HITACHI

GE Hitachi Nuclear Energy

Richard E. Kingston
Vice President, ESBWR Licensing

P.O. Box 780 M/C A-65
Wilmington, NC 28402-0780
USA

T 910.675.6192
F 910.362.6192
rick.kingston@ge.com

MFN 09-559 Docket No. 52-010

August 24, 2009

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

Subject: **Response to NRC Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application – Fuel Storage and Handling - RAI Number 9.1-15 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) 9.1-15 S04 sent by NRC Letter Number 365, Reference 1. The response to RAI Number 9.1-15 S03 was previously submitted to the NRC via Reference 2 in response to Reference 3.

GEH response to RAI Number 9.1-15 S04 is addressed in Enclosure 1. DCD markups associated with this response are provided in Enclosure 2.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 09-555, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application*, August 10, 2009
2. MFN 08-496, Response to Portion of NRC Request for Additional Information Letter Number No. 289 Related to ESBWR Design Certification Application - Fuel Storage and Handling - RAI Number 9.1-15 S03, July 23, 2009
3. MFN 09-006, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 289 Related to ESBWR Design Certification Application*, December 29, 2008

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application - Fuel Storage and Handling - RAI Number 9.1-15 S04
2. Response to Portion of NRC Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application - Fuel Storage and Handling - RAI Number 9.1-15 S04 – DCD Markups

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0106-1671

Enclosure 1

MFN 09-559

Response to Portion of NRC Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application[1]

Fuel Storage and Handling

RAI Number 9.1-15 S04

[1] Original RAI, Supplement 1, Supplement 2, and Supplement 3 with GEH responses previously submitted under MFN Letters 06-309, 06-309 S07, 08-424, and 09-496 (respectively) without DCD updates are included to provide historical continuity.

NRC RAI 9.1-15

DCD Tier 2, Section 9.1.2 states that the SFP is a reinforced concrete structure with a stainless steel liner. Operating experience indicates that damage to the liner from light load handling accidents, such as a fuel assembly drop, are credible and can allow leakage at high rates.

Consistent with the guidance of SRP Section 9.1.3, Revision 3,July 1981, Criterion III.1.f, describe how the makeup capacities and the time required to make associated hookups are consistent with expected leakage from structural damage that causes leakage through the liner.

GE Response

SRP 9.1.3, Section III.1.f states:
"A seismic Category I makeup system and an appropriate backup method to add coolant to the spent fuel pool are provided. The backup system need not be a permanently installed system, nor Category I, but must take water from a Category I source. Engineering judgment and comparison with plants of similar design are used to determine that the makeup capacities and the time required to make associated hookups are consistent with heatup times or expected leakage from structural damage."

Reg. Guide 1.13, Section B.1 discusses acceptable solutions for avoiding structural damage resulting from load handling accidents:
"Possible solutions to this potential problem include (1) preventing, preferably by design rather than interlocks, heavy loads from being lifted over the pool; (2) using a highly reliable handling system designed to prevent dropping of heavy loads as a result of any single failure; or (3) designing the pool to withstand dropping of the load without significant leakage from the pool area in which fuel is stored."

The amount of leakage through the liner in the event of a load handling accident is limited by method 3. The SFP liner has been designed to the requirements contained in DCD Tier, Section 9.1.2.4 and as discussed in response to RAI 9.1-6. The ESBWR SFP liner is similar to existing plants such as ABWR. The liner is Seismic 1 and designed to the acceptance criteria of ASME Section III, Division 2, CC-3700.

In addition to the changes described in the response to RAI 9.1-6, the following sentence will be added to DCD section 9.1.2.4:

Pool liners will be evaluated to ensure structural integrity under fuel handling accidents.

NRC RAI 9.1-15 S01

Supplement received via e-mail dated 5/3/07 from Quinones:

The response is insufficient. Provide analyses demonstrating that the pool liner will retain its leak tight integrity after impact by a dropped fuel assembly, describe an alternative method of assuring an adequate pool inventory will be maintained following a fuel handling accident, or provide redundant safety-related makeup capability.

GEH Response

Using previous analysis methodology as guide, an analysis of the pool liners was performed for the ESBWR. The resulting conclusion demonstrated that a liner thickness of 10.80 mm or greater is sufficient to resist damage from a dropped fuel bundle. This is well within the 16 mm thickness of the liner.

DCD Impact

DCD Tier #2, Section 9.1.2 will be revised as noted in the attached markup.

NRC RAI 9.1-15 S02

The response to RAI 9.1-15S01 states that an analysis of the pool liner was performed for the ESBWR and the resulting conclusion demonstrated that a liner thickness of 10.80 mm or greater is sufficient to resist damage from a dropped fuel bundle. During an audit performed on January 30, 2008, the staff reviewed the applicant's drop analysis on the spent fuel pool (and reactor buffer pool) liner. The staff requests that the applicant responds to the following:

1) What is the basis for the equation used to calculate the required liner thickness?

2) Describe how the material properties of the liner were considered.

3) Describe the type of impact model is assumed (e.g., is all the energy absorbed by the liner)?

4) How is the liner assumed to fail (i.e., fracture, plastic deformation, etc.)?

5) How was operational experience considered during the evaluation? (See INPO Significant Event Report (SER) 15-95, "Spent Fuel Pool Liner Punctured by Dropped Equipment")

GEH Response

1) The equation used to calculate the required liner thickness for ESBWR is the same equation used in the analysis performed for the Lungmen ABWR, "Fuel Assembly Drop Evaluation" (31113-0U71-1129-0012, 8/2000):

$T = [(M*V_s^2)/2]^{2/3}/(672*D)$

The reference for the equation used in the Lungmen analysis is a "First of a Kind Engineering (FOAKE)" report for ABWR prepared by Bechtel, "Reactor Building Fuel Pool Liner" (22362-MLC-1060-001, Rev. 1, 2/1996). The Bechtel report references a topical report, also prepared by Bechtel, "Design of Structures for Missile Impact (BC-TOP-9A, 9/1974), which points to three Ballistic Research Laboratory references for inputs to development of the equation:

a) Russell, C.R., Reactor Safeguards, MacMillan, New York, 1962,

b) Fundamentals of Protective Design, TM 5-855-1, Headquarters, Department of the Army, Washington, D.C., July 1965,

c) Gwaltney, R.C., Missile Generation and Protection in Light-Water-Cooled Power Reactor Plants, ORNL NSIC-22, Oak Ridge National Laboratory, Oak Ridge, Tennessee, for the U.S. Atomic Energy Commission, September 1968.

GEH was unable to obtain the three references above. However, the Bechtel topical report was submitted to the Atomic Energy Commission and approved in November, 1974. The equation was used based on the Regulatory staff approval of this document.

To validate the original analysis, an alternative analysis has been completed. This analysis is attached and used very conservative assumptions to determine that a 304L stainless steel liner of 16 mm thickness has sufficient capability to absorb the impact energy from a dropped fuel assembly. The results provide a margin that is consistent with the result obtained in the original analysis (40% vs. 48%).

2) For the original calculation method, the reference assumed the material to be steel, without any further definition. For the alternate analysis, 304L stainless steel was used for the pool liner material based on its corrosion resistance properties.

3) The fuel assembly impact with the pool liner is assumed to occur at the location of a leak channel, such that the liner absorbs the total energy.

4) Based on analysis results, the liner is not assumed to fail. The alternate analysis considered plastic deformation of the liner.

5) SER 15-95 was reviewed for consideration in the analyses. Both events documented in the SER occurred due to workers using unapproved equipment in and around their respective spent fuel pools.

A dropped fuel assembly is considered the bounding case for the following reasons: 1) analysis was performed with the expectation that work will be performed within analyzed boundaries and according to applicable procedures, 2) the assumptions used in the analyses were conservative and results identified 40-48% margins in relation to the 16 mm pool liner thickness, 3) the fuel assembly geometry and weight is bounding relative to servicing tools that are typically provided to the plant.

DCD Impact

No DCD change was made in response to this RAI Supplement.

NRC RAI 9.1-15 S03

The staff reviewed GEH response to RAI 9.1-15, S02, received via GEH letter MFN 08-424 dated April 29, 2008. The staff generally agrees with the methodology used by GEH for evaluation of the liner plate against impact of a dropped fuel assembly. However, to determine adequacy of the alternative analysis, and to complete its review, the staff requests GEH to provide the following additional information:

1. *The original analysis calculated required thickness of the liner plate considering local effect on the liner plate due to impact of a dropped fuel assembly using the empirical formula (BRL formula) in Bechtel Topical Report BC-TOP-9A (local damage prediction). Provide a description of the alternative analysis including assumptions used, analysis results, and acceptance criteria used, and explain how results of the alternative analysis compare with those of the original analysis.*
2. *Describe evaluation of structural response of the liner plate due to impact of a dropped fuel assembly (overall damage prediction) including assumptions used, analysis results, and acceptance criteria used. Otherwise, provide justification why overall damage prediction for the liner plate due to impact of a fuel assembly need not be performed.*

GEH Response

1. Local liner damage prediction

An alternative analysis is presented below using the Stanford Research Institute (SRI) formula (Reference 1) for portion of the liner plate. This portion of the liner plate is not backed by concrete where leak chase channel is located in the spent fuel pool.

The critical kinetic energy required for penetration, Ep, is defined to be:

$$\frac{E_p}{DF^2} = \frac{S}{46500} \times \left(16000 \times \frac{T^2}{F^2} + 375 \times \frac{W \times T}{F^2} \right) \text{ in ft-lb}$$

Where,

D = diameter of fuel impact area= 0.41 inch (10.5 mm), lower bound value for conservatism.

T = liner plate thickness= 0.63 inch (16 mm).

S = ultimate tensile strength of liner material = 70343 psi (485 MPa)

W = length of side of square window in the target frame = 3 inch (76 mm)

F = scale factor = W/Ws; Ws = 4 inch

The critical kinetic energy Ep is computed to be 4413 ft-lb (5980 J).

The impact energy of the dropped fuel assembly is:

$$E = \frac{1}{2} \times M \times V^2 = 9082 \text{ ft-lb (12307 J)}$$

in which the fuel mass M is 473 lb (215 kg) and the impact velocity V is 35.08 ft/sec (10.7 m/sec) for a dropped height of 27.97 ft (8.526 m).

The critical energy capacity Ep is lower than the demand energy E; therefore, liner perforation could occur.

It should be noted that the SRI formula has limitations on the range of applicability. Table 1 shows the ESBWR values for various parameters in comparison with the range of applicability. Not all parameters fall within the range. Therefore, the SRI formula is not applicable to this ESBWR application.

Table 1 Check for SRI Formula Applicability

	T/D	T/L	L/D	W/D	W/T	W/L	V (ft/sec)
ESBWR Values	1.52	0.004	360	7.23	4.75	0.02	35.08
SRI Range of Applicability	0.1 to 0.8	0.002 to 0.05	10 to 50	5 to 8	8 to 100	0.2 to 1	70 to 400

Note: L is the projectile length

Since the SRI formula is not applicable, the Ballistic Research Laboratory (BRL) formula (Reference 2) should be used.

The BRL formula presented below is used to determine the required liner thickness for the same M, V and D parameters described above,

$$T = \frac{\left(\frac{M \cdot V^2}{2}\right)^{2/3}}{672 \cdot D}$$

The calculated T value is 1.57 inch (40 mm). It is increased by 25% to result in 1.97 inch (50 mm) to prevent perforation in accordance with Reference 2.

To meet the thickness requirement, a cover plate of 1.34 inch (34 mm) thickness is added to the top of the 0.63 inch (16 mm) thick liner plate over the leak chase channel as shown in Figure 1. The cover plate is made of the same material as the liner. Its width is 9.84 inch (250 mm) and the length is sufficient to cover the total length of the leak chase channels. The cover plates are installed above the liner welds that are not covered by the spent fuel racks.

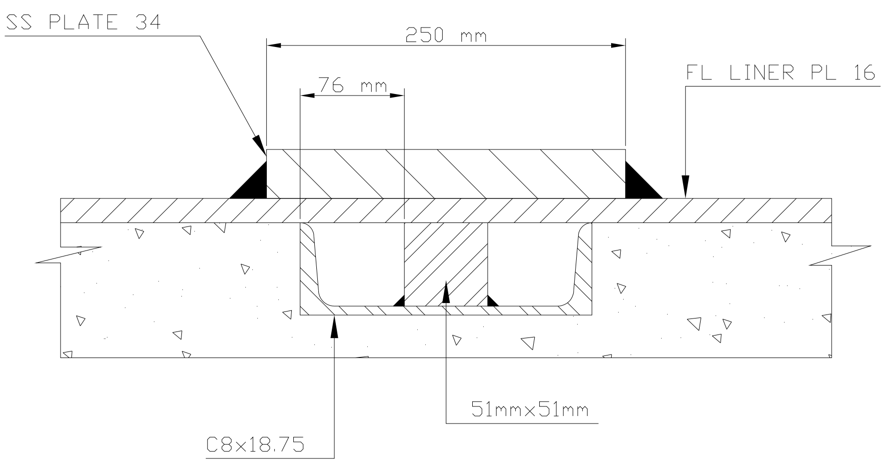

Figure 1. Liner Cover Plate Configuration

2. Overall liner damage prediction

With regard to overall liner damage due to the dropped fuel assembly in the spent fuel pool of Fuel Building, the global effect is negligible because of the following:

- The mass of the concrete of the 18 ft (5.5m) thick basemat and steel around the impact area is much bigger than the mass of the fuel assembly. This means that the velocity of the pool structure after the impact will be zero and, consequently, the energy absorbed by pool vibration will be null.
- For the portion of the liner plate above the leak chase channel only, the unsupported length of 3 inch (76 mm) is too small to undergo bending deformation under the point impact load. The controlling failure mode of the liner plate in this situation is punching shear and it is prevented by maintaining the thickness required for excluding perforation potential as evaluated above for local damage.

References:

1. Oak Ridge National Laboratory, W. B. Cottrell and A. W. Savolainen, “U. S. Reactor Containment Technology,” ORNL-NSIC-5, Vol. 1, Chapter 6, 1965.
2. Bechtel Power Corporation, “Design of Structures for Missile Impact”, Topical Report, BC-TOP-9A, Revision 2, September 1974.

DCD Impact

No DCD change is required in response to this RAI Supplement.

NRC RAI 9.1-15 S04

The staff reviewed GEH response to RAI 9.1-15 S03, received via GEH letter MFN 09-496, dated July 23, 2009. The staff finds the applicant's evaluation of the spent fuel pool liner plate against accidental fuel assembly to be technically acceptable. The staff notes that the evaluation relied upon reinforcing the liner plate in the region of the leak chase channels in areas that are not covered by spent fuel racks by welding 1.34 inch (34 mm) thick cover plates. Since reinforcement of the liner plate is a special design feature relied upon for maintaining integrity of the liner, please include this design requirement in the DCD, or provide justification why a DCD revision is not considered necessary. The staff notes that any design details added to DCD Tier 2 Appendix 3G in response to this RAI should be designated Tier 2 consistent with the response to RAI 3.8-128 in MFN 09-446, dated June 30, 2009.*

In addition, clarify whether the Buffer Pool has comparable leak chase channels and the corresponding need for reinforcement of the liner plate. As applicable, please include this design requirement in the DCD, or provide justification why a DCD revision is not considered necessary.

GEH Response

DCD Tier 2 Subsection 3.8.4.2.5 is being revised in Revision 6 to include as Tier 2* designation the design requirement for the cover plate for the floor liner plate above the spent fuel pool leak chase channels in the areas not occupied by fuel storage racks or other equipment. The entire buffer pool floor is occupied by fuel storage racks or other equipment and does not require a cover plate on top of the liner plate at the leak chase channels.

DCD Impact

DCD Tier 2 Subsection 3.8.4.2.5 will be revised in Revision 6 as noted in the attached markup.

Enclosure 2

MFN 09-559

Response to Portion of NRC Request for Additional Information Letter No. 365 Related to ESBWR Design Certification Application[1]

Fuel Storage and Handling

RAI Number 9.1-15 S04

DCD Markups

The liner welds for all pools outside of the RCCV, including the spent fuel pool, are backed by leak chase channels and a leak detection system to monitor any leakage during plant operation. The leak chase channels are grouped according to the different pool areas and direct any leakage to area drains. This allows both leak detection and determination of where leaks originate. The functioning of the leak chase channels are checked prior to completion of the pool liner installation.

[*For the floor area of the FB spent fuel pool liner that is not occupied by fuel storage racks or other equipment, the liner plates above the leak chase channels have a stainless steel reinforcing strip of material to protect against puncture from dropped objects such as a fuel assembly.*]* The liner plates above the leak chase channels in the RB buffer pool floor do not require a reinforcing strip of material since the buffer pool floor is fully occupied by fuel storage racks or other equipment.

Text sections that are bracketed and italicized with an asterisk following the brackets are designated as Tier 2. Prior NRC approval is required to change.

3.8.4.2.6 Firewater Service Complex

Applicable documents for the FWSC design are the same as the RB, which are listed in Table 3.8-9.

3.8.4.3 Loads and Load Combinations

3.8.4.3.1 Reactor Building

3.8.4.3.1.1 Loads and Notations

This section presents only the loads that are applied to the RB directly. Other loads, which are applied to the RCCV only but have effects on RB structures because of common foundation mat, like P_a and T_a, are also considered in the RB design.

Loads and notations are as follows:

D = Dead load of the structure and equipment plus any other permanent loads, including vertical and lateral pressures of liquids.

L = Conventional floor or roof live loads, movable equipment loads, and other variable loads such as construction loads. The following live loads are used:

- Concrete floor slabs – 4.8 kPa (100 psf).
- Concrete roofs – 2.9 kPa (60 psf).
- Construction live load on floor framing in addition to dead weight of floor – 2.4 kPa (50 psf).

Live load L, includes floor area live loads, laydown loads, nuclear fuel and fuel transfer casks, equipment handling loads, trucks, railroad vehicles and similar items. The floor area live load is omitted from areas occupied by equipment whose weight is specifically included in dead load. Live load is not omitted under equipment where access is provided, for instance, an elevated tank on four legs.