing GOTHIC calculations, which are reported in PRA Chapter 15 and Attachment 15A. DCD Section 6.2.5.3 will be updated to include a reference to Attachment 15A, as indicated in the attached mark-up. In order to evaluate the potential of deflagration to detonation transition (DDT) in containment, Technical Report MUAP-10004 was submitted to the NRC.

The availability of the atmosphere mixing system and the combustible gas control system can be sufficiently ensured because the current US-APWR design fully satisfies the NRC requirements for these systems in RG 1.7 and 1.155 (as described above and in Table 1). Thus, a "complete" station blackout is eliminated from practical design considerations by meeting the NRC guidance. DCD Section 19.2.3.3.2 will be revised to address this conclusion, as indicated in the attached mark-up.

On the other hand, the accident management described in DCD Section 19.2.5 does not eliminate any potential severe accident situation regardless of practical possibility of the events, including "complete" station blackout. During the postulated "complete" station blackout, only the operators' action can control the containment condition to prevent hydrogen detonation. Application of firewater for RWSP flooding will be deleted in accordance with this RAI response.

Table 1 US-APWR Hydrogen Compliance Evaluation

Requirement	Existing condition	Compliance evaluation
50.44(c)(1) Mixed Atmosphere during design-basis and significant beyond design-basis accidents	Mixed atmosphere with containment spray and containment design.	Compliant Meets RG 1.7, Section C3
50.44(c)(2) Combustible Gas Control uniformly distributed less than 10% and maintain containment structural integrity	Hydrogen is appropriately controlled by igniters powered by AAC. Uniformly distributed atmosphere is maintained below 10%.	Compliant Meets RG 1.7, Section C1
R.G. 1.7 C.1 Combustible gas control system should be designed to provide reasonable assurance to be available in the severe accident environment and per RG 1.155.	Igniters are provided as the combustible gas control system. Availability of igniters is examined in the equipment survivability study described in the DCD 19.2.3.3.7. Igniters can be powered by AACs provided to meet RG 1.155.	Compliant The igniters will survive severe accident conditions due to hydrogen burn from a 100% cladding reaction. Loss of the four emergency generators in the Class 1E power system is mitigated by two AACs.
R.G. 1.7 C.3 Atmosphere mixing system prevents local accumulation of hydrogen. Active system should be reliable, single-failure-proof, able to be tested and inspected, and remain operable with a loss of onsite or offsite power.	Containment spray system is provided as the atmosphere mixing system. Large open containment spaces provide a good capability for containment atmosphere mixing.	Compliant Containment spray and igniters satisfy the requirement. (Firewater system is not credited as an atmosphere mixing system.)

Requirement	Existing condition	Compliance evaluation
SECY-93-087 J Containment performance Containment Performance 24hours under more likely severe accident challenges	Based on PRA results, the most likely severe accident is a complete loss of all ac power (four Class 1E generators and two AAC generators).	Compliant DCD Rev.3 PRA shows the NRC safety target is satisfied.
50.63.(c)(2) The alternate ac power source(s), will constitute acceptable capability to withstand station blackout	Power to shutdown buses can be restored from AAC sources within 60 minutes.	Compliant Power to shutdown buses can be restored from AAC sources within 60 minutes. Coping analysis for duration of 60 minutes is performed.
R.G. 1.155 C.3.2.5 AAC power sources are independent and diverse from the normal Class 1E ac power sources	AAC GTGs are independent and diverse from Class 1E GTG.	Compliant AAC GTGs are independent and diverse from Class 1E GTG.
R.G. 1.155 C.3.3.5 Criteria 1 The AAC power source should not normally be directly connected to the preferred or the black-out unit's on site emergency ac power system	The AAC GTGs are connected to the non-Class 1E 6.9 kV permanent buses, P1 and P2 only during LOOP or online test of AAC GTG conditions.	Compliant The AAC GTGs are not normally connected to the offsite or onsite emergency ac power supply systems.

Requirement	Existing condition	Compliance evaluation
R.G. 1.155 C.3.3.5 Criteria 2 A minimum potential for common cause failure with the preferred or the black-out unit's onsite emergency ac power sources. No single-point vulnerability should exist whereby a weather-related event or single active failure could disable any portion of the blacked-out unit's onsite emergency ac power sources or the preferred power sources and simultaneously fail the AAC power sources.	The AAC GTGs and their associated non-Class 1E selector circuits A and B are located in separate rooms. The AAC GTGs and the onsite Class 1E ac power system are electrically isolated by a disconnect switch (non-Class 1E) and a circuit breaker (Class 1E) in series. The auxiliaries and support systems for the AAC GTGs are separate and are not shared with the onsite Class 1E ac systems.	Compliant No single point vulnerability exists whereby a weather-related event or single active failure could disable any portion of the blacked-out unit's onsite Class 1E power sources or the offsite power sources and simultaneously fail the AAC GTGs.
R.G. 1.155 C.3.3.5 Criteria 3 The AAC power source should be available in a timely manner after the onset of station blackout and have provisions to be manually connected to one or all of the redundant safety buses as required. The time required for making this equipment available should not be more than 1 hour as demonstrated by test.	The AAC GTGs are automatically started by the undervoltage signal on the 6.9 kV permanent buses, P1 or P2, and are automatically connected to their respective permanent buses within 100 seconds. The AAC GTGs can be connected manually to the onsite Class 1E buses by closing the non-Class 1E disconnect switch in the selector circuit and the Class 1E incoming circuit breaker in the Class 1E 6.9 kV switchgear	Compliant Power supply to at least one of the onsite Class 1E ac train can be restored from the AAC sources within 60 minutes. The availability of power supply to one of the four Class 1E trains is adequate for coping with an SBO event.
R.G. 1.155 C.3.3.5 Criteria 4 The AAC power source should have sufficient capacity to operate the systems necessary for coping with a station blackout for the time required to bring and maintain the plant in safe shutdown.	Each AAC GTG has sufficient capacity to operate the systems necessary for coping with an SBO event for the time required to bring and maintain the plant in safe shutdown condition. Each AAC GTG has adequate fuel to operate the systems required for coping with an SBO for 8 hours.	Compliant Each AAC GTG has sufficient capacity to operate the systems necessary for coping with an SBO event for the time required to bring and maintain the plant in safe shutdown condition.

Requirement	Existing condition	Compliance evaluation
R.G. 1.155 C.3.3.5 Criteria 5 The AAC power system should be inspected, maintained, and tested periodically to demonstrate operability and reliability. The reliability of the AAC power system should meet or exceed 95 percent	The AAC power system will be inspected and tested periodically based on manufacturer's recommendations and RG 1.155 to demonstrate operability and reliability. The surveillance test interval does not exceed 3 months (Quarterly). During the quarterly test the AAC is started and brought to operating conditions. Additionally, during every refueling outage, the AAC generator is tested by performing a timed start and rated load capacity test. The reliability of the AAC power system will meet or exceed 95% as determined in accordance with NSAC-108 (Reference 8.4-2) or equivalent methodology	Compliant The AAC power system will be inspected and tested periodically based on manufacturer's recommendations and RG 1.155 to demonstrate operability and reliability. The reliability of the AAC power system of US-APWR will meet or exceed 95 percent

Impact on DCD

DCD Sections 6.2.2.2, 6.2.5.3, 19.2.3.3.2 and 19.2.5 will be revised as shown in the attached mark-up. (See Attachment-1)

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

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/9/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.: **NO. 803-5891 REVISION 3**

SRP SECTION: **06.02.05 – Combustible Gas Control in Containment**

APPLICATION SECTION: **6.2.5**

DATE OF RAI ISSUE: **8/11/2011**

QUESTION NO. : 06.02.05-45

Clarify the DCD to provide the results of type tests and analyses that assure that the equipment that is identified as critical equipment in the Severe Accident Survivability Assessment is capable of withstanding the environmental conditions of a severe accident.

In RAI 748-5593, question 06.02.05-42, the staff requested you clarify the DCD to indicate whether it was the responsibility of the plant designer (MHI) or an applicant that references the US-APWR design, to justify the applicability of prototypical survivability studies is representative of the procured equipment.
In part 1 of the RAI response, you clarified that it is the responsibility of MHI to provide such verification, and the type tests and analyses necessary to assure functionality of the severe accident mitigation components will be conducted in the "DCD design certification phase by MHI."

Therefore the staff understands that there will be forthcoming design information that will be documented in a future revision of the DCD that provides assurance that the prototypical studies (e.g. US-APWR Reference 19.2-11) are applicable to the equipment identified in the DCD as severe accident mitigation components. The current description of procurement information in DCD Tier 2 Section 19.2.3.3.7 describes future actions to be performed by the plant designer to define the procurement specification. The staff does not consider this description of future analyses sufficient to provide assurance that the procured equipment will survive a severe accident, in accordance with 10 CFR 50.44(c)(3).

If such studies are to be performed in the Design Certification stage, as indicated in your RAI response, the staff considers that the results of the analysis, along with a justification that it envelops the calculated plant equipment temperature is to be documented in the DCD and reviewed by the staff in the DC stage, prior to certification of the standard design.

The staff requests you provide details of the analysis and the schedule to provide this information. As detailed in Section 6, of US-APWR Reference 19.2.-11, prototypical test results can be applied to support demonstration of equipment survivability by means of "Environment Enveloping" or "Thermal Analysis".

If the "Environment Enveloping" approach is used by MHI, the staff requests you clarify Tier 2 of the DCD to indicate that:

1) This method was used to apply the prototypical test results to the USAPWR design.

2) The procured equipment is:

   a. of the same type (manufacturer and model) as the equipment used in the prototypical study, or

   b. that you state in Tier 2 of the DCD that that the equipment is functionally similar and at least as thermally rugged as the tested equipment types. If you state, this, please include supporting evidence that provides assurance that this is the case.

If the "Thermal Analysis" approach is used by MHI, the staff requests you clarify Tier 2 of the DCD to indicate:

1) This method was used to apply the prototypical test results to the USAPWR design.

2) That the manufacturer/model number of the equipment used in the thermal analysis is the same, as that used in the US-APWR design.

3) The results of the thermal analysis including, a comparison of analysis results vs. calculated plant equipment temperature, which demonstrates survivability.

ANSWER:

MHI would like to change the approach for verifying equipment survivability. In the previous RAI #748-5593, Question 06.02.05-42, MHI responded that type tests or analyses necessary to assure the functionality of the severe accident mitigation components will be performed in the Design Certification (DC) phase as a responsibility of MHI. However, MHI would like to withdraw this answer and instead assign responsibility to the COL applicant to give reasonable assurance that the as-built equipment for severe accident mitigation is capable of withstanding the environmental conditions.

The DC applicant determines the design conditions and functional requirements, but conformance of the as-built equipment to the design requirements will be assessed by the COL applicants.

In accordance with this position, MHI would like to revise the DCD description related to the severe accident equipment survivability, as shown below, to create a new COL Item to assess the as-built equipment. The next DCD revision will include the equipment survivability study as provided in the response to RAI #707-5556, Question 19-499. MHI does not intend to provide GOTHIC calculation results in the DCD; however, an appropriate reference to the PRA Technical Report MUAP-07030 will be provided.

Impact on DCD

DCD Table 1.8-2, Section 19.2.3.3.7 and Section 19.3.3 will be revised as shown in the attached mark-up. (See Attachment-1.)

Impact on R-COLA

COL applicants will need to address the new COL item.

Impact on S-COLA

COL applicants will need to address the new COL item.

Impact on PRA

There is no impact on the PRA

Table 1.8-2 Compilation of All Combined License Applicant Items for Chapters 1-19 (Sheet 34 of 34)

COL ITEM NO.	COL ITEM
COL 18.7(1)	*Deleted*
COL 18.8(1)	*Deleted*
COL 18.9(1)	*Deleted*
COL 18.10(1)	*Deleted*
COL 18.10(2)	*Deleted*
COL 18.11(1)	*Deleted*
COL 18.11(2)	*Deleted*
COL 18.12(1)	*Deleted*
COL 19.3(1)	*The COL Applicant who intends to implement risk-managed technical specifications continues to update Probabilistic Risk Assessment and Severe Accident Evaluation to provide PRA input for risk-managed technical specifications. Peer reviews for the updated PRA will be performed prior to the use of PRA to risk-informed applications.*
COL 19.3(2)	*Deleted*
COL 19.3(3)	*Deleted*
COL 19.3(4)	*The Probabilistic Risk Assessment and Severe Accident Evaluation is updated as necessary to assess specific site information and associated site-specific external events (high winds and tornadoes, external floods, transportation, and nearby facility accidents).*
COL 19.3(5)	*Deleted*
COL 19.3(6)	*The COL Applicant develops an accident management program which includes severe accident management procedures that capture important operator actions. Training requirements are also included as part of the accident management program.*
COL 19.3(7)	*The COL Applicant will provide a milestone for completing the equipment survivability assessment of the as-built equipment required to mitigate severe accidents (electrical penetrations, hydrogen igniters and containment pressure (wide range)) 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.*

DCD_06.02.05-45

The CSS is located in the Reactor Building and the Containment. Both structures are seismic category I and provide tornado missile barriers to protect the CSS. The CSS includes four 50% capacity CS/RHR pump trains and assumes one is out of service for maintenance and one becomes inoperative due to a single failure upon the initiation of the CSS. The CSS is designed with sufficient redundancy to ensure reliable performance, including the failure of any component coincident with occurrence of a design basis event, as discussed in DCD Chapters 3, 7, and 15.

Subsection 6.2.1 discusses the containment environmental conditions during accident conditions, and Chapter 3, Section 3.11 discusses the suitability of equipment for design environmental conditions. All valves required to be actuated during CSS operation are located to prevent vulnerability to flooding.

Protection of the CSS from missiles is discussed in Section 3.5. Protection of the CSS against dynamic effects associated with rupture of piping is described in Section 3.6. Protection from flooding is discussed in Section 3.4.

The CSS is designed for periodic inservice testing and inspection of components in accordance with ASME Code Section XI.

6.2.2.2 System Design

Figure 6.2.2-1 is the flow diagram of the CSS, showing the major components, instruments, and the appropriate system interconnections. Table 6.2.2-1 presents design and performance data for CSS components. The performance data for CS/RHR pump and CS/RHR heat exchanger is shown in Chapter 5, Subsection 5.4.7.

The CSS receives electrical power for its operation and control from onsite emergency power sources and offsite sources, as shown in Chapter 8. In the unlikely event of a LOCA or secondary system line break that significantly increases the containment pressure, the containment spray automatically initiates to limit peak containment pressure to well below the containment design pressure. In addition to preserving containment structural integrity, containment spray limits the potential post-accident radioactive leakage by reducing the pressure differential between the containment atmosphere and the environment and also ensures atmosphere mixing in containment. DCD_06.02.05-44

The CS/RHR system can be manually initiated and operated from the MCR and the remote shutdown console (RSC). In addition to the typical system status and operating information (e.g., valve position indication, pump run status), the containment temperature and pressure are indicated and recorded in the MCR and RSC.

Dual-use components are the CS/RHR heat exchangers and CS/RHR pumps. Motor-operated valves permit CSS or RHRS recirculation of the reactor core. The four CSS containment isolation valves are normally closed, but open automatically on a P signal. The CSS containment isolation valves are interlocked and are allowed to open only if either of the corresponding two in-series RHR hot leg suction isolation valve is closed. Further, the RHR hot leg suction valves are interlocked so that they cannot be opened unless the corresponding CSS containment isolation valves are closed. This arrangement prevents the reactor vessel water inventory from being sprayed into the containment.

independent as practicable from existing safety-related systems. This will be accomplished in part, by locating the 20 igniters in open areas of the containment away from safety-related equipment.

The containment hydrogen monitor is of a type and manufacture widely used in commercial nuclear power plants currently licensed by the NRC. The containment hydrogen monitoring equipment is regularly calibrated and the components verified operable, as required by the plant surveillance test program. The containment hydrogen monitor located outside of the containment analyzes the hydrogen concentration in containment air and continuously indicates hydrogen concentration in the MCR after the containment isolation valves of the RMS containment air sampling line are manually opened.

6.2.5.3 Design Evaluation

Hydrogen monitoring and control is provided for the unlikely occurrence of an accident that is more severe than a postulated design-basis accident. Thus, the hydrogen monitor has detection and display ranges of 0 to 10% by volume in the containment air. This monitoring range satisfies the requirements of 10 CFR 50.34(f)(2)(ix)(A) and 50.44(c)(2) for combustible gas control. The accuracy of the hydrogen monitor is less than or equal to ±10% of full span. The measured value of hydrogen concentration is utilized for operator actions and this accuracy is sufficient to accomplish the actions. These operator actions are briefed in Subsection 19.2.5. The hydrogen igniters are automatically energized by the ECCS actuation signal. However, the design evaluation is neither required nor provided for such a beyond-design-basis event.

Beyond-design-basis evaluations documented in Chapter 19 include a combustible gas release within containment corresponding to the equivalent amount of combustible gas that would be generated from a 100% fuel-clad coolant reaction, uniformly distributed. As discussed in Section B of Revision 3 of RG 1.7 (Ref. 6.2-29), these Chapter 19 evaluations are intended to show that hydrogen concentrations, uniformly distributed, do not exceed 10 volume percent (10 vol.%) and that the structural integrity of the containment pressure boundary is maintained. Detailed evaluation for hydrogen generation and control is provided in the technical report "US-APWR Probabilistic Risk Assessment" Section 15.3 and Attachment 15A (Ref. 6.2-37). DCD_06.02.05-43 DCD_06.02.05-44

6.2.5.4 Tests and Inspections

6.2.5.4.1 Preservice Testing

Chapter 14 describes the initial test program, which includes the pre-operational and startup testing.

Pre-operational testing of the hydrogen monitoring system is performed either before or after installation but prior to plant startup to verify performance. The hydrogen monitor test and design criteria, including those listed in Regulatory Guide 1.7, are incorporated into the hydrogen monitor procurement specifications. Following completion of fabrication, the hydrogen monitor acceptance tests are conducted with known samples. The hydrogen monitor is required to be reflected operating experience on the hydrogen monitor. Test results are collected, checked, and evaluated in a report and are reviewed

to initiate hydrogen burning when hydrogen concentration becomes greater than 8% by volume except under the condition inerted by steam.

Hydrogen concentration in each compartment is either lower than 10% or the compartment is inerted by steam. The pressure in the containment is kept below 68 psia, and this pressure is much lower than the containment ultimate pressure 216 psia as described in DCD section 19.2.4. For several sequences when all ignitors, containment spray trains, and safety injection trains are unavailable, ~~especially when RWSP water is not utilized for decay heat removal,~~the hydrogen concentration in the RWSP may increase to greater than 10% long after the initiation of an accident. ~~Under such a situation, operator action to inject firewater into the containment is initiated. As the result, the RWSP is filled with water, thus preventing high hydrogen in the RWSP air volume.~~The most likely case of this specific severe accident event is "complete" station blackout, when no AC power is available and beyond the time that DC batteries can provide power. However, such "complete" station blackout scenario is beyond the NRC requirements specified in 10 CFR 50.44, 10 CFR 50.63, RG 1.7 and RG 1.155, and hence it is not necessary to consider in design. Therefore, ~~the~~ containment integrity is maintained against hydrogen combustion events, and the requirements of 10 CFR 50.44(c)(1), 10 CFR 50.34(f)(2)(ix), 10 CFR 50.44(c)(2), 10 CFR 50.34(f)(3)(v) (A)(1), and 10 CFR 50.44(c)(5) are ~~therefore~~ met.

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The maximum pressure in the containment vessel under the adiabatic isochoric complete combustion condition is127 psia. This pressure is lower than the containment ultimate pressure of 216 psia thus the requirement of 10 CFR 50.44(c)(5) is met.

19.2.3.3.3 Core Debris Coolability

The fundamental design concept of the US-APWR for severe accident termination is reactor cavity flooding and cool down of the molten core by the flooded coolant water. Therefore, dependable systems are provided to properly flood the reactor cavity during a severe accident. The US-APWR provides a diverse reactor cavity flooding system, which consists of the CSS with a drain line from the SG compartment to the reactor cavity and firewater injection to the reactor cavity. The CSS is automatically activated when the high 3 containment pressure is detected and P-signal is transmitted. This containment spray water flows into the reactor cavity from the SG compartment through the drain line by gravity. The fire protection water supply system is provided outside of containment and in stand-by status during normal operation. The system line-up is modified for emergency operation during a severe accident and provides firewater from outside to the reactor cavity. These two systems are independent and thus provide high reliability reactor cavity flooding.

MCCI is a phenomenon that occurs when the temperature of core debris exceeds the melting temperature of concrete, and concrete is gradually eroded by high-temperature core debris resulting in potential basemat melt-through. Therefore, the primary mitigation of MCCI is cool down of core debris that has been relocated from RV to the reactor cavity. The US-APWR provides a highly reliable reactor cavity flooding system as discussed above, and coolant water is continuously supplied during a severe accident. The reactor cavity floor concrete, which has a thickness of equal to or greater than 3 ft., provides a protection against direct attack to the steel liner plate by the relocated core debris. This

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~~

~~US-APWR design are able to maintain safe shutdown and containment structural integrity with high confidence and to keep their functions under the postulated severe accident environmental conditions created by hydrogen burning. These system design specifications will be appropriately carried forward in procurement documents.~~ DCD_06.02.05-45

Existing experiments and the literatures (References 19.2-11, 19.2-12, and 19.2-13) are also appropriately referred to evaluate the US-APWR equipment survivability.

19.2.3.3.8 Long-term Containment Overpressure

The US-APWR containment is cooled and depressurized primarily by the CSS during a postulated severe accident. The CSS which supplies coolant water from the RWSP is automatically activated upon detecting high 3 containment pressure. Accordingly, the containment pressure is limited to less than the design pressure during a severe accident. In case the CSS is not functional, the US-APWR provides diverse mitigation features against challenges by containment overpressure. One is the alternate containment cooling by containment fan cooler system. This is a system to depressurize containment by promoting natural circulation in containment. The containment fan cooler system is a system provided to stabilize the containment environmental condition during normal operation through forced air circulation by fan. However, the electrical power of fan may not be available during a severe accident. Natural circulation is instead credited to adequately mix the containment atmosphere. The containment fan cooler system employs non-essential chilled water as the coolant under normal operation. Since this non-essential chilled water cannot be available under severe accident conditions, the system line-up is switched from the chilled water system to the CCW system which supplies CCW to the containment fan cooler units as coolant. Although CCW is not as cold as chilled water, it is sufficiently colder than the containment atmosphere under severe accident conditions. This temperature difference between the containment fan cooler units and containment atmosphere causes condensation of surrounding steam. This condensation mechanism promotes more natural circulation flow because of the pressure difference due to condensation of steam. This enhances continuous containment depressurization.

The firewater system is also utilized to promote condensation of steam. The firewater system is lined up to the containment spray header when the CSS is not functional, and provides water droplet from top of containment. This temporarily depressurizes containment. However, the firewater system does not contain a heat exchanger, and thus has no ability to remove heat from containment to terminate the containment pressurization. Instead, this design feature can be expected to temporarily increase the heat sink in containment and extend the critical time of containment failure.

<u>Goals of analysis</u>

For long-term containment overpressure, no specific requirements are stated in the CFRs. The goals of the analysis for long-term containment overpressure are therefore established below to adequately address severe accidents for the US-APWR design features in accordance with 10 CFR 52.47(a)(23) (Reference 19.2-1).

- Demonstrate the effectiveness of diverse mitigation features against containment overpressure

vessel atmosphere to combustible condition under high hydrogen concentration. In such case containment depressurization is suspended at a relatively high containment pressure. It is widely known that the low inert limit of steam concentration is approximately 55% and the low flammability limit of hydrogen concentration is approximately 4%. Hydrogen impact when depressurizing containment is evaluated and a material, such as a map of hydrogen concentration vs. containment pressure to show if hydrogen burn is safe or potential danger, is prepared to support the containment depressurization operation. MCR alarm for hydrogen concentration is also provided through the containment hydrogen monitoring system when the hydrogen concentration reaches 4% and 8%. The control room operators are required to carefully monitor the condition of containment.

- ~~Firewater can be utilized to fill the RWSP in the case when no decay heat removal function is available. This will eliminate the possibility of high hydrogen concentration in the RWSP.~~ DCD_06.02.05-44

(During LPSD operations)

It is likely that containment is not isolated during LPSD operations in order for various maintenance activities. The accident management functions to maintain containment integrity during LPSD include firstly recovery of containment isolation from the environment, and secondary heat removal from the isolated containment. However, the ability to close the containment and to recover heat removal without ac power is minimal and may not be possible. It is evaluated for the LPSD PRA that the losses of offsite power contribute approximately 30% of shutdown risk in total. As a result any period in which the RCS level is low should be planned to be undertaken with maximum confidence in offsite and onsite power reliability. Maintenance activities in the switchyard are minimal or precluded by risk management during mid-loop for example. It may also be preferable to limit undertaking the maintenance activities which require opening the equipment hatch during the inventory is low in the reactor. This limitation will fundamentally eliminate the necessary operator actions for containment closure during mid-loop, and will significantly contribute for LPSD risk reduction.

- According to the identification of some symptoms, such as loss of decay heat removal capability and onset of boiling in core, operators are required to take actions of containment isolation.

- For decay heat removal, accident management functions are fundamentally same with the ones for operations at power, i.e. reactor cavity flooding, activation of CSS or alternate containment cooling by natural circulation, or otherwise firewater injection to spray header.

4. To minimize offsite release

(During operations at power)

Key function of accident management to minimize offsite release during operations at power is fission products removal from containment vessel atmosphere. CSS and fire protection water supply system are utilized to reduce the amount of airborne FP in the containment

COL 19.3(6) The COL Applicant develops an accident management program which includes ~~severe accident management procedures that capture important operator actions. Training requirements are also included as part of the accident management program.~~ emergency operating procedures. [See COL Action Item 13.5(6)] Risk-significant operator actions listed in DCD Table 19.1-119 are to be addressed in the development and implementation of procedures for operation, accident management, training and other human reliability related severe accident guidance programs. Insights gained from the design-specific PRA, including insights created by the incorporation (unless bounded) of site and plant-specific information available at the COL application phase, are to be reflected appropriately. DCD_19-508

COL 19.3(7) The COL Applicant will provide a milestone for completing the equipment survivability assessment of the as-built equipment required to mitigate severe accidents (electrical penetrations, hydrogen igniters and containment pressure (wide range)) 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. DCD_06.02.05-45