August 3, 2006

Mr. David H. Hinds, Manager, ESBWR
General Electric Company
P.O. Box 780, M/C L60
Wilmington, NC 28402-0780

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 45 RELATED TO ESBWR DESIGN CERTIFICATION APPLICATION

Dear Mr. Hinds:

By letter dated August 24, 2005, General Electric Company (GE) submitted an application for final design approval and standard design certification of the economic simplified boiling water reactor (ESBWR) standard plant design pursuant to 10 CFR Part 52. The Nuclear Regulatory Commission (NRC) staff is performing a detailed review of this application to enable the staff to reach a conclusion on the safety of the proposed design.

The NRC staff has identified that additional information is needed to continue portions of the review. The staff's request for additional information (RAI) is contained in the enclosure to this letter. This RAI concerns the evaluation of postulated pipe breaks as described in Section 3.6 of the ESBWR design control document. These questions were sent to you via electronic mail on May 31, 2006, and were discussed with your staff during a telecon on July 19, 2006. Your staff requested that question 3.6-6 be divided into parts "a" and "b" and that the schedule for responding to questions 3.6-6b, and 3.6-11 thru 19 be determined later. Your staff also informed us that they may request further discussions on the remaining questions. Please expedite your staffs review of the remaining questions so that their response may be scheduled.

You agreed to respond to questions 3.6-1 thru 5, 3.6-6a, and 3.6-7 thru 10 on August 25, 2006.

If you have any questions or comments concerning this matter, you may contact me at (301) 415-2863 or lwr@nrc.gov or you may contact Amy Cubbage at (301) 415-2875 or aec@nrc.gov.

Sincerely,

/RA/

Lawrence Rossbach, Project Manager
ESBWR/ABWR Projects Branch
Division of New Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 52-010

Enclosure: As stated

cc: See next page

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ACCESSION NO. ML062070543

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DATE	07/28/2006	08/03/2006

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Requests for Additional Information (RAIs)
ESBWR Design Control Document (DCD) Pipe Break Design

RAI Number	Reviewer	Question Summary	Full Text
3.6-1	Li R	Provide pipe break/crack criteria without OBE	In Section 3.1.1.3 of SECY 93-087, the staff included a Commission-approved staff recommendation to eliminate the Operating Basis Earthquake (OBE) from the design of structures, systems, and components (SSCs). Furthermore, the staff concluded that no replacement earthquake loading should be used to establish the postulated pipe ruptures and leakage cracks locations once the OBE is eliminated from the design and that the criteria for postulating pipe ruptures and leakage cracks in high- and moderate-energy piping systems be based on factors attributed only to normal and operational transients. However, for establishing pipe breaks and leakage cracks due to fatigue effects, the staff concluded that calculation of the cumulative usage factor should continue to include seismic cyclic effects. Since ESBWR is not explicitly designed for OBE loads, clarify whether criteria used in determining postulated high- and moderate-energy pipe break and leakage crack locations for ESBWR design are consistent with the above staff position.
3.6-2	Li R	Identify moderate-energy systems for ESBWR	In DCD Tier 2, Rev. 1, Tables 3.6-3 and 3.6-4, General Electric (GE) identified high-energy piping systems inside and outside the containment that are subject to postulated pipe breaks. However, GE did not identify the moderate-energy systems for both inside and outside the containment applicable to an ESBWR plant. Identify moderate-energy systems that will be subject to postulated leakage cracks in accordance with Standard Review Plan (SRP) Section 3.6.1, Branch Technical Position (BTP) SPLB 3-1 and will be used by the COL applicant, or provide reasons for not including them in the DCD for design certification.

Enclosure

3.6-3	Li R	Clarify if EQ of Class 1E equipment use pipe break environment parameters	In BTP EMEB-3-1, Item B.1.c(5), it is stated that safety-related equipment must be environmentally qualified in accordance with SRP Section 3.11. Required pipe breaks and leakage cracks must be included in the design bases for defining the qualifying environment for these components both inside and outside the containment. Clarify if the design bases for environmental qualification (EQ) of safety-related equipment include the consideration of the environment resulting from pipe breaks or leakage cracks or provide reasons for not including them in the DCD for design certification.
3.6-4	Li R	Provide criteria for breaks in headers and parallel run lines	In BTP EMEB-3-1 Section B.1.d, it is stated that in complex systems such as those containing arrangements of headers and parallel piping running between headers, the designer should identify and include all such piping within the designated run in order to postulate the number of breaks required by the criteria in Item B.1.c. Clarify if this criterion is applicable to ESBWR for identifying pipe break locations.
3.6-5	Li R	Explain break exclusion of HCU fast scram lines	In DCD Tier 2, Rev. 1, Section 3.6.2.1.3, GE discusses the reasons why the 1.25-inch hydraulic control unit (HCU) fast scram lines do not require protection against pipe breaks. The second reason states that the total amount of energy contained in the 1.25-inch piping between the normally closed scram insert valve on the HCU module and the ball-check valve in the control rod housing is small. Provide the actual amount of energy contained in this line and demonstrate how its small value prevents any pipe ruptures in HCU fast scram lines.

3.6-6	Li R	(a) Provide blowdown force calculation at break (b) Explain how potential feedback amplification of blowdown force is considered	In DCD Tier 2, Rev. 1, Section 3.6.2.2, GE states that blowdown forcing functions are determined by the method specified in Appendix B of ANSI/ ANS- 58.2. However, GE did not provide any details as to how the blowdown forces are calculated for the ESBWR design, and also did not provide any sample calculations to illustrate the adequacy of any analytical method. Also, there does not appear to be any consideration of how potential feedback between the jet and any nearby reflecting surface(s), which can increase substantially the dynamic jet forces impinging on the nearby target component and the dynamic thrust blowdown forces on the ruptured pipe through resonance, is considered. (a) Provide details (including the methods and computer programs, if any), with examples, for calculating the blowdown forcing functions at break locations that will be used by the COL applicant. (b) Also, include a description of how feedback amplification of dynamic blowdown forces will be considered in the calculation.

3.6-7	Li R	Discuss pipe dynamic analysis methods due to pipe break	In DCD Section 3.6.2.2 and Appendix 3J, GE provides details regarding assumptions in the piping dynamic analysis. The staff notes that SRP Section 3.6.2, item III.2.a provided dynamic analysis criteria and discusses material capacity limitations for a crushable material type of whip restraint, while SRP Section 3.6.2, item III.2.b discusses various methods of analyses. Also, ANSI/ANS-58.2-1988, Paragraph 6.3 presents several different types of dynamic analysis methods. Provide answers to the following: (a) In SRP Section 3.6.2, item III.2.a, it is stated that for piping pressurized during normal operation at power, the initial condition should be the greater of the contained energy at hot standby or at 102% power. Clarify if this is applicable to all approaches used for the ESBWR. If not, then provide technical justification for the alternate initial conditions assumed in the analyses. (b) Acceptable dynamic models suggested in the SRP include lumped parameter analysis models, energy balance analysis models, and static analysis models. Also, alternate analytical approaches are discussed in ANS standard Paragraphs 6.3.1 through 6.3.5. DCD Appendix 3J presents only two specific approaches: dynamic time-history analysis with simplified models and dynamic time-history analysis with detailed piping models. Clarify if any other analytical (nonlinear) methods and modeling techniques (discussed in the SRP and ANS standard) will be used for ESBWR plants. (c) Discuss acceptable procedures and computer programs to be used to calculate the pipe whip dynamic responses for all those methods not discussed in DCD Appendix 3J. (d) Provide examples illustrating nonlinear and simplified methods of analysis that will be used in the ESBWR design, demonstrating compliance with SRP Section 3.6.2 stress limit requirements. Also, describe the computer programs for selecting the size and different types of whip restraints (i.e., crushable or rigid, if any) (e) Discuss the validation of the computer programs which the NRC staff has not yet approved.

3.6-8	Li R	Provide technical justification for integrity and operability of SSCs	In DCD Section 3.6.2.3.2, GE states that for components on the ruptured piping required for safe shutdown or that serve to protect the structural integrity of a safety-related component, limits to meet the ASME Code requirements for faulted conditions and limits to ensure required operability are met. The staff needs further clarification on what this particular criterion means. If it means that meeting the ASME Code requirements for faulted conditions ensures meeting the required operability of these components, provide technical justification for this criterion. Otherwise, describe the limits to ensure the operability of these components.
3.6-9	Li R	Discuss other than U-Bar type of whip restraint designs	In DCD Section 3.6.2.3.3, GE provides design criteria for one type of whip restraint design (i.e., U-Bar type). Describe the design criteria, including load combination methods, for other types of whip restraints if they will be used in the design of ESBWR piping system.
3.6-10	Li R	Clarify guard pipe versus pipe sleeve design	BTP EMEB 3-1, item B.1.b(6) contains design, testing, and examination guidelines for guard pipes in the containment penetration areas. DCD Tier 2, Rev. 1, Section 3.6.2.4 states that the ESBWR primary containment does not require guard pipes. However, GE identifies these guard pipes as sleeves in the DCD Tier 2, Rev. 1, Section 3.6.2.1.1 and the design, testing, and examination requirements for these sleeves are consistent with the SRP requirements for guard pipes. Clarify this discrepancy.

<u>Introduction for RAIs 3.6-11 through 14</u>: The application makes a reference to the use of ANS 58.2 Appendices C and D to assess which SSCs might be loaded by jets emanating from postulated pipe breaks, and to assess resulting jet impingement loads on the impacted SSCs. The applicant includes additional information regarding SSC loading in DCD Tier 2 that appears to conflict with the contents of ANS 58.2. The staff reviewed the ANS 58.2 Standard and Appendices, and Section 3.6.2 and Appendix J of the applicant DCD Tier 2. The staff also considered the recent scrutiny of the ANS 58.2 expanding jet models by the Advisory Committee on Reactor Safeguards (ACRS) [Wallis - ADAMS ML050830344, Ransom - ADAMS ML050830341], which has revealed several inaccuracies that may lead to nonconservative assessments of the strength, zone of influence, and space and time-varying nature of the loading effects of supersonic expanding jets on neighboring structures.

The ACRS review of the ANS 58.2 jet models was motivated by Generic Safety Issue (GSI) 191, which addresses the blockage of strainers upstream of emergency sump pumps by particulate. The particulate is formed by fibrous ceramic insulation, which can be broken loose by blast waves and/or jets emanating from nearby pipe ruptures. The Wallis and Ransom critiques were cited in ACRS Safety Evaluation letters to the Chairman of the NRC (ACRSR-2097 - ML042920334, and ACRSR-2110 ML043450346). Although the focus of the ACRS was on debris generation and sump blockage, their comments directly impact the assessments of postulated pipe breaks on neighboring SSCs.

The following RAIs (3.6-11 through -14) summarize the ACRS criticisms that relate specifically to possible non-conservatisms in the ANS 58.2 standard along with inconsistencies between the applicant approach and ANS 58.2 and request that inaccuracies and omissions in ANS 58.2 discovered by ACRS, along with inconsistencies between ANS 58.2 and the applicants approach be addressed.

RAI Number	**Reviewer**	**Question Summary**	**Full Text**
3.6-11	Li R	Explain how effects of blast waves will be accounted for	In the event of a high pressure pipe rupture, the first significant fluid load on surrounding structures would be induced by a blast wave. A spherically expanding blast wave is reasonably approximated to be a short duration transient and analyzed independently of any subsequent jet formation. Since the blast wave is not considered in the ANS 58.2 or the ESBWR DCD for evaluating the dynamic effects associated with the postulated pipe rupture, omission of blast wave considerations is clearly non-conservative. Explain how the effects of blast loads on neighboring SSCs will be accounted for.

3.6-12	Li R	Address ANS 58.2 jet expansion model inaccuracies	In the characterization of supersonic jets given by ANS 58.2, some physically incorrect assumptions underlie the approximating methodology. The model of the supersonic jet itself is given in Figures C-1 and C-2 of the Standard and contains references to supposedly universal jet characteristics that are not reasonable. A fundamental problem is the assumption that a jet issuing from a high pressure pipe break will always spread with a fixed 45 degree angle up to an asymptotic plane and subsequently spread at a constant 10 degree angle. Each of these characteristics is generally inapplicable and far from universal. Initial jet spreading rate is highly dependent on the ratio of the total conditions of the source flow to the ambient conditions. In reality, subsequent spreading rates depend, at a given axial position, on the ratio of the static pressure in the outermost jet flow region to the ambient static pressure. In the Standard, the asymptotic plane is described as the point at which the jet begins to interact with the surrounding environment. In his critique, Dr. Wallis takes this to mean that the jet is subsonic downstream of the asymptotic plane. In fact, as shown by Wallis and Ransom, supersonic or not, the jet is highly dependent on the conditions in the surrounding medium, and, at a given distance from the issuing break, will spread or contract at a rate depending on the local jet conditions relative to the surrounding fluid pressure. Supersonic jet behavior can persist over distances from the break far longer than those estimated by the standard, extending the zone of influence of the jet, and the number of SSCs that could be impacted by a supersonic jet. For example, tests in the Seimens-KWU facility in Karlstein, Germany showed that significant damage from steam jets can occur as far as 25 pipe diameters from a rupture (Knowledge Base for Emergency Core Cooling System Recirculation Reliability, February 1996, Issued by the NEA/CSNI, http://www.nea.fr/html/nsd/docs/1995/csni-r1995-11.pdf).

3.6-12 continued			The applicant is requested to: (a) Explain what analysis and/or testing has been used to substantiate the use of the ANS 58.2 Appendices C and D for defining conservatively which SSCs are in jet paths and the subsequent loading areas on the SSCs. (b) The applicant states at the bottom of page 3.6-5 that ‘impingement force becomes negligible beyond 9.1 meters’; provide the maximum piping and postulated break size dimensions to confirm that 9.1 meters is larger than 25 diameters for all postulated breaks.
3.6-13	Li R	Address ANS 58.2 and DCD Tier 2 jet pressure distribution inaccuracies and inconsistencies	The ANS 58.2 standard formulas for the spatial distribution of pressure through a jet cross-section are incorrect, as pointed out by Wallis and Ransom. In some cases, the standard’s assumption that the pressure within a jet cross section is maximum at the jet centerline is correct (near the break, for instance), but far from the break, the pressure variation is quite different, often peaking near the outer edges of the jet. Applying the standard’s formulas could lead to non-conservative pressures away from the jet centerline. The applicant states the following on page 3.6-18 of Section 3.6.2 of ESBWR DCD Tier 2: “The jet impingement force is uniformly distributed across the cross-sectional area of the jet and only the portion intercepted by the target is considered”. The applicant also states that ANS 58.2 Appendix D is used, which defines variable (not uniform) pressures over the cross-section of an expanding jet (see comments above regarding the inaccuracies of ANS Appendix D). The standard does specify a uniform pressure over the cross-section of a non-expanding jet, so it appears that the applicant is mixing the methods of the

3.6-13 continued			standard, combining the shape of an expanding jet with the uniform pressure distribution of a non-expanding jet. The applicant is requested to: (a) Clarify which approach (variable pressure over an expanding jet cross-section as defined in Appendix D of ANS 58.2, or a uniform pressure distribution assumed in DCD) will be used to specify pressure distribution over an expanding jet cross section. In either case, the applicant should explain what analysis and/or testing has been used to substantiate use of the ANS 58.2 Appendix D and/or the formulas in DCD Tier 2 for defining conservatively the net jet impingement loading on SSCs in light of the information presented by Ransom and Wallis (ADAMS ML050830344, ADAMS ML050830341), which challenges the accuracy of the pressure distribution models presented in ANS 58.2. (b) Submit a table of all postulated break types, along with the properties of the fluid internal and external to the ruptured pipe. The table should specify what type of jet the applicant assumes will emanate from each pipe break – incompressible nonexpanding jet, or compressible supersonic expanding jet - along with how impingement forces will be calculated for each jet. Specific examples of jet impingement loading calculations made using the ANS 58.2 standard and/or the methods in DCD Tier 2 for the postulated piping breaks in an ESBWR should be given, along with proof that the calculations lead to conservative impingement loads in spite of the cited inaccuracies and omissions in the ANS 58.2 models pointed out by Ransom and Wallis.

3.6-14	Li R	Justify neglecting jet dynamic loading and structural dynamic response, and neglecting feedback amplification of dynamic jet loads	On page 3.6-18, the applicant states that "The total impingement force acting on any cross-sectional area of the jet is time and distance invariant with a total magnitude equivalent to the steady-state fluid blowdown force given in Subsection 3.6.2.2 and with jet characteristics shown in Figure 3.6-1". While this may be true for some subsonic non-expanding jets, it is certainly not true for supersonic expanding jets, particularly those impinging on nearby structures. The applicant is requested to examine the following reference, "Knowledge Base for Emergency Core Cooling System Recirculation Reliability, February 1996, Issued by the NEA/CSNI," (http://www.nea.fr/html/nsd/docs/1995/csni-r1995-11.pdf), which states that tests in Germany's Heissdampfreactor (HDR) showed high dynamic (oscillating) loads in the immediate vicinity of breaks. The applicant provides additional criteria and procedures for jet loading evaluations in Appendix 3J.5 of the DCD. The applicant explains that the dynamic component of jet loading is considered independently from the static component, and that when static analysis methods are used to assess dynamic jet loads, the results are to be multiplied by a factor of two. However, in Section 3.6.2 of the DCD/Tier 2, Rev. 01, the applicant assumes that all jet loads are time invariant. Free jets are notoriously unsteady and, in the case of supersonic jets, such strong unsteadiness will tend to propagate in the shear layer and induce unsteady (time-varying oscillatory) loads on obstacles in the flow path. Pressures and densities vary nonmonotonically with distance along the axis of a typical supersonic jet and this in turn feeds and interacts with shear layer unsteadiness. In addition, for a typical supersonic jet, interaction with obstructions will lead to backward-propagating transient shock and expansion waves that will cause further unsteadiness in downstream shear layers.

3.6-14 continued			In some cases, synchronization of the transient waves with the shear layer vortices emanating from the jet break can lead to significant amplification of the jet pressures and forces (a form of resonance) that is not considered in the ANS 58.2 standard and DCD Tier 2. Should the dynamic response of the neighboring structure also synchronize with the jet loading time scales, further amplification of the loading can occur, including that at the source of the jet. These feedback phenomena are well-known to those in the aerospace industry who work with aircraft that use jets to lift off and land vertically [see, for example Ho, C.M., and Nosseir, N.S., "Dynamics of an impinging jet. Part 1. The feedback phenomenon," Journal of Fluid Mechanics, Vol. 105, pp. 119-142, 1981]. Some general observations by past investigators are that strong discrete frequency loads are observed when the impingement surface is within 10 diameters of the jet opening, and that when resonance within the jet occurs, significant amplification of impingement loads can result (Ho and Nosseir show a factor of 2-3 increase in pressure fluctuations at the frequency of the resonance). The applicant is requested to: (a) Provide information that establishes that the applicant's interpretation of the jet impingement force as static is conservative. (b) Explain whether any postulated pipe break locations are within 10 diameters of a neighboring SSC (or barrier/shield), and if so, how jet feedback/resonance and resulting dynamic load amplification are accounted for. (c) Clarify whether dynamic jet loads are to be considered, and if so, using what methods. Also, should the dynamic loading include strong excitation at discrete frequencies corresponding to resonance frequencies of the SSC impinged upon, provide the basis for assuming a static analysis with a dynamic load factor of two is conservative.

3.6-15	Li R	Clarify maximum expected high energy line temperature, pressure, and pipe diameter	The applicant defines the limiting temperature (93.3 C) and pressure (1.9 MPaG) which separate the definitions of high energy and moderate energy fluid systems. However, the staff could not locate readily the maximum temperature and pressure in the high energy systems. Many of the staff's RAIs are related to potential errors in modeling the many types of jets which could emanate from different piping breaks; however some of the RAIs may refer to jet types that are not applicable to the ESBWR design. So that the staff may better understand the types of jets and blast waves which might emanate from the postulated breaks in ESBWR, clarify maximum expected high energy line temperature, pressure, and pipe diameter.
3.6-16	Li R	Explain how jet reflections will be assessed	The applicant states at the bottom of page 3.6-17 of Section 3.6.2 of ESBWR DCD Tier 2 that 'reflected jets are considered only when there is an obvious reflecting surface (such as a flat plate)'. Explain quantitatively how the reflections will be considered.
3.6-17	Li R	Explain barrier, shield, and enclosure design considerations related to jet resonance effects	The applicant states that in some cases, barriers, shields, and enclosures around high-energy lines will be specified (page 3.6-6). These nearby surfaces can induce feedback and resonance within jets, potentially destroying the barrier, shield, or enclosure. Explain how the barriers, shields, and enclosures will be designed so that they will not be damaged or destroyed by dynamic jet resonant loading.
3.6-18	Li R	Explain deviation from ANS 58.2 Section 7.2 – targets impinged upon	The applicant states at the top of page 3.6-18 of Section 3.6.2 of ESBWR DCD Tier 2 that 'Potential targets in the jet path are considered at the calculated final position of the broken end of the ruptured pipe'. However, ANS 58.2 Section 7.2 states that: "those targets which are close enough to the jet boundary of the model assumed such that with reasonable variations in the jet geometry or pipe movement parameters they could be impinged upon, shall be assumed to be impinged upon." Justify this departure from the ANS 58.2 standard.

3.6-19	Li R	Clarify use of target shape factors	The section describing how target loads are computed provides an equation (3.6-2) for calculating the jet pressure at the target based on the target area and the jet force (assumed equal to the blowdown force), and also states that 'Target shape factors are included in accordance with ANS-58.2'. The standard uses shape factors for various geometries to adjust the net force on an object, not the pressure distribution over the object. Clarify how target shape factors will be used in their jet load calculations.

cc:

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