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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 109 Related to ESBWR Design Certification Application, RAI Number 19.1-96 S01**

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) sent by NRC letter dated October 12, 2007 (Reference 1). The previous RAI and response was transmitted in References 2 and 3. The GEH response to RAI Number 19.1-96 S01 is in Enclosure 1.

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

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

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NRO

Reference:

1. 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.

2. 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

3. 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. 109 Related to ESBWR Design Certification Application, ESBWR Probabilistic Risk Assessment, RAI Number 19.1-96 S01

cc:		
cc:	AE Cubbage	USNRC (with enclosure)
	GB Stramback	GEH/San Jose (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	eDRFSection	0000-0079-9289

Enclosure 1

MFN 07-485, Supplement 2

Response to Portion of NRC Request for

Additional Information Letter No. 109

Related to ESBWR Design Certification Application

ESBWR Probabilistic Risk Assessment

RAI Number 19.1-96 S01

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

<u>NRC RAI 19.1-96</u>

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.

<u>GEH Response</u>

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.

DCD Impact

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°F 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.