From:	Pederson Ronda M (AREVA NP INC) [Ronda.Pederson@areva.com]
Sent:	Friday, February 20, 2009 3:38 PM
To:	Getachew Tesfaye
Cc:	BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); WELLS Russell D (AREVA NP INC)
Subject:	Response to U.S. EPR Design Certification Application RAI No. 107, Supplement 1
Attachments:	RAI 107 Supplement 1 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. provided responses to 25 of the 31 questions of RAI No. 107 on December 1, 2008. The attached file, “RAI 107 Supplement 1 Response US EPR DC.pdf” provides technically correct and complete responses to the 6 remaining questions, as committed.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 107 Questions 03.06.02-9 and 03.06.02-11.

The following table indicates the respective pages in the response document, “RAI 107 Supplement 1 US EPR DC.pdf,” that contain AREVA NP’s response to the subject questions.

Question #	Start Page	End Page
RAI 107 — 03.06.02-7	2	3
RAI 107 — 03.06.02-9	4	5
RAI 107 — 03.06.02-10	6	6
RAI 107 — 03.06.02-11	7	8
RAI 107 — 03.09.03-9	9	9
RAI 107 — 03.09.03-10	10	10

This concludes the formal AREVA NP response to RAI 107, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

Ronda Pederson
ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
AREVA NP Inc.
An AREVA and Siemens company
3315 Old Forest Road
Lynchburg, VA 24506-0935
Phone: 434-832-3694
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From: Pederson Ronda M (AREVA NP INC)
Sent: Monday, December 01, 2008 5:55 PM
To: 'Getachew Tesfaye'

Cc: BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); WELLS Russell D (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 107 (1285, 1256,1268), FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 107 Response US EPR DC.pdf" provides technically correct and complete responses to 25 of 31 questions.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 107, Questions 03.06.02-2, 03.06.02-4, 03.06.02-5, and 03.09.03-8.

The following table indicates the respective page(s) in the response document, "RAI 107 Response US EPR DC.pdf," that contain AREVA NP's response to each of the subject questions.

Question #	Start Page	End Page
RAI 107 — 03.06.02-1	2	2
RAI 107 — 03.06.02-2	3	3
RAI 107 — 03.06.02-3	4	4
RAI 107 — 03.06.02-4	5	5
RAI 107 — 03.06.02-5	6	7
RAI 107 — 03.06.02-6	8	8
RAI 107 — 03.06.02-7	9	9
RAI 107 — 03.06.02-8	10	11
RAI 107 — 03.06.02-9	12	12
RAI 107 — 03.06.02-10	13	13
RAI 107 — 03.06.02-11	14	15
RAI 107 — 03.06.02-12	16	16
RAI 107 — 03.06.02-13	17	17
RAI 107 — 03.06.02-14	18	18
RAI 107 — 03.06.02-15	19	19
RAI 107 — 03.06.02-16	20	20
RAI 107 — 03.06.02-17	21	22
RAI 107 — 03.09.03-1	23	23
RAI 107 — 03.09.03-2	24	24
RAI 107 — 03.09.03-3	25	25
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RAI 107 — 03.09.03-10	31	31
RAI 107 — 03.09.03-11	32	32
RAI 107 — 03.09.03-12	33	33
RAI 107 — 03.09.03-13	34	34
RAI 107 — 03.09.03-14	35	35
RAI 107 — 03.09.03-15	36	36

A complete answer is not provided for 6 of the 31 questions. The schedule for technically correct and complete responses to these questions is provided below.

Question #	Response Date
RAI 107 — 03.06.02-7	February 27, 2009

RAI 107 — 03.06.02-9	February 27, 2009
RAI 107 — 03.06.02-10	February 27, 2009
RAI 107 — 03.06.02-11	February 27, 2009
RAI 107 — 03.09.03-9	February 27, 2009
RAI 107 — 03.09.03-10	February 27, 2009

Sincerely,

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From: Getachew Tesfaye [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Friday, October 31, 2008 1:36 PM
To: ZZ-DL-A-USEPR-DL
Cc: Yueh-Li Li; Arnold Lee; Jennifer Dixon-Herrity; Michael Miernicki; Joseph Colaccino; John Rycyna
Subject: U.S. EPR Design Certification Application RAI No. 107 (1285, 1256,1268), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on October 20, 2008, and discussed with your staff on October 29, 2008. Draft RAI Questions 03.09.03-5 was deleted and Draft RAI Question 03.09.03-9 was modified as a result of that discussion. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 241

Mail Envelope Properties (5CEC4184E98FFE49A383961FAD402D31B0DA25)

Subject: Response to U.S. EPR Design Certification Application RAI No. 107, Supplement 1
Sent Date: 2/20/2009 3:37:38 PM
Received Date: 2/20/2009 3:37:43 PM
From: Pederson Ronda M (AREVA NP INC)

Created By: Ronda.Pederson@areva.com

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RAI 107 Supplement 1 Response US EPR DC.pdf		129342

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Response to

Request for Additional Information No. 107, Supplement 1

10/31/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.06.02 - Determination of Rupture Locations and Dynamic Effects Associated with the Postulated Rupture of Piping
SRP Section: 03.09.03 - ASME Code Class 1, 2, and 3 Components
Application Section: FSAR Ch. 3

QUESTIONS for Engineering Mechanics Branch 2 (ESBWR/ABWR Projects) (EMB2)

Question 03.06.02-7:

In U.S. EPR FSAR Section 3.6.2.4.1, AREVA provides criteria for evaluation for jet impingement. Such jet impingements depend on the placement of the target relative to the break, the jet energy discharged, the jet shape, and also the target characteristics (shape, structural, and dynamic characteristics). Clarify how the methods discussed are applied to safety-related SSCs (for other than piping systems) for establishing their structural integrity, and ensuring their operability.

Response to Question 03.06.02-7:

The evaluation of jet targets and jet forces is performed by applying the methodology in ANS 58.2 in a conservative manner, as described below.

- Reactor coolant system (RCS) components that are directly impinged by the jet centerline are evaluated for structural integrity by performing a dynamic structural analysis considering the entire jet load (C_TPA) regardless of the fact that the entire jet plume does not strike the component. A thrust factor $C_T = 2.0$ is conservatively used (since it is the greatest factor that can exist for sub-cooled water) in the jet force calculation for all pipe breaks regardless of the thermo-hydraulic conditions at the break plane.

- A dynamic structural analysis with a conservative instantaneous (1 millisecond) ramp time is performed for all RCS components.

- The jet impingement loading calculations do not consider pressure gradients inside the jet. A constant pressure value, based on the high energy pipe properties, is used for the full area of the jet.

- In certain cases where the centerline of the jet does not impinge on the component, but the component is still within the jet field, the axisymmetric nature of the jet is relied upon to calculate the applied loads.

- Other essential components are analyzed structurally either using the same methodology as for the RCS components or by performing a static analysis and applying an imposed dynamic factor of 2.0 to replicate the effect of an instantaneous pulse-type jet impingement load.

- Nozzles and pipes that are larger than 1 inch in diameter are postulated as being subject to a circumferential break. Longitudinal breaks are considered for pipes with diameters 4 inches and larger as specified in SRP 3.6.2 and BTP 3-4. The thrust force at the rupture and the impingement force on the SSC are both considered when performing the structural loading analysis.

- The U.S. EPR jet trajectory calculations for targets that are located at distances $L/D = 4$ (L = distance of target from break plane, D = diameter of break nozzle) or larger are determined by an initial angle for the jet based on Equation C-5 of ANS 58.2, which implicitly provides an expansion half-angle of 45°. While this angle may be greater than the actual expansion angle, the expansion angle is only used to determine which targets are in the jet field, requiring jet impingement loading analyses. Using a larger expansion angle is conservative by nature in that there is a greater likelihood of a component falling within the jet field.

- For targets at distances closer than L/D = 4, a half expansion angle of 60° is used to determine the targets within the jet field. For targets that are very close to the jet (nozzle breaks that impinge on the connected component for example), the full force of the jet may be conservatively applied to the target, regardless of the fact that jet centerline may not impinge on the component.

If the targeted component cannot be qualified using the conservative analytical methods listed, jet shields are used, as described in U.S. EPR FSAR Tier 2, Section 3.6.1.2, to protect the essential component from jet loads.

A listing of high-energy terminal end breaks that could affect essential system components is provided in U.S. EPR FSAR Tier 2, Table 3.6.1-3. A listing of postulated terminal end pipe ruptures per building room is provided in U.S. EPR FSAR Tier 2, Table 3.6.1-2. Based on the information provided in these tables, the condensate system piping break is the only postulated break with pure steam conditions at the break plane and the essential target is the main steam valve room concrete wall. Other breaks would be either sub-cooled water jets or two-phase (water flashing to steam) jets.

Additionally, pipes and nozzles that have been qualified using the leak-before-break (LBB) methodology (see U.S. EPR FSAR Tier 2, Section 3.6.3) are not considered to rupture; therefore, they do not generate any jet impingement forces. Included in this LBB qualification are the surge line, RCS loop piping (i.e., cold legs, hot legs, and cross-over legs), and main steam lines (see U.S. EPR FSAR Tier 2, Section 3.6.3). The LBB methodology applies to the main steam line piping from the steam generators to the first anchor point location at the Containment Building penetration. The jet impingement loads due to the main steam line break are only applicable in the Safeguards Building and, per U.S. EPR FSAR Tier 2, Table 3.6.1-3, do not impinge on an essential component.

Since there are no essential components in the vicinity of high-energy steam breaks, other than the condensate system piping, the Karlstein tests results listed in NEA/CSNI/R (95)11 (see Question 03.06.02-9) are not applicable to the U.S. EPR component loading analysis.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.06.02-9:

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 away as 25 pipe diameters from a rupture (Knowledge Base for Emergency Core Cooling System Recirculation Reliability, NEA/CSNI/R (95)11, February 1996, Issued by the NEA/CSNI, http://www.nea.fr/html/nsd/docs/1995/csni-r1995-11.pdf).

The applicant is requested to:

(a) Explain what analysis and/or testing has been used to substantiate the use of the ANS 58.2 Appendix C for defining conservatively which SSCs are in jet paths and the subsequent loading areas on the SSCs.

(b) The applicant states in FSAR Section 3.6.1.1.1 that ‘Components that are in the path of steam or subcooled liquid that can flash at the break are assumed to fail if they are within a distance of ten (10) pipe diameters (broken pipe outside diameter) from the break’. Substantiate this assumption in light of the findings in NEA/CSNI/R (95)11 that steam jets can cause significant damage at distances up to 25 pipe diameters.

Response to Question 03.06.02-9:

(a) See the response to Question 03.06.02-7.

(b) U.S. EPR FSAR Tier 2, Section 3.6.1.1.1 will be revised to state that components that are in the path of two-phased jets are assumed to fail if they are within a distance of ten (10) pipe diameters (broken pipe outside diameter) from the break. The basis is NUREG/CR-2913 (Reference 1) for two-phase jet loads. As noted in the response to Question 03.06.02-7, the condensate system piping break is the only postulated break with pure steam conditions at the break plane. All other breaks would be sub-cooled water jets or two-phased (water flashing to steam) jets. Based on the plots in Section 2.0 and Appendix A of NUREG/CR-2913, the centerline pressure and load distribution on the target reduce substantially with increasing L/D (L = distance of target from break plane, D = diameter of break nozzle). For a distance of ten (10) pipe diameters (L/D=10), the target load distribution is negligible compared to the jet force at the exit plane. As noted in the response to Question 03.06.02-7, the structural integrity of an SSC is evaluated by performing a dynamic or equivalent static structural analysis considering the entire jet force ($C_T PA$, $C_T = 2.0$) calculated at the exit plane on the component regardless of the fact that the jet force reduces as L/D increases.

The findings in NEA/CSNI/R (95)11 pertain specifically to steam and air jets that can cause significant damage to insulation at distances up to 25 pipe diameters and result in sump blockage due to steam breaks even at long distances. This concern is addressed by GSI-191 regarding the potential for post-accident debris blockage that could interfere with the capability of the recirculation mode of the emergency core cooling system (ECCS) during long-term reactor core cooling. This issue is addressed in U.S. EPR Technical Report ANP-10293 (see U.S. EPR FSAR Tier 2, Section 15.6.5.4.3). The purpose of U.S. EPR FSAR Tier 2, Section 3.6.2 is to address the effects of jet force on essential components (not insulation) due to pipe breaks.

References for Question 03.06.02-9:

1. Weigand, G.G., et al., “Two-Phase Jet Loads,” NUREG/CR-2913, prepared for the U.S. Nuclear Regulatory Commission by Sandia National Laboratory, January 1983.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.6.1.1.1 will be revised as described in the response and indicated on the enclosed markup.

Question 03.06.02-10:

The ANS 58.2 Standard's 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 is requested to:

(a) Explain what analysis and/or testing has been used to substantiate use of ANS 58.2 Appendix D 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) Expand the table of all postulated break types (FSAR Table 3.6.1-1 on pages 3.6-12 to 3.6-13) to include 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 for the postulated piping breaks in an EPR 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.

Response to Question 03.06.02-10:

(a) The pressure distribution models inside the jet presented in Appendix D of ANS 58.2 are not used for the calculation of jet forces for the U.S. EPR. The jet impingement loading calculations for essential components do not consider pressure gradients inside the jet. The worst pressure at the pipe break location is considered for the calculation of the jet force which is applied, without reduction, to the target area. This is conservative because based on the plots in Section 2.0 and Appendix A of NUREG/CR-2913, the forces on the targets reduce with increasing distance of the target from the break plane.

(b) AREVA NP does not understand the regulatory basis for this question, since the requested information is not specified in RG 1.206, SRP 3.6.1, or BTP 3-3. U.S. EPR FSAR Tier 2, Table 3.6.1-1 provides the classification of high- and moderate-energy piping. Properties of the fluid internal and external to the ruptured pipe are specified, in part, in piping and instrument diagrams. Examples of jet impingement loading calculations are available for NRC inspection.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.06.02-11:

On FSAR page 3.6-37, the applicant stated that "…the jet impingement load on a target is the force exerted on the target by the jet. This dynamic problem is not only dependent on the jet forcing function, but also on the dynamic characteristics of the target in question. It can be solved dynamically with a model of the target, and utilizing the jet forcing function; however, it can also be solved using an equivalent static approach." In either approach, there does not appear to be any consideration of 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.

The applicant should consider that supersonic expanding jets are known to be unsteady, particularly those impinging on nearby structures. The applicant should 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.

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.

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 or FSAR 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.

Response to Question 03.06.02-11:

(a) See the response to Question 03.06.02-7.

(b) There are pipe break scenarios with the break locations within 10 diameters of a neighboring SSC (or barrier/shield). The jet feedback/resonance issues mentioned in this question pertain to air or steam jets which are traveling at very high velocities. It is a lesser problem with two-phased jets which consist of the bulk of the pipe break scenarios for the U.S. EPR piping systems. Per Figure 2.7 of "Introduction to Structural Dynamics" by John M Biggs, McGraw Hill, 1964, the dynamic load factor due to resonance effects reduces to 2.0 if the frequency of the input forcing function is separated from the natural frequency of the impinged component by at least 20 percent. The jet frequency is much higher than that of the impinged component so that a frequency separation of at least 20 percent will be maintained. For scenarios where a jet shield or a barrier is designed for specific jet loads, the shield or barrier will be designed such that there exists a frequency separation of at least 20 percent. U.S. EPR FSAR Tier 2, Section 3.6.2.4.1 will be revised to reflect this information.

(c) Dynamic analyses for the jet loads will be performed as described in the response to Question 03.06.02-7. The conservatisms used in case a static analysis with a load factor of 2.0 is performed are also described in the response to Question 03.06.02-7. Also, per Figure 2.7 of "Introduction to Structural Dynamics" by John M Biggs, McGraw Hill, 1964, a factor of 2.0 is conservative if the frequency separation between the applied force and the impinged component is at least 20 percent.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.6.2.4.1 will be revised as described in the response and indicated on the enclosed markup.

Question 03.09.03-9:

In FSAR Table 3.9.3-1 and Table 3.9.3-3 (Load Combinations and Acceptance Criteria for ASME Class 1 Components, for primary plus secondary stress intensity category under Upset condition), explain why earthquake inertial load is not listed as a potential loading. Also, for faulted condition, explain why a secondary stress category is not included and why the anchor motion effect of SSE is not considered in the design of components. Reference SECY 93-087.

Response to Question 03.09.03-9:

U. S EPR FSAR Tier 2, Tables 3.9.3-1 and 3.9.3-3 list earthquake inertial load as potential loading in fatigue analysis of Class 1 components under Upset conditions. As part of the fatigue analysis, the earthquake inertial load is considered while evaluating the maximum primary plus secondary stress intensity range in Upset Condition.

Per Section III of the ASME Code, all applicable primary stress intensity limits are considered for Faulted Conditions. The ASME Code does not require evaluation of secondary stresses for Faulted Conditions. The mechanical loads on the components at the attached nozzles and supports are developed considering the seismic anchor motion effects of the safe shutdown earthquake (SSE). These loads are conservatively evaluated against the primary stress intensity criteria of the ASME Code; therefore, seismic anchor motions are considered in the design of the U.S. EPR Class 1 components.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 03.09.03-10:

In FSAR Section 3.9.3.1, for loads for components and component supports, provide confirmation that safety-related components and component supports required to remain operational and to perform a safety function after a specified plant condition event are designed to lower ASME Section III service level stress criteria.

Response to Question 03.09.03-10:

In accordance with SRP 3.9.3, functional and operational capability requirements apply only to active components (and their supports) such as pumps, valves, snubbers and Class 1, 2 & 3 piping components. Although design of equipment using lower ASME service limits is one acceptable method of demonstrating functional capability of the equipment, it is also acceptable to design to the service limits of ASME corresponding to the specified service condition provided operability and functionality of the component is demonstrated through additional analysis or testing or a combination of these methods.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

U.S. EPR Final Safety Analysis Report Markups

- Systems which are pressurized above atmospheric pressure during plant operating conditions that do not meet the high-energy system requirements are considered moderate-energy.

- Piping systems are also considered moderate-energy if they only exceed 200°F or 275 psig for two percent or less of the time they are in operation, or experience high-energy temperatures or pressures less than one percent of plant operation time.

- The events for which the high- and moderate-energy lines are evaluated include breaks and cracks. Breaks and through-wall leakage cracks are analyzed for their dynamic and environmental effects. Dynamic effects include jet impingement and pipe whip, while the environmental effects include flooding (Section 3.4), spray wetting, and increased temperature, pressure, and humidity inside the rooms affected by the postulated failure. Other considerations in conjunction with these postulated pipe failures include loss of offsite power (LOOP), and single active component failure.

- While breaks are evaluated for both their dynamic effects and their environmental effects, only the environmental effects of through-wall cracks need to be evaluated. Not all through-wall cracks will cause flooding; therefore, cracks need to be analyzed for flooding only if the amount of time taken to correct the failure causes significant flooding.

- If a pipe were to break, split, or crack, the resulting pipe whip and jet plume could damage components and instrumentation that are used to safely shut down the plant or prevent unacceptable offsite doses. Separation, isolation, and train redundancies may be used to limit the evaluations of these failure events.

- Pipe whip restraints and protective enclosures may be used to protect essential systems and components against postulated pipe failures.

- When breaks in high-energy lines (circumferential or longitudinal), or through-wall leakage cracks in high- or moderate-energy lines, are considered they are evaluated separately as single initial events that occur during normal plant operating conditions.

03.06.02-9

- Pumps and valve bodies are excluded from the analysis or evaluation of postulated piping failures due to the larger wall thicknesses than that of the connected pipe.

- Components that are in the path of two-phased jets~~steam or subcooled liquid that can flash at the break~~ are assumed to fail if they are within a distance of ten pipe diameters (broken pipe outside diameter) from the break, per the guidance provided in NUREG\CR-2913 (Reference 4). Jet loads are calculated, as described in Section 3.6.2, when the failure of impinged components adversely affects the safe shutdown of the plant. Components are considered undamaged at distances greater than ten pipe diameters.

- The feasibility of carrying out operator actions is evaluated on the basis of ample time and access to equipment being available for the proposed actions.

be determined exactly, so allowances are made for targets close to the assumed jet shape to be included within that shape for analysis purposes.

Appendix C of ANSI/ANS 58.2 (Reference 5) provides simplified jet shapes for expanding jets. The assumed jet shape is broken down into three separate regions. Region 1 extends from the break to the end of the jet core region, where a target within this region will experience full recovery of the jet stagnation pressure upstream of the break. Region 2 extends from the end of Region 1 out to the asymptotic plane. Between the break and this plane, the jet is assumed to undergo free expansion to the pressure at the asymptotic plane. Beyond the asymptotic plane, the jet is assumed to begin interacting with the surrounding environment, and is postulated to expand at a half angle of 10°. This region beyond the asymptotic plane is called Region 3, and continues until the jet energy has dissipated. These shape conditions are assumed for circumferential breaks with limited separation and for longitudinal breaks. Appendix C of Reference 5 provides the equations and curves necessary to calculate the parameters needed to define the jet shape based on the fluid conditions.

With the jet discharge forces and the jet shapes defined, the jet impingement load on a target is the force exerted on the target by the jet. This dynamic problem is not only dependent on the jet forcing function, but also on the dynamic characteristics of the target in question. It can be solved dynamically with a model of the target, and utilizing the jet forcing function, however, it can also be solved using an equivalent static approach. The equation for this equivalent static approach is:

$$F_s = (DLF)\,(F_{imp})$$

Where:

F_s = equivalent static impingement force.

DLF = a dynamic load factor.

F_{imp} = maximum value of the applied jet impingement force (see below).

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The dynamic load factor may be determined using a dynamic analysis of the target, or may be assumed to be 2.0 for cases where the target can be treated as a single degree of freedom system (refer to Section 7 of Reference 5). The dynamic load factor due to resonance effects reduces to 2.0 if the frequency of the input forcing function is separated from the natural frequency of the impinged component by at least 20 percent. In the event a jet shield or barrier is needed for specific jet loads, the shield or barrier will be designed with a frequency separation of ≥ 20 percent.

The jet impingement force (F_{imp}) is essentially the jet discharge force (F_{jet}), factored as necessary to account for the amount of the jet cross-sectional area intercepted by the