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Proprietary Information Notice
This letter forwards proprietary information in accordance with 10 CFR 2.390. The balance of this letter may be considered non-proprietary upon the removal of Enclosure 1.

MFN 08-930

Docket No. 52-010

December 1, 2008

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

Subject: **Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196**

Enclosures 1 and 2 contain the GE Hitachi Nuclear Energy (GEH) responses to the subject NRC RAIs transmitted via the Reference 1 and Reference 2 letters, respectively.

Enclosure 1 contains proprietary information as defined in 10 CFR 2.390. The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 1 has been handled and classified as proprietary to GEH. GEH hereby requests that the proprietary information in Enclosure 1 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17. Enclosure 2 is the non-proprietary version of the RAI response, which does not contain proprietary information and is suitable for public disclosure.

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 08-317, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 170 Related to ESBWR Design Certification Application*, March 28, 2008
2. MFN 08-658, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 245 Related to ESBWR Design Certification Application*, August 20, 2008

Enclosures:

1. MFN 08-930 - Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196 - GEH Proprietary Information
2. MFN 08-930 - Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196 - Non-Proprietary Version
3. Affidavit - David H. Hinds - dated November 25, 2008

cc:	AE Cubbage	USNRC (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	RE Brown	GEH/Wilmington (with enclosures)
	eDRF	RAI 6.2-173 S01: 0000-0073-5385R4
		RAI 6.2-196: 0000-0093-5425

Enclosure 3

MFN 08-930

Affidavit

David H. Hinds

Dated December 1, 2008

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am the Manager, New Units Engineering, GE Hitachi Nuclear Energy ("GEH"), have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of GEH letter MFN 08-930, Mr. Richard E. Kingston to U.S. Nuclear Regulatory Commission, entitled *Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196,* dated December 1, 2008. The GEH proprietary information in Enclosure 1, which is entitled *MFN 08-930 - Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196 - GEH Proprietary Information,* is delineated by a [[dotted underline inside double square brackets.[3]]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation [3] refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination. A non-proprietary version of this information is provided in Enclosure 2, *MFN 08-930 - Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application - Containment Systems - RAI Numbers 6.2-173 S01 and 6.2-196 - Non-Proprietary Version.*

(3) In making this application for withholding of proprietary information of which it is the owner, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret," within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH competitors without license from GEH constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it can be used to determine the models and methodologies GEH will use in evaluating the consequences of design basis accidents (DBAs) for the ESBWR. GEH performed significant additional research and evaluation to develop a basis for these revised methodologies to be used in evaluating the ESBWR over a period of several years at a substantial cost.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 1st day of December 2008.

David H. Hinds
GE- Hitachi Nuclear Energy Americas LLC

Enclosure 2

MFN 08-930

Response to Portion of NRC Request for Additional Information Letter Nos. 170 and 245 Related to ESBWR Design Certification Application

Containment Systems

RAI Numbers 6.2-173 S01 and 6.2-196

Non-Proprietary Version

NRC RAI 6.2-173 S01:

In response to RAI 6.2-173, GEH proposed to include the following in DCD Tier 2 Section 9.1.3.2: "[t]he suction location in the suppression pool shall be designed with consideration given to the strainer plugging issues encountered in previous operating experience."

(1) Clarify that the suction locations include suction for the suppression pool cooling and low pressure core cooling pumps and GDCS equalization line.

(2) GL 2004-02 and GSI 191: DCD Tier 2, Table 1C-1 which lists the operating experience review results summary of generic letters (GLs), does not list GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation during Design Basis Accidents at Pressurized-Water Reactors," which NRC issued during the resolution of generic issue 191, "Assessment of [Effect of] Debris Accumulation on PWR Sump Performance." Please explain why the issues addressed in GL 2004-02 and Generic Safety Issue 191 are not considered for the ESBWR.

(3) RG 1.82, Revision 3: Regulatory guide (RG) 1.82, Revision 3, provides acceptable guidance for design of BWR suction strainers. RG 1.82, Revision 3, also states that the suction strainers should be designed for chemical and downstream effects. That is, the effects of chemical reaction products on the estimated strainer head loss and the potential for downstream debris to impact long-term core cooling need to be understood. Chemical effects would include the formation of chemical reaction products, sludge, and corrosion products in the post-LOCA environment. In addition to the settling of latent and LOCA debris on the suction strainers, chemical products could also settle on the strainer surfaces, decreasing NPSH margin. The concern with downstream effects within the core is that, debris, either latent, LOCA caused, or chemical reaction products, could slip through the trash racks and suction strainers, lodging in the fuel bundle debris filters, and thus, impeding the coolant flow affecting cooling of the fuel rods.

Allowing for the debris source improvements made by GEH with the ESBWR design, describe what consideration is given for chemical and downstream effects in the sizing of the suction strainers (in meeting regulatory positions 2.1.2.2, 2.3.1.8, and 2.3.3.5 of RG 1.82, Revision 3). Discuss the GEH methodology for determining the content, amount, and loading distribution of the anticipated debris either conservatively or prototypically, with consideration for post-LOCA chemical products, and how suction strainers will be designed to handle the anticipated debris. In formulating a technical response that will be acceptable to the staff, elaborate on your methodology, including supporting calculations, full-scale testing and/or bench-top type experiments. Estimates of head loss caused by debris blockage should be developed from empirical data based on the strainer design (i.e., surface area and geometry), postulated debris (i.e., amount, size distribution, type), and velocity. Any head loss correlation should conservatively account for filtration of particulates by the debris bed.

On September 27, 2007, the staff issued Draft Guidance for Review of Final Licensee Responses to Generic Letter 2004-02, "Potential Impact ff Debris Blockage on Emergency Recirculation during Design Basis Accidents at

Pressurized-Water Reactors," which includes the following: (1) Draft Review Guidance for Strainer Head Loss and Vortexing, (2) Draft Review Guidance for Coatings, and (3) Draft Review Guidance for Chemical Effects (ADAMS package ML072600425). Although the guidance was developed for PWRs, it may be useful to consider in addressing this request. In responding to Item (3), please address the following:

Debris Generation and Transport:

A. *Show that a foreign material exclusion program to keep the formation of latent debris to a minimum will be established and documented either by GEH in the DCD, or by the COL applicant in the application. This cleanliness program should require frequent, inservice inspections of the containment for foreign material. RG 1.82, Revision 3, Regulatory Position 2.1.6 specifies that the COL applicant is responsible for developing a containment cleanliness program, and the inspections will include all of containment: drywell including GDCS pools, downcomers and vents, and the wetwell. If this is GEH's position, the DCD should clearly state that the development of the program is being deferred to the COL applicant.*

B. *Describe the range of different sizes and locations of high energy line break accidents within the containment which were evaluated for debris generation.*

C. *Show that a zone of influence (ZOI) shape and size has been determined for each of these break scenarios. In addition, ascertain whether the ZOI volume should be a basis for estimating debris amount from each break. Provide the basis for the ZOI selected for each material (insulation, coating, etc.)*

D. *Determine analytically or experimentally what percentage of large and small pieces of debris will be eroded by the two-phase jet blowdown and later single-phase water flow, and transported to the suppression pool and on to the debris strainer as fine fibers and particulates. Concurrently, establish what percentage of the debris in the suppression pool would be latent fibers and particulates.*

E. *Compile and organize containment materials expected to entrain in the suppression pool during a LOCA and classify these materials according to their chemical properties.*

F. *Describe the basis of assumed size distribution of the debris, which is generated from unqualified coatings. Discuss how the coatings that don't meet ASTM D 5144 and RG 1.54 react in solution after a design-basis LOCA, to influence the post-LOCA coolant pH in either a basic or acidic direction as a function of time.*

G. *Provide an evaluation determining whether chemical precipitates or other chemical reaction products form as a result of interaction between the plant materials and the post-LOCA environment.*

H. *Show the pH profile of the suppression pool solution as a function of time after a LOCA, for the range of possible post-LOCA materials and plant environments.*

I. *Establish whether protective coatings will be added to metal surfaces inside the containment as a result of a potentially harsh environment.*

Chemical Effects on Head Loss:

J. *Show how the NPSH changes as a function of time during the operation of suppression pool cooling and low pressure core cooling systems.*

K. *Please (i) confirm that the equalization line is equipped with a stack disc debris strainer that is designed in accordance with Regulatory Guide 1.82, revision 3, or (ii) provide a plot of the calculation results showing RPV water level has stabilized 30 days without the need for the GDCS equalization line.*

L. *Discuss how the NPSH of the ECCS suction strainers will be impacted by chemical effects. The evaluation should consider the chemical form of each identified material and the potential for interaction in the post-LOCA environment.*

M. *Discuss how the suction strainer geometry and surface area are designed to handle suppression pool debris material loads with acceptable strainer head losses.*

N. *Discuss to what extent decay heat is a factor in the calculation of the temperature of the suppression pool water and the resultant NPSH calculation.*

Downstream Effects:

O. *To quantify the effect of downstream debris flow, provide an evaluation of the effect of debris that passes the sump screen on long-term core cooling. Show what analysis GEH has completed on the deposition of debris in the core, and within valves or other constricting components. In this analysis, the debris may include chemical products, latent debris, or insulation that has passed through the suppression pool debris strainers. In this analysis, report the thermal conductivity of potential chemical products and debris on fuel rods and the increase in rod temperature due to deposition and blockage in the core. Also report the temperature change in the core with bounding blockages of valves and other components.*

GEH Response:

(1) For the suppression pool, it is confirmed that the suction locations that will be designed with consideration given to the strainer plugging issues include the Fuel and Auxiliary Pools Cooling System (FAPCS) suppression pool cooling function, and the Gravity-Driven Cooling System (GDCS) equalization line. These lines are the only ones that take suction from the suppression pool.

(2) Regarding DCD Tier 2, Table 1C-1, the wording in Section 1C.1 that introduces this table states: "Generic Letter and Bulletin topics deemed not applicable to the ESBWR design or operations (topics pertaining to other reactor types or BWR design features, e.g., a Reactor Recirculation Pump issue) are generally not included in Tables 1C-1 and 1C-2." Since operation during a Design Basis

Accident (DBA) does not require the use of any suction strainers for ESBWR, Generic Letter (GL) 2004-02 was not listed in the table. Generic Safety Issue (GSI) 191 is addressed in DCD Tier 2, Table 1.11-1 with the following statement: "(1) The ESBWR does not have an ECCS pump, and no sump provides ECCS water." Note GSI-191 and GL 2004-02 only apply to Pressurized Water Reactor (PWR) power plants; however, the ESBWR design considers technical issues raised in the resolution of GSI-191 in the design of systems that take suction from the suppression pool but are not required to operate during DBA, as discussed in this response

(3) As stated in the response to RAI 6.3-40 (MFN 06-488, dated December 22, 2006), and confirmed in the response to RAI 6.3-40 S01 (MFN 06-488, Supplement 1, dated December 21, 2007), reactor pressure vessel (RPV) water levels stay above Level 0.5 setpoint for 72 hours and beyond for all loss-of-coolant accident (LOCA) scenarios. In addition, a 30 day analysis confirms RPV water level stays above Level 0.5 setpoint, as discussed in the response to RAI 6.2-140 S02 (MFN 08-633, dated August 18, 2008). Therefore, the squib valves in the GDCS equalization lines never open, and the GDCS equalization lines are not required to function in response to a LOCA and do not perform a safety-related function. Therefore, the application of Regulatory Guide (RG) 1.82, Revision 3, is not required.

Since the GDCS equalization lines are not expected to be opened during normal plant operation or any postulated LOCA events for ESBWR, suction strainers are not required. The GDCS equalizing lines will utilize debris screens at their inlets in the suppression pool. The screens would prevent intrusion of large debris that might block critical flow passages in the GDCS equalizing lines and within the vessel. The driving head for the equalizing lines is provided by a change in elevation from the surface of the suppression pool to the inlet nozzle at the RPV, which is 5.5 feet. This would initially provide a flow rate of about 465 gpm per equalizing line, which would quickly decrease due to RPV level equalizing with the suppression pool. Therefore transporting of any debris to the screens would quickly diminish and any clogging would be inconsequential.

DCD Tier 2, Subsection 6.3.2.7.2 has been revised to specify that screens will be provided for this application instead of strainers. Also, the sentence added by the response to RAI 6.2-6 S01 (MFN 08-254, dated March 28, 2008) pertaining to RG 1.82, Revision 3 has not been incorporated.

The structural design of the GDCS screens includes consideration of load combinations that might occur in the suppression pool, including loads from blowdown, seismic, and a full static head load; this static head load could occur in the very unlikely event that some foreign materials were to completely block the screen. The stresses in the screen meet an equivalent ASME Code limit to that of the GDCS piping line.

Containment integrity is also evaluated for LOCA. Long-term decay heat removal from the containment is provided by the Passive Containment Cooling System (PCCS), and after 72 hours the PCCS vent fans are available to increase the efficiency of the PCCS condensers. The PCCS along with the vent fans are capable of maintaining containment pressure below the design pressure for 30 days as described in the response to RAI 6.2-140 S02.

In addition, the FAPCS lines associated with the suppression pool are not considered to be operational during a LOCA event and would not be considered available for operation until the seventh day after the start of a LOCA event. Therefore, only when determined to be appropriate and available, the FAPCS may be actuated in the low pressure coolant injection (LPCI), suppression pool cooling, or drywell (DW) spray modes to provide additional cooling to bring the plant to cold shutdown. Since the long term operation of the PCCS vent fans is sufficient to protect the integrity of containment, function of the FAPCS suppression pool line is not safety-related and the operation of the FAPCS cooling function is not required. Therefore RG 1.82, Revision 3 is not applicable to this application. For investment protection during normal operation and for post-LOCA operation, a strainer will be located on the FAPCS inlet piping in the suppression pool. This strainer is not safety-related, but is designed to stop the entry of debris greater than 1/8 inch in diameter to reduce the downstream effects on flow passages and rotating equipment. In order to assure a robust strainer design, the guidance given by RG 1.82 is used.

Unlike existing operating plants, the ESBWR is being designed to minimize the amount and consequences of debris within the containment. The following two items summarize these design features.

A. The selection of insulation materials and coatings for the ESBWR plant have benefited from the recent findings stemming from the NRC Generic Letter (GL) 2004-02 regarding the potential for high head losses in debris beds formed from micro-porous debris, unqualified coatings, and with certain chemical precipitants. The ESBWR design utilizes stainless-steel Reflective Metal Insulation (RMI) and qualified coatings inside containment.

B. In order for LOCA-generated debris to enter the suppression pool, it would need to be transported into the suppression pool via the vertical/horizontal vents. The vertical vents have raised "curbs" above the diaphragm floor and protective covers that prevent debris from being dropped directly into them. These two features impede the transport of debris into the suppression pool.

As a result of these design features, the amount and size of debris would be minimized in the suppression pool.

As stated previously for the design basis accident analysis, the FAPCS is not credited until the seventh day post LOCA. This amount of time would allow for debris to fall out of suspension and thereby make it less likely for the strainer to be clogged. Although FAPCS may become available before the seventh day and when deemed appropriate to use (FAPCS is not required to mitigate the effects of a LOCA), the scenario where it would be turned on immediately following a LOCA is unlikely, and some or most of the debris will settle.

The FAPCS strainer is not classified as an ASME Code Section III component. However, applicable Subsections of the ASME Code are used as a guideline for the structural design. The FAPCS strainer meets the ASME Code Section III, Subsections NC and ND stress limits for load combinations produced by blowdown, gravity, seismic, and the crush pressure associated with the debris head loss.

Responses to Parts A through O follow.

A. As stated above, RG 1.82 is not applicable to the ESBWR. Hence, there is no requirement to develop a program based on position 2.1.6 of this RG. Since this type of cleanliness program is not required as part of the safety basis for the ESBWR plant, such a program does not need to be described in either the DCD or Combined License Application (COLA). DCD Section 6.1.2.1 specifies controls for coatings used inside containment. Appropriate housekeeping standards are addressed in COLA quality assurance programs. No additional operational program description is necessary to address cleanliness in containment.

B. For the purpose of selecting pipe breaks that will yield a maximum amount of transportable debris, high energy line break selection is restricted to those systems with piping at or above the containment drywell diaphragm floor. The entrance to the vertical vents (debris transport path to the suppression pool) is located at the same elevation as the diaphragm floor. These systems are listed in Table 3.B.1.

   In the case of ESBWR, piping inside containment will be designed to minimize the stresses and fatigue usage factors such that piping intermediate break locations are avoided. Therefore, all postulated pipe break locations for DBA LOCA are at the terminal end break at the reactor pressure vessel (RPV).

   Except for the main steam lines, all terminal end breaks at the RPV nozzles will be confined between the RPV and shield wall by pipe restraints. Main steam lines will have pipe restraints as well, but its nozzle ends extend outside the shield wall. As a result except for main steam lines, the interactions by jet will be immediate to the rigid structures (shield wall or the RPV) following the break and thus limit the amount of debris created.

C. The guidance provided in topical report NEDO-32686, Revision 0, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," (URG) is used to determine the types and amounts of debris generated during a high energy line break.

   A terminal end break will result in a single jet. However, the Safety Evaluation issued by the NRC on the URG states that breaks that generate the largest amount of debris must be postulated. Therefore, it is assumed that all breaks will result in a spherical zone of influence (ZOI) (double-ended guillotine pipe break) where the greatest amount of debris can be generated.

   Fibrous and microporous types of insulation (e.g., calcium silicate) are prohibited inside the ESBWR containment, and only RMI is allowed, per ESBWR DCD Tier 2, Section 6.1. Therefore, only a ZOI for RMI is calculated using Method 3 of the URG. The following equation from URG Section 3.2.1.2.3.3 is used.

$$V_{ZOI}(i) = A * D^3 \qquad \text{Eq. 1}$$

Where:

$V_{ZOI}(i)$ is the volume (ft^3) of the zone of influence for material (i), in this instance RMI.

A is a constant which is a function of P_{dest} (dynamic pressure at which destruction occurs for material of interest), break medium (steam vs. water) and break geometry, as defined in Table 1 of the URG. For saturated water breaks, multiply the value of A in Table 1 by the appropriate correction factor provided in Note 5 of Table 1; and

D is the inside diameter (ft) of the pipe where the break is postulated.

In order to generate the maximum ZOI, the maximum radial offset, 3D/2, for restrained pipes is used with the axial offset that maximizes the constant A. A spherical shape for the ZOI is used. The input parameters along with the results for each break selected are shown in Table 3.C.1. The main steam line break yields the largest ZOI with the feedwater line break yielding the smallest.

The ZOI created by the main steam line break is found to have the largest amount of RMI debris generation. Results are shown in Table 3.C.2. The ZOI is centered at the most congested piping location along its pipeline to maximize the RMI debris.

Other non-insulation debris types generated and transported to the suppression pool are based on values provided by the URG.

D. Non-insulation debris types and amounts that are assumed to be generated in the drywell and transported to the suppression pool are shown in Table 3.D.1 along with suppression pool sludge. These values were deemed bounding by the URG for BWR Mark I, II, and III type containments and are considered applicable to the ESBWR containment. The ESBWR containment incorporates many features found in all three of these types of containment, except that its design minimizes the amount of debris types generated and transported to the suppression pool. For instance, the Mark III containment utilizes a weir wall to connect the drywell to the suppression pool that is well below most of the RPV nozzles and piping. Whereas, the ESBWR entrance to the vertical vents are well above most RPV nozzles.

It is recognized that debris associated with drywell maintenance might occur. Therefore 1 ft^3 of operational fibrous debris is assumed based on engineering judgment.

Half of the RMI generated is assumed to produce fines as defined in the URG that are less than 6.0 in^2.

The particle distribution of sludge is assumed to be between 1 to 10 microns as given in the URG for approximately 95% of the particles. For plants that do not establish a specific sludge generation rate the URG recommends a bounding 300 lbm/year. The ESBWR is expected to have 24 month fuel cycles, therefore 600 lbm of sludge is assumed in the strainer head loss calculation. This is a conservative assumption, since the suppression pool is stainless steel lined and has less systems that contain carbon steel that are drawing and returning water to the pool.

The dirt/dust assumed is 150 lbm and is treated as sludge as recommended by the URG. This is a conservative assumption. A large portion of the drywell is covered by steel plate, such as the drywell walls, outer walls of the GDCS pools, and the diaphragm floor.

The URG recommends the following particulate size generated by qualified coatings: inorganic zinc (IOZ) 4 – 20 microns and IOZ top coated with epoxy up to 3175 microns.

E. The materials expected to be entrained in the suppression pool during a LOCA are listed in Table 3.E.1.

F. Unqualified coatings are not allowed in the containment as stated in ESBWR DCD Tier 2, Section 6.1. The coating systems applied inside containment meet the regulatory positions of RG 1.54 and the standards of ASTM D 5144. Therefore, coatings on Original Equipment Manufacturer (OEM) equipment inside the containment will be required to meet regulatory positions of RG 1.54 and the standards of ASTM D 5144.

G. Coatings used in containment will be qualified for the range of conditions from a design basis accident and will be resistant to chemical decomposition. Precipitates formed with silica and calcium will not be formed, since insulation types containing silica or calcium are not allowed in containment, per DCD Tier 2, Section 6.1. The contribution of silica by concrete dust will be negligible, since most of the drywell containment will be covered in steel plate. The diaphragm floor is covered with steel plate as well as the GDCS pool walls and drywell walls.

Debris generated by insulation will be stainless steel RMI, which will not significantly corrode to produce any appreciable amount of precipitates.

H. Debris transported into the suppression does not impact pH. Rather, the pH is dependent on the production of nitric acid, the transport of sodium pentaborate from the lower drywell via the vertical vents, and the transport of cesium hydroxide via the PCCS vent lines in case of fuel failure. A more detailed discussion is presented in Licensing Topical Report (LTR) NEDE-33279P, "ESBWR Containment Fission Product Removal Evaluation Model." The suppression pool pH for 30 days post-LOCA is shown in Figures 3.H.1 through 3.H.6 for the three accident scenarios presented in the LTR. The pH reaches a maximum of less than 9.5 within the first few hours and stabilizes at less than 9 for the rest of the event.

I. As stated in ESBWR DCD Tier 2, Section 6.1, qualified protective coatings will be used on the carbon steel containment liner, internal steel structures, equipment and pipe supports inside the drywell and wetwell. Stainless steel liner will be used on wetted surfaces such as the inside of the GDCS pools. These structures and equipment will be coated in accordance with RG 1.54 and ASTM D 5144 standard.

J. The FAPCS pumps are located in the fuel building and were used to evaluate the net positive suction head (NPSH) available. This maximizes frictional head losses, and the FAPCS would be the preferred method for providing suppression pool cooling and is normally used to provide this function. Table 3.J.1 shows the range of NPSH available as a function of temperature without strainer head loss. The maximum NPSH margin occurs at normal suppression pool temperature and the lowest NPSH margin of about 23 feet of head occurs at saturated conditions. The pool is not expected to reach saturated conditions as shown in response to RAI 6.2-140 S02. The maximum temperature reached during 30 days post-LOCA is 169 °F with the minimum of 110 °F occurring at start of the event.

The debris head loss was calculated for a prototypical Boiling Water Reactor (BWR) stacked disc design as shown in Figure 3.J.1 with a 45 inch OD, a 49 inch hydraulic length, and a 388 ft^2 surface area. The amounts and types of debris used to calculate the debris head loss are shown in Table 3.J.2. Even though fibrous debris is not allowed in the ESWR containment design, head loss is analyzed with fibrous debris to show the robustness of the suppression pool cooling function. The surface area for RMI transported to the suppression pool is not used in calculating debris head loss. Instead, the saturated condition of RMI is used and is predicted at 1200 ft^2 RMI surface area, which is about a third of the predicted amount transported to the suppression pool, Table 3.C.2.

The predicted debris head loss along with the clean strainer head loss for a maximum flow rate of 4800 gpm is shown in Table 3.J.3. As seen from the table, debris head loss is higher at the minimum (110 °F) pool temperature than at the maximum (169 °F) pool temperature due to increased water viscosity at the lower temperature. The predicted head loss for a thin fiber bed is also higher than the case with a 100% fiber load, but the thin bed calculation is conservatively based on the assumption of a flat plate strainer geometry, not that of an optimized stacked disk strainer (which is generally regarded as more tolerant of thin debris beds).

At the minimum pool temperature about 36 feet of NPSH margin exists and at the maximum pool temperature about 32 feet of NPSH margin exists.

<u>Summary of Methodology Used to Generate ESBWR FAPCS Strainer Preliminary Design</u>

The head loss performance of several prospective strainer sizes was evaluated under specified ESBWR FAPCS post-LOCA operating conditions. The post-LOCA design conditions include:

- two design temperatures: 169 °F (nominal) and 110 °F (minimum); and
- two fiber loading conditions: 100% debris load (fiber and particulate), and 100% particulate with just enough fiber to create a nominal 1/8 inch thick debris bed.

Different methodologies were used for the 100% debris case and the 1/8 inch fiber bed case. The predicted debris head loss from these calculations was added to the predicted strainer clean head loss and the RMI head loss.

<u>100% Debris Load Evaluation Methodology</u>

On March 24, 2008, GEH sent a letter to the NRC as a follow-up to a March 6 teleconference with the NRC regarding certain issues with the LTR correlation used by GE to design BWR strainers in the 1990's. A revised correlation was developed as part of an operability evaluation to assess actual strainer head loss margin of existing GE strainers relative to the head loss design basis requirements. The revised correlation is a best estimate correlation based on two different debris configurations: 1) the situation where the spaces between the strainer disks are less than fully filled, and 2) the situation where the strainer gaps are filled and the strainer is engulfed in the debris bed. The proposed ESBWR strainer falls into the first category, with a gap-fill ratio of less than 50% when debris bed compression effects are considered.

The revised correlation for the less-than-gap-filled condition uses a multivariate linear regression analysis of a large scale test data set similar, but not identical, to the data set used to support the LTR methodology. The analysis generates a best-estimate head loss prediction, so for the ESBWR strainer evaluation the head loss results were increased by a factor of 1.25X to provide a more conservative prediction.

The test data used in the regression analysis was obtained over a limited range of sludge-to-fiber ratios and therefore the correlation is nominally limited to this range. However, a means of extending the correlation to higher sludge-to-fiber ratios is provided by a separate correlation that evaluates the effect of sludge-to-fiber ratio on head loss characteristics over a wider range of sludge-to-fiber ratios. Factors from the latter work are applied to the output of the regression analysis to obtain the final predicted head loss for the ESBWR FAPCS strainer.

<u>1/8 inch Fiber Bed Evaluation Methodology</u>

A potential for high head loss exists with thin fiber beds and high particulate-to-fiber ratios. Tests performed for the BWR Owners Group (BWROG) and reported in NEDO 23686-A, Utility Resolution Guide for ECCS Suction Strainer Blockage, resulted in the conclusion that "'advanced design" strainers were not susceptible to this effect, although this conclusion was based on debris loadings that did not include microporous insulations. The ESBWR FAPCS strainer will not be subject to microporous insulation.

Nonetheless, the potential for "thin bed" conditions occurring with the proposed ESBWR FAPCS strainer was evaluated using the head loss equations from NUREG/CR-6224, "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris," December, 1995. The fiber load was adjusted according to the assumed strainer size so that a nominal (uncompressed) fiber bed of 1/8 inch was created.

K. Response to RAI 6.2-140 S02 presents 30 days post-LOCA results for containment pressure and temperature. RPV water level for that same scenario is shown in Figures 3.K.1 and 3.K.2. Water level is stabilized after 30 minutes and remains above the top of chimney partition, therefore the GDCS equalizing lines are not used to provide makeup. PCCS remains in operation and provides condensate to the RPV through the GDCS pool injection lines. Therefore, a strainer will not be used on the GDCS equalizing lines. Instead, screens will be utilized as previously discussed. There are total of four equalizing lines.

L. Impact due to chemical effects is not expected in the ESBWR due to the elimination of microporous insulation types, the use of stainless steel RMI, the use of qualified coatings, and non-existing buffers such as trisodium phosphate, which BWR's have not historically used.

M. The suppression pool strainer for the FAPCS will be of a stacked disc design. Figure 3.J.1 shows a prototypical BWR stacked disc design. These types of strainers have been designed and tested to withstand anticipated debris and other structural loads while maintaining acceptable head losses.

N. The decay heat was used in response to RAI 6.2-140 S02 to predict the 30 day post-LOCA containment response and RAI 6.2-140 S01 (MFN 08-332, dated April 4, 2008) which analyzes the scenario of suppression pool cooling and LPCI seven days post-LOCA. These analyses were used to obtain the maximum and minimum suppression pool temperatures, which were used in calculating the resultant debris head losses at both minimum and maximum temperatures (note, highest head loss is at the minimum temperature – not the maximum. But this is often offset by greater NPSH margin at lower temperatures).

O. The long-term core cooling is not dependent on the delivery of low pressure make-up. The PCCS provides long-term core cooling and maintains the core in a safe stable shutdown condition by returning steam generated in the core as condensate via the GDCS pool injection lines. This has been analyzed for 30 days post-LOCA and results were presented in response to RAI 6.2-140 S02.

In order to bring the core to cold shutdown via LPCI, the FAPCS or Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC)♦ heat exchangers can be utilized. When available and deemed appropriate, the suppression pool would undergo cooling for a period of 24 hours prior to LPCI (analysis of suppression

♦ The RWCU/SDC can be used as an alternate means to provide suppression pool cooling and LPCI via a cross-tie to the FAPCS suppression pool suction line.

pool cooling and with LPCI was presented in response to RAI 6.2-140 S01). During pool cooling, debris of 1/8 inch in diameter or less may pass through the strainer. This debris will most likely be composed of iron oxide with some coating particulates, since they make up most of the debris by weight. Fibrous debris is not considered, because a negligible amount is transported to the suppression pool. The amount of fibrous debris assumed in the debris head loss calculation will not exist in the pool; it was used only to demonstrate NPSH margins.

The iron oxide and coating particulates will deposit along the suppression pool recirculation path and returned to the pool to be potentially stirred by the returning flow and possibly passed through the strainer once more.

FAPCS and RWCU/SDC consist of two trains each. Each train has a pump, filter/demineralizers, and heat exchangers. Throttling valves are not used to control flow rates, so the potential for clogging valves does not exist. Although the iron oxide may continue to be passed through the suction strainers, the filters/demineralizers can be placed into service or bypassed if they were to become clogged. Operators can make use of all four trains provided by the FAPCS and RWCU/SDC. Therefore, it is anticipated that small amounts of debris might be injected into the vessel that will have a negligible impact on fuel clad temperatures.

It is important to note that delivery of low pressure injection to the vessel is not time critical. Decay heat removal is provided by the PCCS, and bringing the core to cold shutdown can be accomplished at lower low pressure injection flow rates.

Core flow blockage is addressed in RAI 4.4-23 S01 by analyzing minimum critical power ratio (MCPR) vs. % flow blockage.

DCD Impact:

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

Table 3.B.1

High Energy Lines Above Diaphragm Floor

Systems	**Break Locations**
Main Steam Piping, 30" Sch. 80	Pipe end at the RPV nozzles (Outside of the annulus)
Feed Water Piping at Nozzle, 12" Sch. 80	Pipe end at the RPV nozzle located inside the annular space between the RPV and Shield wall
Isolation Condenser Piping (supply to isolation condensers), 18" Sch. 80	Pipe end at the RPV nozzle located inside the annular space between the RPV and Shield wall
Head Vent[1], Sch. 2"	At RPV

1. Not analyzed for debris generation

Table 3.C.1

ZOI Volumes for Selected ESBWR Breaks

			P_{dest}	Offset[1]		Inside Pipe Dia[2]		Constant	Correction	ZOI (ft^3)	radius
	Fluid	**Insulation**	**(psi)**	**radial**	**axial**	**(in)**	**(ft)**	**A**	**factor (f)**	**$f*A*D^3$**	**(ft)**
Main Steam Line	steam	RMI	190	3D/2	D	30	2.50	99.9	1	1560.94	7.20
Feedwater Line	saturated water	RMI	190	3D/2	D	22	1.83	99.9	0.4	246.24	3.89
Isolation Condenser Line	steam	RMI	190	3D/2	D	18	1.50	99.9	1	337.16	4.32

1. Maximum radial offset used for restrained pipes with the axial offset that maximizes constant "A" value.
2. Nominal pipe size diameter was used. This yields a larger ZOI.

Table 3.C.2

RMI Debris Generated From Main Steam Line Break

	Pipe Length[1] (ft)	Insulation Thickness (in)	Pipe OD (in)	Insulation OD (in)	Insulation Volume (ft^3)	RMI Surface Area (ft^2)	RMI Transported to Supp. Pool[2] (ft^2)
Feedwater Line	24.6	3.5	22	29	47.9	2074.1	1037.1
Main Steam Line A	18.0	4	30	38	53.5	2317.7	1158.9
Main Steam Line B	18.0	4	28	36	50.4	2181.4	1090.7
Main Steam Safety Relief Valve (SRV)	2.9	4.5	19	28	6.6	285.7	142.8
Main Steam SRV	2.9	4.5	19	28	6.6	285.7	142.8
Main Steam SRV	2.9	4.5	19	28	6.6	285.7	142.8
Main Steam SRV	2.9	4.5	19	28	6.6	285.7	142.8
For Large Bore					178.2	7715.9	3857.9
For Small Bore[3]					17.8	771.6	385.8
Total					196.1	8487.5	4243.7

1. Pipe lengths within ZOI of radius 7.2 feet for main steam line break.
2. Transport factor of 0.5 from topical report NEDO-32686, Revision 0, "Utility Resolution Guidance for ECCS Suction Strainer Blockage." ESBWR has vertical vents and horizontal vents similar to those used in Mark II and Mark III containments, respectively.
3. Small bore debris associated with small bore lines estimated at 10% of total large bore.

Table 3.D.1

Non-Insulation Debris Generated in Drywell and Transported to Suppression Pool[1]

Debris Type	Amount
Iron Oxide Sludge[2]	600 lbm
Inorganic Zinc (IOZ)	47 lbm
IOZ Top Coated with Epoxy	85 lbm
Rust Particles	50 lbm
Drywell Dirt and Dust	150 lbm
Operational Fibrous Debris[3] (2.4 lbm/ft^3)	1 ft^3

1. Debris types and amounts are from topical report NEDO-32686, Revision 0, "Utility Resolution Guidance for ECCS Suction Strainer Blockage," (URG).
2. Sludge already in suppression pool. The URG specifies 300 lbs/year for plants that do not conduct a plant specific analysis of sludge. ESBWR is expected to operate on 24 month fuel cycles.
3. Operation fiber is based on engineering judgment and is not provided in the URG.

Table 3.E.1

Material Expected to be Entrained in Suppression Pool During a LOCA

Material	Composition
Sludge	Iron Oxide
Coatings	Inorganic Zinc, Epoxy
Rust Particles	Iron Oxide
Dirt and Dust[1]	---
RMI	Stainless Steel
Fibrous Debris	Rags (2.4 lbm/ft^3)

1. The ESBWR containment diaphragm floor, upper drywell floor, is composed of steel plate, and other structures such as the GDCS pool walls and the drywell walls are covered with steel plate. This greatly limits the exposed area of concrete to any high energy line break, therefore the amount of concrete dust available for transport will be minimal.

Table 3.J.1

Expected NPSH Available for FAPCS Pump

Temperature (°F)	H_F (ft)	H_{VAP} (ft)	H_{ATM}[2] (ft)	H_S (ft)	NPSH Available (ft)	NPSH Required (ft)	NPSH Margin[3] (ft)
110[(1)]	20.4	3.0	33.96	60.9	71.4	16.4	55.0
120	20.4	3.9	33.96	60.9	70.5	16.4	54.1
130	20.3	5.2	33.96	60.9	69.3	16.4	52.9
140	20.2	6.8	33.96	60.9	67.8	16.4	51.4
150	20.2	8.8	33.96	60.9	65.9	16.4	49.5
160	20.1	11.2	33.96	60.9	63.5	16.4	47.1
170	20.1	14.2	33.96	60.9	60.6	16.4	44.2
180	20.0	17.9	33.96	60.9	56.9	16.4	40.5
190	20.0	22.3	33.96	60.9	52.5	16.4	36.1
200	19.9	27.6	33.96	60.9	47.3	16.4	30.9
210	19.9	34.0	33.96	60.9	40.9	16.4	24.5
212	19.9	35.4	33.96	60.9	39.5	16.4	23.1

1. Minimum temperature at normal operating temperature for suppression pool.
2. Atmosphere pressure in wetwell assumed to remain constant at one atmosphere. This is conservative, since wetwell pressure increases during a LOCA and would add to the NPSH available.
3. NPSH margin beyond 33.9 ft is not actually available for strainer design since FAPCS pump can not draw more than 1 atm gage suction.

H_F = Frictional head loss from suction line to FAPCS pump inlet. Does not include strainer head loss.

H_{VAP} = Head loss due to vapor pressure of water.

H_{ATM} = Head provided by atmosphere above suppression pool water.

H_S = Static from change in elevation of inlet source to pump inlet. FAPCS pump is located below the suppression pool.

Table 3.J.2

Debris Types and Amounts Used to Calculate Strainer Debris Head Loss

Debris Type	Amount
Iron Oxide Sludge (1 – 10 microns)	600 lbm
Inorganic Zinc (IOZ) (4 – 20 microns)	47 lbm
IOZ Top Coated with Epoxy (up to 3175 microns)	85 lbm
Rust Particles (>50 microns)	50 lbm
Drywell Dirt and Dust (Same size as sludge)	150 lbm
Operational Fibrous Debris[1] (2.4 lbm/ft^3)	1 ft^3
RMI Insulation[2] (0.0025 inch thickness)	1200 ft^2
Fibrous Debris[3] (2.4 lbm/ft^3)	16.75 ft^3

1. Operational fiber is based on engineering judgment.
2. RMI surface area calculated from ZOI methodology is not used in the head loss calculation. The surface area used represents the saturated condition of the strainer with RMI debris.
3. Fibrous debris from insulation will not occur, since ESBWR containment prohibits this type of debris. This value is used to demonstrate the robustness of the ESBWR suppression pool cooling function. The value used is derived from ABWR piping design, which does use fibrous insulation.

Table 3.J.3

Predicted Strainer Debris Head Loss

Temperature	Clean Strainer Head Loss	RMI Head Loss	Debris Head Loss (100% Fiber Load)	Debris Head Loss (Thin Fiber Bed Effect)	Total Debris Head Loss[1]	NPSH Available	NPSH Required	NPSH Margin[2]
(°F)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
110	1.08	0.03	13.76	18.15	19.26	71.4	16.4	35.74
169	1.08	0.03	8.57	11.16	12.27	60.6	16.4	31.93

1. Total Debris Head Loss = (Clean Strainer Head Loss) + (RMI Head Loss) + (Debris Head Loss (Thin Fiber Bed Effect))
2. NPSH Margin = (NPSH Available) – (NPSH Required) – (Total Debris Head Loss)

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Figure 3.H.1. Suppression Pool pH – Accident Scenario AS-1, 0 to 720 Hours

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Figure 3.H.2. Suppression Pool pH – Accident Scenario AS-1, 0 to 26 Hours

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Figure 3.H.3. Suppression Pool pH – Accident Scenario AS-2, 0 to 720 Hours

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Figure 3.H.4. Suppression Pool pH – Accident Scenario AS-2, 0 to 26 Hours

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Figure 3.H.5. Suppression Pool pH – Accident Scenario AS-3, 0 to 720 Hours

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Figure 3.H.6. Suppression Pool pH – Accident Scenario AS-3, 0 to 26 Hours

0

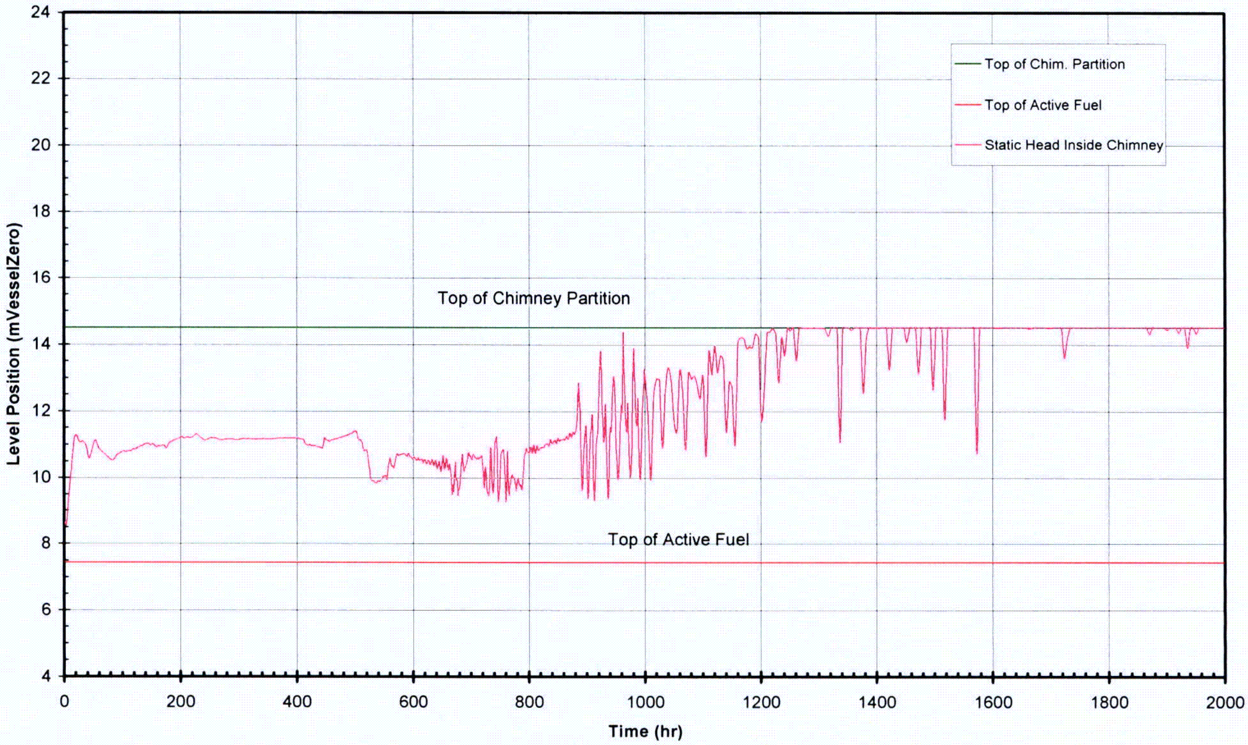

Figure 3.K.1. RPV Water Level: 30 Days Post-LOCA Response – First 2000 Seconds

0

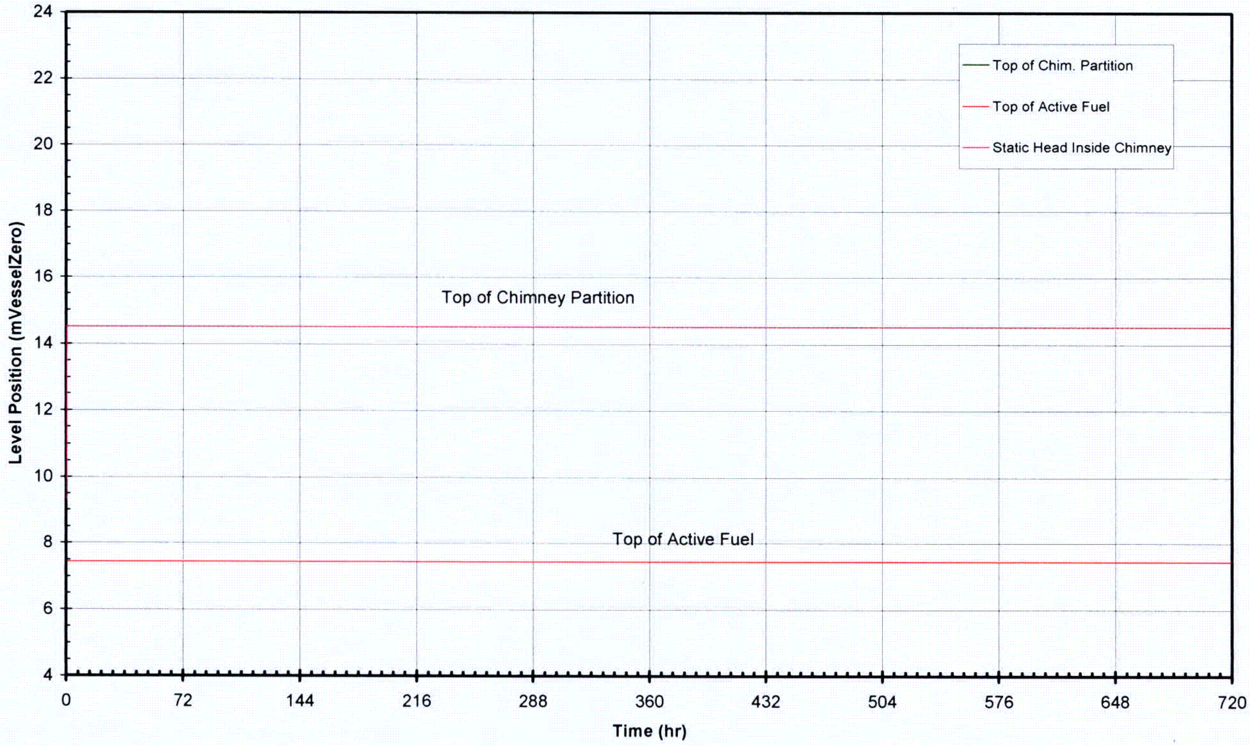

Figure 3.K.2. RPV Water Level: 30 Days Post-LOCA Response

Note: Chimney partition remains full and level is at or above the top of the chimney partition. Data up to the top of the chimney partition is only shown.

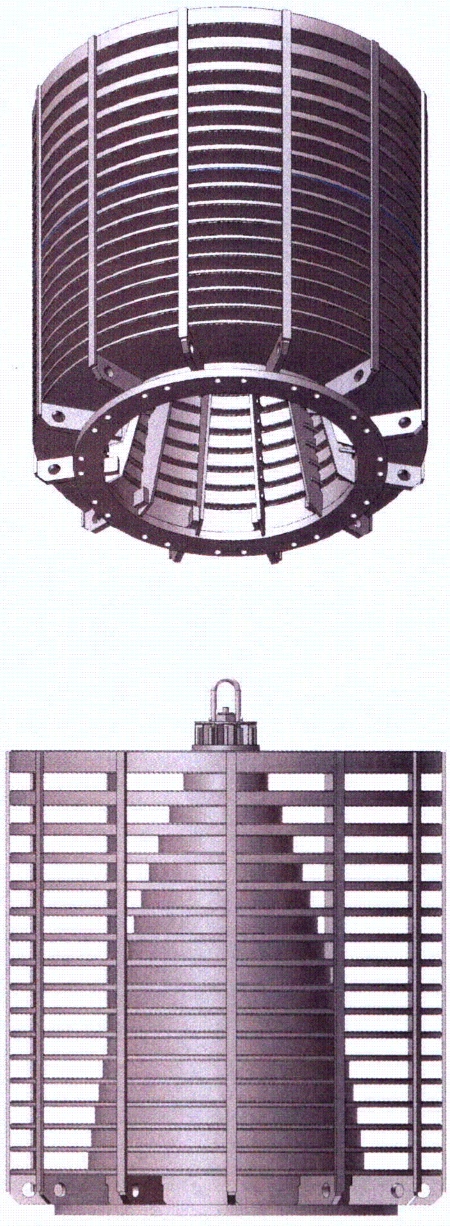

Figure 3.J.1. Typical GE BWR Passive Strainer Design

NRC RAI 6.2-196:

During a LOCA, the suppression pool may contain debris which may be injected into the reactor by the inadvertent and premature actuation of the LPCI by the operator before 72 hours. In the event the FAPCS pumps suction strainers are not designed to meet Regulatory Guide 1.82, Revision 3, describe the consequences of the premature operation of the LPCI mode of the FAPCS and the impact on long-term post-LOCA cooling of the reactor.

GEH Response:

An evaluation of the Fuel and Auxiliary Pool Cooling System (FAPCS) pump suction strainer located in the suppression pool is provided in the response to RAI 6.2-173 S01. The strainer is evaluated for operation with debris prior to 72 hours following a loss-of-coolant accident (LOCA).

DCD Impact:

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