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Subject: **Response to NRC Request for Additional Information Letter No. 371 Related to ESBWR Design Certification Application – Reactor – RAI Number 4.4-23 S04**

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 the Reference 1 NRC letter. GEH response to RAI Number 4.4-23 S04 is addressed in Enclosure 1.

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

Sincerely,

Richard E. Kingston

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Vice President, ESBWR Licensing

Reference:

1. MFN 09-602, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 371 Related to ESBWR Design Certification Application,* September 15, 2009

Enclosure:

1. MFN 09-556 Supplement 1 - Response to Portion of NRC Request for Additional Information Letter No. 371 Related to ESBWR Design Certification Application – Reactor – RAI Number 4.4-23 S04

cc:

AE Cubbage	USNRC (with enclosure)
JG Head	GEH (with enclosure)
DH Hinds	GEH (with enclosure)
SC Moen	GEH (with enclosure)
eDRFSection	0000-0108-6434

Enclosure 1

MFN 09-556 Supplement 1

Response to NRC Request for

Additional Information Letter No. 371

Related to ESBWR Design Certification Application

Reactor

RAI Numbers 4.4-23 S04

NRC RAI 4.4-23 S04

In the response to RAI 4.4-23, Supplement 3 (MFN 09-556), it is stated that the LOCA water level is always above the top of the active fuel, and, in the case of a Main Steam Line Break, will be maintained at or above 7 m (23 ft) after around 1600 seconds. Following a LOCA or Main Steam Line Break, the liquid in all fuel channels will flash to vapor during the initial rapid depressurization. The liquid will be gradually replaced by GDCS flow once the squib valves are opened. The staff believes it is possible to retain or form a vapor bubble within the fuel channels which are partially or totally blocked due to debris buildup at the inlet orifice and debris filter screen. This is most likely early in the transient, when the up-flow due to boil off of water present in the channels (prior to blockage of the inlet flow path) exceeds the gravity-driven down-flow from the static water head above the channels. Later in the transient, the GDCS pool water flow from the top of the blocked channels will offset the vapor up-flow, and water will be restored.

Provide a calculation for the limiting break size, type, and location that demonstrates that the 10CFR50.46(b)(1) limit for peak clad temperature, 2200°F, will not be exceeded, or, if this cannot be shown for a limited number of bundles, demonstrate that the fuel failure acceptance criterion (upon which the radiological source term is based) is not exceeded. The calculation should be similar to that presented by the BWR Owners Group for BWR 2 through 6, which was presented at the July 23, 2009 meeting at NRC Headquarters.

If the TRACG code is used to perform the analysis, provide the basis for code qualification at low pressure (< 700 psia) for the GEXL critical power correlation and also the TRACG countercurrent flow model.

Also, provide an explanation for the significance of the 1600 seconds following a Main Steam line break for the 7 m (23 ft) of water above the top of active fuel (i.e., a timeline for reflood to this level above the core).

GEH Response

Debris Blockage Calculation

A LOCA calculation has been performed to demonstrate compliance with 10CFR50.46(b)(1). The TRACG analysis follows the NRC/BWROG presentation, “BWR LOCA Long Term Cooling Fuel Effects to Debris Blockages” (Ref 4.4-23 S04-6). The analysis shows that no significant deviation in peak cladding temperature occurs as the result of channel blockage.

The LOCA calculation starts with the reactor vessel water level-limiting line break accident. Debris is simulated at the earliest time that debris can be introduced into the reactor vessel from FAPCS, based on debris transport calculations. At the time determined, a percentage of the flow area over the hottest group of channels is blocked, as per Ref 4.4-23 S04-1. The blockage occurs instantaneously and is simulated for the

duration of the calculation. Peak cladding temperature and water level are monitored throughout the rest of the event.

Table 6.3-5 in the DCD shows that the level-limiting LOCA is the isolation condenser drain line break event, with a simulated failure of one GDCS injection valve. And although the isolation drain line break does not have the potential for generating transportable debris in the pools inside containment [Ref. 4.4-23 S04-1], the most level-limiting event should yield the smallest amount of gravity head to push water through the bottom of the core. For this reason, it is used in the analysis to demonstrate ESBWR's ability to cool blocked bundles. As stated in the RAI, blockage is more significant early, as decay heat will drop off with time, reducing steam production which can produce CCFL, and reduces the liquid flow required to provide cooling. For this reason, in this analysis conservatism in the licensing basis level model which delays ADS/ECCS initiation is removed, to produce an earlier depressurization.

Debris transport has two sources: the GDCS injection lines and a single feedwater line (FAPCS in LPCI mode). With the earlier depressurization, flow begins through the GDCS lines at 310 seconds. FAPCS flow could begin when RPV pressure drops below the design maximum tube pressure for the FAPCS heat exchanger, 2.0 MPa (290 psi). RPV pressure drops below this point at 150 seconds. This earlier time is where debris is introduced into the calculation. As an added conservatism, the blockage occurs instantaneously. The three blockage locations are outlined in Table 1 and represent the locations used in the BWROG study.

Table 1. Blockage Input

Blockage location	Percent blockage	Peak Clad temperature after blockage, deg. C (deg. F)	10CFR50.46 acceptance criteria, deg. C (deg. F)
Lower tie plate	100% of one channel group (16 fuel bundles)	217 (423)	1204 (2200)
Spacer #1	75% of one channel group	217 (423)	1204 (2200)
Upper tie plate	75% of one channel group	217 (423)	1204 (2200)

Three LOCA calculations have been run, one for each blockage occurring at 150 seconds instantaneously. Table 1 shows the Peak Clad Temperature after blockage. In all cases the clad does not heat up significantly above the liquid/steam saturation temperature. Large margin is maintained to the 10CFR50.46 acceptance criteria.

Code Qualification

TRACG has documented models and has been qualified for margin to dryout/boiling transition at pressures below 700 psia. As documented in 6.6.6.1 in Ref 4.4-23 S04-2, TRACG is qualified to calculate margin to dryout/boiling transition at lower pressure ranges. At low pressure, MSIV closure is initiated, causing a SCRAM. This prevents a low pressure, high power condition. For the ESBWR LOCA debris assessment where the power has dropped to decay heat levels, by the time blockage could potentially occur, the GEXL correlation will not be applied by TRACG. Instead, the Biasi and modified Zuber critical quality correlations are used to determine critical heat flux. The critical heat flux temperature is then calculated using the Chen correlation, which is applicable from 13 psi (0.09 MPa) to 1000 psi (6.9 MPa), as in 6.6.4.3 of Ref 4.4-23 S04-2.

TRACG has documented models and has been qualified for counter current flow limitation (CCFL). Although PIRT phenomena related to CCFL were shown to be unimportant to ESBWR design basis LOCA analyses (see Table 15.2-1, PIRT Phenomena Added or Deleted for LOCA/ECCS, in Ref 4.4-23 S04-3), they are modeled, documented and qualified in the TRACG04 code. The ESBWR ATWS report (Ref. 4.4-23 S04-4) provides documentation of TRACG models and qualification of the CCFL-related phenomenon, including PIRTs A7, A8, B4, B5, C6, C7 (note that the PIRT IDs are different in the ATWS report versus the LOCA report). Table 4.1.1, ESBWR Phenomena and TRACG Model Capability Matrix, in the ATWS report documents the sections of the TRACG model related to CCFL. Qualification of the countercurrent flow model against the upper tie plate counter current flow limiting tests is documented in Section 3.3 of Ref 4.4-23 S04-5 (see Table 318-1). Additional references to the CCFL qualification in Ref 4.4-23 S04-4 are provided in Table 4.2-1, Qualification Assessment Matrix for ESBWR ATWS Phenomena, in Ref 4.4-23 S04-4.

Significance of Water Level Above TAF

In response to Supplement 3 of this RAI, the water level given inside the shroud was for a main steam line LOCA. And as shown [Ref. 4.4-23 S04-1], a steam line LOCA has the potential for generating the most amount of transportable debris to the pools inside containment when compared to other breaks that can generate transportable debris. For the MSL LOCA, there exists a significant amount of level above TAF to provide cooling for a blocked bundle. At 1600 seconds into the MSL LOCA, the water level is 7 m (23 ft) above TAF and does not go down further than that for the duration of the event. And as discussed above, there also exists sufficient water above TAF to provide cooling for a blocked bundle for the level-limiting LOCA, isolation condenser drain line break.

References

4.4-23 S04-1. RAI 6.2-173 S01, MFN Letter 08-930 dated December 1, 2008

4.4-23 S04-2. *TRACG Model Description,* NEDE-32176P, Rev. 4, GEH Proprietary Report, January 2008.

4.4-23 S04-3 *TRACG Application for ESBWR,* NEDE-33083P-A, Rev. 1, GEH Proprietary Report, March 2005.

4.4-23 S04-4 *TRACG Application for ESBWR Anticipated Transient Without Scram Analyses,* NEDE-33083P Supplement 2, Rev. 2, GEH Proprietary Report, February 2008.

4.4-23 S04-5 *TRACG Qualification*, NEDE-32177P, Rev 2, GEH Proprietary Report, January 2000.

4.4-23 S04-6 *"BWR LOCA Long Term Cooling Fuel Effects to Debris Blockages,"* MFN Letter 09-501 dated July 2009.

DCD Impact

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

No changes to any LTR will be made in response to this RAI.