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Subject: Response to Portion of NRC Requests for Additional Information Letter 45 Related To ESBWR Design Certification Application -- Evaluation of Postulated Pipe Breaks – RAIs 3.6-11, 3.6-14, 3.6-15, 3.6-16, 3.6-17, and 3.6-19.

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to portions of the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI), sent by NRC Letter 45, dated August 3, 2006, Reference 1 (RAIs 3.6-11, 3.6-14, 3.6-15, 3.6-16, 3.6-17, and 3.6-19).

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

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

D068
NRO

Reference:

MFN 06-271, Letter from the U.S. Nuclear Regulatory Commission to David H. Hinds, *Request for Additional Information Letter No. 45 Related To ESBWR Design Certification Application*, dated August 3, 2006.

Enclosure:

MFN 07-674, Response to Portion of NRC Request for Additional Information Letter No. 45 related to ESBWR Design Certification Application Evaluation of Postulated Pipe Breaks as described in Section 3.6 of the ESBWR Design Control Document -- RAI Numbers 3.6-11, 3.6-14, 3.6-15, 3.6-16, 3.6-17, and 3.6-19

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Enclosure 1

MFN 07-674

Response to Portion of NRC Request for

Additional Information Letter No. 45

Related to ESBWR Design Certification Application

Evaluation of Postulated Pipe Breaks

RAI Numbers 3.6-11, 3.6-14, 3.6-15, 3.6-16, 3.6-17, and 3.6-19

NRC RAI 3.6-11

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.

GEH Response

Due to the minute difference in time (fraction of seconds), the effects of the spherically forming blast wave will be overpowered by jet impingement force of the emanating fluid from a pipe rupture. The impact of a blast wave on neighboring SSC's is much smaller as the spherical wave expands and the strength reduces significantly in a much short distance than the jet fluid. The density of air is much smaller that the jet. Therefore, the blast loads on neighboring SSCs is negligible as compared to the jet impingement load and it does not become a controlling load.

DCD Impact

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

NRC RAI 3.6-14

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 (timevarying 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.

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 wellknown 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.

GEH Response

a) When the steady state thrust is greater than the initial thrust, the time dependent thrust force may be assumed to rise to the steady state thrust force and remain constant with time. Using an appropriate thrust coefficient (C_T) based on the fluid properties, the static jet force can be calculated as $F_{jet} = C_T P A$. Where, P = Exit pressure of the broken pipe, and A= Cross sectional area of the broken pipe end. This static load is conservative since f L/D is zero or very small,

   Where,

   f = Pipe Friction factor

   L/D = Pipe Length to Diameter Ratio

b) As part of the detail design, the pipe rupture evaluation will address the exact location of the potential targets such as, SSCs (or barrier/shield), and provide resolutions in mitigating the consequence of pipe rupture impact.

   For feedback/resonance, the resulting dynamic amplification will get automatically accounted for in when blow down time-history dynamic response evaluations for the pipe rupture loads on the impacted component/structure are performed. Also, instead of a dynamic analysis, an equivalent static analysis can be performed with the use of a dynamic load factor as follows:

   $F_S = DLF\ (F_{imp\ max})$

   Where,

   F_S = Equivalent static impingement force
   DLF = Dynamic load factor
   $F_{imp\ max}$ = Maximum value of the jet impingement force

   The impingement force may conservatively be assumed to occur instantaneously and a DLF = 2.0 is used. A separate value for DLF may be analytically established based on DLF = *dynamic deflection/ static deflection* of the object being impinged upon.

c) This question has two parts:

i. *Clarify whether dynamic jet loads are to be considered, and if so, using what methods.*

ANS 58.2 methods will be used to determine the blow-down loads.

ii. *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.*

Refer response to the item b) above for consideration of feedback resonance in design.

As stated in ANS 58.2 section 7.3, an equivalent static analysis, a dynamic load factor (DLF) of 2 is conservative. This is because ANS 58.2 assumes the jet impingement force to have 0.001 second rise time and reaches constant value. The force has no discrete frequencies corresponding to resonance frequencies of the SSC being impinged upon. The figure a) below shows the "Maximum response of one-degree elastic system (undamped) subjected to rectangular and triangular pulse having zero rise time " from "Introduction to structural dynamic" by John M Biggs. The maximum DLF is 2.0. If the rise time is considered, the DLF will be less than 2.0. For multiple degree system subject to jet impingement load, the maximum dynamic load factor (DLF) of 2 is also applicable.

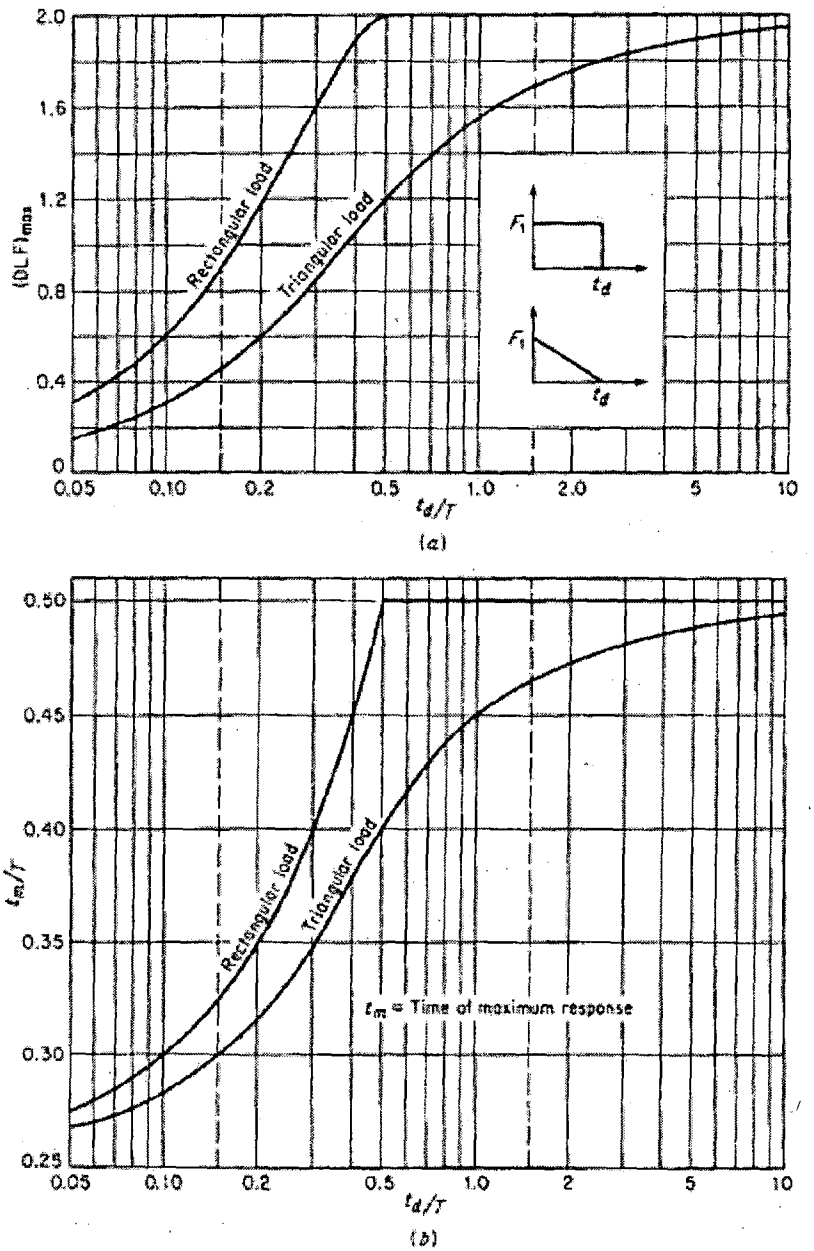

FIGURE 2.7 Maximum response of one-degree elastic systems (undamped) subjected to rectangular and triangular load pulses having zero rise time. (*U.S. Army Corps of Engineers.*[10])

DCD Impact

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

NRC RAI 3.6-15

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.

GEH Response

The ESBWR high energy line parameters are provided below (Ref. DCD Tier 2, subsection 3.6, Tables 3.6-3 (High Energy Piping Inside Containment) and 3.6-4 (High Energy Piping Outside Containment) of DCD Tier 2, Rev.3.

High Energy Piping Inside and Outside Containment

Systems	Maximum Temperature (°F)	Maximum Pressure (Mpa/Psig)	Max. Pipe O.D./ Wall thickness (T) Or, Schedule
Main Steam	575	8.62 Mpa (1250 psig)	OD =28 inch T = 1.45"
Feedwater	420	7.31 Mpa (1060 psig)	12" Sch.80
Control Rod Drive (CRD) System (to and from HCU)	150	23.54 Mpa (3414 psig)	1.25 inch T= 0.183 inch
Reactor Water Cleanup and Shutdown Cooling System (suction and RPV drain lines)	575	9.48 Mpa (1374 psig)	12 " Sch. 120. RWCU drain line 3" Sch. 80
Isolation Condenser System	598	10.34 Mpa (1500 psig)	14 inch/8 inch Sch.80
Gravity-Driven Cooling System Injection Lines (from RPV to isolation valves)	572	8.62 Mpa (1250 psig)	6" Sch. 80
Standby Liquid Control System	533	15.20 Mpa (2204 psig)	2" and 3"sch. 120

Notes:
1. GDCS piping is located inside containment only.
2. The maximum temperature and pressure values used herein for CRD piping are from GE's Lungmen Nuclear Power Project (Taiwan Power Company)

Systems pressure and/or temperature are estimated values only. These values may differ slightly or coincide when final design is complete.

DCD Impact

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

NRC RAI 3.6-16

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.

GEH Response

Conservatively, reflective force of the jet may be assumed equal to the jet striking force based on the jet pressure on the plate neglecting the friction and energy loss of the striking jet upon hitting the plate. The shape factor may be applicable based on the orientation of the plate in the jet stream.

DCD Impact

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

NRC RAI 3.6-17

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.

GEH Response

ANS 58.2 Appendices C and D will be used to determine the jet impingement load. Structures such as, barriers, shield, or enclosures are conservatively designed in order to withstand a large load such as jet impingement loads.

As stated in ANS 58.2 section 7.3, either a dynamic analysis or an equivalent static analysis may be performed for jet impingement loads for evaluations on targets and/or barriers. In absence of a dynamic analysis, an equivalent static analysis may be used where a dynamic load factor (DLF) of 2 may be applied to determine the jet load. A time history analysis or equivalent static load application as input will be adequate in determining the structural response for barriers, shields, and enclosures.

Barriers or shields that are identified as necessary by the High Energy Line Separation Analysis (HELSA) evaluation (i.e., based on no specific break locations) are designed for worst-case loads. The closest high-energy pipe location and resultant loads are used to size the barriers.

DCD Impact

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

NRC RAI 3.6-19

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.

GEH Response

DCD Section 3.6.2.3, Subsection 3.6.2.3.1 under the bullet titled "Target loads are determined using the following procedures". These procedures use the same concept of ANS 58.2 standard using shape factors for various geometries to adjust the net force on an object, not the pressure distribution over the object.

DCD Impact

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