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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 222 Related to ESBWR Design Certification Application ESBWR RAI Number 19.1-96 S03**

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 August 15, 2008 (Reference 1).

The GEH response to RAI Number 19.1-96 S03 is in Enclosure 1. Previous RAIs and Responses were transmitted in References 2 through 7.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

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NRO

References:

1. MFN 08-649, *Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, Request For Additional Information Letter No. 222 Related To ESBWR Design Certification Application,* dated August 15, 2008.

2. MFN 08-426. Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 186 Related To ESBWR Design Certification Application,* dated April 23, 2008

3. MFN 08-558. *Response to Portion of NRC Request for Additional Information Letter No. 186 Related to E5BWR Design Certification Application E5BWR RAI Numbers 19.1-96S02, 19.2-90, 19.2-91, and 22.5-24,* dated July 17, 2008

4. MFN 07-485, Supplement 2, *Response to Portion of NRC Request for Additional Information Letter No. 109 Related to E5BWR Design Certification Application, RAI Number 19.1-96S01*, dated March 17, 2008

5. MFN 07-555. Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown," *Request For Additional Information Letter No. 109 Related To ESBWR Design Certification Application.* October 12, 2007

6. MFN-06-551. Letter from U.S. Nuclear Regulatory Commission to David H. Hinds Request *For Additional Information Letter No.* 88 *Related To ESBWR Design Certification Application.* December 26,2006

7. MFN 07-485. *Response to Portion of NRC Request for Additional Information Letter No. 88 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-96, 19.1-102 through 19.1-108 and 19.1-110 through 19.1-115.* September 17, 2007

Enclosure:

1. Response to Portion of NRC Request for Additional Information Letter No. 222 Related to ESBWR Design Certification Application Probabilistic Risk Assessment RAI Number 19.1-96 S03

cc: AE Cubbage	USNRC (with enclosure)
RE Brown	GEH/Wilmington (with enclosure)
eDRF Section	0000-0092-0132

Enclosure 1

MFN 07-485, Supplement 3

Response to Portion of NRC Request for

Additional Information Letter No. 222

Related to ESBWR Design Certification Application

Probabilistic Risk Assessment

RAI Number 19.1-96 S03

Note: The original text of the RAI is provided for ease of reference. The attached figures have not been included.

NRC RAI 19.1-96 (original)

To address thermal-hydraulic uncertainty regarding shutdown success criteria, please provide additional information (e.g., summary and results of calculations) that justifies short term and long term core cooling using (1) 2 SRVs, (2), 2 out of 8 lines of GDCS, (3) 2 out of 3 GDCS pools, (4) the opening of at least one equalizing line, and (5) the opening of 4 depressurization valves (DPVs) during Mode 5 when the reactor vessel head is on.

GEH Response (original response)

ESBWR Shutdown Mode 5 is described in NEDO-33201 Section 16.2.1.2 as; the time when:

1. heat removal requirements are transferred to the RWCU/SDCS
2. the Main Condenser and circulating water pumps are removed from service and
3. the use of the isolation condensers is terminated.

NEDO-33201 Section 16.2.1.1 assumes Mode 4 is 8 hours long with decay heat removal through the Main Condenser and/or the Isolation Condenser with the RWCU/SDCS put into service ½ hour after control rod insertion.

Thermal-hydraulic uncertainty for short term and long term core cooling in Mode 5 in the ESBWR Shutdown PRA was evaluated using MAAP406. In order to maximize decay heat, these analyses assumed that the events, loss of SDC and LOCAs, as applicable, begin 8 hours after shutdown corresponding to the assumed start of Mode 5. The mission time in the ESBWR Shutdown PRA, NEDO-33201 Section 16.2.2, is 24 hours with consideration of longer times for inventories of water and power to ensure core cooling.

The safety function of 2 SRVs in the Shutdown PRA is to depressurize or maintain depressurization of the reactor pressure vessel and to support low pressure injection using active systems. MAAP analysis indicates that 1 SRV is sufficient to depressurize the RPV to allow low pressure injection, using the FAPCS/LPCI Mode after a loss of SDC event occurring at the beginning of Mode 5 as shown in Case 1.

The safety functions of 2 GDCS lines, 2 GDCS pools, 1 equalizing line and 4 DPVs describe core cooling using passive injection systems. For these analyses, it was assumed that passive containment cooling was not operating. MAAP thermal-hydraulic uncertainty analyses for transients, such as loss of SDC, indicate that depressurization using 3 DPVs, injection using 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 2. It should be noted that the model used was not 1 GDCS injection line from each of the 2 GDCS pools but 1 injection line from the total of two GDCS pools.

MAAP thermal-hydraulic uncertainty analyses for LOCAs below the top of active fuel indicate that depressurization using 4 DPVs, injection using 1 GDCS injection line from

2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 3.

MAAP thermal-hydraulic uncertainty analyses for LOCAs above the top of active fuel indicate that depressurization using 4 DPVs, injection through 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 4.

MAAP thermal-hydraulic uncertainty analysis for a LOCA in the feedwater line indicate that depressurization is not required for injection using 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line to prevent core damage for greater than 72 hours as shown in Case 5. The size and elevation of the break allow the RCS to depressurize without operation of these systems.

Consideration of these thermal-hydraulic uncertainty results in the ESBWR Shutdown PRA leads to changes in the shutdown event trees/success criteria. These changes include the following:

- Addition of depressurization using 4 DPVs in Mode 5 LOCAs. Due to size and elevation of the break, depressurization is not required in LOCAs in FW lines.
- Assuming passive injection using at least 1 GDCS injection lines from each of 2 GDCS pools and 1 GDCS equalizing line, added to success criteria. The previous success criterion was at least 2 GDCS injection lines that could have been from the same GDCS pool.

Implementing these changes in the ESBWR Shutdown PRA changes the shutdown core damage frequency from 8.77E-09/yr to 9.37E-09/yr.

<u>DCD Impact</u>(original response)

No DCD changes will be made in response to this RAI.

NEDO-33201, Rev 2 Chapter 16 will be updated as noted in the attached markup (Enclosure 1, Attachment 2).

NRC RAI 19.1-96 S01

The staff reviewed GEH's response to RAI 19.1-96. In response to RAI 19.1-96, which requested calculations to verify the ESBWR shutdown PRA success criteria, GEH submitted a revised version of the Shutdown PRA with updated success criteria. A successful passive injection now requires automatic operation of 4 DPVs for both Mode 5 Losses of the RWCU/SDC (RHR function) and Mode 5 LOCAs (excluding FW line breaks). Also, passive injection now requires 1 GDCS equalizing line. The DPVs are not currently required to be operable by TS in Mode 5. The information provided is not sufficient to address the issues resulting from the revised PRA shutdown success criteria. Please provide the following additional information as described below:

A. In case 1, GEH used the MAAP 4 code to evaluate the impact of 1 SRV and low pressure injection following a loss of RWCU/SDC. The staff noted that the RCS level dropped below TAF, and fuel temperatures exceeded 1300 EF before low pressure injection was initiated. Therefore, GEH assumed that 1 SRV was sufficient for overpressure protection, and 2 SRVs were sufficient for low pressure injection. GEH has justified the use of the MAAP code by comparing simulations of loss-of-coolant accidents performed with MAAP and the TRACG code. However, these benchmark design basis accident calculations may not reflect thermal-hydraulic conditions in the reactor vessel during severe accidents. Therefore, the success of 2 SRVs and low pressure injection following a loss of RWCU/SDC in Mode 5 should be verified and analyzed using TRACG. Such calculations would also provide a means for adequately benchmarking the MAAP code for use in analyzing additional PRA accident sequences that may be affected by thermal-hydraulic uncertainties associated with passive systems.

B. Regarding Case 1, the staff understands that the opening of 2 SRVs is performed manually, and the SRVs are not required to be operable according to TS. Please revise the PRA and the RTNSS assessment to reflect that the SRVs may not be available for overpressure protection and RCS depressurization in Mode 5.

C. Please document in the PRA why losses of RWCU/SDC and LOCAs are analyzed together in MAAP 4.

D. In Cases 3 and 4, GEH assumed that 4 DPVs were required for GDCS to function, even though short term level below TAF was predicted by MAAP. The success of 4 DPVs and 1 GDCS injection line from each of two GDCS pools and 1 GDCS equalizing line should be verified and analyzed using TRACG to ensure that the success criterion is conservative.

E. Regarding Cases 3 and 4, the staff understands that the revised shutdown PRA assumes that 4 DPVs open automatically. However, the automatic function of the DPVs are not required to be operable according to TS in Mode 5. Please revise the PRA and *the RTNSS assessment to reflect that the DPVs may not be available for RCS depressurization in Mode 5.*

GEH Response

Part A: In case 1 - shown in Attachment 1 of Response to RAI 19.1-96, 1 SRV and low pressure injection following a loss of RWCU/SDC, MAAP calculated peak temperatures above 1300°F last less than 5 minutes. These temperatures are comparable to core temperatures at the beginning of the calculation – start of reactor shutdown. In addition, the calculated H_2 generated during this time, and the whole sequence, was less than 1 kg with a maximum clad temperature of 1417°F. This does not meet the definition of core damage in the ASME PRA Standard (and RG 1.200) – *uncovery and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage involving a large fraction of the core is anticipated.* ASME PRA Standard Supporting Requirement SC-A2 has an example measure for core damage – *code-predicted peak core temperature >2,500°F for BWRs.*

It should be noted that case 1 was run with the 1 SRV opening at the Level 1 setpoint and low pressure injection starting when RPV pressure reaches 100 psia instead of the 150 psi differential pressure described in DCD Tier 2 Section 9.1.3.2. MAAP calculates, in case 1, 11 hours between loss of RWCU/SDC and RPV level reaching Level 1 due to boil off. This is ample time to manually open the SRVs required to support low pressure injection.

Previous evaluations have shown that additional depressurization allows low pressure injection to maintain a higher RPV level. Therefore, 2 SRVs and low pressure injection following a loss of RWCU/SDC would provide margin to core damage above the 1 SRV case.

Since the 1 SRV case (and by engineering judgment the 2 SRV case) does not result in severe accident conditions, the existing comparison of loss-of-coolant accidents performed with MAAP and TRACG provides an adequate benchmark of the MAAP code for these cases. RAI 19.1.0-1 S01 requests analyzing the limiting accident scenarios assuming PRA success criteria with a code such as TRACG. Response to RAI 19.1.0-1 S01 will provide additional benchmarking of the MAAP code.

Part B: Technical Specification requirements for ADS actuation capability and ADS capacity in Mode 5 and Mode 6 prior to removal of RPV head are described in the response to RAI 16.2-74, Supplement 2 (MFN 07-022-Supplement 6). Surveillance Requirement 3.5.3.1 will require operability of sufficient Automatic Depressurization System capacity to support the assumed GDCS injection following loss of decay heat removal capability.

It should be noted that unavailability of SRVs is not expected prior to removal of the reactor pressure vessel head and plugging the main steam lines. Therefore, assuming that the SRVs are available is consistent with the PRA's goal to reflect the expected response of the plant.

Removing credit for the manual action of RPV depressurization using 2 SRVs from the shutdown PRA model has minimal impact. The results for the PRA base shutdown CDF and the shutdown RTNSS assessment are essentially unchanged by removing manual pressure relief from the model. The base shutdown CDF result is 9.37E-9/yr (NEDO 33201 Rev 2, Section 16.6.1). Setting the manual relief to TRUE in the cutsets raises the CDF result to only 9.40E-9/yr. Similarly, the shutdown RTNSS results go from 1.33E-7/yr (NEDO 33201, Section 11.3.5.1) to 1.37E-7/yr by setting the manual SRV function to TRUE in the model.

Part C: The assumption was made in the PRA that RWCU/SDC was lost in LOCAs since RWCU/SDC isolates on low level in RPV. This is discussed in NEDO-33201 Revision 2 Section 16.4.3.1.

Part D: In Cases 3 and 4, bounding analyses for LOCAs were performed using 4 DPVs for depressurization and injection using 1 GDCS injection line from the combined volume of the two smaller GDCS pools and less than 1 equalizing line. This configuration is not possible so the success criteria is at least 1 GDCS injection line from each of two GDCS pools. The success criteria configuration provides a larger flowrate than that analyzed in Cases 3 and 4. The results of these Cases, shown in the response to RAI 19.1-96 (MFN 07-485, dated 9/17/2007), show that the water level in the core is maintained above the top of active fuel.

Part E: Technical Specification requirements for ADS actuation capability and ADS capacity in Mode 5 and Mode 6 prior to removal of RPV head are described in the response to RAI 16.2-74, Supplement 2 (MFN 07-022-Supplement 6, dated 1/17/2008). Surveillance Requirement 3.5.3.1 will require operability of sufficient Automatic Depressurization System capacity to support the assumed GDCS injection following loss of decay heat removal capability.

DCD Impact

No DCD changes will be made in response to this RAI.

No changes to NEDO-33201 will be made in response to this RAI.

NRC RAI 19.1-96 S02

The staff reviewed GEH's response to RAI 19.1.96 S01. This response was discussed with GEH during a telecon on March 6, 2008, during which GEH indicated that they plan to modify the GDCS Technical Specifications in Revision 5 of the DCD to require four DPV valves to be automatically operable by ADS in Modes 5 and 6 until the vessel head is removed. However, if one of the four DPVs fails to open, then the GDCS function fails. The shutdown PRA models all eight DPVs as being operable for ADS (similar to the full power PRA) in Modes 5 and 6 (until the vessel head is removed). The staff is requesting GEH to perform and document a sensitivity study in the shutdown PRA (including internal events, flood, fire, and high winds) assuming only four DPVs are available and operable for ADS. The staff is requesting GEH to evaluate the impact of this sensitivity study on the shutdown PRA results, including the RTNSS shutdown risk results.

GEH Response

A concern about Mode 5 treatment of ADS led to a Technical Specification update. The Technical Specification for GDCS in Mode 5 now requires 6 out of 8 DPV valves to be operable until the reactor head is removed. See DCD Revision 5, Chapter 16 for the specific details contained in the Technical Specifications.

Additionally, the NEDO 33201, Revision 3 contains a sensitivity analysis showing the shutdown PRA results with varying DPV requirements. The sensitivity analysis is included in NEDO 33201 Revision 3, Section 22.16. Cases are evaluated with 4 out of 8, 6 out of 8, and 8 out of 8 DPV valves available throughout mode 5. The results of each case and an analysis of the differences are included in the section.

DCD Impact

No DCD changes will be made in response to this RAI.

The above sensitivity case for the DPV availability in Mode 5 are included in NEDO 33201, Revision 3, Section 22.16. No further changes are required to NEDO 33201, revision 3 as a result of this RAI.

NRC RAI 19.1-96 S03

The staff reviewed GEH's response to RAI 19.1-96S02. The staff requested GEH to perform and document a sensitivity study in the shutdown PRA (including internal events, flood, fire, and high winds) assuming only four DPVs were available and operable for ADS. The staff requested GEH to evaluate the impact of this sensitivity study on the shutdown PRA results, including the RTNSS shutdown risk results. GEH responded that the TS for GDCS now require 6 out of 8 DPV valves to be operable (or equivalent vent area) in Modes 5 and 6 prior to removal of the reactor pressure vessel head. GEH also provided sensitivity analysis in Chapter 22 of the PRA showing the shutdown PRA results with varying DPV operability, including 4, 6, and 8 DPVs operable. The staff then noted that this sensitivity study did not use the Focused PRA or the shutdown external events PRA even though shutdown external events represent 74 percent of the total ESBWR CDF/LRF risk. Therefore, the staff requests GEH to re-evaluate the DPV sensitivity studies with the Focused PRA and the shutdown external events PRA and document these results in the PRA. The staff is also requesting GEH to evaluate these results to ensure that 6 operable DPVs in Modes 5 and 6 prior to removal of the reactor pressure vessel head is adequate.

GEH Response

NEDO-33201 Revision 4 is currently in development. This revision will have full quantification results for every aspect of the model. This will include:

- Shutdown Internal Events
- Shutdown Internal Events RTNSS
- Shutdown Internal Events Focus
- Shutdown Fire
- Shutdown Fire RTNSS
- Shutdown Fire Focus
- Shutdown Flood
- Shutdown Flood RTNSS
- Shutdown Flood Focus
- Shutdown High Winds
- Shutdown High Winds RTNSS
- Shutdown High Winds Focus

The results presented throughout Revision 4 of NEDO-33201 will show the impact to the PRA of having only 6 of 8 DPV's operable during shutdown.

DCD/NEDO-33201 Impact

The response to this RAI results in no impact to the DCD.

NEDO-33201, Rev. 4 will be revised as noted in the above response.