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October 1, 2008

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-08209

Subject: MHI's Responses to US-APWR DCD RAI No.62

Reference: 1) "Request for Additional Information No.62 Revision 0, SRP Section: 06.02.05, Application Section: 6.2.5," dated September 2, 2008.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No.62 Revision 0."

Enclosed are the responses to 21 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.

Enclosure:

1. Responses to Request for Additional Information No.62 Revision 0

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

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NRO

Enclosure 1

UAP-HF-08209
Docket Number 52-021

Responses to Request for Additional Information No.62 Revision 0

October 2008

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

10/01/2008

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO.62 REVISION 0**
SRP SECTION:	**06.02.05 – COMBUSTIBLE GAS CONTROL IN CONTAINMENT**
APPLICATION SECTION:	**06.02.05 COMBUSTIBLE GAS CONTROL IN CONTAINMENT**
DATE OF RAI ISSUE:	**09/02/2008**

QUESTION NO. : 06.02.05-1

Provide additional information about the assumptions used to in the calculations demonstrating the effectiveness of the CHS.

The requirements in 10 CFR 50.44(c)(1),(2) and (5) and in 10 CFR 50.34(f)(2)(ix) and (3)(v) focus on the aspects of the needed hydrogen control. Conformance to these requirements is briefly addressed in Section 6.2.5 and in more detail in Section 19.2.3.3.2 of the DCD. In Section 19.2.3.3.2 the DCD notes that the GOTHIC code was used to evaluate the effectiveness of the hydrogen igniter system, and that the hydrogen generation rate was evaluated with MAAP plus independently calculated amounts of hydrogen generation. Additional detail regarding the assumptions used for this analysis is needed. In particular, describe (1) the accident scenarios assumed for the MAAP calculation(s), (2) the generation rates produced by MAAP, (3) the sensitivity cases, if any, conducted with MAAP and their results for hydrogen generation rates and containment pressures, and (4) the independently calculated hydrogen generation rates used and the resulting containment pressures.

ANSWER:

Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 15 Separate Effect Analysis. Section 15.3 of this report describes the discussion on the hydrogen generation and control; and the particular information requested in the items (1) through (4) can be found there.

(1), (2) and (3): Discussed in Subsection 15.3.3.2
(4): Discussed in Subsection 15.3.3.3 and 15.3.3.4

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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US-APWR Design Certification

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QUESTION NO. : 06.02.05-2

Provide additional detail regarding the assumptions used for the atmospheric mixing part of both the Severe and the Design Basis Accident calculations.

10 CFR 50.44(c)(1) states that all containments must have a capability for ensuring a mixed atmosphere during design-basis and significant beyond design-basis accidents. The DCD briefly discusses mixing of the containment atmosphere in Section 6.2.5 and provides a sketch of typical air flow patterns in Figure 6.5.2-2. In Section 19.2.3.3.2 the discussion on the GOTHIC calculations used to evaluate the effectiveness of the hydrogen ignition system in severe accidents mentions that these calculations included evaluation of atmospheric mixing. However, no additional information on atmospheric mixing is provided. Provide additional detail regarding the assumptions used for the atmospheric mixing part of both the severe and the DBA analyses. In particular, describe (1) the modeled internal structures of the containment that promote and permit the mixing of gases within the containment and sub compartments, (2) any dead ended containment areas identified where hydrogen may not be adequately mixed, (3) the accident scenarios assumed, including primary system failure locations and mass flow composition and rates into containment, (4) the role of the containment spray system in the calculations, (5) analysis/assumptions and mathematical models that ensure that hydrogen does not accumulate within any sub compartment to the level that would support a combustible/detonatable mixture, (6) provide a list by compartment of the calculated hydrogen concentrations by volume, and (7) discuss how it is assured that any hydrogen discharge from the high point vents is mixed into the containment atmosphere and not left to accumulate in any subcompartment.

ANSWER:

Regarding atmosphere mixing under the postulated severe accident conditions, please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 15 Separate Effect Analysis. Section 15.3 of this report describes the discussion on the hydrogen generation and control; and the particular information requested in the items (1) through (7) can be found there.

(1) Discussed in Subsection 15.3.3.4.1. This GOTHIC model is based on the lumped model and the each detailed internal structure is not considered, but treated as volumetric bulk within the compartment. Atmosphere mixing inside the containment is referenced from the literature 15-4 specified in the report.

(2) Discussed in Subsection 15.3.3.4.1. No dead ended areas are identified for the US-APWR. This also references the literature 15-4 specified in the report.

(3) Discussed in Subsection 15.3.3.2 for the accident scenarios and in Subsection 15.3.3.4.1 for the hydrogen release locations, flow rates, etc.

(4) Discussed in Subsection 15.3.3.2.

(5) Discussed in Subsection 15.3.3.4 and 15.3.3.5.

(6) Discussed in Subsection 15.3.3.4.1.

(7) Discussed in Subsection 15.3.3.4 and 15.3.3.5.

Furthermore, MHI considers that the calculation for atmosphere mixing under the postulated severe accident conditions represents the capability of mixing atmosphere in containment both during design-basis and beyond design-basis accidents.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-3

Clarify the capability to address potential hydrogen accumulation of the steam inerted compartments when those compartments change from an inerted condition to a flammable condition.

Section 19.2.3.3.2 of the DCD application provides the result of the analysis that shows that sub compartments are either inerted by steam or less than 10% volume hydrogen. The change of a compartment from an inerted condition to a flammable condition is not discussed.

In order to evaluate whether the US-APWR combustible gas control system design meets the requirements of 10 CFR Part 50, § 50.44, 50.34(f)(2)(ix), and GDC41, to control the concentration of H2 in the containment atmosphere and of GDC 41 to provide systems as necessary to ensure that containment integrity is maintained, additional information is needed. Provide a discussion on capabilities to address potential hydrogen accumulation of the steam inerted compartments when those compartments change from an inerted condition to a flammable condition.

ANSWER:

MHI understands the NRC's concern, and recognizes the point that the NRC commented is one of the biggest issues of usage of the hydrogen igniters for controlling the in-containment hydrogen concentration.

Hydrogen igniters are provided for the US-APWR in order to rapidly and properly control the hydrogen concentration below the detonable range during accidents to prevent explosive combustion of hydrogen and maintain the containment integrity. However in case the atmosphere of compartment is inert, it is impossible to properly control the hydrogen concentration by hydrogen igniters. Alternatively, the containment integrity should be maintained through the rigidly determined operational procedures, not to change the compartment atmosphere composition from an inert condition to a detonable condition immediately. Under this situation, the inert gas of the atmosphere is considered steam. Large amount of steam makes the atmosphere inert although it adversely pressurizes the containment if the amount is too much. In order to prevent over-pressure failure of the containment, operational action should be primarily taken to depressurize the containment. The steam concentration decreases as the containment depressurization operation progresses and the atmosphere conditions changes to flammable when the steam concentration becomes below approximately 55%. Therefore, the operational

procedure should be determined how to control the steam concentration. It is widely observed that the hydrogen combustion speed and the explosive load become lower in the higher steam concentration. The operational procedure should therefore indicate not to rapidly depressurize the containment vessel to very low pressure, instead maintain it relatively high around the hydrogen flammable limit condition. In order to achieve this operation, accurate measurement of the hydrogen detector is also important.

This detailed operational procedure will be developed as a part of the severe accident management program, identified as one of the COL items specified in Subsection 19.2.5 of the DCD.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-4

Clarify if there is an alarm in the main control room (MCR) for the hydrogen monitor.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR hydrogen detector system should meet the provisions of SRP chapter 6.2.5 acceptance criterion #6b. In order to evaluate the US-APWR hydrogen monitoring system as it related to satisfying this criterion, more information is required. Clarify (or indicate where in the DCD it is confirmed) if there is an alarm in the MCR for the hydrogen monitor.

ANSWER:

MHI intends to provide an alarm in the main control room for the hydrogen detector.

The actual design of this alarm, such as when it is alarmed, what alarm is given, etc., is determined in conjunction with the discussions provided in the RAI Question No.06.02.05-3, etc. The signal transmitted from the hydrogen detector is not utilized to control other system, although the detector measurement should be suitably applied for plant operators to maintain the containment integrity.

This alarm is one of the plant specific designs in relation to the severe accident management program, which is discussed in Subsection 19.2.5 of the DCD.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-5

Indicate if the Hydrogen Control System is designed with the capability to remain operable assuming a single failure such as a failure of one igniter or igniter power supply. Discussion of the response of the hydrogen control system assuming a single failure is not provided.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR design should meet the provisions of RG 1.7,Revision 3, Section C.1. In order to evaluate whether the USAPWR meets the requirements of RG 1.7, Revision 3, Reference 7, more information is required. Indicate (or reference where in the DCD it is indicated) if the Combustible Gas Control System is designed with the capability to remain operable assuming a single failure such as a failure of one igniter or igniter power supply. Were calculations carried out with only one train (i.e., one power supply) of igniters operating? If so, describe where the results differed from those with both trains operating. Include a discussion on details of the analysis that was performed for igniter placement in this discussion, i.e. were the distances between igniters (igniter coverage) evaluated to ensure a low probability of flame acceleration, by location of the igniter close to likely hydrogen release points, and was there any considerations in the event that one or more igniters fail to function? Indicate if there are any compartments not covered by an igniter and if any, provide justification.

ANSWER:

As for the MHI's understanding, the hydrogen control system is provided to mitigate the significantly beyond-design-basis accident, and there are no specific requirements for hydrogen control during the design basis accident. The challenge to the containment integrity due to hydrogen generated from the design basis accident has been evaluated negligibly small from the risk point of view. Therefore as specified in the RG1.7, Revision 3, Section C.1, the hydrogen control system is not subject to the environmental qualification requirements of 10 CFR 50.49, quality assurance requirements of Appendix B to 10 CFR Part 50, and redundancy/diversity requirements of Appendix A to 10 CFR Part 50.

Nevertheless, the hydrogen igniters provided for the US-APWR are independent each other and therefore one hydrogen igniter failure does not affect the functionality of other hydrogen igniters. Regarding the power supply, two non-class 1E buses are provided through cross-connection and also two back up non-class 1E alternate ac gas turbine generators are provided. Overall, it is

concluded that the combustible gas control system is designed with the capability to remain operable assuming a single failure such as a failure of one igniter or igniter power supply.

Under the severe accident conditions, single failure criterion cannot be satisfied for the US-APWR because the success criterion of the hydrogen ignition system is determined as 20 out of 20 hydrogen igniters are functional. MHI considers this success criterion is highly conservative and MHI even expects that several malfunction of hydrogen igniters are not very significant to the containment integrity. There are researches reporting that PCCV may withstand the explosive loads from most of uncontrolled in-containment hydrogen burns. This success criterion is therefore carefully reviewed through the Level 2 PRA study, and the contribution to the containment functionality is evaluated. The detailed evaluations are provided in the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) and it is concluded that the containment design satisfies the containment performance goal of less than 1×10^{-6}/ry for LRF. Hence, the 20 out of 20 success criterion is acceptable.

Phenomenological discussions on the hydrogen generation and control are also provided in Chapter 15 of the technical report. It is concluded that the capability to control hydrogen for the US-APWR is adequate and the challenge caused by hydrogen burn can be satisfactorily withstood by the containment system, including hydrogen ignition system.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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QUESTION NO. : 06.02.05-6

Indicate the capability of the CHS to withstand the SSE without loss of function.

As noted in Tier 1, Section 2.11.4.1, of the DCD the hydrogen monitoring and control system is not safety related and is not designed for seismic Category 1 requirements. However, the CHS is an important system for plant protection for beyond-design-basis accidents. More information on the seismic ruggedness of the CHS is needed.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR design should meet the provisions of RG 1.7,Revision 3, Section C.1. Per RG 1.7, the Combustible gas control system equipment reliability expectations under severe accident conditions should consider the circumstances of applicable initiating events (such as earthquakes). As noted in Tier 1,Section 2.11.4.1, the hydrogen monitoring and control system is not safety related and is not designed for seismic Category 1 requirements. Indicate (or reference where in the DCD it is indicated) if the CHS is designed with the capability to withstand the SSE without loss of function. Explain how, in the case of such event, the components of the CHS do not have the potential to adversely affect other safety related components in containment.

ANSWER:

MHI agrees with the NRC's concern that the CHS is an important system to protect the plant safety during beyond-design-basis accident, such as an event that core is significantly damaged.

As stated in Tier 1, Section 2.11.4.1 of the DCD, the CHS is not designed for seismic category I requirements since this system is required for plant protection for beyond-design-basis accident. However, in considering the importance of the hydrogen igniters in order to maintain the containment integrity during postulated severe accidents, it is intended to design satisfying the plant HCLPF (high confidence of low probability failure) is evaluated more than 0.5G.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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US-APWR Design Certification

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QUESTION NO. : 06.02.05-7

Provide more specific design information on the components of the CHS. Table 6.2.5-1of the DCD provides very general CHS design parameters, and Section 19.2.3.3.7 of the DCD discusses equipment survivability, but more design details are needed. In meeting the requirements of 10 CFR Part 50, § 50.44(c)(3), regarding equipment survivability, equipment necessary for achieving and maintaining safe shutdown of the plant and maintaining containment structural integrity should perform its safety function during and after being exposed to the environmental conditions attendant with the release of hydrogen generated by the equivalent of a 100 percent fuel clad-coolant reaction including the environmental conditions created by activation of the combustible gas control system. In order to evaluate if the US-APWR CHS meets this criteria when constructed:

1) Indicate what specific design basis information for the components of the CHS reflect the results of the referenced 19.2.3.3.7 evaluation, and DCD reference 19.2-58.

2) Provide a design description of the hydrogen igniter to be supplied for the US-APWR, and its associated power supplies, transformers and cabling etc, to include performance criteria sufficient to support that such igniter, when installed, will have similar performance as those described in DCD reference 19.2-58.

ANSWER:

Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 15 Separate Effect Analysis. Section 15.7 of this report describes the discussion on the equipment survivability, in which the containment gas temperatures during the postulated severe accident conditions are presented. Hydrogen igniters including the associated power supplies, transformers and cabling, etc. are designed to satisfy the functionality within the evaluated temperature conditions.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-8

Provide additional information on how inspection and test requirements of GDCs 41, 42and 43 are met.

To satisfy the inspection and test requirements of GDC 41, 42, and 43, combustible gas control systems including hydrogen igniters and combustible gas monitors should be designed with provisions for periodic inservice inspection, operability testing, and leak rate testing of the systems or components. The tests should support the analyses of the functional capability of the equipment. In order to evaluate this requirement as it applies to the US-APWR CHS, additional information is required:

1) Provide details on the design features of the hydrogen monitoring system and the hydrogen ignition system that accommodate periodic inspection and testing to assure system integrity and operability of the systems active components.

2) Describe how proposed inservice test criteria will be established and on what design requirements the test criteria will be based.

3) In order to evaluate if the proposed design is capable of achieving the required overall system design basis performance goal of maintaining hydrogen in the containment atmosphere to less than 10% (by volume), provide additional performance data on the hydrogen igniter system such as: performance requirements for each igniter (i.e.) minimum igniter surface temperature, voltage and current. Also indicate the design criteria to be verified in the in-service tests and inspections. Provide a description of the in-service performance test, or indicate if the description of the in-service test and inspection program will be a COL item.

ANSWER:

1) The mechanical design features of the Containment Hydrogen Monitoring and Control System are deferred to the detailed design phase, specifically the design features of the hydrogen monitoring system and the hydrogen ignition system that accommodate periodic inspection and testing to assure system integrity and operability of the systems active components are vendor specific and will be available when the equipment vendors are selected.

2) Upon receipt of Containment Hydrogen Monitoring and Control System design documents from the selected vendor (to include design and fabrication drawings, calculations, bill of materials, reports, vendor specific inservice test procedures, etc.), the specific parameters for the acceptance tests, calibrations, and inservice tests of the monitors and igniters will be defined; the tests of the acceptability and functional capability of the monitor and igniters will include monitor sensitivity and igniter function-upon-demand requirements for maintaining hydrogen in the containment atmosphere to less than 10% (by volume).

3) As part of the hydrogen igniter system submittal, the vendor's specific industrial experience and the hydrogen igniter system performance data will be required for review and evaluation to ensure that the system can achieve the governing design criteria regarding hydrogen control. As an example, the specific igniter surface temperature, voltage and current, and the test conditions will be evaluated against the projected calculated worst-case severe accident hydrogen control needs.

Thus, the description of the inservice test and inspection program will be a COL item.

Impact on DCD

DCD Subsection 6.2.5.4 and Subsection 6.2.8 will be revised to include the above COL item.

6.2.5.4 Tests and Inspections

Testing and inspections (including instrument calibration), as recommended by the hydrogen monitoring and control equipment vendor, are performed.
The COL Applicant is responsible to provide the specific inspection and test features of the containment hydrogen monitoring and control system, including for the hydrogen monitor and the hydrogen igniters, upon receipt of selected equipment vendor information.

6.2.8 Combined License Information

COL 6.2(11) **The COL Applicant is responsible to provide the specific inspection and test features of the containment hydrogen monitoring and control system, including for the hydrogen monitor and the hydrogen igniters, upon receipt of selected equipment vendor information.**

Impact on COLA

There is impact on COLA to incorporate the DCD change.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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QUESTION NO. : 06.02.05-9

Provide a discussion of design requirements to ensure reliability, availability and capability of hydrogen detection system. Design requirements for this single instrument are not provided.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR H2 detector system should meet the provisions of RG 1.7, Revision 3, Section C.2. Provide a discussion of design requirements to ensure reliability, availability and capability of this single instrument.

ANSWER:

As for the MHI's understanding, the hydrogen control system is provided to mitigate the significantly beyond-design-basis accident, and there are no specific requirements for hydrogen control during the design basis accident. The challenge to the containment integrity due to hydrogen generated from the design basis accident has been evaluated negligibly small from the risk point of view. Therefore as specified in the RG1.7, Revision 3, Section C.1, the hydrogen control system is not subject to the environmental qualification requirements of 10 CFR 50.49, quality assurance requirements of Appendix B to 10 CFR Part 50, and redundancy/diversity requirements of Appendix A to 10 CFR Part 50.

Nevertheless, regarding the power supply of the hydrogen monitoring system, two non-class 1E buses are provided through cross-connection and also two back up non-class 1E alternate ac gas turbine generators are provided. Overall, it is concluded that the hydrogen monitoring system is designed with the capability to remain operable assuming a single failure such as a failure of one power supply.

The hydrogen detector is installed outside the containment and hence it is evaluated as not subject to the equipment survivability analysis. In addition it should be noted that the signal transmitted from the hydrogen detector is not utilized to control other system. The role of the hydrogen detector for the US-APWR is to provide supportive information for the operators' action, as discussed in the RAI Question No.06.02.05-3.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-10

Discuss the accessibility of the CIV's of the PASS for manual operation during a severe accident.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR H2 detector system should meet the provisions of RG 1.7, Revision 3, Section C.2. In order to evaluate the US-APWR hydrogen monitoring system as it related to satisfying the criteria of RG 1.7, Revision 3, Section C.2.1(7), provide a discussion as to the accessibility of the CIV's of the PASS for manual operation during a severe accident.

ANSWER:

The CIVs (RMS-MOV-001 and RMS-MOV-002) for the containment air sampling line are schematically presented in Figure 6.2.4-1, sheet 44 of 50. These valves and penetration are also used for post accident sampling of the containment atmosphere. These valves are designed with seismic category I and are equipped with Class 1E power. This Class 1E power allows the valve to remain operational during a severe (design basis) accident.

RG 1.7, Revision 3 Section C.2.1 (7) deals with Human Factors. Section C.2.1 (7) requires, "To the extent practicable, the same instruments should be used for accident monitoring as are used for the normal operations of the plant to enable the operators to use, during accident situations, instruments with which they are most familiar." The current design satisfies the requirement to be used during accident; and the design also includes provision of Class 1E power to insure operability during and post accident.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-11

Discuss why the operating principle and accuracy of the combustible gas analyzer are provided by the COL applicant.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR hydrogen detector system should meet the provisions of RG 1.7, Revision 3, Section C.2. 10 CFR 52.47 (c)(1) states that an application for certification of a nuclear power reactor design that is an evolutionary change from light–water reactor designs of plants that have been licensed before April 18, 1989, must provide an essentially complete nuclear power plant design. In order to evaluate the US-APWR hydrogen monitoring system as it related to satisfying the criteria of RG 1.7, Revision 3, Section C.2 more information is required. Discuss why the operating principle and accuracy of the combustible gas analyzer is provided by the COL applicant (COL 6.2(7)).

ANSWER:

The Combustible Gas Control Systems and their components are non-safety. The basic concept meets the provisions of RG 1.7. The design of the structures, systems, and components are deferred until receipt of information based on the particular vendor equipment. Hence COL 6.2(7) will be established in the FSAR to track the requirements for provision of the operating principle and accuracy of the combustible gas analyzers.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO.62 REVISION 0**
SRP SECTION:	**06.02.05 – COMBUSTIBLE GAS CONTROL IN CONTAINMENT**
APPLICATION SECTION:	**06.02.05 COMBUSTIBLE GAS CONTROL IN CONTAINMENT**
DATE OF RAI ISSUE:	**09/02/2008**

QUESTION NO. : 06.02.05-12

Indicate how information on tests conducted to demonstrate the performance capability of the hydrogen analyzer will be verified following the construction phase, and how criteria for the Hydrogen Analyzer design will be verified. More information than is provided in Section 14.2.12.1.64 of the DCD is needed.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR hydrogen detector system should meet the provisions of RG 1.7, Revision 3, Section C.2. In order to evaluate the US-APWR hydrogen monitoring system, as it relates to satisfying this section, more information is required. Indicate how information on tests conducted to demonstrate the performance capability of the hydrogen analyzer will be verified following the construction phase, and how criteria for hydrogen analyzer design specified in RG 1.7, Section C.2 will be verified.

ANSWER:

The hydrogen analyzer test and design criteria, including those listed in Regulatory Guide 1.7, will be incorporated into the analyzer procurement specifications in the detailed design phase. Following completion of fabrication, equipment acceptance tests will be conducted with known samples, under a certified QA program, and/or witnessed by engineering representatives. Each vendor will also be required to provide operating experience on the hydrogen analyzer as part of the equipment bid submittal. Test results will be collected, checked, and evaluated in a report for submittal and will be reviewed by the Owner (Purchaser) and/or an engineering representative to verify the performance capability of the hydrogen analyzer.

Equipment vendors will be evaluated for qualifications to meet a certified Quality Assurance Program, and further consideration will be based on industrial experiences for the hydrogen analyzer. The successful vendor chosen to provide the hydrogen analyzer will be required to provide design documents (design and fabrication drawings, calculations, bill of materials, test conditions and procedures, reports, etc.) to be reviewed and approved by the Owner, or a representative, to verify that the design and fabrication meet the criteria specified in the procurement specifications. The analyzer equipment package, when completed, will undergo acceptance testing in the presence of engineering witnesses or under a certified QA program. This procedure will insure that the equipment is consistent with the procurement specifications.

After installation, the hydrogen analyzer design will undergo calibration tests prior to start-up. Based on industrial experience and the manufacturer's recommendation, the calibration tests will also be conducted periodically to insure that the performance capability of the hydrogen analyzer meets the design criteria.

The details of the test and calibration procedures are vendor specific and will be available after an equipment vendor is selected. DCD Subsection 14.2.12.1.64 captures the preoperational test requirements.

Based on this evaluation, more information in DCD Subsection 14.2.12.1.64 is not available or needed.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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DATE OF RAI ISSUE:	**09/02/2008**

QUESTION NO. : 06.02.05-13

Clarify if a failure mode and effects analyses (FMEA) of the combustible gas control system, i.e., the hydrogen ignition system, was performed for the Probabilistic Risk Assessment. The DCD mentions the use FMEA in a general way in chapter 19 but no discussion is provided.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR CHS should meet the provisions of RG 1.7,Revision 3, Section C.2. In order to evaluate the US-APWR combustible gas control system as it related to satisfying the criteria of RG 1.7, Revision 3, Section C.2 more information is required. The DCD mentions the use of failure mode and effects analyses (FMEA) in a general way in chapter 19. No discussion of a FMEA for the hydrogen ignition system is provided. Was a FMEA of the hydrogen ignition system performed for the Probabilistic Risk Assessment? If not, provide justification for not conducting a FMEA on this system. If a FMEA was carried out for the system, provide a list of failure modes considered, and the modes included in the PRA model.

ANSWER:

FMEA of the hydrogen ignition system has been performed for the US-APWR and the results have been incorporated into the fault trees of the hydrogen control system, although it is not properly documented as the FMEA tabular format.

MHI agrees that FMEA is a very powerful tool to identify any single point failures of a system and thus the US-APWR PRA utilizes the FMEA results as one of the input in a general way. However, regarding the hydrogen ignition system, the failure analysis is not documented as the tabular format of FMEA; instead it is directly incorporated into development of the fault tree. Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 6 Attachment 6A Section 6A.15.3 Hydrogen Control System, in which the considered failure modes of the hydrogen ignition system, including the hydrogen igniter and the related power supply systems, can be identified as the basic events of the fault tree.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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DATE OF RAI ISSUE:	**09/02/2008**

QUESTION NO. : 06.02.05-14

Provide the assumptions that were used in the CHS effectiveness calculations for the generation of hydrogen from the inventory of materials within the containment that would yield hydrogen gas by corrosion from the ECCS or containment spray solutions.

SRP 6.2.5 acceptance criteria #1 and RG 1.7 Revision 3 Section C, paragraph 4, refer to the identification of materials within the containment that would yield hydrogen gas by corrosion from the ECCS or containment spray solutions. Provide the assumptions used in the accident progression analyses for hydrogen generation and control, described in Chapter 19.2.3.3.2, for the generation of hydrogen from the inventory of such materials within the containment.

ANSWER:

Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 15 Separate Effect Analysis. Section 15.3 of this report describes the discussion on the hydrogen generation and control, and the accident progression analyses in Subsection 15.3.3 consider 100% zirconium of the active fuel length cladding reaction as well as the remaining cladding reaction shortly after RV failure with ECCS or containment spray water spilled into the reactor cavity. In the global hydrogen burn analyses in Subsection 15.3.4 considers 100% zirconium of the active fuel length cladding reaction as the basic case, and 100% zirconium in whole in-core structures reactions as the sensitivity case.

Hydrogen generation other than zirconium-water reaction is not considered in the study because the generation rates are considered significantly slower than that from zirconium reaction. It can be therefore considered the hydrogen generated from the MCCI, etc. is negligible in terms of the discussion on the CHS effectiveness.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-15

Indicate and justify what, if any, inspections, test analysis and acceptance criteria would be required to verify that the hydrogen load produced by materials within the containment that would yield hydrogen gas would not exceed the hydrogen load assumptions used in the severe accident progression analysis contained in the design certification.

COL Item Number 6.1(4) states that "The COL applicant is responsible to identify materials within the containment that would yield hydrogen gas by corrosion from the emergency cooling or containment spray solutions, and their use should be limited as much as practicable." In support of meeting the requirements of 10 CFR Part 50, §50.44, and GDC 41 and pursuant to SRP 6.2.5 acceptance criteria #1 and RG 1.7 revision 3 section C, paragraph 4, describe (or indicate where in the DCD it is described) any specific criteria to be used by a COL applicant to demonstrate that the use of such materials were minimized during construction. Indicate and justify what if any inspections, test analysis and acceptance criteria (ITAAC) would be required to verify that the hydrogen load produced by such materials would not exceed the hydrogen load assumptions used in the severe accident progression analysis contained in the design certification.

ANSWER:

RG 1.7 revision 3, states (emphasis added):

"In an accident more severe than the design-basis loss-of-coolant accident (LOCA), combustible gas is <u>predominately</u> generated within the containment as a result of the following factors:

(1) fuel clad-coolant reaction between the fuel cladding and the reactor coolant

(2) molten core-concrete interaction in a severe core melt sequence with a failed reactor vessel"

Also, 10 CFR 50.44 (c) (3), states:

"The amount of hydrogen to be considered must be equivalent to that generated from a fuel clad-coolant reaction involving 100 percent of the fuel cladding surrounding the active fuel region."

However, materials to be used for components within the containment will be selected for their compatibility with the spray solution in the LOCA and severe accident environment and for their

intended normal service. These materials will be identified as they are selected, and their use will be limited as much as practicable per RG 1.7 revision 3.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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DATE OF RAI ISSUE:	**09/02/2008**

QUESTION NO. : 06.02.05-16

Clarify if a failure mode and effects analyses (FMEA) of the containment hydrogen monitoring system was performed. The DCD mentions the use FMEA in a general way in chapter 19 but no discussion is provided.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR design should meet the provisions of RG 1.7,Revision 3, Section C.1. In order to evaluate whether the USAPWR meets the requirements of RG 1.7, Revision 3 Reference 7, more information is required. Was a FMEA of the containment hydrogen monitoring system performed? If not, provide justification for not conducting a FMEA on this system. If a FMEA was carried out for the system, provide a list of failure modes considered, and the conclusions of the analysis.

ANSWER:

FMEA of the hydrogen monitoring system has been performed for the US-APWR and the results have been incorporated into the fault trees of the hydrogen control system, although it is not properly documented.

MHI agrees that FMEA is a very powerful tool to identify any single point failures of a system and thus the US-APWR PRA utilizes the FMEA results as one of the input in a general way. However, regarding the hydrogen monitoring system, it is identified through a very simple engineering consideration that any failures of the hydrogen monitoring system do not impact the CDF or LRF. It is because the hydrogen ignition system is designed to automatically activate upon issuance of the ECCS actuation signal and the signal transmitted from the hydrogen monitoring system is not utilized to control other system. The role of the hydrogen detector for the US-APWR is to provide supportive information for the operators' action, as discussed in the RAI Question No.06.02.05-3.

Fault tree for the hydrogen control system including hydrogen monitoring system is developed as a part of the US-APWR PRA although the failure of the hydrogen monitoring system does not appear as the basic events in the fault tree. Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 6 Attachment 6A Section 6A.15.3 Hydrogen Control System.

Next presented table is an example of FMEA of the hydrogen monitoring system.

Failure mode	Cause	Local effect	System effect	Plant effect	Detection
Spurious measurement	- Hydrogen detector malfunction - Calibration error	Hydrogen detector transmit wrongly measured value	Hydrogen monitoring system shows wrong value	No effect on the plant operation.	Operator action
No measurement	- Hydrogen detector failure - Power supply failure	Hydrogen detector does not transmit any measured value	Hydrogen monitoring system does not show any value	No effect on the plant operation	Operator action

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-17

Indicate what ITAAC will be used to confirm the adequacy of the igniter capability, including design criteria to be verified, and the ITACC acceptance criteria for igniter location.

10 CFR 52.47 (c)(1) states that an application for certification of a nuclear power reactor design that is an evolutionary change from light–water reactor designs of plants that have been licensed before April 18, 1989, must provide an essentially complete nuclear power plant design. To satisfy the design requirements of GDC 41, performance tests should be performed on system components, such as hydrogen igniters and combustible gas monitors. The tests should support the analyses of the functional capability of the equipment. In order to evaluate this requirement, provide a description of what design criteria will be verified in the pre-service tests of the CHS. Indicate what ITAAC will be used to confirm the adequacy of the igniter capability including design criteria to be verified and the ITACC acceptance criteria for igniter location.

ANSWER:

Section I.A.(3), Appendix C.II.1-A of RG 1.206 discusses the ITAAC for the severe accident features, as follows.
"The design description should describe these features, and the functional arrangement ITAAC should verify that they exist. In general, the ITAAC need not include the capabilities of these features."
Thus, ITAAC for the non-safety systems with severe accident features should focus on verification of the existence (not capabilities) of the systems, components, or equipment, and the ITAAC for the severe accident features which are linked to the capabilities are not proposed in Tier 1.

DCD Tier 1, Subsection 2.11.4 will be used to confirm the adequacy of the CHS. Based on the above consideration, MHI will revise the DCD Tier 1, Subsection 2.11.4. Refer to the response to RAI No.51 question No.14.03.11-1.

Impact on DCD

Refer to RAI No.51 Question No.14.03.11-1.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-18

Provide a discussion of how the design addresses the installation of non safety related equipment such that it does not adversely affect safety related equipment, and how measures are established to ensure that purchased material, equipment, and services conform to the procurement documents.

In meeting the requirements of 10 CFR Part 50, § 50.44, and GDC 41 regarding the functional capability of the combustible gas control systems to ensure that containment integrity is maintained, the US-APWR design should meet the provisions of RG 1.7,Revision 3, Section C.1. In order to evaluate whether the USAPWR meets the requirements of RG 1.7, Revision 3 Reference 7, provide a discussion of how the design addresses the following criteria:

- Installation of non safety related equipment such that it does not adversely affect safety related equipment (i.e. is independent from safety related equipment)(Appendix A)
- Measures to assure that all design related guidelines used to comply with 10 CFR 50.44 and 10 CFR 50.34(f)(2)(ix), GDC 5, 41, 42 and 43 is carried forward to procurement documents (appendix A) and that deviations there from are controlled.
- Measures should be established to ensure that purchased material, equipment, and services conform to the procurement documents.

ANSWER:

As per DCD section 3 Table 3.2-1, igniters for the containment hydrogen control system are classified as Equipment Class 4 and Quality Group D in accordance with RG 1.26. However, it is identified through the Level 2 PRA study for the US-APWR that the hydrogen igniters are risk significant during severe accident.

Igniters are installed in a manner ensuring that they do not degrade the existing safety-related systems, including making the non-safety equipment as 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 combustible gas control system the procurement specifications will establish measures and state the equipment compliance with 10 CFR 50.44, 10 CFR 50.34(f)(2)(ix) and GDC 5, 41, 42, 43. Also, vendors will be pre-qualified to bid, ensuring that vendors who produce the equipment are known to use approved materials and methods. After a vendor is selected, the design will be reviewed to ensure it meets the stated criteria in procurement specifications. QA procedures will be in place for the performance of necessary audits of the vendor to ensure that the material, equipment, and services conform to the design related guidelines and procurement documents.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-19

Clarify whether the load associated with dead load plus 45 psig, would result in higher containment loadings than would result from the loads associated with the releases of hydrogen generated from 100% metal-water reaction of the fuel cladding and accompanied by uncontrolled hydrogen burning.

In section 3.8.1.3.2.2 of the DCD a discussion is provided on how the US-APWR containment structural design satisfies the requirements of Subarticle CC-3720 of the ASME code Section III for factored load design. It is stated that since the design meets the minimum design condition of D+45 psig (RG1.136, Revision 3, Section C.5.B.(3)),the design does not require a design evaluation. Clarification is needed.

In meeting the requirements of 10 CFR Part 50, § 50.44(c)(3) and § 50.44(c)(5),requirements that containment structural integrity be demonstrated by an analysis acceptable to the NRC staff, the US-APWR design should meet the provisions of RG1.7, Revision 3, Section C.5. In order to evaluate whether the USAPWR meets the requirements of this section more information is required. In section 3.8.1.3.2.2 of the DCD a discussion is provided on how the US-APWR containment structural design satisfies the requirements of Subarticle CC-3720 of the ASME code Section III for factored load design. It is stated that since the design meets the minimum design condition of D+45 psig (RG1.136, Revision 3, Section C.5.B.(3)), the design does not require a design evaluation. Clarify whether the load associated with dead load plus 45 psig, would result in higher containment loadings than would result from the loads associated with the releases of hydrogen generated from 100% metal-water reaction of the fuel cladding and accompanied by uncontrolled hydrogen burning. If this is not the case, provide additional information that demonstrates that containment structural integrity will be maintained in such an event.

ANSWER:

MHI agrees that the NRC's concern is true, that the load associated with the release of hydrogen generated from 100% cladding-water reaction exceeds the one associated with dead load plus 45 psig. As for the MHI's understanding, it is necessary to separately consider the design-basis accident and severe accident for this issue.

The discussion provided in Section 3.8.1.3.2.2 of the DCD is based on the design-basis accident, thus 100% cladding reaction is not taken into account. The postulated condition with 100%

cladding reaction is obviously significantly beyond the design-basis. The conclusion in Section 3.8.1.3.2.2 is therefore good only for the evaluation on the design-basis accidents. The US-APWR PCCV is designed based on a DBA pressure Pa of 68 psig and a corresponding design test pressure of 1.15 x Pa, hence the minimum design condition of D+45 psig is satisfied under the postulated conditions of DBA.

On the other hand, Section 19.2 of the DCD describes the severe accident analyses, including the pressure load associated with the hydrogen released from 100% cladding-water reaction. Please refer to the technical report "US-APWR Probabilistic Risk Assessment" (MUAP-07030) Chapter 15 Separate Effect Analysis, in which detailed discussions on severe accident evaluations are provided. Section 15.3 of this report describes the discussion on the hydrogen generation and control, and the evaluations of the containment integrity under the hydrogen burning condition, including local burn and global burn, are described. Chapter 16 of this technical report describes the discussion on the containment ultimate pressure capability, in which the ultimate containment capability is evaluated as 216 psia. It is concluded from these evaluations that the containment integrity is sufficiently maintained against the challenge from hydrogen burn associated with 100% cladding-water reactions.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-20

Clarify information in DCD Chapter 1 Table 1.9.3-2.

10CFR50.34(f)(2)(ix) is not included in DCD Chapter 1 Table 1.9.3-2., 'Location of Description for Additional TMI-Related requirements', However Section 6.2.5.1 of the DCD states that the containment hydrogen monitoring and control system is designed in accordance with 10CFR50.34(f)(2)(ix).Clarify this by amending the table or the Section 6.2.5.1 as appropriate.

ANSWER:

Containment hydrogen monitoring and control systems mentioned in section 6.2.5.1 of the DCD are designed in accordance with 10CFR50.34 (f) (2) (ix). DCD Chapter 1 Table 1.9.3-2., 'Location of Description for Additional TMI-Related Requirements' will be revised to include 10CFR50.34(f)(2)(ix).

Impact on DCD

DCD Chapter 1 Table 1.9.3-2., 'Location of Description for Additional TMI-Related Requirements' will be revised with the following added row inserted after the row for 50.34(f) Item (2) (viii):

50.34(f) Item	Action Plan Item	Requirement	Location in DCD
(2)(ix)	II.B.8	Provide a system for hydrogen control that can safely accommodate hydrogen generated by the equivalent of a 100% fuel-clad metal water reaction. Preliminary design information on the tentatively preferred system option of those being evaluated in paragraph (f)(1)(xii) of this section is sufficient at the construction permit stage. The hydrogen control system and associated systems shall provide, with reasonable assurance, that: (A) Uniformly distributed hydrogen concentrations in the containment do not exceed 10% during and following an accident that releases an equivalent amount of hydrogen as would be generated from a 100% fuel clad metal-water reaction, or that the post-accident atmosphere will not support hydrogen combustion.	6.2.5.1

		(B) Combustible concentrations of hydrogen will not collect in areas where unintended combustion or detonation could cause loss of containment integrity or loss of appropriate mitigating features. (C) Equipment necessary for achieving and maintaining safe shutdown of the plant and maintaining containment integrity will perform its safety function during and after being exposed to the environmental conditions attendant with the release of hydrogen generated by the equivalent of a 100% fuel-clad metal water reaction including the environmental conditions created by activation of the hydrogen control system. (D) If the method chosen for hydrogen control is a post-accident inerting system, inadvertent actuation of the system can be safely accommodated during plant operation.	

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

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QUESTION NO. : 06.02.05-21

Clarify RG 1.7 title reference in DCD section 6.2.5-1.

DCD section 6.2.5.1 incorrectly refers to the title of RG 1.7 as "Control of Combustible Gas Concentrations in Containment following a loss of Coolant Accident" This is the title of the previous version of the RG (Revision 2) The title of the current version of the RG is "Control of Combustible Gas Concentrations in Containment". You reference RG 1.7 Revision 3 in reference 6.2-29. Confirm that the containment hydrogen monitoring and control system is designed in accordance with RG 1.7 Revision 3.

ANSWER:

The title of RG 1.7 in the text is incorrect. The reference correctly states RG 1.7, Revision 3 and the correct title. The system is designed in accordance with RG 1.7, Revision 3 listed in the references.

Impact on DCD

The title of RG 1.7 in the text of DCD Subsection 6.2.5.1 will be revised to correct title.

6.2.5.1 Design Bases

The containment hydrogen monitoring and control system is designed in accordance with 10CFR50.34(f)(2)(ix), "Additional TMI-related requirements;" 10CFR50.44, "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~~ Following a Loss-of-Coolant Accident~~;" and NUREGs 0737 and 0660, as presented in Section 1.9.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.