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MFN 07-324, Supplement 1

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 107 Related to ESBWR Design Certification Application, RAI Number 19.1.0-1 S01 (parts B, C and E)**

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 31, 2007 (Reference 1). The previous RAIs and responses were transmitted in References 2 and 3. The GEH responses to RAI Number 19.1.0-1 S01 (parts B, C and E) are in Enclosure 1. RAI 19.1.0-1 S01 (parts A and D) will be provided by June 20, 2008 in a separate transmittal.

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

Sincerely,

James C. Kinsey
Vice President, ESBWR Licensing

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NRO

References:

1. MFN 07-492, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 107 Related to ESBWR Design Certification Application*, August 31, 2007.

2. MFN 05-156, Letter from U.S. Nuclear Regulatory Commission to David H. Hinds, *Request for Additional Information Letter No. 3 for The ESBWR Design Certification Application*, December 8, 2005.

3. MFN 07-324, Response to Portion of NRC Request for Additional Information Letter No. 3 Related to ESBWR Design Certification Application, RAI Number 19.1.0-1, June 14, 2007.

Enclosure:

1. MFN 07-324, Supplement 1. Response to Portion of NRC Request for Additional Information Letter No. 107 Related to ESBWR Design Certification Application, ESBWR Probabilistic Risk Assessment RAI Number 19.1.0-1 S01 (parts B, C and E)

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)
	eDRF Section	0000-0081-8286

Enclosure 1

MFN 07-324, Supplement 1

Response to Portion of NRC Request for

Additional Information Letter No. 107

Related to ESBWR Design Certification Application

ESBWR Probabilistic Risk Assessment

RAI Number 19.1.0-1 S01 (parts B, C and E)

For ease of reference, the original text of RAI 19.1.0-1 and the GEH response is included. The RAI does not include the graphical results transmitted with the original response.

NRC RAI 19.1.0-1

Please address passive system T-H uncertainty. The issue of T-H uncertainty, also called passive system performance uncertainty, is not addressed in the ESBWR PRA. The issue of T-H uncertainty rises from the "passive" nature of the safety-related systems used for accident mitigation. Passive safety systems rely on natural forces, such as gravity, to perform their functions. Such driving forces are small compared to those of pumped systems and the uncertainty in their values, as predicted by a "best-estimate" T-H analysis, can be of comparable magnitude to the predicted values themselves. Therefore, some accident sequences with frequency high enough to impact results, which are not predicted to lead to core damage by a "best-estimate" T-H analysis, may actually lead to core damage when T-H uncertainty is considered in the PRA models. T-H uncertainty, and its impact on PRA models, has been addressed in the certification of the AP600 and AP1000 designs through the use of a structured "margins" approach. This approach accounted for T-H uncertainty in the PRA by adopting conservative success criteria for safety systems and operator actions. It is stated in the submitted PRA for the ESBWR design that the issue of T-H uncertainty has been addressed "by increased design redundancies in the key passive systems and components." The staff believes that the issue of T-H uncertainty cannot be resolved by this statement alone, even though increased system redundancies may have a beneficial effect in addressing this issue. The accounting for T-H uncertainty may result in more conservative success criteria than those currently assumed in the PRA, which in turn will result in higher risk estimates. For example, the assumed success criteria for core cooling using the gravity driven cooling system could change to require the opening of two out of four equalizing lines instead of the one out of four lines currently assumed in the PRA. Such potential changes can have a significant impact on the results and insights of the PRA and could lead to additional design certification requirements, such as requirements for regulatory treatment of non-safety systems (RTNSS).

GE Response

The ESBWR relies on several passive systems to perform safety functions including

- Gravity Driven Cooling System (GDCS) – primary coolant injection,
- Passive Containment Cooling System (PCCS) – primary containment cooling,
- Isolation Cooling System (ICS) – RPV pressure control and decay heat removal, and
- Automatic Depressurization System (ADS) using depressurization valves (DPV) – RPV pressure reduction to allow GDCS success.

These systems do not rely on active sources such as electric motor driven pumps. The motive forces, for these passive systems, are gravity and the pressure differential resulting from condensation of steam. By not relying on active sources, degradation modes such as motor/pump wear and lost/degraded electric power are eliminated. The motive forces for the passive systems while more constant/reliable provide less driving force.

RAI 19.1.0-1 considers the effect on success criteria for the passive systems used in the ESBWR and the effect on the core damage frequency (CDF) if more conservative success criteria are used for these passive systems. The uncertainty in the success criteria for the passive systems was evaluated and showed little effect on the CDF. The success criteria of the passive systems were found to have a low sensitivity to changes to input parameters. As a result of this evaluation, adequate margin in the success criteria and/or CDF is present in the success criteria assumed for the passive ESBWR systems in the PRA.

Background

The performance of these passive systems was analyzed using TRACG in design basis evaluations and MAAP in PRA evaluations.

In 2002, General Electric Nuclear Energy (GENE) requested a pre-application review of the ESBWR with a focus on the TRACG program. On August 19, 2004, the NRC staff issued a safety evaluation regarding the application of TRACG to ESBWR loss-of coolant accident (LOCA) analyses. The NRC staff concluded, based on discussions in the SER, that TRACG is an acceptable evaluation model for ESBWR LOCA Analyses as presented in NEDC-33083P, TRACG Application for ESBWR.

The Electric Power Research Institute (EPRI) and GE sponsored research to develop an ESBWR version of EPRI's MAAP code (MAAP 4.0.6) and its application to perform calculations required for ESBWR design certification. This research is described in EPRI Report: Program on Technology Innovation: MAAP Analysis of ESBWR and Comparison to TRACG, Technical Report 1011712. The consistency and accuracy of the MAAP response with the spectrum of TRACG cases were investigated. The comparison of results indicates that MAAP provides adequate and reasonable thermal hydraulic response for ESBWR specific passive containment systems.

Investigation

In order to investigate the thermal-hydraulic (T/H) uncertainty of the ESBWR passive systems and its effect on the success criteria of the passive systems, the four systems listed above were reviewed to identify input parameters, which include uncertainty. These parameters were then investigated to determine the sensitivity of passive system success criteria to these parameters.

Chapter 6 of the ESBWR Design Control Document (DCD) includes TRACG analyses of 4 loss-of-coolant-accidents. These 4 LOCAs were analyzed using nominal conditions and single failures. MAAP results were compared to two of these accidents described in DCD Tier 2 Rev 3, Steam Line Break Inside Containment and GDCS Injection Line Break.

The MAAP model (parameter file) was developed using best available inputs for design of the ESBWR plant. The model was evaluated as described in the EPRI Draft Applications Guide. This evaluation included running a steady-state case and comparing the resulting primary system masses and volumes from MAAP with the GE calculation of primary system weights and volumes. The water masses calculated by MAAP for the 3 main primary system volumes were within approximately 2% of the GE calculation.

The comparison of MAAP results to TRACG results for the two accidents is shown in the graphs in Attachments 2 – 5. The title of the graphs of the MAAP analyses are identified as MAAP runs, while the TRACG graphs do not identify any computer code in their title. The figure numbers correspond to the figure numbers in DCD Tier 2 Chapter 6. The comparison with the main steam line break inside containment – ECCS-LOCA Performance Analysis is shown in Attachment 2. This accident is a complete break of a main steam line with a failure of a GDCS injection valve to open. In this analysis, MAAP is shown to actuate ADS sooner because it initiates on collapsed liquid level in the shroud. The TRACG model includes an instrument model that calculates collapsed liquid level above the instrument tap. The difference from the bottom of the downcomer to the lower instrument tap explains why TRACG initiates ADS with a downcomer collapsed level lower than Level 1 (see Attachment 2). This accident was re-evaluated in MAAP with ADS and GDCS set to operate at the same times as in the TRACG analysis. The results showed little changes except the flow rate of the SRVs decreased due to opening at a lower RPV pressure. The SRV flow rate in this MAAP case was closer to the flow rate in TRACG.

The comparison with the GDCS injection line break – ECCS-LOCA Performance Analysis is shown in Attachment 3. This accident is a complete break of a GDCS injection line with a failure of a GDCS injection valve to open.
The comparison with the main steam line break – Containment analysis is shown in Attachment 4. This accident is a complete break of a main steam line with a failure of a DPV to open. It is noted that the Containment pressures in the TRACG graphs rise above the MAAP graphs, because TRACG models the radiolytic decomposition of water. The MAAP results show a larger difference between decay heat and PCCS heat removal than the difference shown in TRACG graphs, because additional containment heat sinks are modeled in MAAP.

The comparison with the GDCS injection line break – Containment analysis is shown in Attachment 5. This accident is a complete break of a GDCS injection line with a failure of a DPV to open.

<u>GDCS System</u>

The first passive system reviewed was the GDCS system. The success criteria for the GDCS system is 2 of 8 injection valves from at least 1 of 3 GDCS pools for most PRA sequences. A design basis success criterion (i.e. allowing a single failure) would be 7 of 8 injection valves as used in TRACG evaluations in DCD Chapter 6. The GDCS system includes input parameters that have uncertainty such as injection line pressure losses and input parameters that have less uncertainty such as pool size and elevation. The important function of the GDCS system is primary coolant injection, which is dependent on system flow rate. The comparison of MAAP results for GDCS flow rate with TRACG results described above showed good agreement between the two programs.

A sensitivity analysis of the success criteria for the GDCS system was conducted for selected successful events/sequences using MAAP. For both the GDCS short-term (injection) and long-term (equalization) operation, a success sequence from the most limiting large break LOCA (LLOCA) event was evaluated to determine the sensitivity of change to the operation of GDCS and key RPV performance parameters. The limiting LLOCA was found to be a break at the RWCU tap based on the challenge to inventory in the RPV. Parameters varied to evaluate the GDCS system included the number of valves, size of valves/openings and other model parameters that are specific to MAAP for modeling of breaks and natural circulation. Successful GDCS operation was demonstrated using slightly less than 1 of 8 injection lines in the LOCA case. The success criteria used for GDCS injection and the ADS system below is peak cladding temperature less than 2200°F. This success criteria agrees with the description in the ASME PRA Standard Supporting Requirement SC-A2, example (b). This sensitivity analysis shows margin in the success criteria for the GDCS system in both the number of valves required to operate and the available GDCS flow area (size of the GDCS valves).

PCCS System

The next passive system reviewed was the PCCS system. The function of the PCCS system is to remove the decay heat from primary containment by condensing steam released to the drywell either through the DPVs or the RPV break in large LOCA sequences. The success criteria for the PCCS system is 4 of 6 PCCS heat exchangers operating. The design basis evaluations assumed 6 of 6 PCCS heat exchangers operating because the system does not include active components to perform its function. The input parameters for the PCCS include the configuration of the heat exchangers and the junctions between the upper drywell and the heat exchangers and the condensate drain junctions. However, the important uncertainty in the performance of the PCCS system is the heat removal capacity of the system. Whether it's the number of PCCS heat exchangers in service or the heat transfer surface area of each heat exchanger or material properties of the heat exchanger, the uncertainty results in more or less heat removal capacity of the PCCS system. MAAP sensitivity runs have shown the primary containment pressure is maintained less than design pressure with 2 PCCS heat exchangers in service or 4 PCCS heat exchangers in service assuming 50% heat transfer area. The maximum primary containment pressures obtained were 345 kPa and 343 kPa, respectively, versus a primary containment design pressure of 414 kPa. The ultimate pressure capability of the containment structure is 1.305 MPa at 533°K per Appendix B.8 of NEDO-33201 Rev 1.

ICS System

The success criteria assumed in the PRA, 3 of 4 ICS heat exchangers in operation, agrees with the design of the system as described in DCD Tier 2 Section 5.4.6. Given the extensive experience with isolation condensers in operating BWRs and the operating conditions of this system, normal RPV pressure, large thermal-hydraulic uncertainty is not expected and the ICS system was not reviewed for thermal-hydraulic uncertainty further.

ADS System – DPV Valves

The success criteria of the DPV valves assumed in the PRA is 4 of 8 DPVs open to support operation of the GDCS system and the PCCS in non-large LOCA events.

A sensitivity analysis of the success criteria for the ADS system using the DPVs was conducted using a medium-break LOCA (MLOCA) event. It was found that a break at the SLCS line resulted in similar challenges to inventory in the RPV and initiation of GDCS as other MLOCA events. Parameters varied to evaluate the ADS system included the number of valves and size of valves. Successful ADS operation during a SLCS MLOCA was demonstrated using slightly less than 3 of 8 DPV valves.

CDF Results

To investigate the effect on core damage frequency (CDF), the success criteria of the passive systems was varied from the PRA success criteria using design basis single failure criteria. It should be noted that the failure probability of the GDCS injection check valves, which are normally open valves failing closed or plugging, has been increased by a factor of 10 both because of the uncertainty in check valve design and the uncertainty in whether the check valve closes when the GDCS injection squib valve is opened. The GDCS injection squib valves are timed to open 100 seconds after first group of DPVs open and 50 seconds after second group of DPVs opens. This opening sequence should allow the RPV to be de-pressurized prior to opening the GDCS injection squib valves. However, if the RPV is not de-pressurized below the GDCS valve inlet head, the GDCS injection check valves may be forced closed.

The base CDF using the assumed success criteria in the PRA, 2 of 8 GDCS injection lines, 2 of 8 DPVs opening, 4 of 6 PCCS heat exchangers operating, was 1.07E-8/yr. This CDF, and the CDF for the sensitivity cases were calculated using a truncation level of 1E-13. This truncation level was used because of the large calculation times required for the sensitivity cases.

A sensitivity, Case 1, was run which assumed design basis success criteria for the passive systems, 7 of 8 GDCS injection lines, 6 of 6 PCCS heat exchangers, 7 of 8 DPV. The CDF obtained from this sensitivity case was 1.97E-7/yr. This is an order of magnitude increase in CDF but still well under the quantitative probabilistic risk goals. The results of this case indicate a high importance of 2 GDCS injection valves, check valves or squib valves, failing from random causes.

A second sensitivity, Case 2, was run which used a success criteria of 6 of 8 GDCS injection lines but retained the design basis success criteria for the other passive systems. The CDF obtained from this sensitivity case was 7.13E-8/yr, a decrease of 64% from Case 1. In this case, the results indicate a high importance of test and maintenance of a single PCCS heat exchanger – assumed a technical specification allowable outage time of 8 hours once per year. It should be noted that this allowable outage time has nothing to do with TH uncertainty, but configuration control. If the test and maintenance term for a single PCCS heat exchanger is removed from the results for sensitivity cases 1, 2 and 3 (PCCS success criteria = 6 of 6 heat exchangers), the CDF lowers to the second red bars displayed for these cases shown on attachment 1.

Case 3 reduced the success criteria of DPVs to 6 of 8 but retained the success criteria of GDCS, 6 of 8, and PCCS, 6 of 6, from Case 2. The CDF obtained from this sensitivity case was 6.12E-8/yr. This result is a small decrease in CDF from Case 2. This indicates that CDF is not sensitive to DPV success criteria.

Case 4 reduced the success criteria of PCCS to 5 of 6 heat exchangers but retained the success criteria of 6 of 8 GDCS, and 6 of 8 DPVs from Case 3. The CDF obtained from this sensitivity case was 1.83E-8/yr. This result is a 70% decrease in CDF from Case 3 versus a 14% decrease in CDF from Case 2 to Case 3. This difference validates the importance of a single PCCS heat exchanger unavailable for test and maintenance if the PCCS success criteria was 6 of 6 heat exchangers.

Case 5 reduced the success criteria of GDCS to 5 of 8 but retained the success criteria of DPVs, 6 of 8, and PCCS, 5 of 6, from Case 4. The CDF obtained from this sensitivity case was 1.11E-8/yr.

Case 6 reduced the success criteria of DPVs to 4 of 8 and PCCS to 4 of 6, PRA success criteria, but retained the GDCS success criteria of 5 of 8 from Case 5. The CDF obtained from this sensitivity case was 1.08E-8/yr. This result is an increase of less than 1% from the base case.

Reviewing the CDF changes related to individual passive systems shows the following:

- There is little change in CDF, 0.9%, due to changing GDCS success criteria from 2 of 8 to 5 of 8. The increase in CDF due to changing the GDCS success criteria from 5 of 8 to 6 of 8 is 65%. The increase in CDF due to changing the GDCS success criteria from 6 of 8 to 7 of 8 is 176%. This shows CDF is insensitive to GDCS success criteria until it is increased to 6 of 8 or 7 of 8.

- There is little change in CDF, 3%, due to changing PCCS success criteria from 4 of 6 to 5 of 6 and DPV success criteria from 4 of 8 to 6 of 8. The change in CDF due to changing the PCCS success criteria from 5 of 6 to 6 of 6 is 234%. This indicates CDF is insensitive to PCCS success criteria until it is increased to 6 of 6.

- The change in CDF due to changing the DPV success criteria from 6 of 8 to 7 of 8 is 16.5%.

<u>Conclusion</u>

This analysis has shown there is margin in the passive system success criteria and that the redundancy shown preserves the base CDF results. Therefore, CDF is not sensitive to a change in the success criteria of 1 GDCS injection valve or 1 DPV. There is little CDF sensitivity to a change in the success criteria of 1 PCCS heat exchanger.

DCD Impact

No DCD changes will be made in response to this RAI.
The revision to NEDO-33201 Chapter 11, Revision 2 will include the results of this analysis.

RAI Response 19.1.0 S01 (partial)

B. The applicant's response to the RAI does not include enough information for the staff to understand the basis for selecting the limiting accident scenarios used to determine minimum success criteria. Please provide the rationale for accident scenarios selected. Please include any criteria that were applied in making the selections and/or the results of any parametric studies that may have been used to identify limiting scenarios.

C. In order to understand the uncertainty in the determination of minimal success criteria, the staff needs to know how key thermal-hydraulic parameters that could affect the results are selected. For example: Are nominal values or bounding values being used? Such parameters may include: decay heat rate, containment pressure, flow resistance in piping, heat transfer area and heat transfer coefficient in the IC and PCCS, and flow area through the break, SRVs, DPVs and check valves in the GDCS. Please list the key parameters and describe how each was treated in the analysis. If nominal parameter values are used in the analyses, please discuss the impact on the results of the analyses when bounding parameter values are used.

E. The staff agrees that setting the PRA success criterion for the IC as three of four condensers (i.e., same as design basis single failure criterion) is a bounding assumption in the analyses. However, it has been observed in the design basis accident analysis that there are pipe break scenarios involving isolation condenser piping which leave only two IC available for mitigation. Please explain whether the safety function provided by the IC will always fail in these scenarios or there are circumstances in which two of four IC can provide minimal success.

GEH Response to RAI 19.1.0-1 S01 Part B

The selection of the limiting accident scenario used to determine the minimum success criteria was based on the challenge to the safety function being evaluated.

For the GDCS system, this challenge is to the water level in the reactor pressure vessel. For the ADS system, which supports the GDCS system via depressurization, the challenge is based on loss of inventory which also requires depressurization. For the PCCS system, the challenge is energy released as steam to primary containment.

NEDO-33201, Rev. 2, Section 11.A contains details of the thermal hydraulic (T-H) sensitivities evaluating the function and operation of the ESBWR passive systems. Accident scenarios evaluated as part of the T-H sensitivity were based on Large Break Liquid LOCAs (LLOCA) scenarios, Medium Break Liquid LOCAs (MLOCA) and transients associated with Inadvertently Opened Relief Valves (IORV). From the accident event trees, an individual success path was selected that incorporated functions of the each of the passive systems with the following exceptions.

In the LLOCA case, the accident scenario did not include ADS because LLOCAs provide sufficient depressurization of the RPV without the need for additional depressurization methods to allow GDCS injection. As a result, the sensitivity results for the ADS function were evaluated by the MLOCA and IORV scenarios. The ICS function is not credited in the LLOCA, MLOCA or IORV event trees. Additional discussions of T-H sensitivities as they relate to ICS are provided in the GEH response to RAI 19.1.0-1S01 Part C, provided below.

Using the selected accident scenarios, possible LLOCA and MLOCA breaks identified in Table 2.2-3 of NEDO-33201, Rev. 2 were evaluated. Discussion of the results for the LLOCA and MLOCA breaks are contained in NEDO-33201, Rev. 2 Section 11A.1.1 and 11A.1.2. A review of break results showed the RWCU/SDC line to be the limiting LLOCA and the SLCS line to be the limiting MLOCA based on the early core uncovery and challenge to the water levels in both the reactor pressure vessel and shroud. Data supporting the identification of the limiting LOCA breaks are contained in Tables 11A-1 through 11A-2 and Figures 11A-1 through 11A-20.

Successful operation of the PCCS was determined based on the control of pressures developed in the drywell and wetwell to levels below the primary containment ultimate pressure capability. PCCS is only credited in non-ATWS sequences after operation of at least 4 DPVs or in LLOCAs. The energy released as steam into primary containment is comparable in both of these cases. A large break on the main steam line was selected as the accident scenario for PCCS due to the potential to produce elevated pressures in the drywell.

<u>GEH Response to RAI 19.1.0-1 S01 Part C</u>

In the ESBWR PRA, as is standard practice in nuclear power plant PRAs, thermal-hydraulic parameters were selected as nominal values to perform best-estimate analyses. If there is considerable uncertainty in a parameter value or equipment response, it is chosen to be a bounding value. An example of this is the timing of the ADS valve opening. ADS valve actuation is sequenced so all valves are not opening at the same time. Since it is not possible to know which valves are not operating, it is assumed that the operating valves are last in the sequence which delays depressurization.

The keys to the response/success of the passive systems evaluated are described below. If bounding values were used for key thermal-hydraulic parameters, the margin to the success criteria would be reduced or the success criteria would be increased. As shown in the core damage frequency sensitivity case 4 in GE Response RAI 19.1.0-1, there was a only small change in CDF even if success criteria were changed to 6 out of 8 GDCS injection lines (from 2 out of 8), 6 out of 8 DPVs (from 4 out of 8) and 5 out of 6 PCCS (from 4 out of 6).

Appendix 11.A contained in NEDO-33201, Rev.2 Chapter 11 provides the results of the thermal hydraulic (T-H) sensitivities of the ESBWR passive systems using the MAAP code. In the execution of the T-H sensitivity analysis, multiple parameters were evaluated to better define the uncertainty of the passive systems for limiting accident scenarios. The selection and application of the sensitivity parameters were focused on the specific function and success criteria for each of the individual passive systems. In addition, the draft MAAP Application Guide was used to identify parameters within MAAP that might impact the operation of the passive systems. A discussion of the sensitivity data was provided in GE Response RAI 19.1.0-1 for the GDCS, PCCS, ICS and ADS systems. In addition, more detailed data tables and parameter plots are provided in Appendix 11.A.

GE's original response to RAI 19.1.0-1 addressed T-H uncertainty in the manner discussed below.

GDCS System – "The important function of the GDCS system is primary coolant injection which is dependent on system flow rate." For the sensitivity analysis, parameters related to the GDCS system flow rate or parameters that have the ability to impact the flow rate were used in the evaluation of GDCS. Successful GDCS operation, as defined by peak cladding temperature of less than 2200 °F (1477 K), was demonstrated by one of eight GDCS lines functioning at less than full flow capacity of the injection line. The PRA success criteria is 2 out of 8 GDCS lines.

This limit of the GDCS was evaluated in NEDO-33201, Rev.2, Chapter 11, Appendix 11.A. To facilitate this GDCS sensitivity analysis, a combination of parameters that affect the GDCS system flow rate was varied for the limiting LLOCA, MLOCA and IORV accident scenarios. These parameters included the number of injection lines, line size, friction coefficient for flow through injection lines, and source of water available for injection. A summary of the sensitivity parameters and other information obtained from the sensitivity analysis are contained in the tables provided below.

PCCS System - "The function of the PCCS system is to remove the decay heat from primary containment by condensing steam to the drywell..." For the sensitivity analysis, parameters related to the PCCS system heat removal capacity were used in the evaluation of PCCS. Successful PCCS operation, as defined by primary containment pressures of less than the ultimate pressure capability of 1.587 MPaG (230 psig), was demonstrated by two out of six PCCS units functioning or four out of six PCCS units functioning with a 50% heat transfer area maintaining primary containment pressure less than the design pressure of 414 kPa (60 psia). The PRA success criteria is 4 out of 6 PCCS units.
This limit of PCCS was evaluated and provided in GEH's response to RAI 19.1.0-1.

ICS System – The PRA success criteria for the ICS system requires three out of four units to function which agrees with the design basis for the system. As a result, no subsequent uncertainty evaluation of the ICS system was conducted.

ADS System – DPV valves - The ADS system functions to provide automatic depressurization of the reactor pressure vessel (RPV) which is dependent on flow rate exiting the valves. For the sensitivity analysis, parameters related to the ADS valves or having the ability to impact the flow rate from the valves were used in the evaluation of ADS. Successful ADS operation, as defined by peak cladding temperature of less than 2200 °F (1477 K) after operation of GDCS, was achieved by three of eight DPV valves functioning at less than full flow capacity through each valve. Additional conservatism in this analysis and the PRA success criteria included no credit for operation of ADS SRVs, which are opened prior to the DPVs and use of the last DPVs to open in the ADS sequence. The PRA success criteria is 4 out of 8 DPVs.

This limit of the ADS was evaluated in NEDO-33201, Rev.2, Chapter 11, Appendix 11.A. To facilitate this ADS sensitivity analysis, a combination of parameters that affect the flow through the ADS valves was varied for the limiting MLOCA and IORV accident scenarios. These parameters included number of ADS valves and valve size. In addition, the operation of other methods of depressurizing the RPV was limited. A summary of the sensitivity parameters and other information obtained from the sensitivity analysis are contained in the attached tables. These tables provide the parameters used in the T-H evaluation, their range of application, results and insights based on the impact to success criteria for both the LLOCA and MLOCA limiting accident scenarios.

GEH Response to RAI 19.1.0-1 S01 Part E

In the case of a break in the ICS steam line or the ICS return line, the PRA does not credit the ICS function.

DCD/NEDO-33201 Impact

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

No change to the NEDO-33201, Rev. 2 will be made in response to this RAI.

T-H Sensitivity Results - LLOCA

T-H Sensitivity	Sensitivity Parameter	MAAP Run GDCS - Injection: LL-VI1e	Application of Parameter: Bounding	Application of Parameter: Nominal	Comments	T-H Insights
Type of LOCA	Line associated with the Reactor Coolant Pressure Boundary	Single 300-mm RWCU/ SDC line	✔		Small breaks assumed to be bounded by larger breaks. Inadvertantly opened relief valves (IORV) are considered as well.	LLOCA is bounded by 12-inch steam break of 1/2 RWCU lines.
Break Parameters	FCDBRK	0.75		✔	MAAP code accepts values in the range 0.1-1.0. Sensitivity values varied from 0.25 to 0.80.	LLOCA results (flow rates through the break) are sensitive to changes to this parameter. As shown in RAI 19.1.0-1 Response, MAAP compares well to LOCA flow rates calculated in TRACG cases.
	FELOCA	0.0		✔	MAAP code accepts values in the range 0-1; MAAP guide recommends value of 0.0 in the absence of plant specific values representing the combined processes of entrainment, breakup, and impingement. Sensitivity run using value of 0.1.	LLOCA results show minimial changes due to variation of this parameter.
GDCS - Injection	Number of Valves: N_GDCS_VALVES	1	✔		Success criteria for GDCS injection requires 2 of 8 injection lines. Sensitivity runs varied the number of injection lines from 1 to 8.	Success critieria is bounded by 2 of 8 injection lines.
	Area of Injection Flow: AGO(1)	3.011E-03 m^2; 66% area of single valve	✔		Area of injection is a function of the number of injection lines available. Sensitivity values varied GDCS injection flow from 25% to 100% of the total available area of a GDCS injection line.	LLOCA sensitivity demonstrates limit of 66% flow from a single GDCS injection line; margin available in ESBWR GDCS injection success critieria.
	Configuration of GDCS	GDCS pool 1 available	✔		Success criteria for GDCS injection requires 1 of 3 pools available. GDCS pool 1 is a smaller volume pool.	Success critieria for GDCS injection is bounded by 1 of 3 GDCS pools.
GDCS - Equalization	Number of Valves: N_EQU_VALVES	1	✔		Success criteria for GDCS equalization requires 1 of 3 injection lines. Sensitivity runs varied the number of injection lines from 0 to 4.	Accident scenario is not impacted by changes to this parameter.
	Area of Equalization Flow: AGO(2)	2.027E-03 m^3	✔		Area of equalization is a function of the number of equalization lines available.	No sensitivities run due to lack of impact to accident scenario.
Natural Circulation Parameters	FFRICX	0.25		✔	MAAP code accepts values in the range of 0-1; MAAP guide indicates nominal values are generally between 0.25 and 0.45. Sensitivity runs varied the value from 0 to 1.	LLOCA results show no changes due to variation to this parameter.
	FNCBP	1.0		✔	MAAP code accepts values in the range of 0-1 and recomments a value of 0 if the in-vessel natural circulation flow return is in the outer fuel assemblies or 1 if return is down the outer bypass region. Sensitivity runs varied the value from 0 to 1.	LLOCA results show no changes due to variation to this parameter.

T-H Sensitivity Results - MLOCA

T-H Sensitivity	Sensitivity Parameter	MAAP Runs ADS: ML_XD3a	Application of Parameter		Comments	T-H Insights
			Bounding	Nominal		
Type of LOCA	Line associated with the Reactor Coolant Pressure Boundary	Single SLCS line 50-mm dia.	✔		Small breaks assumed to be bounded by larger breaks. Inadvertantly opened relief valves (IORV) are considered as well.	MLOCA is bounded by 2-inch liquid break of 1/2 SLCS lines.
Break Parameters	FCDBRK	0.75	NA	NA	MAAP code accepts values in the range 0.1-1.0.	No MLOCA sensitivity was conducted on this parameter.
	FELOCA	0.0	NA	MA	MAAP code accepts values in the range 0-1; MAAP guide recommends value of 0.0 in the absence of plant specific values representing the combined processes of entrainment, breakup, and impingement.	No MLOCA sensitivity was conducted on this parameter.
GDCS - Injection	Number of Valves: N_GDCS_VALVES	2	✔		Success criteria for GDCS injection requires 2 of 8 injection lines. Sensitivity runs varied the number of injection lines from 0 to 8.	Accident scenario successful using 1 of 8 injection lines. Success critieria is bounded by 2 of 8 injection lines.
	Area of Injection Flow: AGO(1)	9.124E-03 m^3	✔		Area of injection is a function of the number of injection lines available. Sensitivity values varied GDCS injection flow from 25% to 100% of the total available area of a GDCS injection line.	MLOCA sensitivity demonstrates limit of 75% flow from a single GDCS injection line; margin available in ESBWR GDCS injection success critieria.
	Configuration of GDCS	GDCS pool 1 available	✔		Success criteria for GDCS injection requires 1 of 3 pools available. GDCS pool 1 is a smaller volume pool.	Success critieria for GDCS injection is bounded by 1 of 3 GDCS pools.
GDCS - Equalization	Number of Valves: N_EQU_VALVES	1	✔		Success criteria for GDCS equalization requires 1 of 3 injection lines. Sensitivity runs varied the number of injection lines from 0 to 4.	Accident scenario is not impacted by changes to this parameter.
	Area of Equalization Flow: AGO(2)	2.027E-03 m^3	✔		Area of equalization is a function of the number of equalization lines available.	No sensitivities run due to lack of impact to accident scenario.
ADS Parameters	Number of Valves: DPV_#	3	✔		Success criteria for ADS is the operning 4 of 8 valves. Sensitivity runs varied the number of ADS valves from 1 to 4.	Accident scenario was successful using 3 of 8 valves. Success critieria is bounded by 4 of 8 ADS valves.
	Area of valve: ASRV(20)-(26)	1.575E-02 m^2; 75% area of single valve	✔		Depressurization is a function of the number of valve opened. Sensitivity values varied the flow area of a single ADS valve from 75% to 100%.	MLOCA sensitivity demonstrates limit of 75% flow from a single GDCS injection line; margin available in ESBWR ADS success critieria.
Natural Circulation Parameters	FFRICX	0.25	NA	NA	MAAP code accepts values in the range of 0-1; MAAP guide indicates nominal values are generally between 0.25 and 0.45.	No MLOCA sensitivity was conducted on this parameter.
	FNCBP	1.0	NA	MA	MAAP code accepts values in the range of 0-1: Specify a value of 0 if the in-vessel natural circulation flow return is in the outer fuel assemblies or 1 if return is down the outer bypass region, i.e., between the fuel cans and the shroud wall in a BWR	No MLOCA sensitivity was conducted on this parameter.