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MFN 09-407 Docket No. 52-010

June 18, 2009

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 342 Related to ESBWR Design Certification Application ESBWR RAI Number 19.2-127**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) dated May 15, 2009 (Reference 1). The response to RAI Number 19.2-127 is in Enclosure 1. DCD markups are in Enclosure 2.

If you have any questions or require additional information, please contact me.

Sincerely,

Lee F. Dougherty for

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 09-332, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, GEH, *Request For Additional Information Letter No. 342 Related To ESBWR Design Certification Application*, dated May 14, 2009.

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 342 Related to ESBWR Design Certification Application Probabilistic Risk Assessment RAI Number 19.2-127

2. DCD Revision 6 Markups

cc:	AE Cubbage	USNRC (with enclosure)
	JG Head	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRFSection	0000-0103-1723

Enclosure 1

MFN 09-407

Response to Portion of NRC Request for

Additional Information Letter No. 342

Related to ESBWR Design Certification Application

Probabilistic Risk Assessment

RAI Number 19.2-127

NRC RAI 19.2-127

Question Summary: Provide an analysis of the effects of erosion of sacrificial concrete.

Full Text:

The NRC staff discovered that a change had been made by GEH in the type of material on the lower drywell floor that would lie above the Basemat Internal Melt Arrest and Coolability (BIMAC). Instead of zirconia, a concrete sacrificial layer would be used. Please provide an analysis of the effects of erosion of the sacrificial concrete above the BIMAC on containment integrity during representative severe accident scenarios. The analyses need to consider the following:

- *the effects of gases and fission product aerosols produced from the core debris/concrete interactions (CCI) on PCCS performance and pressure increases in the containment regions;*
- *ranges of potential containment failure times for the representative scenarios;*
- *any changes to the release category frequencies and the large release frequency (LRF), relative to those reported in Revision 3 of the ESBWR PRA;*

and

- *changes to the fission product releases to the environment for the representative scenarios, relative to those reported in Revision 3 of the ESBWR PRA.*

Please provide any design requirements for the concrete type (e.g., composition), and modify the DCD appropriately.

Please include the appropriate changes in Revision 4 of the PRA and Revision 6 of the DCD to reflect the responses to this RAI.

GEH Response

The effects of the erosion of the concrete used as a Protective Layer on the Basemat Internal Melt Arrest and Coolability (BiMAC) component are evaluated below.

The Modular Accident Analysis Program (MAAP) version 406 was used to analyze the effects of gases and fission product aerosols produced from the core debris/concrete interactions (CCI) of the concrete to be used to cover the BiMAC.

References

1. **ESBWR PRA Section 21 Severe Accident Management,** *Revision 3, May 2008.*
2. **ESBWR Licensing Topical Report – The MAC Experiments: Fine Tuning of the BiMAC Design NEDE-33392P,** *Revision 0, March 2008.*
3. **ESBWR Design Control Document Tier 2 Chapter #19,** *26A6642BY, Revision 5, May 2008.*

Assumptions

The results for PRA Section 9 Revision 4 were used for comparison. This was done to better illustrated the effects due to CCI of the concrete covering the BiMAC.

Analysis

The BiMAC was originally designed using zirconia as a protective layer for the BiMAC pipes lining the lower drywell floor [Reference 1]. As a result of prototype testing of the BiMAC design [Reference 2], it was determined that a layer of concrete can be used to protect the BiMAC pipes until the deluge system floods the BiMAC and lower drywell.

The models in MAAP406 predict that the overlying pool will cool the corium pool and stop CCI early. However due to uncertainties concerning the heat transfer between a debris bed and an overlying water pool, CCI of concrete used to cover the BiMAC was investigated. A protective layer of concrete 0.5 m (1.6 ft) thick was assumed. The input heat transfer characteristics were adjusted so that CCI would take place until concrete is eroded to a depth of 0.5 m (1.6 ft). At this point, the MAAP models were returned to default values which resulted in halting CCI. This initial CCI releases non-condensable gases and fission product aerosols into containment.

The release of CCI generated aerosols into the lower drywell when flooded is addressed in the response to RAI 19.1-8 and does not impact PCCS performance.

The representative sequences for the Section 9 Source Terms were analyzed using MAAP as follows:

- Case 1 - BOCsd_nIN: this run was re-evaluated considering CCI to a depth of 0.5 m.
- Case 2 - BOCdr_nIN: this run was re-evaluated considering CCI to a depth of 0.5 m and late injection.
- Case 3 - T_nIN_BYP: this run was re-evaluated considering CCI to a depth of 0.5 m.
- Case 4 - T_nDP_nIN_BYP: this run was re-evaluated considering CCI to a depth of 0.5 m and late injection.

- Case 5 - T_nIN_nD_CCID: this run was not evaluated as it already models CCI via failure of deluge to actuate.
- Case 6 - T_nDP_nIN_nD_CCID: this run was not evaluated at it already models CCI via failure of deluge to actuate.
- Case 7 - T_nIN_CCIW: this run was not evaluated as it already models CCI via failure of BiMAC to cool the corium pool from below and overlying pool from above.
- Case 8 - T_nDP_nIN_CCIW: this run was not evaluated as it already models CCI via failure of BiMAC to cool the corium pool from below and overlying pool from above.
- Case 9 - T_nIN_nD_EVE: this run was not evaluated at it already includes CCI via failure of deluge to actuate with containment failure at the time of RPV failure.
- Case 10 - T-AT_nIN_nCHR_FR: this run was re-evaluated considering CCI to a depth of 0.5 m.
- Case 11 - T_nDP_nIN_VB: this run was re-evaluated considering CCI to a depth of 0.5 m and late injection.
- Case 12 - T_nIN_VB: this run was re-evaluated considering CCI to a depth of 0.5 m.
- Case 13 - T_nDP_nIN_nCHR_W1: this run was re-evaluated considering CCI to a depth of 0.5 m and late injection.
- Case 14 - T_nDP_nIN_nCHR_W2: this run was re-evaluated considering CCI to a depth of 0.5 m and late injection.
- Case 15 - T_AT_nIN_TSL2x: this run was re-evaluated considering CCI to a depth of 0.5 m.

Previous studies of release categories in Section 9 of the PRA have showed that as the overlying pool is lost due to decay heat evaporating water which escapes through the containment failure, the CsI release fraction increases. This is predicted in most cases in which it occurs 48 hours after the beginning of the sequence. In this analysis it occurs sooner than in the previous analysis but not dramatically different. Since there are multiple ways to inject water into the ESBWR containment, this analysis models external injection 48 hours after the beginning of the sequence for Cases 2, 11, 13 and 14 to better represent expected recovery 2 days into an event.

The results from this analysis are evaluated in the following sections for each item requested in the RAI.

Representative sequences in Case 5 – 9 are not affected by this analysis since the previous evaluations of these representative sequences included CCI which continued through the sequence.

PCCS Effectiveness and Pressure Increases in Containment

Sequences Not Affected:

PCCS effectiveness in Cases 1-4 is not affected due to the assumed break outside of containment in Cases 1 and 2 and containment bypass in Cases 3 and 4. Cases 10 and 13 assumed PCCS was not available as part of the sequence. Cases 11 and 12 include failure of the drywell to wetwell vacuum breakers which fails PCCS irrespective of the CCI of the BiMAC protective layer.

Case 15 Analysis:

Case 15 is the representative sequence for successful operation of containment heat removal by PCCS. A comparison of PCCS heat removal in Case 15 as analyzed for PRA Section 9 Revision 4 to this analysis is shown in Figures 1 and 2 below. These figures show that the assumption of CCI depresses PCCS heat removal until cooling of the corium is allowed. This is an expected result due to the reduction of heat transfer from corium to the overlying pool required for CCI results in less steam being produced. The condensation of steam is the main heat removal mechanism for the PCCS.

The long term pressure in containment increases from approximately 0.54 MPa gage (78 psig) in the base case to approximately 0.76 MPa gage (110 psig) when including CCI due to the additional non-condensable gases in containment. These pressures are below the limiting containment failure pressure in DCD App 19C Table 19C-13 [Reference 3]. The limiting 95% confidence value at a containment temperature of 533 K (500°F) is 1.095MPa gage (158.8 psig).

Case 14 Analysis:

Case 14 assumed PCCS fails at 24 hours as a conservative representation of failure to replenish to upper pools which MAAP indicates would be required much later. The effectiveness of PCCS in Case 14 during the first 24 hours is slightly affected as described in analysis for Case 15 above.

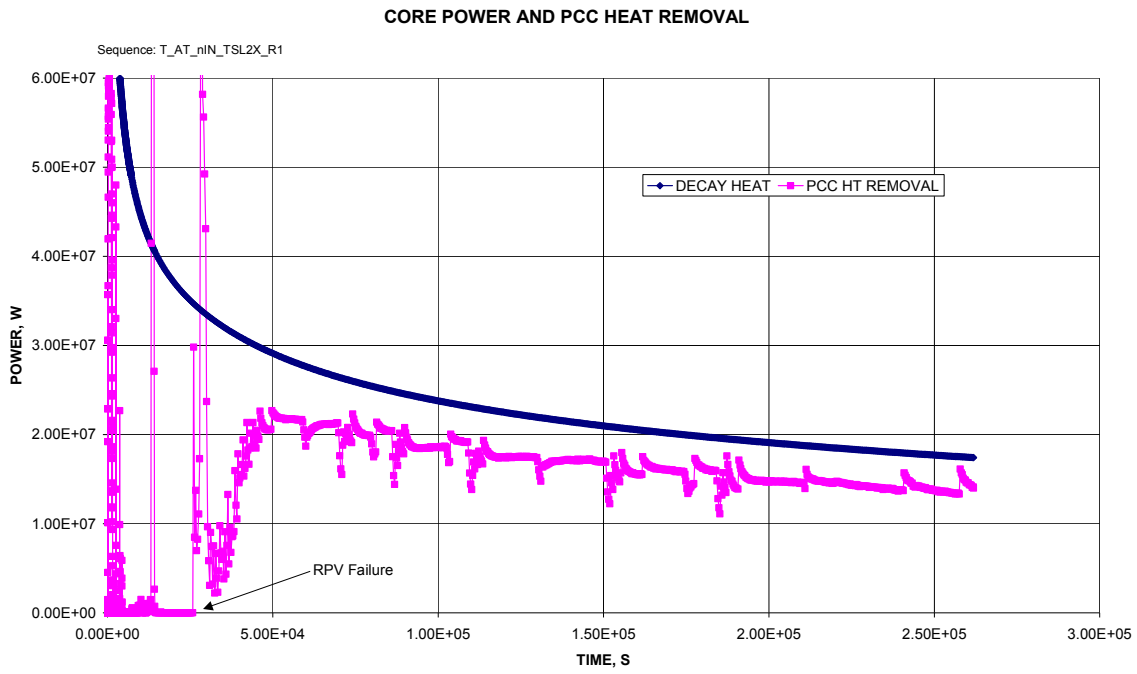

Figure 1: PCCS Heat Removal without BiMAC CCI

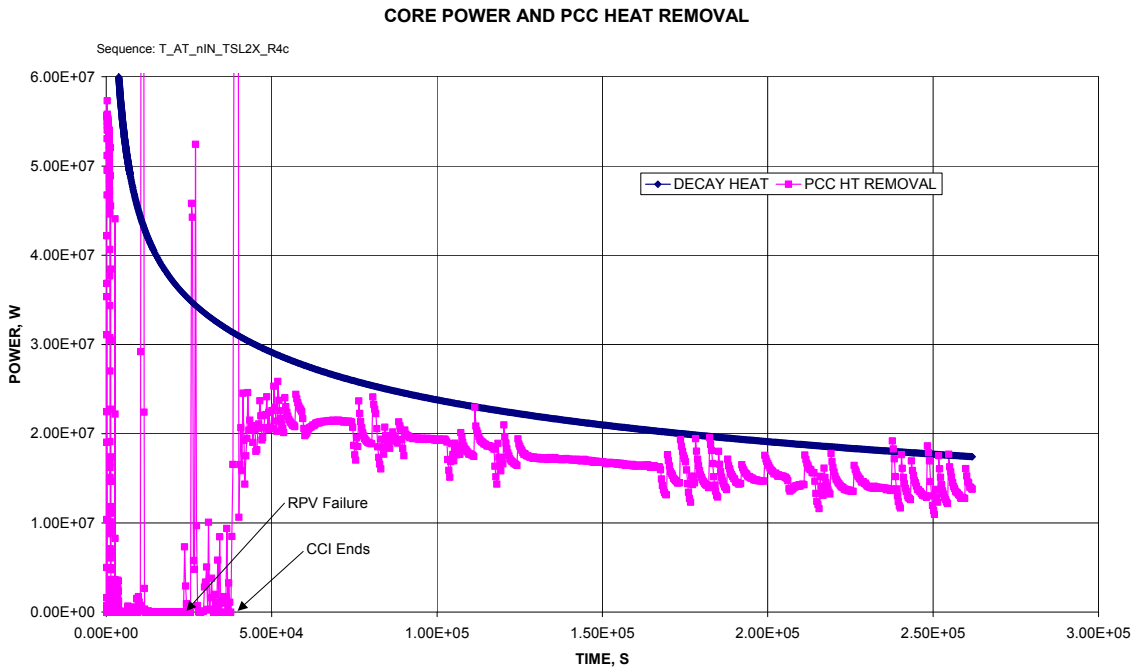

Figure 2: PCCS Heat Removal with BiMAC CCI Assumed

Ranges of Potential Containment Failure Time

Sequences Not Affected

Containment failure times in Cases 1-4 are not affected due to the assumed break outside of containment in Cases 1 and 2 and containment bypass in Cases 3 and 4. Case 15 did not result in containment failure as described above.

Containment Failure Results

Case 10 indicates that containment is vented at 90% of containment ultimate strength 1 hour sooner than previously calculated.

Case 11, RPV failure at high pressure with vacuum breaker failure, shows containment failing 3 hours earlier with CCI but Case 12, RPV failure at low pressure with vacuum breaker failure, shows containment failing 3.5 hours later with CCI. This is due to the assumed time of vacuum breaker failure at RPV failure for Case 11 and 12. Since Case 12 includes RPV depressurization prior to RPV failure, the energy of depressurization is absorbed by the wetwell and the steam produced in cooling the corium is delayed until the assumed CCI is complete.

Cases 13 and 14 have containment failure times which are not significantly changed by the CCI.

The ranges of containment failure times excluding Case 12 are 13.0 to 50.1 hours without CCI and 10.4 to 48.9 hours with CCI.

Release Category and Large Release Frequency

Release Category Frequency

CCI of the BiMAC protective layer does not affect the frequency of the release categories since CCI has no affect on plant response prior to RPV failure. The discussion above shows the performance of PCCS will not be changed significantly and therefore, the frequency of each release category is also not changed.

Large Release Frequency

A release other than Case 15 (TSL) is considered a large release. Since containment failure in Case 15 is not expected due to CCI of the BiMAC protective layer, the Large Release Frequency is not changed.

Fission Product Releases for Representative Scenarios

The fission product releases for representative scenarios are reported in the following tables. The tables 9-1a, 9-2a and 9-3a are the results for PRA Revision 4 and tables 9-1b, 9-2b and 9-3b are the results including CCI.

The results from Case 1 show that the Noble Gas and CsI release fractions 24 hours after core damage increase slightly, Noble Gas release fraction 72 hours after core damage is not significantly changed and CsI release fraction 72 hours after core damage increases slightly.

The results from Case 2 indicates that the Noble Gas release fraction 24 hours after core damage increases less than 50%, CsI release fraction 24 hours after core damage is not significantly changed, Noble Gas release fraction 72 hours after core damage increases more than 50% and CsI release fraction 72 hours after core damage increases slightly.

The results from Case 3 indicates that the Noble Gas release fraction 24 hours after core damage is not significantly changed, CsI release fraction 24 hours after core damage increases approximately 20%, Noble Gas release fraction 72 hours after core damage is not significantly changed and CsI release fraction 72 hours after core damage is not significantly changed.

The results from Case 4 indicate that the Noble Gas release fraction 24 hours after core damage increases over 50%, CsI release fraction 24 hours after core damage increases over 100%, Noble Gas release fraction 72 hours after core damage increases over 20% and CsI release fraction 72 hours after core damage increases over 100%. The CsI release fraction remains less than 0.1.

The results from Case 10 indicate that no release is indicated 24 hours after core damage and Noble Gas release fraction and CsI release fraction 72 hours after core damage is not significantly changed.

The results from Case 11 indicate that the Noble Gas release fraction 24 hours after core damage increases 20%, CsI release fraction 24 hours after core damage increases over 400%, Noble Gas release fraction 72 hours after core damage is not significantly changed and CsI release fraction 72 hours after core damage increases less than 100%. The CsI release fraction remains less than 0.01.

The results from Case 12 indicate that the Noble Gas and CsI release fractions 24 hours after core damage and 72 hours after core damage do not change significantly.

The results from Case 13 indicate that there is no release 24 hours after core damage and this is not changed from previous evaluations. Noble Gas release fraction 72 hours after core damage is not significantly changed and CsI release fraction 72 hours after core damage increases more than one order of magnitude.

The results from Case 14 indicate that there is no release 24 hours after core damage and this is not changed from previous evaluations. Noble Gas release fraction 72 hours after core damage increases by 1% and CsI release fraction 72 hours after core damage increases less than 50%.

The results from Case 15 indicate that the Noble Gas and CsI release fractions are not significantly changed.

Table 9-1

Table 9-1a: Release Categories for PRA Revision 4

Release Category	Representative Sequence	Core Damage Onset (TClad Max >1478K)	Time to Initial Release (hr)	Noble Gas Release Fraction @24 hrs after onset of core damage	CsI Release Fraction @24 hrs after onset of core damage	Noble Gas Release Fraction @72 hrs after onset of core damage	CsI Release Fraction @72 hours after onset of core damage
1: BOC	BOCsd_nIN_R1	2545s = 0.7hr	0.7	9.7E-01	7.0E-01	9.8E-01	7.0E-01
2: _dr	BOCdr_nIN_R1	1474s = 0.4hr	0.6	2.4E-01	1.1E-01	2.6E-01	1.3E-01
3: BYP	T_nIN_BYP_R1	2405s = 0.7hr	0.7	9.5E-01	2.1E-01	9.7E-01	3.0E-01
4: _nDP	T_nDP_nIN_BYP_R1	4496s = 1.2hr	1.3	5.3E-01	3.3E-02	6.8E-01	3.5E-02
5: CCID	T_nIN_nD_CCID_R4	2948s = 0.8hr	23.4	7.5E-01	1.3E-03	9.0E-01	1.7E-01
6: _nDP	T_nDP_nIN_nD_CCID_R4	5264s = 1.5hr	15.9	9.1E-01	6.8E-02	9.4E-01	3.4E-01
7: CCIW	T_nIN_CCIW_R4	2948s = 0.8hr	23.1	2.5E-01	1.6E-06	8.8E-01	2.5E-05
8:_nDP	T_nDP_nIN_CCIW_R4	5254s = 1.5hr	17.5	6.4E-01	1.5E-04	8.2E-01	1.3E-02
9: EVE	T_nIN_nD_EVE_R1	2362s = 0.7hr	7.4	8.3E-01	2.8E-02	8.3E-01	1.5E-01
10: FR	T-AT_nIN_nCHR_FR_R4	1635s = 0.5hr	25.4	0.0	0.0	1.0E+00	7.3E-03
11:OPVB	T_nDP_nIN_VB_R4	4502s = 1.3hr	13.0	4.5E-01	6.7E-05	9.7E-01	4.8E-03
12: _DP	T_nIN_VB_R4	2399s = 0.7hr	8.4	7.8E-01	3.3E-03	9.9E-01	8.1E-03
13:OPW1	T_nDP_nIN_nCHR_W1_R4	5253s = 1.5hr	31.7	0.0	0.0	9.9E-01	8.4E-04
14:OPW2	T_nDP_nIN_nCHR_W2_R4	5254s = 1.5hr	50.1	0.0	0.0	9.7E-01	1.4E-04
15: TSL	T_AT_nIN_TSL2x_R1	2045s = 0.6hr	0.5	2.7E-03	1.6E-04	2.7E-03	1.6E-04

Table 9-1b: Release Categories with CCI

Release Category	Representative Sequence	Core Damage Onset (TClad Max >1478K)	Time to Initial Release (hr)	Noble Gas Release Fraction @24 hrs after onset of core damage	CsI Release Fraction @24 hrs after onset of core damage	Noble Gas Release Fraction @72 hrs after onset of core damage	CsI Release Fraction @72 hours after onset of core damage
1: BOCsd	BOCsd_nIN_R4c	2553s = 0.7hr	0.7	9.8E-01	7.2E-01	9.8E-01	7.2E-01
2: BOCdr	BOCdr_nIN_R4c_wltinj	1470s = 0.4hr	0.6	3.3E-01	1.1E-01	4.1 E-01	1.4E-01
3: BYP	T_nIN_BYP_R4c	2343s = 0.7hr	0.7	9.4E-01	2.5E-01	9.4E-01	2.5E-01
4: _nDP	T_nDP_nIN_BYP_R4c	4491s = 1.2hr	1.3	8.3E-01	7.6E-02	8.4E-01	7.6E-02
5: CCID	T_nIN_nD_CCID_R4	2948s = 0.8hr	23.4	7.5E-01	1.3E-03	9.0E-01	1.7E-01
6: _nDP	T_nDP_nIN_nD_CCID_R4	5264s = 1.5hr	15.9	9.1E-01	6.5E-02	9.4E-01	3.4E-01
7: CCIW	T_nIN_CCIW_R4	2948s = 0.8hr	23.1	2.5E-01	1.6E-06	8.8E-01	2.5E-05
8: _nDP	T_nDP_nIN_CCIW_R4	5254s = 1.5hr	17.5	6.4E-01	1.5E-04	8.2E-01	1.3E-02
9: EVE	T_nIN_nD_EVE_R1	2362s = 0.7hr	7.4	8.3E-01	2.8E-02	8.3E-01	1.5E-01
10: FR	T-AT_nIN_nCHR_FR_R4c	1632s = 0.5hr	24.7	0.0	0.0	9.9E-01	3.3E-05
11:OPVB	T_nDP_nIN_VB_R4c_wltinj	4498s = 1.2hr	10.4	5.4E-01	3.7E-04	9.0E-01	8.7E-03
12: _DP	T_nIN_VB_R4c	2399s = 0.7hr	11.9	6.5E-01	2.8E-04	9.9E-01	7.8E-04
13:OPW1	T_nDP_nIN_nCHR_W1_R4c_wltinj	5251s = 1.5hr	32.9	0.0	0.0	9.9E-01	1.2E-02
14:OPW2	T_nDP_nIN_nCHR_W2_R4c_wltinj	5254s = 1.5hr	48.9	0.0	0.0	9.8E-01	2.0E-04
15: TSL	T_AT_nIN_TSL2x_R4c	1604s = 0.4hr	0.3	2.5E-03	1.5E-04	2.6E-03	1.5E-04

Table 9-2

Table 9-2a: Radionuclide Source Terms (Release Fraction 24 hours after onset of core damage) for PRA Revision 4

Release Category	Xe/Kr	CsI	TeO_2	SrO	MoO_2	CsOH	BaO	La_2O_3	CeO_2	Sb	Te_2	UO_2
1: BOC	9.7E-01	7.0E-01	4.6E-01	1.3E-02	1.7E-01	3.6E-01	3.1E-02	2.5E-04	1.2E-03	4.6E-01	6.4E-04	3.0E-06
2: _dr	2.4E-01	1.1E-01	1.2E-01	4.5E-04	1.6E-02	3.3E-02	2.0E-03	3.1E-05	1.4E-04	5.7E-02	1.1E-06	1.0E-06
3: BYP	9.5E-01	2.1E-01	1.3E-01	4.6E-03	6.2E-02	1.0E-01	1.3E-02	1.8E-04	8.5E-04	1.9E-01	5.1E-04	5.5E-06
4: _nDP	5.3E-01	3.3E-02	2.0E-03	4.1E-02	2.3E-02	1.2E-02	4.0E-02	4.1E-02	4.1E-02	7.2E-02	3.6E-04	3.4E-06
5: CCID	7.5E-01	1.3E-03	1.3E-04	6.6E-08	3.8E-07	8.2E-04	6.6E-07	4.0E-09	1.0E-08	2.7E-02	5.0E-07	5.3E-09
6: _nDP	9.1E-01	6.8E-02	4.1E-02	7.6E-07	3.9E-07	2.3E-02	6.9E-06	3.2E-07	4.4E-07	9.4E-02	1.9E-06	1.8E-07
7:CCIW	2.5E-01	1.6E-06	6.6E-07	2.7E-08	1.8E-07	1.3E-06	9.2E-08	1.8E-09	1.0E-08	8.8E-04	4.9E-08	1.4E-10
8: _nDP	6.4E-01	1.5E-04	2.2E-05	3.5E-06	2.9E-06	5.5E-05	3.7E-06	3.4E-06	3.4E-06	1.9E-04	2.6E-07	1.0E-09
9: EVE	8.3E-01	2.8E-02	7.0E-02	1.7E-03	6.5E-05	1.3E-01	7.2E-04	4.9E-05	6.6E-04	1.9E-01	4.9E-04	3.3E-06
10: FR	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
11:OPVB	4.5E-01	6.7E-05	6.1E-06	2.6E-06	2.8E-06	7.2E-06	2.9E-06	2.5E-06	2.5E-06	1.3E-04	1.7E-06	2.8E-10
12: _DP	7.8E-01	3.3E-03	1.1E-04	1.8E-05	9.3E-06	7.0E-04	1.1E-05	1.8E-06	1.3E-05	4.3E-02	5.1E-06	1.2E-07
13:OPW1	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
14:OPW2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
15: TSL	2.7E-03	1.6E-04	9.9E-05	2.6E-06	6.2E-05	5.9E-05	1.3E-05	1.1E-07	3.7E-07	1.6E-04	7.5E-10	3.3E-10

Table 9-2b: Radionuclide Source Terms (Release Fraction 24 hours after onset of core damage) with CCI

Release Category	Xe/Kr	CsI	TeO_2	SrO	MoO_2	CsOH	BaO	La_2O_3	CeO_2	Sb	Te_2	UO_2
1: BOCsd	9.8E-01	7.2E-01	4.8E-01	1.0E-02	1.5E-01	3.6E-01	2.9E-02	2.6E-04	9.6E-04	4.1E-01	1.1E-04	1.3E-06
2: BOCdr	3.3E-01	1.1E-01	1.2E-01	4.2E-04	1.8E-02	3.7E-02	2.3E-03	2.7E-05	9.5E-05	6.2E-02	6.2E-07	4.5E-07
3: BYP	9.4E-01	2.5E-01	1.2E-01	6.5E-03	6.4E-02	1.5E-01	2.0E-02	2.6E-04	5.9E-04	1.4E-01	5.4E-05	1.5E-06
4: _nDP	8.3E-01	7.6E-02	5.3E-03	5.3E-02	2.1E-02	1.5E-02	5.1E-02	5.3E-02	5.3E-02	1.5E-01	1.8E-03	4.0E-06
5: CCID	7.5E-01	1.3E-03	1.3E-04	6.6E-08	3.8E-07	8.2E-04	6.6E-07	4.0E-09	1.0E-08	2.7E-02	5.0E-07	5.3E-09
6: _nDP	9.1E-01	6.8E-02	4.1E-02	7.6E-07	3.9E-07	2.3E-02	6.9E-06	3.2E-07	4.4E-07	9.4E-02	1.9E-06	1.8E-07
7: CCIW	2.5E-01	1.6E-06	6.6E-07	2.7E-08	1.8E-07	1.3E-06	9.2E-08	1.8E-09	1.0E-08	8.8E-04	4.9E-08	1.4E-10
8: _nDP	6.4E-01	1.5E-04	2.2E-05	3.5E-06	2.9E-06	5.5E-05	3.7E-06	3.4E-06	3.4E-06	1.9E-04	2.6E-07	1.0E-09
9: EVE	8.3E-01	2.8E-02	7.0E-02	1.7E-03	6.5E-05	1.3E-01	7.2E-04	4.9E-05	6.6E-04	1.9E-01	4.9E-04	3.3E-06
10: FR	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
11:OPVB	5.4E-01	3.7E-04	3.3E-05	8.1E-06	7.6E-06	7.2E-05	8.4E-06	8.0E-06	8.0E-06	2.5E-04	4.2E-06	6.7E-10
12: _DP	6.5E-01	2.8E-04	7.9E-06	9.6E-07	1.0E-06	9.9E-05	7.6E-07	1.3E-07	8.5E-07	5.7E-02	9.2E-08	8.3E-09
13:OPW1	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
14:OPW2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
15:TSL	2.5E-03	1.5E-04	7.4E-05	1.6E-06	2.8E-05	5.2E-05	7.2E-06	5.3E-08	2.8E-07	8.4E-05	1.0E-07	8.1E-10

Table 9-3

Table 9-3a: Radionuclide Source Terms (Release Fraction 72 hours after onset of core damage) for PRA Rev 4

Release Category	Xe/Kr	CsI	TeO_2	SrO	MoO_2	CsOH	BaO	La_2O_3	CeO_2	Sb	Te_2	UO_2
1: BOC	9.8E-01	7.0E-01	4.6E-01	1.3E-02	1.7E-01	3.7E-01	3.1E-02	2.5E-04	1.2E-03	5.0E-01	6.5E-04	3.0E-06
2: _dr	2.6E-01	1.3E-01	1.2E-01	4.5E-04	1.6E-02	3.6E-02	2.0E-03	3.1E-05	1.4E-04	6.0E-02	1.3E-06	1.0E-06
3: BYP	9.7E-01	3.0E-01	1.3E-01	4.6E-03	6.2E-02	1.2E-01	1.3E-02	1.8E-04	8.5E-04	3.1E-01	5.1E-04	5.5E-06
4: _nDP	6.8E-01	3.5E-02	6.1E-03	4.1E-02	2.3E-02	2.5E-02	4.0E-02	4.1E-02	4.1E-02	7.5E-02	3.8E-04	3.4E-06
5:CCID	9.0E-01	1.7E-01	1.6E-01	2.0E-07	4.6E-07	2.4E-01	3.9E-06	1.3E-08	2.2E-08	2.8E-01	7.9E-07	8.6E-08
6: _nDP	9.4E-01	3.4E-01	7.4E-02	7.8E-07	4.9E-07	5.8E-02	1.1E-05	3.2E-07	4.4E-07	1.7E-01	1.9E-06	2.0E-07
7:CCIW	8.8E-01	2.5E-05	1.2E-06	5.2E-08	3.4E-07	3.8E-05	1.9E-07	3.5E-09	1.9E-08	4.9E-02	7.5E-07	5.7E-10
8: _nDP	8.2E-01	1.3E-02	1.3E-02	3.5E-06	3.0E-06	3.1E-02	3.8E-06	3.4E-06	3.5E-06	7.0E-03	4.7E-07	1.4E-09
9: EVE	8.3E-01	1.5E-01	1.5E-01	1.7E-03	6.5E-05	2.3E-01	7.5E-04	4.9E-05	6.6E-04	2.8E-01	4.9E-04	3.4E-06
10: FR	1.0E+00	7.3E-03	3.1E-04	1.2E-08	5.6E-08	4.8E-03	6.0E-08	8.8E-10	3.7E-09	1.7E-01	2.5E-05	2.6E-11
11:OPVB	9.7E-01	4.8E-03	9.2E-03	2.6E-06	2.8E-06	1.3E-02	2.9E-06	2.5E-06	2.5E-06	7.7E-02	3.2E-06	2.8E-10
12: _DP	9.9E-01	8.1E-03	1.8E-04	1.8E-05	9.3E-06	2.9E-03	1.1E-05	1.8E-06	1.3E-05	3.5E-01	6.6E-06	1.2E-07
13:OPW1	9.9E-01	8.4E-04	2.3E-03	7.9E-08	1.3E-07	1.5E-02	1.0E-07	7.7E-08	7.7E-08	3.6E-03	1.7E-07	8.1E-13
14:OPW2	9.7E-01	1.4E-04	5.5E-05	1.5E-08	1.0E-08	1.0E-03	1.5E-08	1.5E-08	1.5E-08	6.7E-03	7.4E-08	4.7E-13
15: TSL	2.7E-03	1.6E-04	9.9E-05	2.6E-06	6.2E-05	5.9E-05	1.3E-05	1.1E-07	3.7E-07	1.7E-04	7.6E-10	3.3E-10

Table 9-3b: Radionuclide Source Terms (Release Fraction 72 hours after onset of core damage) with CCI

Release Category	Xe/Kr	CsI	TeO_2	SrO	MoO_2	CsOH	BaO	La_2O_3	CeO_2	Sb	Te_2	UO_2
1: BOCsd	9.8E-01	7.2E-01	4.8E-01	1.0E-02	1.5E-01	3.6E-01	2.9E-02	2.6E-04	9.6E-04	4.3E-01	1.1E-04	1.3E-06
2: BOCdr	4.1E-01	1.4E-01	1.2E-01	4.2E-04	1.8E-02	4.0E-02	2.3E-03	2.7E-05	9.5E-05	6.8E-02	6.7E-07	4.5E-07
3: BYP	9.4E-01	2.5E-01	1.2E-01	6.5E-03	6.4E-02	1.5E-01	2.0E-02	2.6E-04	5.9E-04	1.5E-01	5.9E-05	1.5E-06
4: _nDP	8.4E-01	7.6E-02	5.3E-03	5.3E-02	2.1E-02	1.5E-02	5.1E-02	5.3E-02	5.3E-02	1.5E-01	1.8E-03	4.0E-06
5:CCID	9.0E-01	1.7E-01	1.6E-01	2.0E-07	4.6E-07	2.4E-01	3.9E-06	1.3E-08	2.2E-08	2.8E-01	7.9E-07	8.6E-08
6: _nDP	9.4E-01	3.4E-01	7.4E-02	7.8E-07	4.9E-07	5.8E-02	1.1E-05	3.2E-07	4.4E-07	1.7E-01	1.9E-06	2.0E-07
7:CCIW	8.8E-01	2.5E-05	1.2E-06	5.2E-08	3.4E-07	3.8E-05	1.9E-07	3.5E-09	1.9E-08	4.9E-02	7.5E-07	5.7E-10
8: _nDP	8.2E-01	1.3E-02	1.3E-02	3.5E-06	3.0E-06	3.1E-02	3.8E-06	3.4E-06	3.5E-06	7.0E-03	4.7E-07	1.4E-09
9: EVE	8.3E-01	1.5E-01	1.5E-01	1.7E-03	6.5E-05	2.3E-01	7.5E-04	4.9E-05	6.6E-04	2.8E-01	4.9E-04	3.4E-06
10: FR	9.9E-01	3.3E-05	5.8E-07	8.9E-09	1.9E-07	3.3E-05	4.3E-08	6.9E-10	3.9E-09	4.7E-03	1.1E-05	3.4E-11
11:OPVB	9.0E-01	8.7E-03	7.7E-03	8.1E-06	7.6E-06	1.7E-02	8.4E-06	8.0E-06	8.0E-06	5.2E-02	9.6E-06	6.7E-10
12: _DP	9.9E-01	7.8E-04	8.8E-06	9.6E-07	1.0E-06	3.7E-04	7.6E-07	1.3E-07	8.5E-07	1.2E-01	1.8E-07	8.3E-09
13:OPW1	9.9E-01	1.2E-02	6.6E-04	2.2E-07	1.6E-07	6.4E-03	2.2E-07	2.2E-07	2.2E-07	1.5E-02	7.5E-07	1.2E-12
14:OPW2	9.8E-01	2.0E-04	5.2E-06	1.4E-08	1.1E-08	1.1E-04	1.4E-08	1.4E-08	1.4E-08	1.0E-03	3.5E-07	3.1E-13
15:TSL	2.6E-03	1.5E-04	7.4E-05	1.6E-06	2.8E-05	5.2E-05	7.2E-06	5.3E-08	2.8E-07	8.5E-05	1.1E-07	8.1E-10

Design Requirements for Concrete Type

The composition of concrete protecting the BiMAC will not be specified at this time. A design requirement will be added to DCD Table 19.2-3 which requires that the material covering the BiMAC is designed, for the more likely severe accident sequences, to prevent melt impingement due to corium ablation, and also to prevent noncondensable gas generation in quantities that would lead to exceeding the containment ultimate pressure.

Conclusions

Modeling CCI of the concrete used to cover the BiMAC results in small changes to the containment failure times and release fractions calculated by MAAP406. The performance of PCCS is not significantly changed when modeling this CCI. These results with the results from sequences which were not affected by CCI of the BiMAC protective layer are shown in the tables above.

DCD Impact

DCD Table 19.2-3 will be changed to include a design requirement as shown in the markup attached to this RAI response.

DCD Tier 1 Section 2.4.2 and Table 2.4.2-3 will be changed as shown in the markup attached to this RAI response.

NEDO-33201, Revision 4 will include the above sensitivity study in Section 11 as described above.

Enclosure 2

DCD Revision 6 Markups

DCD Tier 1

Section 2.4.2 Emergency Core Cooling System - Gravity-Driven Cooling System

Table 2.4.2-3 ITAAC For The Emergency Core Cooling System – Gravity-Driven Cooling System

DCD Tier 2

Table 19.2-3: "Risk Insights and Assumptions"

(25) Deluge system has redundant nonsafety-related programmable logic controllers (PLCs) that are connected to thermocouples in each cell of the lower drywell Basemat-internal Melt Arrest Coolability (BiMAC) system.

(26) When temperatures exceed the setpoint at one set of thermocouples coincident with setpoints being exceeded at a second set of thermocouples in adjacent cells, each PLC starts an adjustable deluge squib valve non-bypassable timer.

(27) The GDCS deluge valve squib initiation signals are inhibited when either of the safety-related deluge system lower drywell temperature switches sense temperatures lower than a preset value coincident with the presence of both deluge squib valve timer signals.

(28) a. Valves on lines attached to the RPV that require maintenance have maintenance valves installed such that freeze seals will not be required.

b. The as-built location of valves on lines attached to the RPV in the GDCS system that require maintenance shall be reconciled to design requirements.

(29) a. The BiMAC has an available volume, up to a height of the vertical segments of the BiMAC pipes, sized to contain approximately 400% of the full-core debris.

b. The BiMAC has a material located on top of the BiMAC pipes to protect against melt impingement during the initial corium relocation event.

c. The BiMAC is designed with a cover so that debris will penetrate it in a short period of time while providing protection for the BiMAC from CRD housings falling from the vessel.

d. The BiMAC piping is inclined from horizontal to permit natural circulation flow.

e. The material located on top of the BiMAC pipes does not generate non-condensable gases in quantities that would result in exceeding the containment ultimate pressure.

~~Refer to Subsection 2.2.15 for "Instrumentation and Controls Compliance with IEEE Standard 603."~~

Inspections, Tests, Analyses and Acceptance Criteria

Table 2.4.2-3 provides a definition of the inspections, test and/or analyses, together with associated acceptance criteria for the Gravity-Driven Cooling System.

Table 2.4.2-3

ITAAC For The Emergency Core Cooling System – Gravity-Driven Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
28b. The as-built location of valves on lines attached to the RPV in the GDCS system that require maintenance shall be reconciled to design requirements..	A reconciliation evaluation of valves on lines attached to the RPV using as-designed and as-built information will be performed.	Report(s) exist and conclude that a design reconciliation has been completed for the as-built location of valves relative to the design requirements. The report documents the results of the reconciliation evaluation.
29a. The BiMAC has an available volume, up to a height of the vertical segments of the BiMAC pipes, sized to contain approximately 400% of the full-core debris.	Inspections of the as-built system will be conducted.	Report(s) exist and conclude that the as built BiMAC is sized to contain approximately 400% of the full-core debris.
29b. The BiMAC has a material located on top of the BiMAC pipes to protect against melt impingement during the initial corium relocation event.	Inspections of the as-built system will be conducted.	Report(s) exist and conclude that the as built BiMAC contains a material located on top of the BiMAC pipes to protect against melt impingement during the initial corium relocation event.
29c. The BiMAC is designed with a cover plate so that debris will penetrate it in a short period of time while providing protection for the BiMAC from CRD housings falling from the vessel.	Inspections of the as-built system will be conducted.	Report(s) exist and conclude that the BiMAC includes a cover plate providing protection for the BiMAC from CRD housings falling from the vessel while allowing debris to penetrate it in a short period of time.
29d. The BiMAC piping is inclined at from horizontal to permit natural circulation flow.	Inspections of the as-built system will be conducted.	Report(s) exist and conclude that the as built BiMAC includes piping inclined sufficiently from horizontal to permit natural circulation flow.

Table 2.4.2-3

ITAAC For The Emergency Core Cooling System – Gravity-Driven Cooling System

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
29e. The material located on top of the BiMAC pipes does not generate non-condensable gases in quantities that would result in exceeding the containment ultimate pressure.	Inspections of the as-built system will not be conducted.	Report(s) exist and conclude that the as-built BiMAC contains a material located on top of the BiMAC pipes that does not generate non-condensable gases in quantities that would result in exceeding the containment ultimate pressure.

Table 19.2-3
Risk Insights and Assumptions

Insight or Assumption	Disposition
The composition of the layer of material on the lower drywell floor that covers the BiMAC piping is designed, for the more likely severe accident sequences, to prevent melt impingement due to corium ablation, and also to prevent noncondensable gas generation in quantities that would lead to exceeding the containment ultimate pressure.	Design Requirement (DCD Tier 2, Subsection 19.3.2.6)
The ATWS sequences experience core damage at high pressure because ADS is inhibited as part of the core damage mitigation effort. However, it is assumed that Emergency Operating Procedures (EOPs) will instruct the operator to depressurize after core damage has occurred in an attempt to preserve containment. It is shown in Appendix 8A that the frequency of ATWS sequences experiencing RPV rupture at high pressure is negligible, so only failures at low pressure were analyzed.	Operational Program – Procedure Development
Venting is assumed to occur when the containment pressure reaches 90% of the ultimate containment strength.	Operational Program – Procedure Development
During shutdown conditions, a continuous fire watch is required for the following scenarios with breached fire barriers for maintenance activities: • The breaching of the fire door between fire areas F1152 and F1162 (the reactor building fire areas that house RWCU pumps). • The simultaneously breaching of the multiple fire barriers that can open fire areas F3301 and F3302 (the N-DCIS room fire areas) to fire area F3100 (the corridor fire area) at the same time. Shutdown fire risks related to the fire barriers are evaluated and managed in accordance with the outage risk management program of 10 CFR 50.65(a)(4).	Operational Program – Maintenance Rule
All LOCAs below TAF during shutdown require closure of lower drywell hatch. The hatch can be opened during shutdown. If a break occurs in the lower drywell and the hatch is not closed, core damage is assumed to occur (once the water level reaches the bottom of the hatch, it is assumed that the door can not be closed and the leak not isolated).	Operational Program – Procedure Development