**MITSUBISHI HEAVY INDUSTRIES, LTD.**
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**TOKYO, JAPAN**

July 3, 2009

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-09345

**Subject: MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2**

Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") the document entitled "MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2". The enclosed materials provide MHI's response to the NRC's "Request for Additional Information (RAI) 310-2346 Revision 2," dated May 4, 2009.

As indicated in the enclosed materials, this document contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential. A non-proprietary version of the document is also being submitted in this package (Enclosure 3). In the non-proprietary version, the proprietary information, bracketed in the proprietary version, is replaced by the designation "[ ]".

This letter includes a copy of the proprietary version of the RAI response (Enclosure 2), a copy of the non-proprietary version of the RAI response (Enclosure 3), and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all material designated as "Proprietary" in Enclosure 2 be withheld from disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

Please contact Dr. C. Keith Paulson, Senior Technical Manager, Mitsubishi Nuclear Energy Systems, Inc., if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

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

D081
NRO

Enclosures:

1. Affidavit of Yoshiki Ogata
2. MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2 (proprietary)
3. MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2 (non-proprietary)

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

Contact Information

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## ENCLOSURE 1

Docket No. 52-021

MHI Ref: UAP-HF-09345

**MITSUBISHI HEAVY INDUSTRIES, LTD.**

**AFFIDAVIT**

I, Yoshiki Ogata, being duly sworn according to law, depose and state as follows:

1. I am General Manager, APWR Promoting Department, of Mitsubishi Heavy Industries, Ltd. ("MHI"), and have been delegated the function of reviewing MHI's US-APWR documentation to determine whether it contains information that should be withheld from disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2" dated July 3, 2009, and have determined that the document contains proprietary information that should be withheld from public disclosure. Those pages containing proprietary information are identified with the label "Proprietary" on the top of the page and the proprietary information has been bracketed with an open and closed bracket as shown here "[ ]". The first page of the document indicates that all information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The basis for holding the referenced information confidential is that it describes the unique design of the safety analysis, developed by MHI (the "MHI Information").

4. The MHI Information is not used in the exact form by any of MHI's competitors. This information was developed at significant cost to MHI, since it required the performance of research and development and detailed design for its software and hardware extending over several years. Therefore public disclosure of the materials would adversely affect MHI's competitive position.

5. The referenced information has in the past been, and will continue to be, held in confidence by MHI and is always subject to suitable measures to protect it from unauthorized use or disclosure.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information.

7. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of supporting the NRC staff's review of MHI's application for certification of its US-APWR Standard Plant Design.

8. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without the costs or risks associated with the design and testing of new systems and components. Disclosure of the information identified as proprietary would therefore have negative impacts on the competitive position of MHI in the U.S. nuclear plant market.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 3rd day of July, 2009.

Y. Ogata

Yoshiki Ogata

ENCLOSURE 3

UAP-HF-09345
Docket No. 52-021

MHI's Response to US-APWR DCD RAI No. 310-2346 Revision 2

July 2009

(Non-Proprietary)

## RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**7/03/2009**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

| | |
|---|---|
| **RAI NO.:** | **NO. 310-2346 REVISION 2** |
| **SRP SECTION:** | **15.04.03 – CONTROL ROD MISOPERATION (SYSTEM MALFUNCTION OR OPERATOR ERROR)** |
| **APPLICATION SECTION:** | **15.4.3** |
| **DATE OF RAI ISSUE:** | **5/04/2009** |

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**QUESTION NO.: 15.4.3-1**

In Section 15.4 it states, "The uncontrolled withdrawal of a single RCCA and the spectrum of rod ejection are classified as postulated accidents (PAs)." Provide explicit details and a probabilistic analysis justifying the reclassification of RCCA withdrawal. Specifically, the staff requests the applicant to provide risk assessment studies and radiological consequences for RCCA withdrawal.

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**ANSWER:**

The uncontrolled withdrawal of a single RCCA event cannot be caused by a single failure or malfunction; this event occurs only in the case of multiple failures. As a result MHI considers this event to be a PA rather than an AOO.

The evidence for this conclusion is given in Appendix A to this response. A system description and failure modes and effects analysis (FMEA) are provided there to support this conclusion. The fault tree analysis (FTA) and probability estimation are shown in Appendix-B. The frequency of this event is estimated as 4.7E-4 per year. This frequency is a factor of two lower than the typical frequencies of PAs and two orders of magnitude lower than the typical frequencies of AOOs. From a probabilistic point of view, the uncontrolled withdrawal of a single RCCA event can be categorized as a PA rather than an AOO.

As described in DCD Subsection 15.4.3.3.3.3, the minimum DNBR is above the 95/95 limit using a more detailed analysis method. Therefore, dose and risk evaluations are unnecessary.

## Appendix A The Failure Mode for a Single RCCA Withdrawal

### A.1. System Description

The system for the control rod drive mechanism (CRDM) control is divided into several parts as shown in Figure A.1-1. These divisions are the Logic Cabinet (processing part and output part), the Power Cabinet (transformer part, Molded Case Circuit Breaker [MCCB] part, and current control unit part) in the control rod drive mechanism control system (CRDMCS) and the Coils (stationary gripper [S/G] coil, movable gripper [M/G] coil, LIFT coil).

The CRDMCS in the plant control and monitoring system (PCMS) adjusts the position of the control rod banks in the reactor core. Each control rod bank is divided into two or more groups to obtain smaller incremental reactivity changes per step. The control rod groups within the same bank are moved such that the relative position of the groups does not differ by more than one-step. Each control rod in a group is paralleled so that rods of the same group move simultaneously. Power to the CRDMs is supplied by motor-generator sets. AC power is distributed to the CRDMCS power cabinet through reactor trip breakers (RTBs) and the CRDM distribution panel. The CRDMCS consists of a logic cabinet and power cabinet. The PCMS controller group of the CRDMCS is located within the logic cabinet. The logic cabinet consists of microprocessor-based digital systems with redundant controllers. The controller group controls solid-state CRDM power supplies that are located in the power cabinet. The mechanical part of the CRDM, which consists of the S/G, M/G, and LIFT mechanisms, is actuated by the coil current generated from the control signals from the CRDMCS through the S/G coil, M/G coil, and LIFT coil. These mechanical parts adjust the control rods directly.

The detailed system descriptions for the CRDM and CRDMCS are provided in the US-APWR DCD Subsections 3.9.4.1.1 and 7.7.1.3, respectively.

There are 69 control rods for the US-APWR. The control rods are controlled bank by bank or group by group. The segmentation of the control rod bank and control rod group is shown in Figure A.1-2.

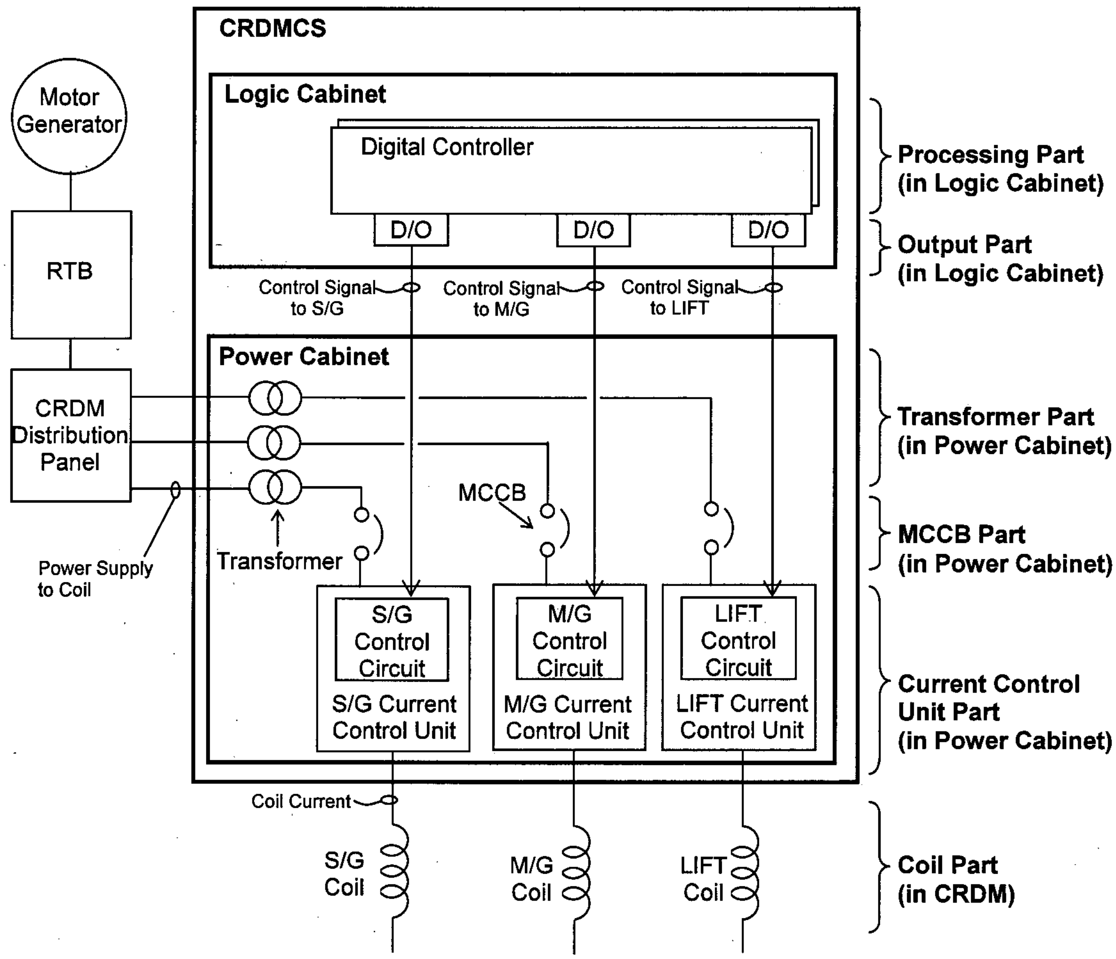


**Figure A.1-1 CRDMCS Configuration**

**Figure A.1-2 Segmentation of Control Rod Bank and Group**

## A.2. Failure Modes and Effects Analysis

This section describes the failure modes and effects analysis (FMEA) on each CRDMCS component. Technical Report MUAP-07015 provides the FMEA of the CRDMCS for the US-APWR. The report provides a description and the configuration of the CRDMCS for FMEA. The FMEA demonstrates the achievement of safety functions during the single failure of each component of CRDMCS. Table A.2-1 shows the FMEA summary. Additional information for components related to electrical power has also been added. When a single failure occurs in the CRDMCS and related electrical power components, control rods are either dropped or are inoperable. The withdrawal of a single control rod cannot occur through a single failure. Thus the withdrawal of a single control rod can be defined as an event beyond a single failure (i.e., a postulated accident) based on the FMEA.

**Table A.2-1**
**FMEA Summary of CRDMCS**

| **Component** | **Failure Mode** | **Failure Effect** |
|---|---|---|
| Motor Generator | Loss of Power Supply | Rod drop due to loss of power supply. |
| RTB | Loss of Power Supply | Rod drop due to loss of power supply. |
| CRDM Distribution Panel | Loss of Power | Rod drop due to loss of power supply. |
| **CRDMCS Logic Cabinet** Processing Part | Fail due to no data output | Processing Part consists of two digital controllers. One operates in Control Mode while the other operates in Standby Mode. One digital controller operating in Standby Mode will automatically switch to Control Mode due to its Redundant Standby Controller Configuration. |
| **CRDMCS Logic Cabinet** Output part to S/G Coil | Fail ON | S/G coils are ON state; this causes S/G latches of one group to be closed. |
| | Fail OFF | S/G coils are OFF state; this causes control rods to drop due to S/G latches of one group being open when control rods are operating. |
| **CRDMCS Logic Cabinet** Output part to M/G Coil | Fail ON | M/G coils are ON state; this causes M/G latches of one group to be closed. |
| | Fail OFF | M/G coils are OFF state; this causes control rods to drop due to M/G latches of one group being open when control rods are operating. |
| **CRDMCS Logic Cabinet** Output part to LIFT Coil | Fail ON | LIFT coils are maintained their hold-up state; this causes control rods of one group to be inoperable. |
| | Fail OFF | LIFT coils will be inoperable; this causes control rods of one group to be inoperable when control rods are operating. |
| **CRDMCS Power Cabinet** Transformer for S/G Coil | Failure due to disconnection or short circuit | Rods drop due to S/G latches of one cabinet (three groups) being open when control rods are operating. |
| **CRDMCS Power Cabinet** Transformer for M/G Coil | Failure due to disconnection or short circuit | Control rods drop due to M/G latches of one cabinet (three groups) being open when control rods are operating. |
| **CRDMCS Power Cabinet** Transformer for LIFT Coil | Failure due to disconnection or short circuit | Control rods of one cabinet (three groups) are inoperable when control rods are operating. |
| **CRDMCS Power Cabinet** MCCB for S/G Current Control Unit | Failure due to breaking or overcurrent | Control rods drop due to S/G latches of one cabinet (three groups) being open when control rods are operating. |
| **CRDMCS Power Cabinet** MCCB for M/G Current Control Unit | Failure due to breaking or overcurrent | Control rods drop due to M/G latches of one cabinet (three groups) being open when control rods are operating. |
| **CRDMCS Power Cabinet** MCCB for LIFT Current Control Unit | Failure due to breaking or overcurrent | Related control rods of the selected group are inoperable. |
| **CRDMCS Power Cabinet** S/G Current Control Unit | Failure due to spurious actuation | S/G latches of one group are closed, or control rods drop due to S/G latches of one group being open when control rods are operating. |
| | Inoperable | S/G latches of one group are inoperable. |

| Component | Failure Mode | Failure Effect |
|---|---|---|
| **CRDMCS Power Cabinet**<br>M/G Current Control Unit | Failure due to spurious actuation | M/G latches of one group are closed, or control rods drop due to M/G latch of one group being opened when control rods are operating. |
| | Inoperable | M/G latches of one group are inoperable. |
| **CRDMCS Power Cabinet**<br>LIFT Current Control Unit | Failure due to spurious actuation | Related control rods of the selected group are inoperable. |
| | Inoperable | Related control rods of the selected group are inoperable. |
| **CRDM Coil**<br>S/G Coil | Failure due to disconnection or short circuit | Control rods drop due to S/G latch of the related control rods being open. |
| **CRDM Coil**<br>M/G Coil | Failure due to disconnection or short circuit | Control rods drop due to M/G latch of the related control rods being open. |
| **CRDM Coil**<br>LIFT Coil | Failure due to disconnection or short circuit | Related control rods are inoperable. |

## A.3. Identification of Scenarios for Uncontrolled Withdrawal of a Single Rod

This section provides identification of the scenarios where the withdrawal of a single rod can occur.

**Figure A.3-1 Configuration of Lift Coil Control in Power Cabinet**

The possibility of the withdrawal of a single rod is summarized as follows:

Therefore, it is concluded that an uncontrolled withdrawal of a single RCCA event cannot be caused by a single failure or malfunction; this event occurs only in the case of multiple failures. As a result MHI considers this event to be a PA rather than an AOO.

## Appendix-B Probabilistic Analysis Justifying the Reclassification of RCCA Withdrawal

### B.1. Quantification of Uncontrolled Withdrawal of a Single RCCA Event Frequency

The frequency of an uncontrolled withdrawal of a single RCCA event during at-power operation has been quantified by a fault tree analysis (FTA). Combinations of failures that can result in the uncontrolled withdrawal of a single RCCA are summarized in Appendix A Section A.3.

The rod withdrawal signal can be actuated either by a malfunction of the CRDMCS or by normal control during plant operation. The frequency of a spurious rod withdrawal signal occurrence was evaluated from the failure rate of the CRDMCS causing such signals. The estimated yearly frequency of spurious rod withdrawal signals is shown in Table B.1-1. Considering load power operation, it is assumed that a normal control rod withdrawal signal is initiated two times per day. The frequency of normal rod control signals per day was rounded up to five times per day to conservatively estimate the yearly frequency of normal rod control initiation. The frequency of rod withdrawal signal caused by normal rod control was thus estimated to be 1825 times per year.

Unavailability of CRDM lift coils, lift coil units and signal output circuits were estimated from their failure rates and intervals of verified functional operability. Failure of LIFT coils, LIFT coil units and signal output circuits that occur during normal rod control are likely to be recognized by the operator since such failure will cause an unexpected response of the reactor or unexpected rod position indication. Therefore, it is expected that the operability of these devices are verified each time a rod control operation is performed. Taking into consideration load power operation, operability of CRDM LIFT coils, LIFT coil units and signal output circuits are assumed to be verified every 4 to 12 hours. Here, it is assumed that the operability of the devices are verified every 12 hours.

The unavailability of failure detection circuits were also estimated from their failure rates and intervals of verified functional operability. It is assumed that the failure of the failure detection circuits can only be identified during refueling outages, which is planned every 24 months.

Failure rates of the devices that can potentially result in an unexpected single rod event are shown in Table B.1-1. The test interval, which is defined here as the average interval between times the operability of the devices has been checked and unavailability of the devices, are also shown in Table B.1-1.

Common cause failures of the LIFT coils and LIFT coil current control units that result in 3 out of 4 LIFT coil failures were estimated using the Multiple Greek Letter (MGL) Method, which is a standard methodology to quantify common cause failure probabilities. MGL parameters for generic components reported in NUREG/CR-5485 were applied in this analysis.

The frequency of the uncontrolled withdrawal of a single RCCA event is estimated to be 4.7E-4 per year.

**Table B.1-1**
**Failure Rates of Devices Related to Single Rod Withdrawal Event**

## B.2. Comparison of Calculated Event Frequency with Other AOO and PA Frequencies

The yearly frequencies of postulated accidents (PAs) and Anticipated Operational Occurrences (AOOs) expected for the US-APWR design are estimated in the probabilistic risk assessment described in Chapter 19 of the DCD. Frequencies of typical postulated accidents are listed below.

- Small pipe break LOCA: 3.6E-3 /RY
- Steam generator tube rupture: 4.0E-3 /RY
- Steam line break: 1.1E-2 /RY
- Feed water line break: 3.4E-3 /RY

Frequencies of typical AOOs are listed below.

- Loss of feed water flow :1.9E-1 /RY
- Loss of offsite power :4.0E-2 /RY

The frequency of uncontrolled withdrawal of a single RCCA event, which is 4.7E-4 per year, is a factor of two lower than the frequencies of PAs and two order of magnitudes lower than the frequencies of AOOs. From a probabilistic point of view, the uncontrolled withdrawal of a single RCCA can be categorized as a PA rather than an AOO.

**Figure B.1-1 Fault Tree Analysis for Uncontrolled Withdrawal of a Single RCCA**

**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

**7/03/2009**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

| | |
|---|---|
| **RAI NO.:** | **NO. 310-2346 REVISION 2** |
| **SRP SECTION:** | **15.04.03 – CONTROL ROD MISOPERATION (SYSTEM MALFUNCTION OR OPERATOR ERROR)** |
| **APPLICATION SECTION:** | **15.4.3** |
| **DATE OF RAI ISSUE:** | **5/04/2009** |

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**QUESTION NO.: 15.4.3-2**

Provide a list of the various combinations of dropped RCCA locations and rod worths that are used to identify the limiting hot channel factor for that event.

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**ANSWER:**

The RCCA drop analysis has been performed for BOC, MOC (the burnup step where $F_{\Delta H}^{N}$ takes the maximum value during the cycle), and EOC of the first cycle described in Section 4.3 of the US-APWR DCD assuming one RCCA dropped from the All Rod Out (ARO) position. The combinations of dropped RCCA locations and rod worths at BOC, MOC, and EOC are shown below in Table 15.4.3-2.1 along with the hot channel factors. Both the dropped rod worths and hot channel factors in the table include[ ]margin for conservatism. The identifiers for the control rod locations are shown in Figure 15.4.3-2.1.

The RCCA drop analysis has also been performed for multiple dropped RCCAs for BOC, MOC, and EOC for the first cycle. The combinations of dropped RCCA locations and rod worths for all three times in core life are shown below in Table 15.4.3-2.2 along with the hot channel factors. The cases in Table 15.4.3-2.2 consider all possible combinations of multiple dropped RCCAs within a group, including asymmetric distributions due to one rod being assumed stuck in the group. The identifiers for the control rod locations are also shown in Figure 15.4.3-2.1.

Figure 15.4.3-2.2 provides the minimum DNBR versus dropped RCCA worth of all of the multiple RCCA drop cases indicated in Table 15.4.3-2.2. As shown in the figure, the minimum DNBR of the single dropped RCCA case analyzed in the DCD bounds the minimum DNBR of all of the multiple dropped RCCA cases. Note that the multiple RCCA drop analysis credits the high neutron flux negative rate trip.

**Table 15.4.3-2.1**
**Possible Locations and Parameters for Single RCCA Drop**
**(Sheet 1 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| BOC | | | |
| 1 | J-09 | | |
| 2 | J-11 | | |
| 3 | J-13 | | |
| 4 | J-15 | | |
| 5 | H-16 | | |
| 6 | G-11 | | |
| 7 | G-13 | | |
| 8 | G-15 | | |
| 9 | F-16 | | |
| 10 | E-13 | | |
| 11 | E-15 | | |
| 12 | D-14 | | |
| 13 | C-15 | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1

**Table 15.4.3-2.1**
**Possible Locations and Parameters for Single RCCA Drop**
**(Sheet 2 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| MOC | | | |
| 1 | J-09 | | |
| 2 | J-11 | | |
| 3 | J-13 | | |
| 4 | J-15 | | |
| 5 | H-16 | | |
| 6 | G-11 | | |
| 7 | G-13 | | |
| 8 | G-15 | | |
| 9 | F-16 | | |
| 10 | E-13 | | |
| 11 | E-15 | | |
| 12 | D-14 | | |
| 13 | C-15 | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1

**Table 15.4.3-2.1**
**Possible Locations and Parameters for Single RCCA Drop**
**(Sheet 3 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| EOC | | | |
| 1 | J-09 | | |
| 2 | J-11 | | |
| 3 | J-13 | | |
| 4 | J-15 | | |
| 5 | H-16 | | |
| 6 | G-11 | | |
| 7 | G-13 | | |
| 8 | G-15 | | |
| 9 | F-16 | | |
| 10 | E-13 | | |
| 11 | E-15 | | |
| 12 | D-14 | | |
| 13 | C-15 | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1

**Table 15.4.3-2.2**
**Possible Combinations and Parameters for Multiple RCCA Drop within a Group**
**(Sheet 1 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| BOC | | | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| 22 | | | |
| 23 | | | |
| 24 | | | |
| 25 | | | |
| 26 | | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1
**Considering 1 rod stuck

**Table 15.4.3-2.2**
**Possible Combinations and Parameters for Multiple RCCA Drop within a Group**
**(Sheet 2 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| MOC | | | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
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| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| 22 | | | |
| 23 | | | |
| 24 | | | |
| 25 | | | |
| 26 | | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1
**Considering 1 rod stuck

**Table 15.4.3-2.2**
**Possible Combinations and Parameters for Multiple RCCA Drop within a Group**
**(Sheet 3 of 3)**

| No. | Dropped Rod Identifier* | Dropped Rod Worth(%Δk/k) | Hot Channel Factor |
|---|---|---|---|
| EOC | | | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |
| 19 | | | |
| 20 | | | |
| 21 | | | |
| 22 | | | |
| 23 | | | |
| 24 | | | |
| 25 | | | |
| 26 | | | |

*Consistent with the identifier shown in Figure 15.4.3-2.1
**Considering 1 rod stuck

**Figure 15.4.3-2.1 US-APWR RCCA Locations Including Group Information**

Figure 15.4.3-2.2 Minimum DNBR for all Rod Drop Cases

**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

**7/03/2009**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

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| **APPLICATION SECTION:** | **15.4.3** |
| **DATE OF RAI ISSUE:** | **5/04/2009** |

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**QUESTION NO.: 15.4.3-3**

Discuss how does the assumed dropped rod worth of 0.25% compare with the actual maximum dropped rod worth?

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**ANSWER:**

The assumed dropped rod worth of 0.25%Δk/k used in the safety analysis has been determined to bound the maximum calculated dropped rod worths for one RCCA drop events. These analyses were performed for BOC, MOC (the burnup step where $F_{\Delta H}^{N}$ takes the maximum value during the cycle), and EOC of the first cycle described in Section 4.3 of the US-APWR DCD assuming that one RCCA was dropped from the All Rod Out (ARO) position.

The maximum values, including [ ] margin for conservatism, are shown in Table 15.4.3-3.1. All the values in the table are bounded by the assumed dropped rod worth of 0.25%Δk/k with sufficient margin.

**Table 15.4.3-3.1 Maximum Reactivity Worth of Dropped Rods**

| | Dropped Rod Worth (%Δk/k) |
|---|---|
| BOC | [ |
| MOC | |
| EOC | ] |

**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**

7/03/2009

**US-APWR Design Certification**

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| **DATE OF RAI ISSUE:** | **5/04/2009** |

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**QUESTION NO.: 15.4.3-4**

Discuss how does the assumed hot channel factor of 1.90 compare to the maximum value expected during a dropped rod event?

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**ANSWER:**

The assumed hot channel factor ($F_{\Delta H}^{N}$) of 1.90 used in the safety analysis has been determined to bound the maximum calculated hot channel factors for one RCCA drop events. These analyses were performed for BOC, MOC (the burnup step where $F_{\Delta H}^{N}$ takes the maximum value during the cycle), and EOC of the first cycle described in Section 4.3 of the US-APWR DCD assuming that one RCCA was dropped from the All Rod Out (ARO) position.

The maximum values, including[ ]margin for conservatism, are shown in Table 15.4.3-4.1. All the values in the table are bounded by the assumed hot channel factor ($F_{\Delta H}^{N}$) of 1.90 with sufficient margin.

**Table 15.4.3-4.1 Maximum Hot Channel Factors ($F_{\Delta H}^{N}$) Expected During a Dropped Rod Event**

| | Hot Channel Factor |
|---|---|
| BOC | |
| MOC | |
| EOC | |

**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.: 15.4.3-5**

Calculations were carried out to determine the limiting configuration with one or more misaligned RCCAs. What configurations were sampled? It is assumed that the limiting misalignment is with one RCCA completely withdrawn. What is the effect of two RCCAs, or a control rod group, withdrawn?

---

**ANSWER:**

It is MHI's position that to misalign more than one RCCA within a group or one RCCA in more than one group would require multiple failures and is therefore not an AOO, but a PA. However, consistent with the SRP, MHI has analyzed multiple misaligned RCCAs as described in this response.

The sampled configurations include one RCCA completely withdrawn or inserted and the other RCCAs at the insertion limits. These are the extreme cases of misalignment compared to the maximum possible misalignment of ±24 steps considering the accuracy of RPI (Rod Position Indicator). The general limiting configuration was described in DCD Subsection 15.4.3.3.2.2, but since the limiting configuration may vary for different cores, the DCD will be revised as shown below.

Table 15.4.3-5.1 below shows the results of core analyses for the first cycle described in Section 4.3 of the US-APWR DCD performed assuming one or more RCCAs misaligned by ±24 steps. The table shows that $F^N_{\Delta H}$ with the configuration of one RCCA fully withdrawn or inserted bounds the other configurations of one or more RCCAs misaligned. The $F^N_{\Delta H}$ values in Table 15.4.3-5.1 include[ ]margin for conservatism.

To assure sufficient margin, a bounding $F^N_{\Delta H}$ value of 1.90 was used for the safety analysis as described in the DCD Subsection 15.4.3.3.2.2.

**Table 15.4.3-5.1 $F^{N}_{\Delta H}$ Evaluation Results with One or More RCCAs Misaligned**

| RCCA Status | $F^{N}_{\Delta H}$ |
|---|---|
| | |
| | |
| | |
| | |
| | |

*1 Maximum value of all the combinations of RCCAs misaligned within Control Bank-D

**Impact on DCD**

The limiting configuration for the misalignment may vary for different cores. Therefore, the statement in DCD Subsection 15.4.3.3.2.2 that was meant to generally describe the limiting configuration will be removed since it may not be correct for all core and cycles. This change to DCD Subsection 15.4.3.3.2.2 is shown as follows:

- Various static rod misalignment scenarios are identified and modeled for the purpose of defining the limiting nuclear enthalpy rise hot channel factor for use in the DNBR channel analysis. Scenarios considered include, but are not limited to, a single RCCA fully inserted, one RCCA fully withdrawn with the remaining bank RCCAs at their insertion limits, and other intermediate misalignment conditions. ~~The limiting RCCA misalignment for the analysis is assumed to be one RCCA fully withdrawn with the remaining RCCAs in the bank at their insertion limit.~~

**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.: 15.4.3-6**

It is stated that the minimum DNBR calculated for the misaligned RCCA satisfies the acceptance criterion. What is the calculated value for the minimum DNBR?

---

**ANSWER:**

The bounding nuclear enthalpy rise hot channel factor ( $F_{\Delta H}^{N}$ ) is 1.90 for this event as described in DCD Subsection 15.4.3.3.2.2. MHI has performed VIPRE01-M static calculations based on this bounding $F_{\Delta H}^{N}$. The calculated value of minimum DNBR is [ ].

**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.: 15.4.3-7**

What are the configurations sampled to determine the limiting condition for the uncontrolled withdrawal of an RCCA? (See also Question 15.4.3-5)

---

**ANSWER:**

The sampled configuration is one RCCA completely withdrawn and the other RCCAs at the insertion limits. Each single RCCA belonging to Control Bank-D was withdrawn to determine the worst case. This is consistent with the response to Question 15.4.3-5 of this RAI. Consequently, a bounding $F^N_{\Delta H}$ value of 1.90 was used for the safety analysis.

**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.: 15.4.3-8**

For the withdrawal of a single RCCA, it is understood that the minimum DNBR at the hot spot will not satisfy the 95/95 limits. Discuss how the number of rods below the DNBR limit is obtained?

---

**ANSWER:**

For this event, a single RCCA is withdrawn and positive reactivity is inserted into the core. The plant transient response for this event is basically the same as for the uncontrolled RCCA bank withdrawal at power event, except that the distortion of the radial power distribution is larger. This is because only one RCCA is withdrawn and there is no symmetry in the radial power distribution in the single RCCA withdrawal. Thus, based on the MARVEL-M input file for the uncontrolled RCCA bank withdrawal at power event, a sensitivity analysis of the heat flux due to the distortion of the radial power distribution is done and a search is performed for the nuclear enthalpy rise hot channel factor ($F_{\Delta H}^{N}$) that just gives DNB occurrence in the number of rods in DNB evaluation. The number of rods in DNB is obtained by the $F_{\Delta H}^{N}$ in which the DNBR reaches the safety analysis limit and the $F_{\Delta H}^{N}$ census curve for this event. The reactivity insertion continues until the reactor trips in the uncontrolled RCCA bank withdrawal at power event, but since the reactivity insertion is a finite value for this event, the evaluation method is conservative. This methodology is the same as the evaluation of the number of rods in DNB for the spectrum of RCCA ejection event which is shown in Figure 5.3-3 of the Non-LOCA Methodology Topical Report (MUAP-07010). The conceptual diagram of the number of rods in DNB evaluation for the single RCCA withdrawal event is shown below in Figure 15.4.3-8.1.

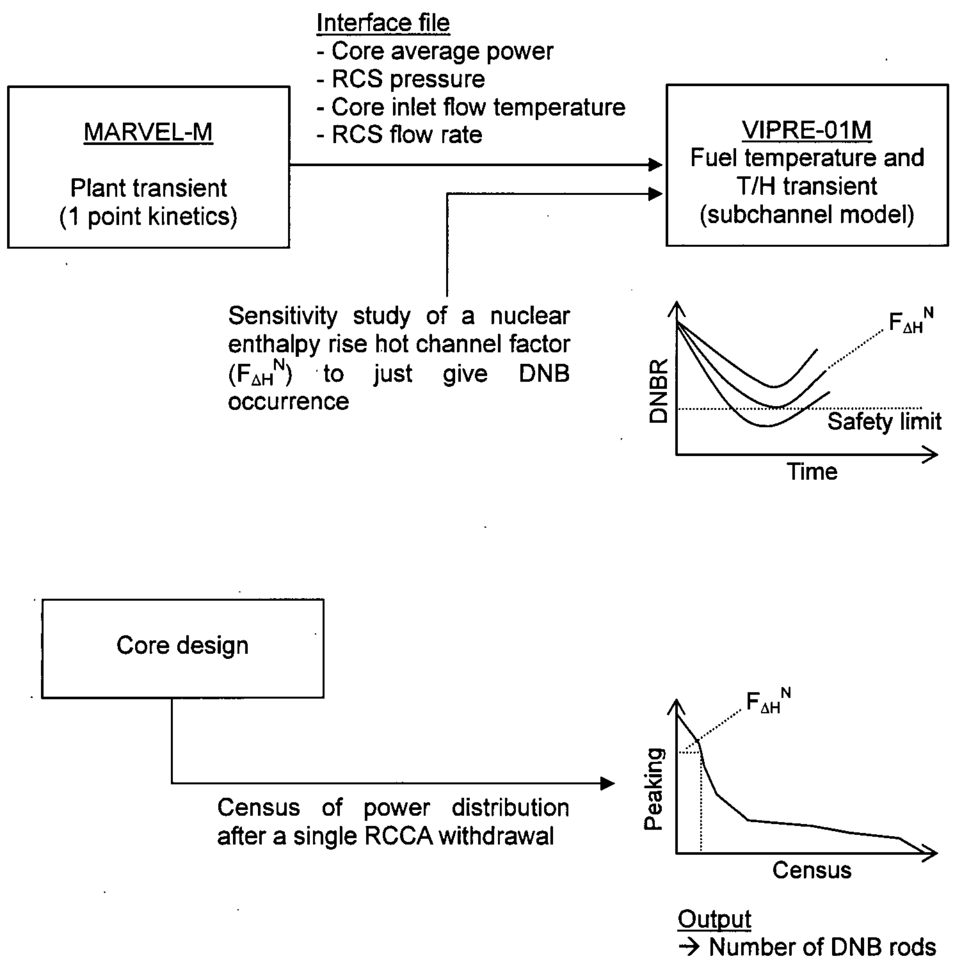


**Figure 15.4.3-8.1 Calculation Flow Diagram of the Number of Rods in DNB Methodology**

**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.: 15.4.3-9**

What is the fuel centerline temperature for the withdrawal of a single RCCA?

---

**ANSWER:**

As stated in DCD Subsection 15.4.3.3.3.3, using a more detailed analysis method, the minimum DNBR is above the 95/95 limit and no fuel failures are predicted. Consistent with the assumption of no DNB, this case was re-analyzed to calculate peak fuel centerline temperature. The initial conditions were changed to estimate the fuel temperature conservatively. The initial power level is 102% of the licensed core thermal power level with an initial reactor coolant temperature 4°F above the nominal value and a pressurizer pressure 30 psi below the nominal value. This combination of uncertainties for the initial conditions maximizes the fuel centerline temperature. The reactivity insertion rate of( )maximizes fuel centerline temperature for the case at 100% power. The hot channel factor is assumed to be( ). The uncertainty in fuel temperature is added to the fuel initial temperature. The calculation results are indicated below in Figures 15.4.3-9.1 and 15.4.3-9.2 and in Table 15.4.3-9.1. The maximum fuel centerline temperature for this analysis is( )which is less than the fuel pellet melting temperature. The fuel pellet melting temperature is a function of burnup and is calculated per the methodology described in DCD Subsection 4.2.1.2.1.

**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.

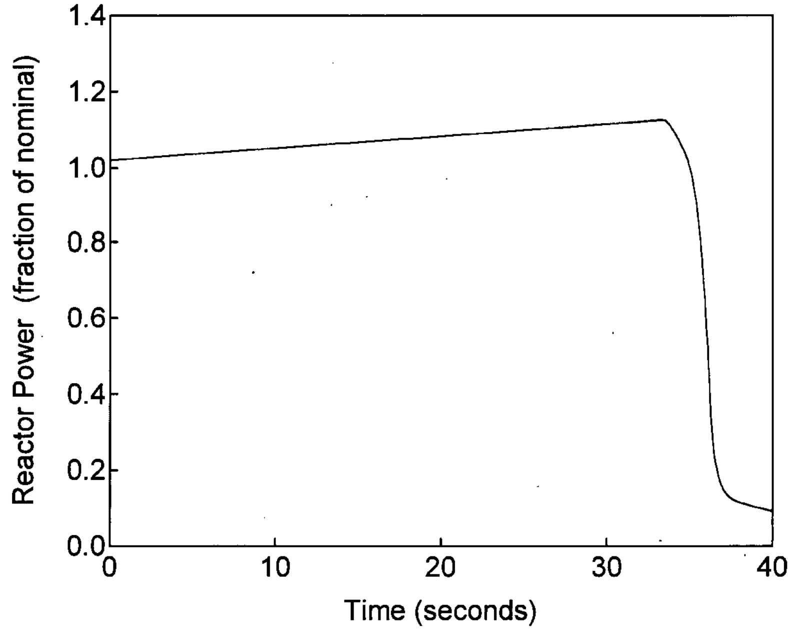


**Figure 15.4.3-9.1** **Reactor Power versus Time**
**Uncontrolled Withdrawal of a Single RCCA**

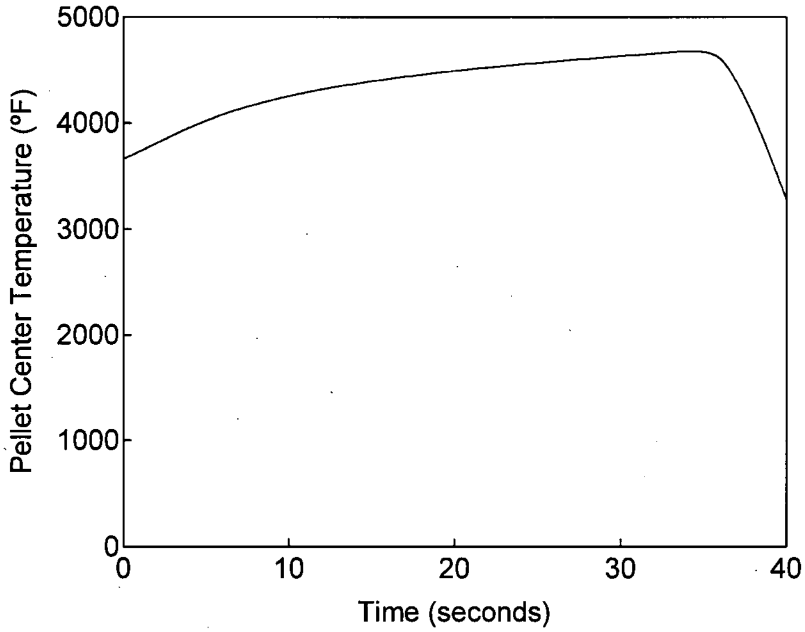


**Figure 15.4.3-9.2** **Fuel Temperature versus Time**
**Uncontrolled Withdrawal of a Single RCCA**

Table 15.4.3-9.1
Time Sequence of Events for Uncontrolled Withdrawal of a Single RCCA

| Event | Time (sec) |
|---|---|
| RCCA withdrawal begins | 0.0 |
| Over temperature ΔT analytical limit reached | 27.2 |
| Reactor trip initiated (rod motion begins) | 33.2 |
| Peak pellet center temperature occurs | 34.2 |

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**QUESTION NO.: 15.4.3-10**

Specify which steady-state core design codes were used throughout the analysis and include references to the codes. Be specific with code versions and provide reference.

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**ANSWER:**

As described in Subsection 15.0.2.2.5 and Table 15.0-1 of US-APWR DCD, the ANC code was used for the steady-state core analysis. The methodology is described in DCD Subsection 4.3.3.1 and no changes have been made to the approved methodology described in the topical reports: References 4.3-12, 4.3-14, and 4.3-15 of DCD Subsection 4.3.6.

**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.: 15.4.3-11**

Demonstrate that the limiting RCCA misalignment is one RCCA fully withdrawn with the remaining RCCAs in the bank at their insertion limits.

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**ANSWER:**

Please refer to the response to Question 15.4.3-5 of this RAI.

**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.