**ESBWR DCD SECTION 3.6.2**
**RAI RESPONSES REVIEW FINDINGS AND FOLLOW-UP RAIS**
**ENGINEERING MECHANICS BRANCH-2**

**RAI 3.6-6 and Follow-up 3.6-6 S01 and S02**

**RAI Summary:**
This RAI is related to how potential feedback amplification of blowdown force is considered. The applicant is requested to explain the following:

(a) Which analysis approach will GEH use – the time domain calculations or the equivalent static calculations with a dynamic load factor of 2?

(b) If the time domain calculations will be used, what tools are employed? How have they been validated and certified? What are the bias errors and uncertainties associated with the tools? Also, how are the time-varying jet impingement loads simulated?

(c) If the static analysis approach is used, how has GEH established that it is conservative in light of the questions raised in follow-up RAI 3.6-14?

**Review Findings and New Follow-up RAIs**

In response to (a), GEH provides detailed tables and figures of postulated pipe break locations and conditions. For each postulated pipe break, GEH describes one of two analysis approaches to be used for computing reaction loads on the piping, and jet loads on neighboring barriers or structures:

(1) For high energy lines near barriers, such as the Reactor Shield Wall (RSW) or the pool walls of the Gravity Driven Cooling System (GDCS), GEH will perform unsteady Computational Fluid Dynamics (CFD) analysis using the ANSYS CFX software. The analyses will include the effects of turbulence, jet unsteadiness, reflections from nearby surfaces, feedback effects and amplification, and compressibility. GEH also plans to use the RELAP5 computer program to determine thrust force and jet flow time histories. Once the loads on the neighboring structures are determined, they are applied to ANSYS dynamic finite element models of the structures to confirm structural integrity. In some cases, GEH may take advantage of geometric similarity between pipes to reduce the number of analyses they perform.

(2) for smaller lines which contain limited amounts of fluid and which are not near safety related components (such as the 8” diameter Isolation Condenser [IC] return nozzles, the 6” diameter GDCS nozzles, the 2” diameter stand by liquid control pipes, the 2” diameter RWCU drain piping nozzles, the 2” diameter nozzles of the Reactor Vessel Level Instrument System [RVLIS], and the 8” and 12” diameter RWCU pump outlet nozzles), an equivalent static analysis is performed which does not consider blast waves or jet unsteadiness effects.

GEH's response to (a) is thorough and acceptable with one exception: it is not clear to the staff when and how RELAP5 and CFX are used. We ask for clarification in a follow-up RAI:

> **New Follow-up RAI 3.6-6 S03 (a)**
> GEH states in their response to RAI 3.6-6 S02 (a) that the RELAP5 computer code will be used to determine thrust force and jet flow time history. GEH also states that CFX will be used to model jet flow pressure and force time history. It is unclear to the staff if both codes are used for all applications, or if GEH chooses a specific code for a particular application. GEH should clarify when the respective codes are used, and explain in detail how they are exercised, and how time histories of impingement pressure and blowdown force are determined and applied to finite element models of the ruptured pipe and neighboring structures.

GEH responds to (b) by describing the CFD methodology that will be used to compute the nonlinear unsteady time histories of dynamic forces and pressures induces by jets. GEH cites test cases used to validate CFX, including an analysis of the effects of a pipe break on ABWR steam dryers (ICONE 16-48410 by Jin Yan, et.al.). While the CFX benchmarks and the example calculations are necessary, they are not sufficient to establish that the procedures are conservative for LOCA events in an ESBWR design. In particular, the ICONE paper does not describe jet loads, only shock waves. Also, GEH has not responded fully to the RAI, not providing the bias errors and uncertainties associated with their methodologies. We therefore ask GEH to provide relevant benchmark(s) and accompanying bias errors and uncertainties in a follow-up RAI:

> **New Follow-up RAI 3.6-6 S03 (b)**
> GEH should provide benchmark(s) which establish that their methodologies for computing jet and thrust loads are conservative. The staff does not find the citation of CFX benchmarks, nor the ICONE paper submitted previously by GEH to be sufficient. The benchmark(s) should be representative of the worst-case conditions in an ESBWR plant, and establish any bias errors and uncertainties in the procedures (if any). The benchmark(s) should include a jet impinging on a nearby surface. GEH should note that the staff defines a procedure as not only the use of specific software, but also as the application of that software. Therefore, GEH should provide a complete description of their approach, beginning with a basic statement of the problem and the governing physics, including the governing equations. It is acceptable to reference existing manuals and literature, provided that GEH submit relevant sections of those references as part of their response. GEH should also supply the spatial and temporal discretizations used, the boundary conditions applied, and some figures pictorially showing the grids (vertices, volumes, etc.) applied in a critical region. Since jet loads are unsteady, GEH should provide a time step convergence study, or established guidelines based on the grids used and instantaneous solution wave speeds. GEH should also provide a spatial grid convergence study. A relevant parameter for establishing convergence and accuracy must be chosen, such as the integrated maximum force, or a peak pressure, on a critical structure during the transient calculation. The staff offers the attached guidance from the *Journal of Fluids Engineering* for GEH's consideration.

In their response to (c), GEH states that they plan to use an equivalent static analysis method for break locations where the blowdown and jet forces are expected to be small relative to those from larger, higher energy breaks. GEH lists these locations in their response. The staff finds this approach acceptable. However, it is not clear to the staff how GEH determines the maximum value of the jet impingement force, and we ask for clarification in a follow-up RAI:

**New Follow-up RAI 3.6-6 S03 (c)**
GEH should explain how $F_{imp\ max}$ (maximum value of the jet impingement force) is determined for their equivalent static analyses.

Finally, although GEH provides significant detail in this RAI response, they decline to include this detail in their DCD. The staff feels the DCD should include much of the information included in the RAI response, and ask the following:

**New Follow-up RAI 3.6-6 S03 (d)**
GEH should include most of the material in their response to RAI 3.6-6 S02 in a revised DCD, including the analysis methodologies, and tables and figures explaining the break locations.

**RAI 3.6-11 Follow-up RAI 3.6-11 S01**

**RAI Summary:**
This RAI is related to how effects of blast waves will be accounted for.
Based on ACRS concerns, and the information in the 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, all high pressure and temperature pipes should be considered as sources of blast waves with initial energy and mass roughly equal to the exposed volume from a hypothesized break. The subsequent damage from such waves has been well documented and is not properly accounted for by the isolated analysis of a pure spherically expanding wave. GEH should provide a rigorous and thorough explanation of their procedures for estimating the effects of blast waves on nearby SSCs.

**Review Findings and New Follow-up RAI**

GEH will now consider the effects of blast waves on neighboring structures and SSCs. If the blast emanates into an open space, spherical decay is assumed. If the blast occurs in an enclosed space, then a CFD analysis of the time history of the blast wave is performed. GEH includes an example for the annulus between the Reactor Pressure Vessel (RPV) and the Reactor Shield Wall (RSW) and shows that high pressures occur throughout the annulus, and do not obey spherical decay laws. GEH will use the higher annulus pressures in their evaluation of the integrity of other RPV nozzles and attached piping. GEH includes a detailed description of their annulus analysis. However, GEH does not include a convergence study to establish the conservatism of their analysis. We request this study in a follow-up RAI:

> **New Follow-up RAI 3.6-11 S02**
> GEH should supplement their description of the annulus blast wave analysis with the information requested in Follow-up RAI 3.6-6 S03 (b). The staff acknowledges that some of this information is already provided in GEH's response to RAI 3.6-11 S01, but much is not.

**RAI 3.6-13 and Follow-Up RAI 3.6-13 S01**

**RAI Summary:**
This RAI is related to ANS 58.2 and DCD Tier 2 jet pressure distribution inaccuracies and inconsistencies. The applicant is requested to:

(a) GEH clarifies in its response to part (a) of RAI 3.6-13 that it will use Appendix D of ANS 58.2 methods to compute pressure distributions on a target, and that DCD Tier 2, Subsection 3.6.2.3 has been modified accordingly. However, GEH has not addressed the second question in part (a), which is to explain what analysis and/or testing has been used to substantiate the use of Appendix D of ANS 58.2 in light of ACRS criticisms. Instead GEH states that it complies with ANS 58.2. It should be noted that the ANS 58.2 standard, including Appendix D, is no longer universally acceptable for specifying jet pressure distributions over SSCs in nuclear power plants. In particular, the effects of compressibility and unsteadiness are neglected. GEH is encouraged to review the original RAI, along with the criticisms raised by Wallis (Wallis, G., "The ANSI/ANS Standard 58.2-1988: Two-Phase Jet Model," ADAMS ML050830344, 15 Sep 2004) and Ransom (Ransom, V., "COMMENTS ON GSI-191 MODELS FOR DEBRIS GENERATION," ADAMS ML050830341, 15 Sep 2004) and prepare a thorough response.

(b) GEH has provided only general, incomplete and vague information in response to RAI 3.6-13(b). GEH does state, however, that the pipes have been designed such that breaks may only occur at the terminal ends. The original RAI requested the applicant to 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. GEH is requested to provide a detailed and thorough response to the original RAI 3.6 -13 (b).

**Review Findings and New Follow-up RAI**

In their response to (a), GEH states that it will no longer use ANS 58.2 for determining jet pressure distributions, and refers to their response to RAI 3.6-6 S02 for details on their new analysis approaches. RAI 3.6-13 S01 (a) is now closed.

In their response to (b), GEH provides detailed tables of pipe break locations, environmental conditions, and break conditions. However, it appears that these tables may not include all the terminal end that need to be considered for the postulated pipe break evaluation. GEH is requested to address the staff's concern in a follow-up RAI:

**New Follow-up RAI 3.6-13 S02 (b)**

GEH provides two tables of terminal end pipe break locations. It appears that these lists may not be complete. For an example, it does not include terminal end pipe break locations at some pipe anchors that act as rigid constraints to pipe motion and thermal expansion. It should be noted that GEH has assumed the pipe element between the containment penetration as anchor point in its ESBWR main steam piping analysis that was previously provided to the staff during its main steam piping design review. However, the staff noted that containment penetration is not considered as anchor point in the tables included in this RAI response. GEH is requested to clarify this inconsistency and also explain how its criteria are consistent with the terminal end defined by Note 3 on Page 3-4-5 of BTP 3-4. In addition, GEH is requested to modify the DCD to clarify that all ESBWR piping design will be designed to minimize the stresses and fatigue usage factors such that piping intermediate pipe break locations are avoided as stated in this RAI response. The staff noted that criteria for postulating intermediate break are still included in the DCD Revision 5. Finally, Pending final resolution of this RAI, GEH should include these pipe break location tables in a revised DCD.

**RAI 3.6-16 and Follow-up RAI 3.6-16 S01**

**RAI Summary:**
In its response to RAI 3.6-16, GEH states that the reflective force of the jet may be conservatively addressed using a shape factor and the assumed momentum of the jet. GEH has not discussed how they address the unsteadiness, compressibility, and coupled structural interaction with the jet. GEH is requested to modify DCD to clearly delineate how candidate reflecting surfaces are chosen and how this analysis addresses the unsteadiness, compressibility, and coupled potentially resonant, structural interaction with the jet. GEH is also requested to summarize its quantitative approach for modeling reflections in a revised DCD.

**Review Findings and New Follow-up RAI**

GEH provides tables showing configurations with potential reflection interactions between jets and targets. GEH will perform detailed unsteady CFD analyses for those configurations per the methods outlined in their response to RAI 3.6-6 S02. The staff finds GEH's response acceptable. GEH summarizes their approach for modeling reflections in a revised DCD, but does not include the tables provided in their RAI response in their DCD revision.

> **New Follow-up RAI 3.6-16 S02**
> GEH should include the tables provided in their response to RAI 3.6-16 S01 in a revised DCD.