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Subject: **Partial Response to NRC RAI Letter No. 315 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.6 – Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping; RAI Numbers 3.6-6 S03 parts a, c & d, 3.6-13 S02 and 3.6-16 S02**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) partial response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) letter number 315 sent by NRC letter dated March 5, 2009 (Reference 1). RAI Numbers 3.6-6 S03 parts a, c & d, 3.6-13 S02 and 3.6-16 S02 are addressed in Enclosure 1. Enclosure 2 contains the DCD changes as a result of GEH's response to these RAIs. Verified DCD changes associated with these RAI responses are identified in the enclosed DCD markups by enclosing the text within a black box.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

Reference:

1. MFN 09-175 Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 315 Related to ESBWR Design Certification* dated March 5, 2009

Enclosures:

1. Partial Response to NRC RAI Letter No. 315 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.6 – Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping; RAI Numbers 3.6-6 S03 parts a, c & d, 3.6-13 S02 and 3.6-16 S02

2. Response to Portion of NRC Request for Additional Information Letter No. 315 Related to ESBWR Design Certification Application - DCD Markup for RAI Numbers 3.6-6 S03 parts a, c & d, 3.6-13 S02 and 3.6-16 S02

| | | |
|---|---|---|
| cc: | AE Cubbage | USNRC (with enclosures) |
| | JG Head | GEH/Wilmington (with enclosures) |
| | DH Hinds | GEH/Wilmington (with enclosures) |
| | eDRF Section | 0000-0101-4639<br>(RAIs 3.6-6 S03 a, c & d, 3.6-13 S02 & 3.6-16 S02) |

# Enclosure 1

# MFN 09-298

**Partial Response to NRC RAI Letter No. 315**

**Related to ESBWR Design Certification Application –**

**DCD Tier 2 Section 3.6 –**

**Protection Against Dynamic Effects Associated**

**with the Postulated Rupture of Piping;**

**RAI Numbers 3.6-6 S03 parts a, c & d,**

**3.6-13 S02 and 3.6-16 S02**

**NRC RAI 3.6-6 S03**

*Clarification on RELAP5 and CFX codes use.*

*(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.*

*(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.*

*(c) GEH should explain how Fimp max (maximum value of the jet impingement force) is determined for their equivalent static analyses.*

*(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.*

**GEH Response**

Response to Part (a);
The jet impingement effect to a target from a high energy line break will be performed as follows:

<u>Step 1</u>: <u>Thermal Hydraulic Analysis By RELAP5 Code</u>: The RELAP5 hydrodynamic model is a 1-D transient two-phase model with the capability for modeling non-condensable components in the steam phase and/or a soluble component in the water phase. The calculation scheme is based on the Continuity equations (mass, momentum and energy) for each phase, the state equations and constitutive relations (steam generation, wall heat transfer, etc.).

The hydrodynamic model is based on the use of fluid control volumes and junctions to represent the spatial character of the flow. Velocities are located at the junctions and are associated with mass and energy flow between control volumes. The control system provides the capability to evaluate simultaneous algebraic and ordinary differential equations. The capability is primarily intended to simulate control systems typically used in hydrodynamic systems.

A broken (circumferential break) pipe geometry is modeled as the control volumes and the required fluid parameters are provided as the input with the appropriate boundary conditions. A thermal hydraulic transient system analysis as a series of control volumes connected by junctions will be carried out. The RELAP code solves one-dimensional mass, momentum and energy equations for volumes assumed to contain homogeneous fluid with the vapor and liquid phases in thermodynamic equilibrium.

The analysis results include the mass flow rate time history through the break and the pipe reaction force time history among other desired output.

<u>Step 2</u>: <u>ANSYS Computational Fluid Dynamics (CFD) Analysis</u>: This program uses CFX, solver version 11.0 or the solver Fluent V6.3 included in ANSYS. Using the mass flow rate derived from the RELAP analysis and considering a worst case pipe displaced configuration (a pipe position that would cause maximum jet impact to the target structure) and defining the target location and its surface geometry in the CFD program as input, the CFD analysis will provide results such as the time history of the force on the target. The CFD analysis will capture the flow effects associated with the jet unsteadiness, nonlinearity, feedback amplification and jet reflections.

<u>Step 3</u>: <u>ANSYS Finite Element Method Analysis</u>: This program will be used to model the target structure by finite element method. Using force time history as the input load resulting from the CFD analysis on the target structure, the transient dynamic analysis is performed. This dynamic time history analysis will address the resonance (if any) with the input forcing function.

<u>*Response to Part (c)*</u>

Per the telephone call between GEH and the NRC on March 4, 2009, the NRC requested GEH to identify the source of the term (*Fimp max)* in the equation

$F_S = DLF^* (F_{imp\ max})$ in response to 3.6-6 S02 (item c). The term (*Fimp max)* in the equation came from Section 7.3 of the ANS 58.2 standard.

*Response to Part (d)*

Per the telephone call between GEH and the NRC on March 4, 2009, both GEH and the NRC agreed that GEH will include tables pertaining to pipe break locations in DCD Tier 2. Furthermore, GEH will provide ESBWR pipe break data in the tables but not all the technical data that GEH had previously provided in the responses to RAI 3.6-6 S02 (Tables 1 & 2), RAI 3.6-13 S01 (Tables 1 & 2), and RAI 3.6-16 S01, (Tables 1 & 2) since the information contained in these tables has GEH proprietary information.

**DCD Impact**

a) DCD Tier 2, Chapter 3.6, Subsection 3.6.2.3.1 is being revised in Revision 6 to add the dynamic analysis methods (Steps 1, 2, and 3) for jet impingement effects as shown in the attached markup.

b) In response to part (d), DCD Tier 2, Chapter 3.6, is being revised in Revision 6 to add Tables 3.6-5 and 3.6-6, as shown in the attached markup.

c) DCD Tier 2, Chapter 3.6, Subsection 3.6.2.1.1 is being revised in Revision 6 to add a statement with regard to the addition of Tables 3.6-5 and 3.6-6, as shown in the attached markup.

**NRC RAI 3.6-13 S02**

*Clarification on tables of terminal end pipe break locations*

*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.*

**GEH Response**

Consistent with BTP 3-4, Note 3 on Page 3-4-5, GEH agrees with the NRC that terminal end breaks will need to be postulated at the containment penetration. A table (Table 3.6-7) will be added in DCD Tier 2, Chapter 3.6, to identify the terminal end breaks at the containment penetration for all high energy piping inside and outside the containment boundary. In addition, GEH will also add a figure in DCD Tier 2, Chapter 3.6, to clarify typical terminal end break locations inside and outside of the containment penetrations.

In addition, DCD tier 2, Subsection 3.6.2.1.1 will be revised to include the following statement:

*'Piping will be designed to minimize the stresses and fatigue usage factors such that piping intermediate pipe break locations are avoided'.*

**DCD Impact**

a) DCD Tier 2, Chapter 3.6, is being revised in Revision 6 to add Table 3.6-7 and Figure 3.6-3, as shown in the attached markup.

b) DCD Tier 2, Chapter 3.6, Section 3.6.2.1.1 is being revised in Revision 6 to add a statement with regard to the addition of the Figure 3.6-3, as shown in the attached markup.

c) DCD Section 3.6.2.1.1 is being revised in Revision 6 to add the statement "*Piping will be designed to minimize the stresses and fatigue usage factors such that piping intermediate pipe break locations are avoided.*"

d) DCD Section 3.6.2.1.1 is being revised in Revision 6 to add the statement, "*including the locations shown in Fig. 3.6-3*" to the terminal end bullet.

**NRC RAI 3.6-16 S02**

*Tables showing configurations with potential reflection interactions between jets and targets*

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

**GEH Response**

Per the telephone call between GEH and the NRC on March 4, 2009, GEH agreed to include the requested pipe break data in table format in DCD Tier 2, Section 3.6.

**DCD Impact**

No DCD changes will be made in response to this RAI other than those described in the responses to RAIs 3.6-6 S03 and 3.6-13 S02.

**Enclosure 2**

**MFN 09-298**

**Response to Portion of NRC Request for**

**Additional Information Letter No. 315**

**Related to ESBWR Design Certification Application**

**DCD Markup for RAI Numbers:**

**3.6-6 S03 parts a, c & d, 3.6-13 S02 and 3.6-16 S02**

- Sleeves provided for those portions of piping in the containment penetration areas are constructed in accordance with the rules of Class MC, Subsection NE of the ASME Code, Section III, where the sleeve is part of the containment boundary. In addition, the entire sleeve assembly is designed to meet the following requirements and tests:
  - The design pressure and temperature are not less than the maximum operating pressure and temperature of the enclosed pipe under normal plant conditions.
  - The Level C stress limits in NE-3220, ASME Code, Section III, are not exceeded under the loadings associated with containment design pressure and temperature in combination with the safe shutdown earthquake (SSE).
  - The assemblies are subjected to a single pressure test at a pressure not less than its design pressure.
  - The assemblies do not prevent the access required to conduct the in-service examination specified below.
- A 100% volumetric in-service examination of all pipe welds is conducted during each inspection interval as defined in IWA-2400, ASME Code, Section XI.

**ASME Code Section III Class 1 Piping in Areas Other Than Containment Penetration**

With the exception of those portions of piping identified above, breaks in ASME Code, Section III, Class 1 piping are postulated at the following locations in each piping and branch run:

- At terminal ends including the locations shown in Figure 3.6-3.
- At intermediate locations where the maximum stress range as calculated by Equation 10 in NB-3653, ASME Code, Section III exceeds 2.4 $S_m$, and either Equation 12 or Equation 13 in Paragraph NB-3653 exceeds 2.4 $S_m$.
- At intermediate locations where the cumulative usage factor exceeds 0.1. As a result of piping reanalysis caused by differences between the design configuration and the as-built configuration, the highest stress or cumulative usage factor locations may be shifted; however, the initially determined intermediate break locations need not be changed unless one of the following conditions exists:
  - The dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.
  - A change is required in pipe parameters, such as major differences in pipe size, wall thickness, and routing.

  For the piping system with reactor water, if the environmental fatigue is included in accordance with RG 1.207, the fatigue usage limit should be □ 0.40 as the criteria instead of □ 0.10 for determining pipe break locations.

**ASME Code Section III Class 2 and 3 Piping in Areas Other Than Containment Penetration**

With the exceptions of those portions of piping identified above, breaks in ASME Code, Section III, Class 2 and 3 piping are postulated at the following locations in those portions of each piping and branch run:

- At terminal ends.
- At intermediate locations selected by one of the following criteria:
  - At each pipe fitting (e.g., elbow, tee, cross, flange, and nonstandard fitting), welded attachment, and valve.
  - At one location at each extreme of the piping run adjacent to the protective structure for piping that contains no fittings, welded attachments, or valves.
  - At each location where stresses calculated by the sum of Equations 9 and 10 in NC/ND-3653, ASME Code, Section III, exceed 0.8 times the sum of the stress limits given in NC/ND-3653.

Piping will be designed to minimize the stresses and fatigue usage factors such that piping intermediate pipe break locations are avoided.

As a result of piping reanalysis caused by differences between the design configuration and the as-built configuration, the highest stress locations may be shifted; however, the initially determined intermediate break locations may be used unless a redesign of the piping resulting in a change in the pipe parameters (diameter, wall thickness, routing) is required, or the dynamic effects from the new (as-built) intermediate break location are not mitigated by the original pipe whip restraints and jet shields.

For complex piping systems such as those containing arrangements of headers and parallel piping running between headers, the pipe breaks are postulated pursuant to the applicable criteria identified in this subsection and in conformance with BTP 3-4.

The terminal end pipe break locations for high energy lines inside and outside containment are provided in Tables 3.6-5 and 3.6-6. The high energy line breaks at the containment penetration outside of the containment penetration zone are provided in Table 3.6-7. Terminal end break locations in piping systems on both sides of the containment penetration are shown in Figure 3.6-3.

**Non-ASME Class Piping**

Breaks in seismically analyzed non-ASME Class (not ASME Class 1, 2, or 3) piping are postulated according to the same requirements for ASME Class 2 and 3 piping above. Separation and interaction requirements between seismically analyzed and non-seismically analyzed piping are met as described in Subsection 3.7.3.8.

**Separating Structure With High-Energy Lines**

If a structure separates a high-energy line from a safety-related component, the separating structure is designed to withstand the consequences of the pipe break in the high-energy line at locations that the aforementioned criteria require to be postulated. However, as noted in

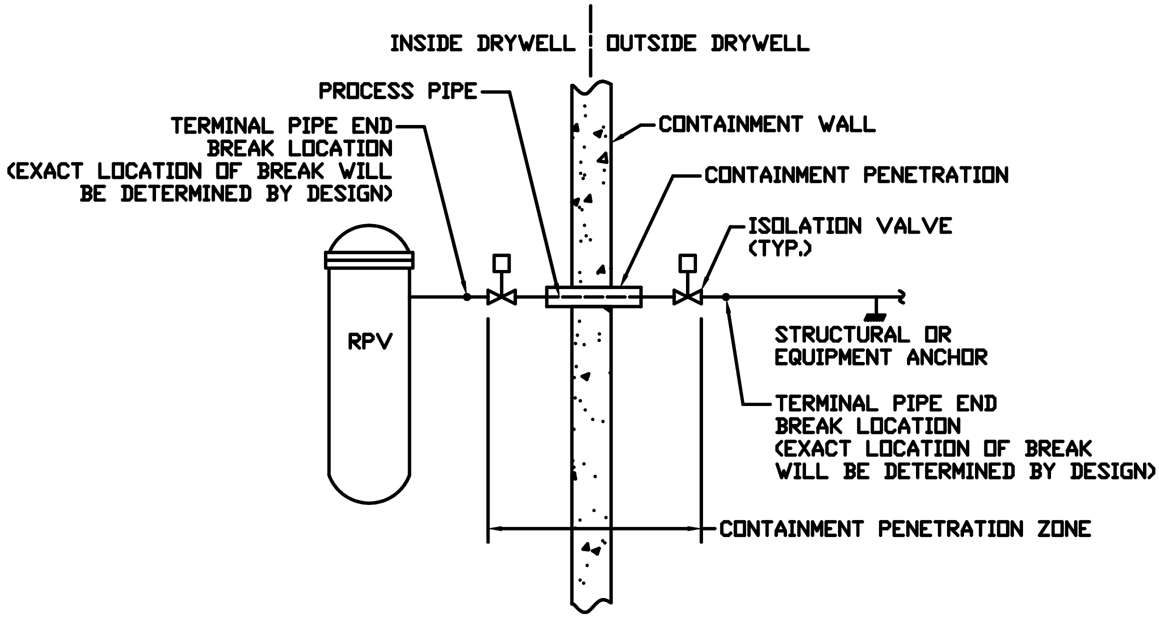


Figure 3.6-3. Typical Terminal End Break at Containment Penetration

feedback amplification, jet reflection are deemed significant in the jet modeling. For this purpose, other dynamic analysis method is appropriate such as computational fluid dynamic analysis. This method of analysis is capable in defining parameters associated with the jet flow properties, ambient condition, and a surface profile of the interacting targets. The resulting force time history, jet pressures on target surface are obtained from such computational fluid dynamics analysis application. The detailed jet analysis evaluation method is described later as analysis Steps 1, 2, and 3 in this subsection.

- The break opening is assumed to be a circular orifice of cross-sectional flow area equal to the effective flow area of the break.
- The jet impingement force is equal to the steady-state value of the fluid blowdown force calculated by the methods described in Subsection 3.6.2.2.
- The distance of jet travel is divided into two or three regions. Region 1 (Figure 3.6-1, items a, b and c) extends from the break to the asymptotic area. Within this region the discharging fluid flashes and undergoes expansion from the break area pressure to the atmospheric pressure. In Region 2 the jet expands further. For partial-separation circumferential breaks, the area increases as the jet expands. In Region 3, the jet expands at a half angle of 10 degrees (Figure 3.6-1, items a and c).
- The analytical model for estimating the asymptotic jet area for subcooled water and saturated water assumes a constant jet area. For fluids discharging from a break that are below the saturation temperature at the corresponding room pressure or have a pressure at the break area equal to the room pressure, the free expansion does not occur.
- The distance downstream from the break where the asymptotic area is reached (Region 2) is calculated for circumferential and longitudinal breaks.
- Both longitudinal and fully separated circumferential breaks are treated similarly. The value of fL/D used in the blowdown calculation is also used for jet impingement.
- Circumferential breaks with partial (i.e., h<D/2) separation between the two ends of the broken pipe not significantly offset (i.e., no more than one pipe wall thickness lateral displacement) are more difficult to quantify. For these cases, the following assumptions are made.
  - The jet is uniformly distributed around the periphery.
  - The jet cross-section at any cut through the pipe axis has the configuration depicted in Figure 3.6-1, item b. The jet regions are also shown.
  - The jet force $F_j$ = total blowdown.

  The pressure at any point intersected by the jet ($P_j$) is:

$$P_j = \frac{F_s}{A_R} \tag{3.6-1}$$

where

$A_R$ = the total 360° area of the jet at a radius equal to the distance from the pipe centerline to the target expected to be reduced. For conservatism, no credit is taken for this reduction and the pipe is assumed to be impacted with the full impingement load. However, where shape factors are justifiable, they may be used. The effective target area $A_{te}$ is:

$$A_{te} = (D_A)(D) \quad (3.6\text{-}4)$$

where

$D_A$ = diameter of the jet at the target interface

$D$ = pipe OD of target pipe for a fully submerged pipe

When the target (pipe) is larger than the area of the jet, the effective target area equals the expanded jet area

$$A_{te} = A_x \quad (3.6\text{-}5)$$

- For all cases, the jet area ($A_x$) is assumed to be uniform and the load is uniformly distributed on the impinged target area $A_{te}$.
- Where applicable, on a case-by-case basis detailed structural analysis of protective devices for safety-related components necessary to achieve and maintain stable shutdown of the plant is performed due to the jet load impact. The analysis steps involved are as follows:

**Step 1: Thermal Hydraulic Analysis By RELAP5 Code.** The RELAP5 hydrodynamic model is a 1-D transient two-phase model with the capability for modeling non-condensable components in the steam phase and/or a soluble component in the water phase. The calculation scheme is based on the Continuity equations (mass, momentum and energy) for each phase, the state equations and constitutive relations (steam generation, wall heat transfer, etc.).

The hydrodynamic model is based on the use of fluid control volumes and junctions to represent the spatial character of the flow. Velocities are located at the junctions and are associated with mass and energy flow between control volumes. The control system provides the capability to evaluate simultaneous algebraic and ordinary differential equations. The capability is primarily intended to simulate control systems typically used in hydrodynamic systems.

A ruptured (circumferential break) pipe geometry is modeled as the control volumes and the required fluid parameters are provided as the input with the appropriate boundary conditions. A thermal hydraulic transient system analysis as a series of control volumes connected by junctions will be carried out. The RELAP code solves one-dimensional mass, momentum and energy equations for volumes assumed to contain homogeneous fluid with the vapor and liquid phases in thermodynamic equilibrium.

This analysis results include the mass flow rate time history through the break and the pipe reaction force time history among other desired output.

**Step 2: ANSYS Computational Fluid Dynamics Analysis.** This program uses CFX, solver version 11.0 or the solver Fluent V6.3 included in ANSYS. Using the mass flow rate derived from the RELAP analysis and considering a worst case pipe displaced configuration (a pipe position that would cause maximum jet impact to the target structure) and defining the target location and its surface geometry in the computational fluid dynamics program as input, the computational fluid dynamics analysis will provide results such as the time history of the force on the target. The computational fluid dynamics analysis will capture the flow effects associated with the jet unsteadiness, nonlinearity, feedback amplification and jet reflections.

**Step 3: ANSYS Finite Element Method (FEM) Analysis.** This program will be used to model the target structure by finite element method. Using force time history as the input load resulting from the computational fluid dynamics analysis on the target structure, the transient dynamic analysis is performed. This dynamic time history analysis will address the resonance (if any) with the input forcing function.

### 3.6.2.3.2 Pipe Whip Effects on Safety-Related Components

This subsection provides the criteria and methods used to evaluate the effects of pipe displacements on safety-related structures, systems, and components following a postulated pipe rupture.

Pipe whip (displacement) effects on safety-related structures, systems, and components can be placed in two categories: (1) pipe displacement effects on components (nozzles, valves, tees, etc.) which are in the same piping run that the break occurs in; and (2) pipe whip or controlled displacements onto external components such as building structure, other piping systems, cable trays, and conduits, etc.

#### Pipe Displacement Effects on Components in the Same Piping Run

The criteria for determining the effects of pipe displacements on inline components are as follows:

- Components such as vessel safe ends and valves which are attached to the broken piping system and do not serve a safety function or failure of which would not further escalate the consequences of the accident need not be designed to meet ASME Code Section III-imposed limits for safety-related components under faulted loading.
- If these components are required for safe shutdown or 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 operability qualification of active pipe mounted components is described in Subsection 3.9.3.
- The methods used to calculate the pipe whip loads on piping components in the same run as the postulated break are described in Subsection 3.6.2.2 under paragraph titled. "Pipe Whip Dynamic Response Analyses".

#### Pipe Displacement Effects on Safety-Related Structures, Other Systems, and Components

The criteria and methods used to calculate the effects of pipe whip on external components consist of the following:

- The effects on safety-related structures and barriers are evaluated in accordance with the barrier design procedures given in Subsection 3.5.3.

## Table 3.6-5
## Terminal Pipe End Breaks at RPV Nozzles – High Energy Piping Systems

| Terminal Pipe End Breaks for Systems | Location | System Condition | Jet Type | Rupture Restraint Device Required (Note 6) |
|---|---|---|---|---|
| 30" MS Nozzle (Note 2) | RPV (Four nozzles) | Steam | Compressible, supersonic, turbulent, unsteady and expanding<br>Quality: superheated steam | Note 3 |
| 12" FW Nozzle | RPV (Six nozzles) (Note 1) | Saturated Water | Compressible (mildly), expanding<br>Quality: subcooled (some flashing can occur) | Note 3 |
| 12" RWCU Nozzle | RPV (Two nozzles) (Note 1) | Saturated Water | Compressible (mildly), expanding<br>Quality: subcooled (some flashing can occur) | Note 3 |
| 2" RWCU Drain Nozzle | RPV (Four nozzles located on bottom head of the RPV) (Note 1) | Saturated Water | Compressible, expanding<br>Quality: subcooled (some flashing can occur) | Note 4 |
| 18" IC Nozzle (Note 2) | RPV (Four nozzles) (Note 1) | Steam | Compressible, supersonic, turbulent, unsteady and expanding<br>Quality: superheated steam | Note 3 |
| 8" IC Return Nozzle | RPV (Four nozzles) (Note 1) | Saturated Water | Compressible, expanding<br>Quality: subcooled (some flashing can occur) | Note 4 |
| 6" GDCS Nozzle (Note 2) | RPV (Eight nozzles) (Note 1) | Saturated Water | Compressible, expanding<br>Quality: subcooled (some flashing can occur) | Note 4 |
| 6" GDCS Equalizing Nozzle (Note 2) | RPV (Four nozzles) (Note 1) | Saturated Water | Compressible, expanding<br>Quality: subcooled (some flashing can occur) | Note 4 |
| 2" Stand-by Liquid Control Nozzle | RPV (Two nozzles) (Note 1) | Low Temp. Water | Compressible, expanding<br>Quality: subcooled | Note 4 |
| 2" RPV Level Inst. System (RVLIS) Piping (4 nozzles) | RPV (Four nozzles) (Note 1) | Steam | Compressible, supersonic, expanding<br>Quality: superheated steam | Note 4 |
| 2" Head Vent Nozzle | RPV (One nozzle) (Note 1) | Steam | Compressible, Supersonic, Expanding<br>Quality: Super heated Steam | Note 4 |
| 1-1/4" CRD Pipe at CRD Housing | 269 Housings (On bottom shell of the RPV) | Low Temp. Water | Compressible, Non-expanding<br>Quality: Subcooled | Note 5 |

Notes:
1. The terminal end location is within the Annulus formed by the RPV and Shield wall.
2. The nozzle has Venturi.
3. Rupture restraint device is required.
4. Rupture restraint function can be achieved by stiff pipe support structural hardware.
5. Rupture restraint device is not required.
6. The use of pipe restraints are subject to the final results of the high energy line break evaluations.

## Table 3.6-6
## Terminal Pipe End Breaks for the Outside Containment – High Energy Piping Systems

| Terminal Pipe End Breaks for Systems | Pipe Break Locations | Building | System Condition | Jet Type | Rupture Restraint Device Required Note 4 |
|---|---|---|---|---|---|
| 30" MS Pipe | At header near Turbine Stop Valve | Turbine Building | Steam | Compressible, supersonic, expanding, turbulent, and unsteady<br>Quality: superheated steam | Note 2 |
| 24" FW Pipe | At FW Heater nozzles<br>Number of heaters = 6 (all in concrete wall enclosures) | Turbine Building | Saturated Water | Compressible, expanding<br>Quality: subcooled | Note 2 |
| 6" & 8" RWCU Piping | At Regenerative Heat Exchanger (in a room) | Reactor Bldg. | Hot Water (for Regen Hx inlet)<br>Low Temp. Water (for Regen Hx inlet) | Compressible, expanding (for Regen Hx inlet), non-expanding for outlet (for Regen Hx inlet)<br>Quality: subcooled | Note 2 |
| 12" RWCU Piping | At Non- Regenerative Heat Exchanger (in a room) | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 2 |
| 8" and 12" RWCU Pump nozzles | RWCU pumps inlet (in a room) | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 1 |
| 8" and 12" RWCU Pump | RWCU pumps outlet (in a room) | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 1 |
| 6" RWCU piping | RWCU Demineralizer tank inlet & outlet | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 1 |
| 8" IC Piping with $\approx$ 3"Dia. Venturi | At Inlet of Isolation Condenser in IC/PCCS Pool submerged in the water | Reactor Bldg. | Hot Water | HX nozzles submerged in the pool (jetting will not occur) | Note 3 |
| 4" IC Piping | At Outlet of Isolation Condenser in IC/PCCS Pool submerged in the water | Reactor Bldg. | Hot Water | HX nozzles submerged in the pool (jetting will not occur) | Note 3 |
| 3" Stand-by Liquid Control Piping | At SLC Tank Outlet (in a room) | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 1 |
| 1-1/4" CRD Piping (269 Lines) | At HCU (Hydraulic Control Units) | Reactor Bldg. | Low Temp. Water | Compressible, non-expanding<br>Quality: subcooled | Note 3 |

Notes:
1. This break is located in a separate room & has no other safety related components. The pipe whip and jet interactions are limited within its system and components. A pipe rupture device may not be necessary.
2. Rupture restraint device is required.
3. Rupture restraint device is not required.
4. The use of pipe restraints are subject to the final results of the high energy line break evaluations.

## Table 3.6-7
## Terminal End Breaks at Containment Penetrations
## (Inside and Outside the Drywell)

| Penetration Number | Description | Pipe Dia, mm (in) (Note 6) | System Condition | Jet Type | Rupture Restraint Device Required (Note 5 & Note 7) |
|---|---|---|---|---|---|
| B21-MPEN-0001 thru 4 | Main Steam Line A thru D | 750 (30) | Steam | Same as in Tables 3.6-5 and 3.6-6 | Note 1 |
| B21-MPEN-0006 & 7 | Feedwater Line A & B | 550 (22) | Steam | Same as in Tables 3.6-5 and 3.6-6 | Note 1 |
| B21-MPEN-0005 | Main Steam Drain Header | 100 (4) | Steam/Hot Water (*) | Compressible, supersonic, turbulent, unsteady and expanding<br>Quality: superheated steam | Note 1 |
| B32-MPEN-0001 thru 4 | IC Train A, B, C & D Steam Supply Line | 350 (14) | Steam | Compressible, supersonic, turbulent, unsteady and expanding<br>Quality: superheated steam | Note 2 |
| B32-MPEN-0005 thru 8 | IC Train A, B, C & D Condensate Return | 200 (8) | Hot water | Compressible, expanding<br>Quality: subcooled (some flashing can occur) | Note 3 |
| C12-MPEN-0001 thru 12 | FMCRD: Hydraulic Lines | 32 (1.25) | Low Temp. Water | Compressible & non-expanding<br>Quality: Sub-cooled | Note 4 |
| C41-MPEN-0001 & 2 | SLC (Train A & B) | 80 (3) | Low Temp. Water | - Compressible, Expanding<br>Quality: Sub-cooled (inside Cont.)<br>- Compressible, non-Expanding<br>Quality: Low temp water (outside) | Note 3 |
| G31-MPEN-0001 & 2 | RWCU | 300 (12) | Hot water | Compressible (mildly)<br>Expanding<br>Quality: Subcooled<br>(Some flashing can occur ) | Note 1 |
| G31-MPEN-0003 & 4 | RPV Bottom Drain Line | 150 (6) | Hot Water | Compressible, Expanding<br>Quality: sub-cooled<br>(Some flashing can occur) | Note 1 |

Notes:
1. Rupture restraint device is required on piping (Inside and Outside the penetration) near isolation valve.
2. Rupture restraint device is required inside the drywell side of the penetration only. This line penetrates the upper drywell through penetration into the IC/PCCS pool.
3. Rupture restraint function can be achieved by stiff pipe support structural hardware.
4. Rupture restraint device is not required.
5. See Figure 3.6-3 (Typical) for pipe break location.
6. Pipe diameter may be reduced at the containment penetration.
7. The use of pipe restraints is subject to the final results of the high energy pipe break evaluations.

(*) – System is functional during plant startup only.