ABB
ASEA BROWN BOVERI

January 24, 1992
LD-92-007

Docket No. 52-002

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: Response to NRC Requests for Additional Information

Reference:
- A) Letter, Materials and Chemical Engineering Branch RAIs, T. V. Wambach (NRC) to E. H. Kennedy (C-E), dated August 8, 1991
- B) Letter, Structural and Geosciences Branch RAIs, T. V. Wambach (NRC) to E. H. Kennedy (C-E), dated September 26, 1991
- C) Letter, Plant Systems Branch RAIs, T. V. Wambach (NRC) to E. H. Kennedy (C-E), dated October 10, 1991

Dear Sirs:

References A) through C) requested additional information for the NRC staff review of the Combustion Engineering Standard Safety Analysis Report - Design Certification (CESSAR-DC). Enclosure I to this letter provides our responses to a number of these questions including corresponding revisions to CESSAR-DC.

Should you have any questions on the enclosed material, please contact me or Mr. Stan Ritterbusch of my staff at (203) 285-5206.

Very truly yours,

COMBUSTION ENGINEERING, INC.

S. E. Ritterbusch for EHK
E. H. Kennedy
Director
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/lw
Enclosures: As Stated
cc: J. Trotter (EPRI)
T. Wambach (NRC)

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Enclosure I to
LD-92-007

RESPONSE TO NRC REQUESTS FOR ADDITIONAL INFORMATION
MATERIALS AND CHEMICAL ENGINEERING BRANCH, STRUCTURAL AND GEOSCIENCES BRANCH, PLANT SYSTEMS BRANCH

Question 210.8

Section 10.4.9.1.2, paragraph M. states, "The EFW [Emergency Feedwater System] system piping in the vicinity of the steam generators is arranged to minimize the potential destructive water hammer during startup." A brief description of the EFW pipe routing and how it physically interfaces with other systems is given. Provide piping layout drawings showing this arrangement along with any special design considerations demonstrating how a potential water hammer event is minimized.

Response 210.8

The design criteria which will be used to minimize water hammer in the EFW piping include:

- A 90 degree elbow at each steam generator feedwater nozzle. This feature minimizes the amount of horizontal piping susceptible to steam void formation.
- Continuously rising emergency feedwater (EFW) piping to each steam generator. Each EFW line has a check valve inside containment. This piping arrangement, along with the feedwater ring outlet design in the steam generators maintain the piping full in low flow conditions and prevent column separation during transients.
- Adequate filling and venting provisions to minimize voids in piping.
- Water hammer consideration in specification of valve operating times.
- Preoperational testing to ensure no unacceptable water hammer in the FW and EFW systems during startup, normal operation and transients.

The detailed design (piping and support layout drawings, stress reports, operating procedures etc.) will depend on vendor-supplied information. As presented to the Staff at the meeting of November 26 this detailed information (1) is not required for certification, (2) depends on plant-specific details not finalized at the certification stage, and (3) is subject to revision until specific details of piping and other plant design are finalized. It was also agreed at that meeting that a Distribution Systems Design Guide would be prepared to ensure that the final design would be completed consistent with the design basis and methodology in CESSAR-DC.

Prevention of water hammer will be addressed in the System 80+ Distribution Systems Guide, which was discussed during the November 26 meeting. This guide will provide an integrated approach for optimizing the layout and detailed design of piping, HVAC, cable trays and conduits. The purpose of this guide is to facilitate a final design which meets all safety criteria and which optimizes plant operation and maintenance. An outline of the guide is currently being prepared. Design considerations and guidance in preventing destructive water hammer will be one of the major topics of this document.

(See Also 210.92 Question and Answer)

Question 210.12

CESSAR-DC Section 3.6 states that protection of vital equipment is achieved primarily by separation of redundant safe shutdown systems and of high-energy pipe lines from safe shutdown systems.

BTP MEB 3-1, Rev. 2, Subsections B.1.a and B.2.a, states that for the purpose of satisfying the separation provisions of plant separation, reviews of the piping layout and plant arrangement drawings should verify that the effects of: 1) postulated piping breaks at any location in high-energy fluid system piping, and 2) postulated through-wall leakage cracks at any location in moderate-energy fluid system piping designed to seismic and non-seismic standards are isolated or physically remote from essential systems and components.

Inform the staff when the piping layout and plant arrangement drawings will be available for these reviews.

Response 210.12

As presented to the Staff at the meeting of November 26, 1991, the piping layout and plant arrangement drawings that are requested (1) are not required for certification, (2) depends on plant-specific details not finalized at the certification stage and (3) are subject to revision until specific details of piping and other plant design are finalized.

CESSAR-DC currently provides acceptance criteria and analysis methodology for postulated pipe ruptures in high-energy piping and postulated through-wall leakage cracks in moderate energy piping based on BTP MEB 3-1. It also provides some of the information needed for these evaluations, such as pipe sizes, and P&IDs, and building and seismic response information. Specific plant data, such as piping layout and arrangement drawings which are necessary for these evaluations are not currently available.

In lieu of detailed drawings based on detailed piping design and specific plant data, C-E offers the following technical approach to respond to this RAI. This approach was outlined during the November 26th meeting.

1. Preparation of a Distribution Systems Guide. This guide will provide an integrated approach for optimizing the layout and detailed design of piping, HVAC, cable trays and conduits. The purpose of the guide is to facilitate a final design which meets all safety criteria and which optimizes plant operation and maintenance. An outline of the guide is currently being prepared. Design considerations and guidance for pipe routing and postulated pipe rupture analyses will be one of the major topics of the document. The outline for the section on postulated pipe ruptures as developed to date is as follows:

   Postulated Pipe Ruptures

   - Classifications
   - Piping Interactions
   - Interaction Analysis Assumptions
   - Protection Methods

2. Preparation of a set of sample piping layouts and analyses, which will include a preliminary postulated pipe rupture evaluation of an economizer feedwater line.

   The purpose of preparing these samples is to demonstrate the use of the guide in performing detailed design of distribution systems. The economizer feedwater line was specifically chosen to be the sample piping system for demonstration of postulated pipe ruptures since it is the largest high-energy line inside containment that will not have LBB demonstrated.

   The samples will use best available information. Where detailed information is not available, design parameters will be assumed based on experience or previous designs. The sample layouts and analyses using the guide are intended to demonstrate that the information currently in CESSAR-DC and further developed in the guide supports the safety review by the staff and provides additional assurance that plant design safety criteria will be met.

A Distribution Systems Guide and sample layouts and analyses are being prepared. It is C-E's position that the above information will preclude the necessity for including in the design basis the detailed piping layout drawings for verification of dynamic effects of postulated ruptures of pipes.

Question 210.13

Section 3.6.2.1.4 in CESSAR-DC states that the information in this Section relative to the postulation of pipe breaks does not apply to those systems identified in Section 3.6.2.1.3 for which leak-before-break (LBB) evaluations will be performed. Unless the detailed information identified in RAI 252.03 is submitted and approved by the staff, the implementation of LBB for the CESSAR-DC System 80+ is not acceptable. Pending the resolution of RAI 252.03, the criteria in Section 3.6.2 of the CESSAR-DC should be applicable to all high and moderate energy piping systems and Sections 3.6.2.1.3 and 3.6.2.1.4 should be either deleted or revised. In addition, all other references to the implementation of LBB in the CESSAR-DC should be revised.

Response 210.13

The System 80+ design is optimized through an internal process of review and integration. It is the intent of CESSAR-DC to present a total optimized design package for Staff review. In the area of leak-before-break vs. inclusion of the dynamic effects of large diameter pipe breaks, the commitment to demonstrate LBB for selected piping systems is integral to the optimization of such diverse design features as embedment and supporting structure design for jet shields and pipe whip restraints, the permanent pool seal, piping and component supports, snubber reduction, and simplification of asymmetric blowdown loads analyses on reactor internals components. Some of these features may in turn affect layouts and arrangements of piping, ducting, cabling and other equipment in the vicinity of these piping systems.

In response to a question by the staff during the November 26th meeting, the use of LBB does not preclude designing subcompartment walls and floors for pressurization due to postulated pipe break. Subcompartments are vented and/or designed to the pressure developed from a postulated double-ended guilotine rupture in the largest high energy line in that subcompartment.

It is therefore requested that the Staff reconsider their current position requiring that the current design include the dynamic effects of those pipe breaks identified in CESSAR-DC to be eliminated by LBB. In consideration of this request, please refer to the response to RAI 252.03, which outlines the technical approach being taken to answer your request for additional information on the LBB evaluation of those selected lines.

Question 210.14

A) Criteria for not postulating ruptures in piping near containment isolation valves are defined in CESSAR-DC, Section 3.6.2.1.4.1.F. The criteria are not in accordance with: 1) the design stress and fatigue limits specified in BTP MEB 3-1, Rev. 2, Section B.6.b.(1), for ASME Code Section III, Class 1 and 2 high-energy fluid system piping; and 2) the stress limits specified in BTP MEB 3-1, Rev. 2, Section B.2.b, for moderate-energy fluid system piping.

Provide justification for the CESSAR-DC, Section 3.6.2.1.4.1.F criteria or modify the criteria in accordance with BTP MEB 3-1, Rev. 2.

B) In addition: 1) the requirement specified in Item 3 of Section 3.6.2.1.4.1.F to satisfy the design and in-service inspection requirements specified in MEB 3-1, Rev. 2 lacks specificity; and 2) the BTP MEB 3-1, referenced is no longer in effect.

Provide details of the design and in-service inspection requirements in accordance with BTP MEB 3-1, Rev. 2 Section B.1.b; and update Reference 4 to BTP MEB 3-1, Rev. 2.

Response 210.14

A) Section 3.6.2.1.4.1.A of CESSAR-DC will be revised in accordance with BTP MEB 3-1, Rev. 2, Section B.1.b.(1). CESSAR-DC Section 3.6.2.1.4.1.F Item 5 will be added to specify the stress limits for moderate-energy piping per BTP MEB 3-1 Section B.2.b.

B) CESSAR-DC Section 3.6.2.1.4.1.F Item 3 will be revised to reference Section 6.6. In service inspection requirements are given in CESSAR-DC Section 6.6.

Also, reference 4 will be updated to BTP MEB 3-1, Rev. 2.

RAI 210.14

2. Leakage Cracks

   A leakage crack is postulated in place of a circumferential break, or longitudinal break, or through-wall crack, if justified by an analysis performed on the pipeline in accordance with the requirements of Section 3.6.3.

F. Piping Near Containment Isolation Valves

Ruptures are not postulated between the containment wall and the inboard or outboard isolation valves in piping, which is designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III (Reference 2), and which meets the following additional requirements:

1. The limits for postulating intermediate rupture locations, as specified in Item A.2.b for Class 1 piping and Item B.2.b for Class 2 and 3 piping, are not exceeded in that portion of piping.

2. Following a postulated pipe break of high-energy piping beyond either isolation valve, the stresses in the piping from the containment wall, to and including the length of the isolation valve, are maintained within Level C Service Limits as specified in the ASME Boiler and Pressure Vessel Code, Section III, (Reference 2).

INSERVICE INSPECTION PROGRAM REQUIREMENTS ARE GIVEN IN CESSAR-DC SECTION 6.6.

3. The design and in-service inspection requirements, as specified in MEB 3-1 (Reference 4), are satisfied. E

4. The containment isolation valves are appropriately qualified to assure that operability and leak tightness are maintained when subjected to any combination of loadings, which may be transmitted to the valves from postulated pipe breaks beyond the valves.

5. FOR MODERATE-ENERGY PIPING, THE STRESSES CALCULATED BY THE SUM OF EQs. (9) AND (10) IN ASME CODE, SECTION III, NC-3653 DO NOT EXCEED .4 TIMES THE SUM OF THE STRESS LIMITS GIVEN IN NC-3653.

3.6.2.1.4.2 Postulated Rupture Configurations

A. Break Configurations

Where the postulated break location is at a tee, elbow, or the following pipe locations, the configurations and types of breaks are determined as follows:

1. Without the benefit of a detailed stress analysis, the following are assumed:

RAI 210.14

3.6.2.1.3 Piping Evaluated for Leak-Before-Break

A leak-before-break evaluation is performed for Class 1 piping with a diameter of ten inches or greater (i.e., the reactor coolant system (RCS) main loop piping, surge line, shutdown cooling and safety injection lines) and for the main steam line inside containment in order to eliminate the dynamic effects of pipe rupture from the design basis. The evaluation is intended to meet the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 4. The evaluation is performed using the guidelines of NUREG 1061, Vol. 3 (Reference 1) as described in Section 3.6.3.

3.6.2.1.4 Piping Other than Piping Evaluated for Leak-Before-Break

This section applies to all high- and moderate-energy piping other than that whose dynamic effects due to pipe breaks are eliminated from the design basis by leak-before-break evaluation, as identified in Section 3.6.2.1.3.

3.6.2.1.4.1 Postulated Rupture Locations

A. Class 1 Piping

Ruptures, as specified in Items D and E below, are postulated to occur at the following locations in each piping network designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III (Reference 2) for Class 1 piping:

1. ~~the terminal ends of the pressurized portions of the network.~~
2. ~~intermediate locations where S from equation (10) exceeds $2.4S_m$.~~
3. ~~intermediate locations where U exceeds 0.1.~~

~~where, as defined in Subarticle NB-3650,~~

ADD INFORMATION AS SHOWN ON ATTACHED SHEET.

RAI 210.14

-Insert-

1. The terminal ends of the pressurized portions of the run.

2. At intermediate locations selected by either one of the following methods:

   a. At each location of potential high stress and fatigue such as pipe fittings (elbows, tees, reducers, etc.), valves, flanges, and welded attachments, or

   b. At each location specified by the following:

      1) Where the maximum stress range between any two load sets (including the zero load set) calculated by Eq.(10) in Paragraph NB-3653, ASME Code, Section III, exceeds the limit (2.4 Sm) but is not greater than 3.0 Sm, and $U>0.1$.

      2) Where the maximum stress range of Eq.(10) exceeds 3.0 Sm, and the stress range calculated by either Eq.(12) or Eq.(13) in Paragraph NB-3653 exceeds 2.4 Sm, and $U<0.1$.

OR

RAI 210.14

REFERENCES FOR SECTION 3.6

1. "Evaluation of Potential for Pipe Breaks," NUREG-1061, Vol. 3.

2. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, Class 1, 2 or 3, 1986 Edition.

3. ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1986 Edition.

4. USNRC Branch Technical Position MEB 3-1 Rev. 2 - Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment, attached to Standard Review Plan 3.6.2, ~~July~~ June ~~1981~~. 1987

5. American National Standard Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture, ANSI/ANS 58.2-1988.

6. R. T. Lahey, Jr. and F. J. Moody, "Pipe Thrust and Jet Loads," The Thermal Hydraulics of a Boiling Water Nuclear Reactor, Section 9.2.3, pp. 375-409, Published by American Nuclear Society, Prepared by the Division of Technical Information United States Energy Research and Development Administration, 1977.

7. RELAP 4/MOD 5, Computer Program User's Manual 098. 026-5.5. E

8. USNRC Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems," May 1973.

9. NUREG/CR-1319, "Cold Leg Integrity Evaluation," Battelle Columbus Laboratories, February 1980.

10. PICEP: Pipe Crack Evaluation Program, EPRI NP 3596-SR, August, 1984.

11. "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI NP2931, by V. Kumar, M. D. German, C. F. Shih, July 1981.

12. "Analysis of Cracked Pipe Weldments," EPRI NP-5057, February 1987.

Question 210.15

BTP MEB 3-1, Rev. 2, Section B.1.c.(1) and B.1.c.(2), specify criteria for the effect of piping re-analysis due to differences between the design configuration and the as-built configuration on the postulation of pipe breaks in high-energy fluid system piping in areas other than containment.

These BTP MEB 3-1, Rev. 2 criteria are not included in the criteria for postulated rupture locations defined in CESSAR-DC, Sections 3.6.2.1.4.1.A and B.

Provide justification for not including these BTP MEB 3-1, Rev. 2 criteria in CESSAR-DC, Sections 3.6.2.1.4.1A and B; or modify the criteria in these Sections to include the BTP MEB 3-1, Rev. 2 criteria.

Response 210.15

CESSAR-DC Sections 3.6.2.1.4.1.A and B will be revised to incorporate the criteria provided in BTP MEB 3-1 Sections B.1.c(1) and B.1.c.(2).

RAI 210.15

S = primary-plus-secondary stress-intensity range under the combination of loadings for which either Level A or Level B service limits have been specified, as calculated from equation (10).

S_m = allowable stress-intensity value.

U = the cumulative usage factor.

B. Class 2, Class 3, or Seismically Analyzed ANSI B31.1 Piping

Ruptures, as specified in Items D and E below, are postulated to occur at the following locations in each piping network designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, (Reference 2) for Class 2 and Class 3 piping, or with the rules of the ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1983 (Reference 3) for seismically analyzed ANSI B31.1 piping:

1. the terminal ends of the pressurized portion of the network, and E
2. either
   a. intermediate locations of potential high stress or fatigue such as pipe fittings, valves, flanges and welded-on attachments, or
   b. intermediate locations where the stress, S, exceeds 0.8(X + Y).

   where, as defined in Subarticle NC-3650,

   S = stresses under the combination of loadings for which either Level A or Level B service limits have been specified, as calculated from the sum of equations (9) and (10).

   X = equation (9) Service Level B allowable stress.

   Y = equation (10) allowable stress.

ADD PARAGRAPH TO READ AS SHOWN ON ATTACHED SHEET.

RAI 210.14 AND 210.15

3.6.2.1.4.1

A.

1) The terminal ends of the pressurized portions of the run.

2) At intermediate locations selected by either one of the following methods:

   (a) At each location of potential high stress and fatigue such as pipe fittings (elbows, tees, reducers, etc.), valves, flanges, and welded attachments, or

   (b) At all intermediate locations between terminal ends where the following stress and fatigue limits are exceeded.

      (1) The maximum stress range should not exceed 2.4 Sm except as noted below.

      (2) The maximum stress range between any two load sets (including) the zero load set) should be calculated by Eq. (10) in Paragraph NB-3653, ASME Code, Section III, ~~for normal and upset plant conditions and an operating basis earthquake (OBE) event transient.~~

      If the calculated maximum stress range of Eq. (10) exceeds the limit (2.4 Sm) but is not greater than 3 Sm, the limit of U < 0.1 should be met.

      If the calculated maximum stress range of Eq. (10) exceeds 3 Sm, the stress ranges calculated by both Eq. (12) and Eq. (13) in Paragraph NB-3653 should not exceed 2.4 Sm and the limit of U < 0.1.

210.14

210.15

As a result of piping reanalysis due to 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:

(i) The dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.

(ii) A change is required in pipe parameters such as major differences in pipe size, wall thickness, and routing.

RAI 210.15

3.6.2.1.4.1

B.

As a result of piping reanalysis due to 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 pipe parameters (diameter, wall thickness, routing) is required, or the dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.

Question 210.16

BTP MEB 3-1, Rev. 2, Section B.1.c.(2)(b)(1), provides criteria for the postulation of intermediate pipe breaks in high-energy fluid system piping in areas other than containment penetration for ASME Code Section III, Class 2 and 3 piping which contains no fittings, welded attachments, or valves. These criteria are not included in the criteria in CESSAR-DC, Section 3.6.2.1.4.B.

Provide justification for not including these criteria; or modify the criteria in CESSAR-DC, Section 3.6.2.1.4.1.B in accordance with BTP MEB 3-1, Rev. 2

Response 210.16

The following paragraph will be added to CESSAR-DC Section 3.6.2.1.4.1.B.2.b.

"...where the piping contains no fittings, weld attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure, or..."

Section 3.6.2.1.4.1.B.2.b will be relabeled 3.6.2.1.4.1.B.2.C. These "locations at each extreme of the piping run" in many cases may coincide with intermediate locations where stress exceeds 0.8 (X+Y), i.e., criteria in Section 3.6.2.1.4.1B.2.b.

Question 210.17

BTP MEB 3-1, Rev. 2, Section B.1.(c).4, requires that the consequences of high-energy line breaks on structures which separate high-energy lines from essential components be considered in areas other than containment penetration, but does not limit such consideration to structures outside containment only.

CESSAR-DC Section 3.6.2.1.1, "General Requirements," states: "Irrespective of the fact that the criteria in Section 3.6.2 may not require specific breaks, if a structure outside containment separates a high-energy line from the essential component, that separating structure is designed to withstand the consequences of the pipe break in the high-energy line that produces the greatest effect at the structure."

Explain why the consequences of high-energy line breaks on structures which separate high-energy lines from essential components are limited only to structures outside containment; or modify CESSAR-DC Section 3.6.2.1.1, to be consistent with BTP MEB 3-1, Rev. 2.

Response 210.17

The words "outside containment" in CESSAR-DC Section 3.6.2.1.1, last paragraph, will be deleted, making the criteria applicable to structures inside and outside containment.

Question 210.18

BTP MEB 3-1, Rev. 2 Section B.1.c(5), specifies environmental qualification requirements for safety-related electrical and mechanical equipment inside and outside containment resulting from the postulation of pipe breaks in high-energy fluid system piping in areas other than containment penetration.

Provide justification for not including these requirements in CESSAR-DC Section 3.6.2 or modify this Section in accordance with BTP MEB 3-1, Rev. 2.

Response 210.18

The following sentence will be added to CESSAR-DC, Section 3.6.2.1.1, in second paragraph.

"The effects of pipe rupture and/or leakage crack are included in the environmental qualification of safety-related electrical and mechanical equipment. (Environmental qualification of safety-related equipment is discussed in Section 3.11).

Question 210.19

BTP MEB 3-1, Rev. 2, Section B.1.d, requires that each piping run considered in the postulation of break locations in ASME Code, Section III, Class 1, 2 and 3 and seismically analyzed non-ASME Class high energy fluid system piping in areas other than containment penetration be identified.

Identify the ping runs considered.

Response 210.19

Piping runs utilized for postulating break locations per BTP MEB 3-1, Rev. 2, are identified in CESSAR-DC in Table 3.6-3, "High-Energy Lines Within Containment," and Table 3.6-4, "High-Energy Lines Outside Containment." Tables 3.6-3 and 3.6-4 will be updated in the next amendment to CESSAR-DC.

Question 210.20

BTP MEB 3-1, Rev. 2, Section B.1.e.(3), specifies criteria for the postulation of break locations in high-energy nonsafety class fluid system piping which has not been analyzed to obtain stress information in areas other than containment penetration.

Provide justification for not including these criteria in CESSAR-DC Section 3.6.2.1.4.1 or modify the subsection in accordance with BTP MEB 3-1, Rev. 2.

Response 210.20

The following paragraph will be added to the end of Section 3.6.2.1.4.1.C in CESSAR-DC:

"For non-safety class piping which is not seismically analyzed, leakage cracks are postulated at axial locations such that they produce the most severe environmental effects."

Question 210.21

BTP MEB 3-1, Rev. 2, Section B.2.c, items (2) and (3) specify criteria for the postulation of leakage cracks in: 1) ASME Code, Section III, Class 1, 2 and 3 moderate-energy fluid system piping; and 2) other moderate-energy fluid system piping designed to non-seismic standards which are located in areas other than containment penetration.

Provide justification for not including these criteria in CESSAR-DC, Section 3.6.2.1.4.1 or modify the subsection in accordance with BTP MEB 3-1, Rev. 2.

Response 210.21

The following paragraph will be added to the end of Section 3.6.2.1.4.1.E of CESSAR-DC:

"For moderate-energy fluid systems in areas other than containment penetration leakage cracks are postulated at axial and circumferential locations that result in the most severe environmental consequences. Where a break in a high-energy fluid system is postulated which results in more limiting environmental conditions, the leakage crack in the moderate-energy fluid system is not postulated.

Question 210.22

BTP MEB 3-1, Rev. 2, Section B.2.d, specifies criteria for the postulation of leakage cracks in moderate-energy fluid systems in proximity to high-energy fluid systems.

Provide justification for not including these criteria in CESSAR-DC, Section 3.6.2.1.4.1 or modify the subsection in accordance with BTP MEB 3-1, Rev. 2.

Response 210.22

See response to Question 210.21. (Section 3.6.2.1.4.1.E of CESSAR-DC will be revised)

Question 210.23

BTP MEB 3-1, Rev. 2, Section B.2.e, specifies criteria for the postulation of leakage cracks in fluid systems qualifying as high-energy or moderate-energy systems.

Provide justification for not including these criteria in CESSAR-DC, Section 3.6.2.1.4.1 or modify the subsection in accordance with BTP MEB 3-1, Rev. 2.

Response 210.23

The following paragraph will be added to Section 3.6.2.1.4.1.E of CESSAR-DC:

"Leakage cracks, instead of breaks, are also postulated in the piping of fluid systems that qualify as high-energy fluid systems for short operational periods of time but that qualify as moderate-energy fluid systems for the major operational period."

RAI's 210.16, 17, 18, 20, 21, 22, 23

portion of the same train; for example, a "B" train high-energy pipe may cause failure of a "B" train electrical tray, but not failure of any "A" train component. The capability to shut the plant down safely under such a failure will therefore remain intact.

Given the separation criteria above, and the pipe break criteria in Section 3.6.2.1.2, the effects of high-energy pipe breaks are not analyzed where it is determined that all essential systems, components, and structures are sufficiently physically remote from a postulated break in that piping run.

3.6.2 DETERMINATION OF BREAK LOCATIONS AND DYNAMIC EFFECTS ASSOCIATED WITH THE POSTULATED RUPTURE OF PIPING

Described herein are the design bases for locating breaks and cracks in piping inside and outside containment, the procedure used to define the thrust at the break location, the jet impingement loading criteria, and the dynamic response models and results.

3.6.2.1 Criteria Used to Define Break and Crack Locations and Configurations

3.6.2.1.1 General Requirements

Postulated pipe ruptures are considered in all plant piping systems and the associated potential for damage to required systems and components is evaluated on the basis of the energy in the system. System piping is classified as high-energy or moderate-energy, and postulated ruptures are classified as circumferential breaks, longitudinal breaks, leakage cracks, or through-wall cracks. Each postulated rupture is considered separately as a single postulated initiating event.

For each postulated circumferential and longitudinal break, an evaluation is made of the effects of pipe whip, jet impingement, compartment pressurization, environmental conditions, and flooding. Also, if required to demonstrate safe plant shutdown, an internal fluid system load evaluation is performed on the effects of fluid forces on components within or bounding the fluid system. For each postulated leakage crack, an evaluation is made of the effects of compartment pressurization, environmental conditions and flooding. For each postulated through-wall crack, an evaluation is made of the effects of environmental conditions and flooding. The evaluation of the required systems and components demonstrate that the protection requirements of Section 3.6.1 are met.

The effects of pipe ruptures and/or leakage cracks are included in the environmental qualification of safety-related electrical and mechanical equipment.

Environmental qualification of safety related equipment is discussed in Section 3.11.

RAI'S 210.16, 17, 18, 20, 21, 22, 2

Irrespective of the fact that the criteria in Section 3.6.2 may not require specific breaks, if a structure ~~outside containment~~ separates a high-energy line from an essential component, that separating structure is designed to withstand the consequences of the pipe break in the high-energy line that produces the greatest effect at the structure.

3.6.2.1.2 Postulated Rupture Descriptions

A. Circumferential Break

A circumferential break is assumed to result in pipe severance with full separation of the two severed pipe ends unless the extent of separation is limited by consideration of physical means. The break plane area (A_e) is assumed perpendicular to the longitudinal axis of the pipe, and is assumed to be the cross-sectional flow area of the pipe at the break location. The break flow area (A_f) from each of the broken pipe segments for a circumferential break, with full separation of the two broken pipe segments, is equal to the break plane area (A_e). The break flow area, discharge coefficient and discharge correlation are substantiated analytically or experimentally. E

B. Longitudinal Break

A longitudinal break is assumed to result in a split of the pipe wall along the pipe longitudinal axis, but without severance. The break plane area (A_e) is assumed parallel to the longitudinal axis of the pipe and equal to the cross-sectional flow area of the pipe at the break location. The break flow area (A_f) is equal to the break plane area (A_e). The break is assumed to be circular in shape or elliptical (2D x D/2) with its long axis parallel to the axis. The discharge coefficient and any other values used for the area or shape associated with a longitudinal break are substantiated analytically or experimentally.

C. Leakage Crack

A leakage crack is assumed to be a crack through the pipe wall where the size of the crack and corresponding flow rate are determined by analysis and a leak detection system, as described in Section 3.6.3.

D. Through-Wall Crack

A through-wall crack is assumed to be a circular orifice through the pipe wall of cross-sectional flow area equal to the product of one-half the pipe inside diameter and one-half the pipe wall thickness.

RAI 252.21, 22
10, 17, 18, 20,

3.6.2.1.3 Piping Evaluated for Leak-Before-Break

A leak-before-break evaluation is performed for Class 1 piping with a diameter of ten inches or greater (i.e., the reactor coolant system (RCS) main loop piping, surge line, shutdown cooling and safety injection lines) and for the main steam line inside containment in order to eliminate the dynamic effects of pipe rupture from the design basis. The evaluation is intended to meet the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 4. The evaluation is performed using the guidelines of NUREG 1061, Vol. 3 (Reference 1) as described in Section 3.6.3.

3.6.2.1.4 Piping Other than Piping Evaluated for Leak-Before-Break

This section applies to all high- and moderate-energy piping other than that whose dynamic effects due to pipe breaks are eliminated from the design basis by leak-before-break evaluation, as identified in Section 3.6.2.1.3.

3.6.2.1.4.1 Postulated Rupture Locations

A. Class 1 Piping

Ruptures, as specified in Item~~s D and E~~ D below, are postulated to occur at the following locations in each piping network designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III (Reference 2) for Class 1 piping:

1. the terminal ends of the pressurized portions of the network.

2. intermediate locations where S from equation (10) exceeds $2.4S_m$.

3. intermadiate locations where U exceeds 0.1.

where, as defined in Subarticle NB-3650,

¶ Leakage crack locations ~~are specified~~ for Class 1 piping are specified in Item E below.

RAI 3.6.2

S = primary-plus-secondary stress-intensity range under the combination of loadings for which either Level A or Level B service limits have been specified, as calculated from equation (10).

S_m = allowable stress-intensity value.

U = the cumulative usage factor.

B. Class 2, Class 3, or Seismically Analyzed ANSI B31.1 Piping

Ruptures, as specified in Item~~s~~ D ~~and E~~ below, are postulated to occur at the following locations in each piping network designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, (Reference 2) for Class 2 and Class 3 piping, or with the rules of the ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1983 (Reference 3) for seismically analyzed ANSI B31.1 piping:

1. the terminal ends of the pressurized portion of the network, and

2. either

   a. intermediate locations of potential high stress or fatigue such as pipe fittings, valves, flanges and welded-on attachments, or

   b. where the piping contains no fittings, weld attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure, or

   c b. intermediate locations where the stress, S, exceeds 0.8(X + Y).

   where, as defined in Subarticle NC-3650,

   S = stresses under the combination of loadings for which either Level A or Level B service limits have been specified, as calculated from the sum of equations (9) and (10).

   X = equation (9) Service Level B allowable stress.

   Y = equation (10) allowable stress.

¶ Leakage crack locations in Class 2 and Class 3 piping are specified in Item E below.

RAI's [illegible] 16, 17, 18, 20, 21, 22, 23

4.

C. Non-Seismically Analyzed ANSI B31.1 Piping

Ruptures as specified in Items D ~~and E~~, are postulated to occur at the following locations in each ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1983 (Reference 3) piping network that is not seismically analyzed.

1. at terminal ends of the pressurized portions of the network, and
2. at each intermediate location of potential high stress or fatigue, such as pipe fittings, valves, flanges, and welded-on attachments.

D. Break Locations

Both circumferential and longitudinal breaks are postulated to occur, but not concurrently, in all high-energy piping systems at the locations specified in Items A, B, or C, except as follows:

1. Circumferential breaks are not postulated in piping runs of a nominal diameter equal to or less than 1 inch.
2. Longitudinal breaks are not postulated in piping runs of a nominal diameter less than 4 inches.
3. Longitudinal breaks are not postulated at terminal ends.

4 For nonsafety class piping which is not seismically analyzed, leakage cracks are postulated at axial locations such that they produce the most severe environmental effects.

: AI's 3.10 10, 17, 18, 20, 21, 22, 23

For moderate-energy fluid systems in areas other than containment penetration, leakage cracks are postulated at axial and circumferential locations that result in the most severe environmental consequences. Where a break in a high-energy fluid system is postulated which results in more limiting environmental conditions, the leakage crack in the moderate-energy fluid system is not postulated.

3. Leakage Cracks

~~A leakage crack is postulated in place of a~~ circumferential break, or longitudinal break, or through-wall crack, if justified by an analysis performed on the pipeline in accordance with the requirements of Section 3.6.3.

Leakage cracks, instead of breaks, are also postulated in the piping of fluid systems that qualify as high-energy fluid systems for short operational periods of time but that qualify as moderate-energy fluid systems for the major operational period.

F. Piping Near Containment Isolation Valves

Ruptures are not postulated between the containment wall and the inboard or outboard isolation valves in piping, which is designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III (Reference 2), and which meets the following additional requirements:

1. The limits for postulating intermediate rupture locations, as specified in Item A.2.b for Class 1 piping and Item B.2.b for Class 2 and 3 piping, are not exceeded in that portion of piping.

2. Following a postulated pipe break of high-energy piping beyond either isolation valve, the stresses in the piping from the containment wall, to and including the length of the isolation valve, are maintained within Level C Service Limits as specified in the ASME Boiler and Pressure Vessel Code, Section III, (Reference 2).

3. The design and in-service inspection requirements, as specified in MEB 3-1 (Reference 4), are satisified.

4. The containment isolation valves are appropriately qualified to assure that operability and leak tightness are maintained when subjected to any combination of loadings, which may be transmitted to the valves from postulated pipe breaks beyond the valves.

3.6.2.1.4.2 Postulated Rupture Configurations

A. Break Configurations

Where the postulated break location is at a tee, elbow, or the following pipe locations, the configurations and types of breaks are determined as follows:

1. Without the benefit of a detailed stress analysis, the following are assumed:

RAI's 210.16,17,18,20 21,22,23

gpm per square inch for the primary system for the range of pipe sizes of interest. The crack opening area corresponding to the 10 gpm rate is found to be 0.04 square inch. This crack opening area is used to determine the length of the detectable crack for stability evaluation.

3.6.3.4 Screening of Leakage Crack Sizes Using EPRI/GE Estimation Scheme

Prior to detailed calculations of through-wall leakage cracks and corresponding margins on loads and crack sizes, a preliminary scoping valuation is performed. In this part, all possible locations in the piping evaluated are screened to identify the most critical candidates for detailed study. The screening study is performed using the EPRI/GE estimation scheme (Reference 11) for the determination of crack opening areas using elastic plastic fracture mechanics methods, and the C-E developed JEST computer program for the leakage rates through cracks.

This estimation procedure is used to compare the severity of hypothesized flaws in all piping locations in order to reduce the number of cases to be subjected to detailed analysis. The procedure also provides an estimate of the leakage crack length for input to the detailed finite-element analysis. ~~discussed in Section 3.6.3.1.6.~~

3.6.3.5 Material Properties

For the main coolant loop, the hot and cold leg piping material is SA516 Gr70. All hot- and cold-leg pipe-to-pipe welds and the pipe-to-reactor vessel, steam generator and reactor coolant pump safe end welds are carbon steel. All main loop component nozzles are SA508 CL 2 or 3 carbon steel or SA541 CL 1, 2 or 3. The surge line is SA351 GR CF8M stainless steel, resulting in bimetallic safe end welds. The shutdown cooling line and the direct vessel safety injection line are both Type 304 stainless steel. The main steam line is SA516 Gr70.

The detailed analysis of cracks in pipe welds requires consideration of the properties of the pipe and the weld materials. Previous work by C-E has shown that a conservative bounding analysis results when the material stress-strain properties of the base metal (lower yield) and the fracture properties of the weld (lower toughness) are used for the entire structure, (Reference 12). This material representation is used for all analyses. The tensile (stress-strain) curves and the J_D vs. Δa curves are required for each material type.

RAI's 210.16, 17, 18, 20, 21, 22, 23

REFERENCES FOR SECTION 3.6

1. "Evaluation of Potential for Pipe Breaks," NUREG-1061, Vol. 3.
2. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, Class 1, 2 or 3, 1986 Edition.
3. ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1986 Edition.
4. USNRC Branch Technical Position MEB 3-1 Rev. 2 - Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment, attached to Standard Review Plan 3.6.2, ~~July 1981.~~ June, 1987.
5. American National Standard Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture, ANSI/ANS 58.2-1988.
6. R. T. Lahey, Jr. and F. J. Moody, "Pipe Thrust and Jet Loads," The Thermal Hydraulics of a Boiling Water Nuclear Reactor, Section 9.2.3, pp. 375-409, Published by American Nuclear Society, Prepared by the Division of Technical Information United States Energy Research and Development Administration, 1977.
7. RELAP 4/MOD 5, Computer Program User's Manual 098. 026-5.5.
8. USNRC Regulatory Guide 1.45 "R[illegible] Coolant Pressure Boundary Leakage Detection Systems," [illegible] 1973.
9. NUREG/CR-1319, "Cold Leg Integrity Evaluation," Battelle Columbus Laboratories, February 1980.
10. PICEP: Pipe Crack Evaluation Program, EPRI NP 3596-SR, August, 1984.
11. "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI NP2931, by V. Kumar, M. D. German, C. F. Shih, July 1981.
12. "Analysis of Cracked Pipe Weldments," EPRI NP-5057, February 1987.

Question 210.24

BTP MEB 3-1, Rev. 2, Section B.3, specifies criteria for the type of breaks and leakage cracks in high-energy fluid system piping. The corresponding criteria for the postulated break and crack configurations provided in CESSAR-DC, Section 3.6.2.1.4.2, are not in full accordance with these BTP MEB 3-1, Rev. 2 criteria. For example, the criteria for: 1) circumferential breaks in instrumentation lines, one inch and less nominal pipe or tubing size in BTP MEB 3-1, Rev. 2, Section B.3.a.(1); 2) circumferential breaks selected without the benefit of stress calculations at piping welds to valves in BTP MEB 3-1, Rev. 2, Section B.3.a(2); 3) longitudinal breaks in general in BTP MEB 3-1, Rev. 2 Section B.3.b.(3); and 4) leakage cracks in BTP MEB 3-1, Rev. 2 Sections B.3.c(2) and B.3..c(4); are not accurately reflected in CESSAR-DC Section 3.6.2.1.4..2.

Provide justification for the differences between the BTP MEB 3-1, Rev. 2 and the CESSAR-DC criteria or modify the latter in accordance with former.

Response 210.24

CESSAR-DC will be revised to incorporate the criteria of BTP MEB 3-1, Rev. 2 Section B.3.

Section 3.6.2.1.4.2 will be completely revised.

Section 3.6.2.2.2.1.E will be added.

NRC Regulatory Guide 1.11 reference will be added to the references for Section 3.6 of CESSAR-DC.

Q. 210.24

2. Leakage Cracks

A leakage crack is postulated in place of a circumferential break, or longitudinal break, or through-wall crack, if justified by an analysis performed on the pipeline in accordance with the requirements of Section 3.6.3.

F. Piping Near Containment Isolation Valves

Ruptures are not postulated between the containment wall and the inboard or outboard isolation valves in piping, which is designed in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III (Reference 2), and which meets the following additional requirements:

1. The limits for postulating intermediate rupture locations, as specified in Item A.2.b for Class 1 piping and Item B.2.b for Class 2 and 3 piping, are not exceeded in that portion of piping.

2. Following a postulated pipe break of high-energy piping beyond either isolation valve, the stresses in the piping from the containment wall, to and including the length of the isolation valve, are maintained within Level C Service Limits as specified in the ASME Boiler and Pressure Vessel Code, Section III, (Reference 2).

3. The design and in-service inspection requirements, as specified in MEB 3-1 (Reference 4), are satisified. E

4. The containment isolation valves are appropriately qualified to assure that operability and leak tightness are maintained when subjected to any combination of loadings, which may be transmitted to the valves from postulated pipe breaks beyond the valves.

~~**3.6.2.1.4.2 Postulated Rupture Configurations**~~

~~A. Break Configurations~~

~~Where the postulated break location is at a tee, elbow, or the following pipe locations, the configurations and types of breaks are determined as follows:~~

~~1. Without the benefit of a detailed stress analysis, the following are assumed:~~

REPLACE WITH ATTACHED INSERT

Q. 210.24

REPLACE WITH ATTACHED INSERT

a. ~~Circumferential breaks are postulated to occur individually at each tee or elbow pipe-to-fitting weld where the criteria in Section 3.6.2.1.4.1, Item C are exceeded, and longitudinal breaks postulated to occur individually on each side of the tee or elbow at its center and oriented perpendicular to the plane of the fitting.~~

b. ~~At a branch run connection, a circumferential break is postulated at the branch run-to-main run weld, or the branch run-to-fitting weld, and the break plane area (A_e) is assumed to be the cross-sectional flow area of the branch.~~

c. ~~At a welded attachment (lug, stanchion, etc.) a longitudinal break is postuluted at the centerline of the welded attachment with an area equal to the pipe surface area that is bounded by the attachment weld.~~

d. ~~At an axisymmetric pipe location, such as a reducer, circumferential and longitudinal breaks are postulated at each pipe-to-fitting weld where the criteria in Section 3.6.2.1.4.1, Item C are exceeded. Longitudinal breaks are oriented to produce out-of-plane bending of the piping configuration.~~

2. ~~Alternatively, where a detailed stress analysis or test is performed, the results are used to predict the most probable rupture location(s) and type of break.~~

B. ~~Crack Configurations~~

~~At a postulated leakage crack or through-wall crack location, the orifice is assumed to be located noncurrently at each and every point about the circumference of the pipe, unless otherwise substantiated.~~ E

3.6.2.1.5 Details of Containment Penetrations

Details of containment penetrations are discussed in Sections 3.8.1 and 3.8.2.

RAI 210.24

3.6.2.1.4.2 Postulated Rupture Configurations

A. Break Configurations

Where break locations are postulated at fittings without the benefit of a detailed stress calculation, breaks should be assumed to occur at each pipe-to-fittings weld. If detailed stress analyses or tests are performed, the maximum stressed location in the fittings may be selected as the break location.

Circumferential breaks shall be postulated in fluid system piping and branch runs as specified in CESSAR-DC Section 3.6.2.1.4.1.D. Instrument lines, one inch and less nominal pipe of tubing size shall meet the provisions of Regulatory Guide 1.11.

Longitudinal breaks in fluid system piping and branch runs shall be postulated as specified in Section 3.6.2.1.4.1.D.

B. Crack Configurations

Leakage cracks shall be postulated at those axial locations specified in Section 3.6.2.1.4.1.E.

For high-energy piping, leakage cracks shall be postulated to be in those circumferential locations that result in the most severe environmental consequences. The flow from the crack shall be assumed to wet all unprotected components within the compartment with consequent flooding in the compartment and communicating compartments. Flooding effects shall be determined on the basis of a conservatively estimated time period required to effect corrective actions.

RAI 210.24

positive pump-controlled flow, and the absence of energy reservoirs are taken into account, as applicable, in the reduction of jet discharge.

Piping movement is assumed to occur in the direction of the jet reaction, unless limited by structural members, piping restraints, or piping stiffness.

C. Pipe Blowdown Force and Wave Force

The fluid thrust forces that result from either postulated circumferential or longitudinal breaks, are calculated using a simplified one step forcing function methodology. This methodology is based on the simplified methods described in ANSI 58.2 (Reference 5) and in Reference 6.

When the simplified method discussed above leads to impractical protective measures, then a more detailed computer solution which more accurately reflects the postulated pipe rupture event is used. The computer solution is based on the NRC's computer program developed for calculating two-phase blowdown forces (Reference 7).

D. Evaluation of Jet Impingement Effects E

Jet impingement force calculations are performed only if structures or components are located near postulated high energy line breaks and it cannot be demonstrated that failure of the structure or component will not adversely affect safe shutdown capability.

ADD ITEM E. AS SHOWN ON ATTACHED PAGE.

E.

3.6.2.2.2.2 Methods for the Dynamic Analysis of Pipe Whip

Pipe whip restraints usually provide clearance for thermal expansion during normal operation. If a break occurs, the restraints or anchors nearest the break are designed to prevent unlimited movement at the point of break (pipe whip). A finite difference model will be used to analyze simplified models of the local region near the break. Displacements and strains of the pipe and restraint will be estimated using a power law moment curvature relationship.

A. Finite Difference Analysis

A finite difference formulation specialized to the case of a straight beam and neglecting axial inertia and large deflection effects is used for the analysis of pipe whip. The dynamic analysis is performed by direct numerical time integration of the equations of motion presented in Appendix 3.6A.

3.6.2.2.2.1

RAI 210.24

E. LONGITUDINAL BREAKS

A longitudinal break results in an axial split without severance. The split shall be assumed to be orientated at any point about the circumference of the pipe, or alternatively at the point of highest stress as justified by detaile stress analyses. For the purpose of design, the longitudinal break shall be assumed to be circular or ellipical (2D x 1/2D) in shape, with an area equal to the largest piping cross-sectional flow area at the point of the break and have a discharge coefficient of 1.0. Any other values used for the area, diameter and discharge coefficiant associated with a longitudinal break shall be verified by test data which defines the limiting break geometry.

Q. 210.24

REFERENCES FOR SECTION 3.6

1. "Evaluation of Potential for Pipe Breaks," NUREG-1061, Vol. 3.
2. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, Class 1, 2 or 3, 1986 Edition.
3. ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1986 Edition.
4. USNRC Branch Technical Position MEB 3-1 - Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment, attached to Standard Review Plan 3.6.2, July 1981.
5. American National Standard Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture, ANSI/ANS 58.2-1988.
6. R. T. Lahey, Jr. and F. J. Moody, "Pipe Thrust and Jet Loads," The Thermal Hydraulics of a Boiling Water Nuclear Reactor, Section 9.2.3, pp. 375-409, Published by American Nuclear Society, Prepared by the Division of Technical Information United States Energy Research and Development Administration, 1977.
7. RELAP 4/MOD 5, Computer Program User's Manual 098. 026-5.5.
8. USNRC Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems," May 1973.
9. NUREG/CR-1319, "Cold Leg Integrity Evaluation," Battelle Columbus Laboratories, February 1980.
10. PICEP: Pipe Crack Evaluation Program, EPRI NP 3596-SR, August, 1984.
11. "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI NP2931, by V. Kumar, M. D. German, C. F. Shih, July 1981.
12. "Analysis of Cracked Pipe Weldments," EPRI NP-5057, February 1987.

E

ADD?

13. NRC Regulatory Guide 1.11 (Safety Guide 11), Instrument Lines Penetrating Primary Reactor Containment; including supplement, Backfitting Considerations, February 1972

Question 210.25

SRP 3.6.2, Subsection III.1.b, specifies items to be reviewed to ensure that the pipe break criteria have been properly implemented. These items include sketches showing the locations of the postulated piping ruptures and the data developed to select the break locations as described in SRP 3.6.2, Subsection III.1.b.(1) and (2), respectively. These items have not been provided.

Provide the items described in SRP 3.6.2, Subsections III.1.b.(1) and (2), for review.

Response 210.25

See the response to NRC RAI 210.12 for C-E's proposed actions to resolve level of detail issues for postulated pipe ruptures.

Question 210.26

SRP 3.6.2, Subsection III.2, specifies that analyses of pipe motion caused by the dynamic effects of postulated breaks be reviewed. Areas to be reviewed include dynamic analysis criteria, dynamic analysis models of piping system and justification of dynamic analysis models for jet thrust. These analyses have not been provided.

A) Provide the analyses described in SRP 3.6.2, Subsection III.2, for review.

B) In addition, CESSAR-DC Section 3.6.2.2.2.1 states that fluid thrust forces that result from either postulated circumferential or longitudinal breaks will be calculated using, in part, a simplified one step forcing function based on the ANSI/ANS-58-1988 standard. Clarify the use of this standard.

Response 210.26

(A) CESSAR-DC currently provides acceptance criteria and analysis methodology for postulated pipe ruptures and pipe whip. It also provides some of the information needed for these evaluations, such as pipe sizes, P&IDs, and building and seismic response information. Specific plant data, such as piping layout and arrangement drawings which are necessary for these evaluations are not currently available.

A description of the methods for analyzing the interaction effects of a whipping pipe with a restraint is provided in the response to RAI 210.30.

As presented to the Staff at the meeting of November 26, 1991, piping layout, analysis of pipe motion caused by the dynamic effects of postulated pipe breaks, and pipe whip restraint design represents detailed information (1) are not required for certification, (2) depend on plant-specific details not finalized at the certification stage and (3) are subject to revision until specific details of piping and other plant design are finalized. It was also agreed at that meeting that a Distribution Systems Guide would be prepared to ensure that the final design would be completed consistent with the design basis and methodology in CESSAR-DC.

See response to NRC RAI 210.12 for further discussion of C-E's proposed actions to resolve level of detail issues for postulated pipe rutures.

B) ANSI/ANS-58.2-1988, Appendix B, presents conservative approximations for the time dependent thrust force acting at the break location of a ruptured pipe. In cases where the steady state thrust > initial thrust, ANS-58.2 describes a simplified approximation for which the applied thrust rises from zero to steady state thrust in one millisecond, where it remains constant for the duration of the time history analysis. In cases where steady state thrust < initial thrust, ANS-58.2 describes a simplified approximation for which the applied thrust is suddenly applied at time zero and is reduced to a steady state thrust level when steady state is reached.

The ANS-58.2 approach defines the applied thrust forcing function for fluid systems where the thrust coefficient, C_t, is less than, equal to or greater than 1.0.

The approach described in CESSAR-DC refers to the use of the following one-step forcing functions based on the method discussed in ANS-58-2. For the first case above, where $C_t > 1.0$, a suddenly applied thrust equal to C_t p A and remaining at that level for the entire analysis, is used. For the second case above, where $C_t \leq 1.0$, a suddenly applied thrust equal to the initial thrust, 1.0 p A, and remaining at that level for the entire analysis, is used. These one-step forcing functions are at least as conservative as the simplified forcing functions described in ANS-58.2.

Question 210.27

CESSAR-DC Sections 3.6.2.1.1 and 3.6.2.1.1 and 3.6.2.1.2 identify "leakage cracks" which are to be postulated as described in CESSAR-DC Section 3.6.3, "Leak-Before Break Evaluation Procedure." The piping to which this LBB procedure is to be applied is defined in Subsection 3.6.2.1.3.

Currently, the LBB procedure has not been approved by the staff for the CESSAR-DC standard design (reference RAI's 210.13 and 252.03). Pending such approval, the CESSAR-DC, including Sections 3.6.2, 3.9.1 through 3.9.6, and 3.10, should be revised to account for the effects of postulated ruptures, in accordance with BTP MEB 3-1, Rev. 2, in the piping described in Subsection 3.6.2.1.3.

Response 210.27

Refer to response to RAI 210.13.

Question 210.28

In CESSAR-DC Section 3.6.2.4.1 "Postulated Rupture Locations," the definition for S, the primary-plus-secondary stress-intensity range for ASME Code, Section III, Class 1 piping, does not include the zero load set as specified in BTP MEB 3-1, Rev. 2, Subsection B.1.b.(1).(a).

Modify the definition to include the zero load set.

Response 210.28

CESSAR-DC Section 3.6.2.1.4.1 will be revised to incorporate the information in BTP MEB 3-1 Rev. 2 Section B.1.b.(1).(a) which specifies the use of the zero load set in the stress range calculation.

Revision is incorporated in the response to question 210.14.

Question 210.29

In CESSAR-DC Section 3.6.2.1.4.1.C "Non-Seismically Analyzed ANSI B31.1 Piping," the criteria for the postulation of rupture is not in total agreement with the applicable criteria specified in BTP MEB 3-1, Rev. 2, Subsection B.1c(3). The BTP MEB 3-1, Rev. 2 criteria require that breaks in non-seismic, i.e., non-Category I, piping are to be taken into account as described in SRP 3.9.2, Subsection II.2.K.

Provide justification for differences between the CESSAR-DC and BTP MEB 3-1, Rev. 2 criteria or modify the former in accordance with the latter.

Response 210.29

CESSAR-DC Section 3.6.2.1.4.1.C will be revised in accordance with SRP 3.9.2 Section II.2.K (interaction of other piping with Category I piping).

C. ~~Non-Seismically Analysed ANSI B31.1 Piping~~

~~Ruptures, as specified in Items D and E, are postulated to occur at the following locations in each ASME Code for Pressure Piping, B31, Power Piping, ANSI/ASME B31.1-1983 (Reference 3) piping network that is not seismically analyzed.~~

1. ~~at terminal ends of the pressurized portions of the network, and~~

2. ~~at each intermediate location of potential high stress or fatigue, such as pipe fittings, valves, flanges, and welded-on attachments.~~

D. Break Locations

Both circumferential and longitudinal breaks are postulated to occur, but not concurrently, in all high-energy piping systems at the locations specified in Items A, B, or C, except as follows:

1. Circumferential breaks are not postulated in piping runs of a nominal diameter equal to or less than 1 inch. E

2. Longitudinal breaks are not postulated in piping runs of a nominal diameter less than 4 inches.

3. Longitudinal breaks are not postulated at terminal ends.

C. NON-SAFETY RELATED ANSI B31.1 PIPING

SYSTEM 80+ PIPING ~~WILL BE~~ IS DESIGNED SO AS TO ISOLATE SEISMICALLY ANALYZED PIPING FROM NON-SEISMICALLY ANALYZED PIPING. IN CASES WHERE IT IS NOT POSSIBLE OR PRACTICAL TO ISOLATE THE SEISMIC PIPING, ADJACENT NON-SEISMIC PIPING ~~SHALL~~ IS ~~BE~~ ANALYZED ACCORDING TO THE SAME SEISMIC CRITERIA AS APPLICABLE TO SEISMIC PIPING. FOR NON-SEISMIC PIPING ATTACHED TO SEISMIC PIPING, THE DYNAMIC EFFECTS OF THE NON-SEISMIC PIPING are ~~SHALL BE~~ SIMULATED IN THE MODELING OF THE SEISMIC PIPING. THE ATTACHED NON-SEISMIC PIPING UP TO THE ANALYZED/UNANALYZED BOUNDARY ~~SHOULD BE~~ IS DESIGNED ~~TO~~ NOT TO CAUSE A FAILURE OF THE SEISMIC PIPING DURING A SEISMIC EVENT.

Question 210.30

In CESSAR-DC Section 3.6.2.2.2.2, it is stated that pipe whip dynamic analyses at pipe whip restraints will be performed to estimate displacements and strains of the pipe and restraint. These analyses will be based on the power law moment curvature model in Appendix 3.6A.

SRP 3.9.1, Subsection III.4, specifies criteria for the review of elastic-plastic methods for safety-related Code or Non-Code items for which Service Level D limits have been specified.

Provide justification for the Appendix 3.6A power law movement curvature inelastic model in accordance with SRP 3.9.1.

Response 210.30

Section 3.6.2.2.2.2 will be modified to present a more comprehensive description of the approach to pipe whip analysis (see paragraphs below). Since the methods involved do not employ the power law moment curvature model, Appendix 3.6A will be deleted and applicable descriptive information included in the text of Section 3.6.2.2.2.2. The methods presented are consistent with SRP 3.9.1.

In general, the loading that may result from a break in piping is determined using either a dynamic blowdown or a conservative static blowdown analysis. The method for analyzing the interaction effects of a whipping pipe with a restraint will be one of the following: (1) Equivalent Static Method, (2) Lumped Parameter Method, or (3) the Energy Balance Method.

In cases where time history or energy balance method is not used, a conservative static analyses model will be assumed.

The lumped parameter method is carried out by utilizing a lumped mass model. Lumped mass points are interconnected by springs to take into account inertia and stiffness properties of the system. A dynamic forcing function or equivalent static loads may be applied at each postulated break location with unacceptable pipe whip interactions. A nonlinear elastic-plastic analysis of the piping-restraint system is used.

The energy balance method is based on the principle of conservation of energy. The kinetic energy of the pipe generated during the first quarter cycle of movement is assumed to be converted into equivalent strain energy, which is distributed to the pipe or the whip restraint.

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positive pump-controlled flow, and the absence of energy reservoirs are taken into account, as applicable, in the reduction of jet discharge.

Piping movement is assumed to occur in the direction of the jet reaction, unless limited by structural members, piping restraints, or piping stiffness.

C. Pipe Blowdown Force and Wave Force

The fluid thrust forces that result from either postulated circumferential or longitudinal breaks, are calculated using a simplified one step forcing function methodology. This methodology is based on the simplified methods described in ANSI 58.2 (Reference 5) and in Reference 6.

When the simplified method discussed above leads to impractical protective measures, then a more detailed computer solution which more accurately reflects the postulated pipe rupture event is used. The computer solution is based on the NRC's computer program developed for calculating two-phase blowdown forces (Reference 7).

D. Evaluation of Jet Impingement Effects

Jet impingement force calculations are performed only if structures or components are located near postulated high energy line breaks and it cannot be demonstrated that failure of the structure or component will not adversely affect safe shutdown capability.

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3.6.2.2.2.2 Methods for the Dynamic Analysis of Pipe Whip

Pipe whip restraints usually provide clearance for thermal expansion during normal operation. If a break occurs, the restraints or anchors nearest the break are designed to prevent unlimited movement at the point of break (pipe whip). ~~A finite difference model will be used to analyze simplified models of the local region near the break. Displacements and strains of the pipe and restraint will be estimated using a power law moment curvature relationship.~~

~~A. Finite Difference Analysis~~

~~A finite difference formulation specialized to the case of a straight beam and neglecting axial inertia and large deflection effects is used for the analysis of pipe whip. The dynamic analysis is performed by direct numerical time integration of the equations of motion presented in Appendix 3.6A.~~

[~~See~~ Add insert next page]

- Insert -

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The dynamic nature of the piping thrust load ~~shall be~~ is considered. In the absence of analytical justification, a dynamic load factor of 2.0 is applied in determining restraint loading. (Elastic-plastic) pipe and whip restraint material properties may be considered as applicable. The effect of rapid strain rate of material properties is considered. A 10 percent increase in yield strength is used to account for strain rate effects.

In general, the loading that may result from a break in piping is determined using either a dynamic blowdown or a conservative static blowdown analysis. The method for analyzing the interaction effects of a whipping pipe with a restraint ~~will be~~ is one of the following: (1) Equivalent Static Method (2) Lumped Parameter Method, or (3) the Energy Balance Method.

In cases where time history or energy balance method is not used, a conservative static analyses model will be assumed.

The lumped parameter method is carried out by utilizing a lumped mass model. Lumped mass points are interconnected by springs to take into account inertia and stiffness properties of the system. A dynamic forcing function or equivalent static loads may be applied at each postulated break location with unacceptable pipe whip interactions. A nonlinear elastic-plastic analysis of the piping-restraint system is used.

The energy balance method is based on the principle of conservation of energy. The kinetic energy of the pipe generated during the first quarter cycle of movement is assumed to be converted into equivalent strain energy, which is distributed to the pipe or the whip restraint.

3.6.2.2.2.3 Method of Dynamic Analysis of Unrestricted Pipes

The impact velocity and kinetic energy of unrestricted pipes is calculated on the basis of the assumption that the segments at each side of the break act as rigid-plastic cantilever beams subject to piecewise constant blowdown forces. The hinge location is fixed either at the nearest restraint or at a point determined by the requirement that the shear at an interior plastic hinge is zero. The kinetic energy of an accelerating cantilever segment is equal to the difference between the work done by the blowdown force and that done on the plastic hinge. The impact velocity V is found from the expression for the kinetic energy:

$$KE = (1/2)\, M_{eg} V_I^2$$

where M_{eg} is the mass of the single degree of freedom dynamic model of the cantilever. The impacting mass is assumed equal to M_{eg}.

3.6.2.3 Dynamic Analysis Methods to Verify Integrity and Operability

3.6.2.3.1 Pipe Whip Restraints and Jet Deflectors for Piping Evaluated for Leak-Before-Break

There are no pipe whip restraints and jet deflector for the reactor coolant loop, surge line, shutdown cooling line, safety injection line and main steam line based upon elimination of dynamic effects due to pipe breaks by leak-before-break evaluation.

3.6.2.3.2 Pipe Whip Restraints and Jet Deflectors for Piping Other than that Evaluated for Leak-Before-Break

This section applies to pipe whip restraints for all piping other than that whose dynamic effects due to pipe breaks are eliminated from the design basis by leak-before-break evaluation.

3.6.2.3.2.1 General Description of Pipe Whip Restraints

When required, pipe whip restraints are provided to protect the plant against the effects of whipping during postulated pipe break. The design of pipe whip restraints is governed not only by the pipe break blowdown thrust, but also by functional requirements, deformation limitations, properties of whipping pipe and the capacity of the support structure. Typically, a pipe whip restraint consists of a ring around the pipe and components supporting the ring from

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~~APPENDIX 3.6A~~

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1.0 EQUATIONS OF MOTION

The equations of motion used in the Finite Difference Analysis of Section 3.6.2.2.2.2 are of the form:

$$h(P_k - m_k y_k = -M_{k+1} + 2M_k - M_{k-1}) \qquad (3.6A\text{-}1)$$

where:

h = the node spacing

P_k = the externally applied lateral loads at node k

m_k = the lumped mass at node k

y_k = the lateral deflection at node k

M_k = the internal resisting moment in the beam at node k.

Power law moment-curvature relationship is assumed and the central difference approximation for the curvature,

$$\frac{1}{h^2} = (-Y_{k+1} + 2y_k - Y_{k-1}) \qquad (3.6A\text{-}2)$$

is used.

A timewise central-difference scheme is used to solve the dynamic equations

$$y(t + \Delta t) = \Delta t^2 y(t) + 2y(t) - y(t - \Delta t) \qquad (3.6A\text{-}3)$$

and for the first time step

$$y(t) = \Delta t^2 y(0) \qquad (3.6A\text{-}4)$$

A time step equal to 1/10 the shortest period of vibration is used in the integration.

2.0 ELASTIC-PLASTIC MOMENT-CURVATURE LAW

The pipe is assumed to obey an elastic-strain hardening plastic moment-curvature law with isotropic strain hardening. The symbols used are defined as follows:

M = moment

$\bar{M}$ = current yield moment

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E = elastic modulus of material at temperature

I = moment of inertia

Z = IE

ϕ = curvature

ϕ_e = M/Z = elastic curvature

$\Delta\phi_p$ = increment of plastic curvature

ϕ_p = $\Sigma|\Delta\phi|$ = effective plastic curvature

ϕ_o = $\Sigma\Delta\phi_p$ = permanent set curvature

At the end of each integration step, new values of ϕ are calculated at each node.

The known values of ϕ_p, ϕ_o, and M at the start of the step are used to calculate M, $\bar{M}$ and $\Delta\phi_p$ by the following procedure:

if $|\phi - \phi_o| < \bar{M}/Z$

$$M = Z\,(\phi - \phi_o) \tag{3.6A-5}$$

and

$$\Delta\phi_p = 0 \tag{3.6A-6}$$

if $|\phi - \phi_o| > \bar{M}/Z$

$$M = \bar{M} = F(|\phi - \phi_o| + \phi_p)\,\mathrm{sgn}\,(\phi - \phi_o)$$

and

$$\Delta\phi_p = \phi - \phi_o - M/Z$$

where

$$F\,(\phi) = K\,(\phi)n.$$

3.0 POWER LAW MOMENT-CURVATURE RELATIONSHIP

The following stress strain law is assumed in the plastic range:

$$\sigma = K\,(\epsilon)^n \tag{3.6A-7}$$

The corresponding moment-curvature law is:

$$M = K\,(\phi)^n \tag{3.6A-8}$$

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where:

$$K = \frac{2\pi}{3 + n} (R_o^{3+n} - R_i^{3+n}) \frac{\Gamma[(1/2)n + 1]}{\Gamma[(1/2)n + 3/2]} \bar{K} \qquad (3.6A-9)$$

or, to a good approximation,

$$K = \frac{4\bar{K}}{3+n} (1 - .291n + .076n^2) (R_o^{3+n} - R_i^{3+n}) \qquad (3.6A-10)$$

in which:

R_o = pipe outside radius

R_i = pipe inside radius

In the elastic range the moment-curvature law is:

$$M = EI\Phi \qquad (3.6A-11)$$

The transition from elastic to plastic behavior on initial loading occurs at:

$$\Phi = \frac{(EI)^{\frac{1}{n-1}}}{K} \qquad (3.6A-12)$$

4.0 STRAIN RATE EFFECTS

The effect of strain rate in carbon steel is accounted for by using a rate dependent stress strain law of the form:

$$\sigma(\epsilon, \dot{\epsilon}) = (1 + \frac{\dot{\epsilon}}{(40.4)})^{1/5} G(\epsilon) \qquad (3.6A-13)$$

Where $G(\epsilon)$ is the static stress stain relationship. For stainless steel, the effect of strain rate is less pronounced so that a 10% increase in yield and ultimate strength is used.

5.0 RESTRAINT BEHAVIOR

The analysis is capable of handling a bilinear or power law restraint behavior. The behavior of the restraint is unidirectional. The restraint unloads elastically only to zero state, being left with a permanent set, and reloads along a bilinear or power law curve.

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Question 210.31

In CESSAR-DC Section 3.6.2.2.2.4, the allowable stresses for the design of whip restraints are not in accordance with the criteria of SRP 3.6.2, Subsection III.2.a.

Provide justification for the differences between the CESSAR-DC and SRP 3.6.2 criteria.

Response 210.31

CESSAR-DC Section 3.6.2.3.2.4 will be revised in accordance with the criteria of SRP 3.6.2, Subsection III 2.a. as follows:

Allowable stresses used in the design of the pipe break restraint components are consistent with the component function. In general, the allowable stresses associated with the total reaction force, including impact, on the structure extension, anchorage and structure are taken as the minimum yield stress for structural steel and concrete embedments. For those situations where structure load limiting features cannot be provided to maintain the allowable stresses to within yield, plastic deformation in structural components is tolerated as long as the structure is capable of continuing its functional requirements after the deformation occurs. The upper design limit for pipe break restraint is 50 percent of the restraint material ultimate strain.

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REVISE AS SHOWN ON ATTACHED SHEET.

3.6.2.3.2.4 Allowable Stresses

The allowable stresses are as follows:

A. For energy absorbing members: 0.95 F_{yd} with 0.5 ϵu strain for steel in tension, where the dynamic yield strength, F_{yd} is considered 15% higher than the static yield strength F_{ys} and ϵ is the ASTM specified minimum elongation for the rod given as a percentage with 50% usable strain for crushable energy absorption material in compression as determined by dynamic testing.

B. For non-energy absorbing member: 1.6 times the AISC allowable stress, but not to exceed 0.95 F_{yd} for bending and 0.55 F_{yd} for shear where F_{yd} is considered 10% higher than F_{ys} for compression members, the allowable stress is 0.9 times the buckling stress F_{CRC} as follows:

$$F_{CRC} = 5/3 \times F_a \times DIF$$

where

5/3 = Lower bound factor of safety in AISC for compression stress

F_a = AISC allowable compression stress

DIF = Dynamic increase factor = 1.1

C. For structural attachments and structural components - allowable stresses will be the same as described in Sections 3.8.3 and 3.8.4.

3.6.2.3.2.5 Design Criteria

E

The unique features in the design of pipe whip restraint components relative to the structural steel design are geared to the loads used and the allowable stresses. These are as follows:

A. Energy-absorbing members are designed for the restraint reaction and the corresponding deflection established according to the pipe size and material and the blowdown force using the criteria delineated in Section 3.6.2.2.

B. Non-energy-absorbing members and their attachments are designed for 1.25 times the restraint reaction to ensure that the required deflection occurs in the energy absorbing members and that the connecting members remain elastic.

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3.6.2.3.2.4 Allowable Stresses

The allowable stresses are as follows:

Allowable stresses used in the design of the pipe break restraint components are consistent with the component function. In general, the allowable stresses associated with the total reaction force, including impact, on the structure extension, anchorage and structure is taken as the minimum yield stress for structural steel and concrete embedments. For those situations where structure load limiting features cannot be provided to maintain the allowable stresses to within yield, plastic deformation in structural components is tolerated so long as the structure is capable of continuing its functional requirement after the deformation occurs. The upper design limit for pipe break restraint is 50 percent of the restraint material ultimate strain.

3.6.2.3.2.5 Design Criteria

E

The unique features in the design of pipe whip restraint components relative to the structural steel design are geared to the loads used and the allowable stresses. These are as follows:

A. Energy-absorbing members are designed for the restraint reaction and the corresponding deflection established according to the pipe size and material and the blowdown force using the criteria delineated in Section 3.6.2.2.

B. Non-energy-absorbing members and their attachments are designed for 1.25 times the restraint reaction to ensure that the required deflection occurs in the energy absorbing members and that the connecting members remain elastic.

Question 210.32

In CESSAR-DC Section 3.6.2.3.2.5, criteria for the design of whip restraints are defined. These criteria specify: 1) a 1.25 load factor of the restraint, and 2) an unspecified dynamic load factor for structural components and their attachment to the building structure.

Provide justification for the whip restraint load factor and specify the component and attachment load factor.

Response 210.32

Item C to CESSAR-DC Section 3.6.2.3.2.5 will be deleted and Item B will be revised to read as follows:

Non-energy-absorbing members, structural components, and their attachment to the building structure are designed for 2.0 times the restraint reaction to ensure that the required deflection occurs in the energy absorbing members and that the connecting members remain elastic.

RAI 210.32

3.6.2.3.2.4 Allowable Stresses

The allowable stresses are as follows:

A. For energy absorbing members: 0.95 F_{yd} with 0.5 ϵu strain for steel in tension, where the dynamic yield strength, F_{yd} is considered 15% higher than the static yield strength F_{ys} and ϵ is the ASTM specified minimum elongation for the rod given as a percentage with 50% usable strain for crushable energy absorption material in compression as determined by dynamic testing.

B. For non-energy absorbing member: 1.6 times the AISC allowable stress, but not to exceed 0.95 F_{yd} for bending and 0.55 F_{yd} for shear where F_{yd} is considered 10% higher than F_{ys} for compression members, the allowable stress is 0.9 times the buckling stress F_{CRC} as follows:

$$F_{CRC} = 5/3 \times F_a \times DIF$$

where

$5/3$ = Lower bound factor of safety in AISC for compression stress

F_a = AISC allowable compression stress

DIF = Dynamic increase factor = 1.1

C. For structural attachments and structural components - allowable stresses will be the same as described in Sections 3.8.3 and 3.8.4.

3.6.2.3.2.5 Design Criteria

E

The unique features in the design of pipe whip restraint components relative to the structural steel design are geared to the loads used and the allowable stresses. These are as follows:

A. Energy-absorbing members are designed for the restraint reaction and the corresponding deflection established according to the pipe size and material and the blowdown force using the criteria delineated ~~in Section 3.6.2.2~~.

B. Non-energy-absorbing members , STRUCTURAL COMPONENTS, ~~and their attachments~~ TO THE BUILDING STRUCTURE are designed for ~~1.25~~ 2.0 times the restraint reaction to ensure that the required deflection occurs in the energy absorbing members and that the connecting members remain elastic.

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~~C. Structural components and their attachment to the building structure are designed for the restraint reaction with an appropriate dynamic load factor.~~ E I

All essential components are evaluated for jet impingement and pipe whip effects using a dynamic or an equivalent static analysis of testing to demonstrate either the functional capability and/or operability in addition to the structural integrity of the component.

3.6.2.3.2.6 Materials

The materials used are as follows:

A. For energy-absorbing members: ASTM A-1093 Grade B7 or equivalent for tension rods, and crushable honeycomb made of stainless steel for compression.

B. For other components: ASTM A-588, ASTM A-572 Grade 50, and ASTM A-36. Charpy tests will be performed on steels subjected to impact loads and lamination tests are performed on steels subjected to through thickness tension.

3.6.2.3.2.7 Jet Impingement Shields

Protection from jets is provided by using separation and redundancy, as described in Section 3.6.1, in lieu of jet shields. E

3.6.2.4 Guard Pipe Assembly Design Criteria

Guard pipes to limit pressurization effects in the containment penetration area will not be used.

3.6.3 LEAK-BEFORE-BREAK EVALUATION PROCEDURE

This section describes Leak-Before-Break (LBB) analysis to all applicable piping. LBB analysis is used to eliminate, from the structural design bases the dynamic effects of double-ended guillotine breaks and equivalent longitudinal breaks for an applicable piping system.

3.6.3.1 Applicability of LBB

Piping evaluated for LBB is first shown to meet the applicability requirements for NUREG 1061, Volume 3. The piping is designed to meet the requirement to be not particularly susceptible to

Question 210.37

CESSAR-DC Sections 3.7.1.3 and 3.7.3.b states that damping values are based on RG 1.61 or ASME Code Case N-411-1 as given in Table 3.7-1. Damping values for piping in Table 3.7-1 are based on RG 1.61 but a footnote states that when response spectra method of analysis is used, piping damping values may be based on Code N-411-1.

RG 1.84 specifies additional limitations on the use of Code Case N-411 damping values. Either revise the footnote in Table 3.7.1 to include a commitment to all of the conditions in RG 1.84 or provide justification, for not including these additional RG 1.84 limitations on the use of Code Case N-411 damping values.

Response 210.37

When the response spectra method of analysis is used, damping values may be based on Code Case N-411-1. When employed the Code Case damping will be used completely and consistently and limited to only response spectral analyses. The Code Case damping will not be used for piping systems analyzed by the time history or independent support motion method, for those systems using supports designed to dissipate energy by yielding, or for those piping systems in which stress corrosion cracking has historically occured.

The footnote in Table 3.7.1 will be revised to include the above restrictions to the use of Code Case N-411-1 by including a commitment to all of the conditions of Regulatory Guide 1.84.

RAI 210.37

TABLE 3.7-1

DAMPING VALUES**

Structure	Operating Basis Earthquake (Percent of Critical)	Safe Shutdown Earthquake (Percent of Critical)
Welded steel structures	2.0	4.0
Bolted steel structures	4.0	7.0
Prestressed concrete structures	2.0	5.0
Reinforced concrete structures	4.0	7.0
Equipment (steel assembly)	2.0	3.0
Piping* (diameter <12 inches)	1.0	2.0
Piping* (diameter >12 inches)	2.0	3.0

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* When response spectra method of analysis is used, damping values may be based on Code Case N-411-1 as limited by Regulatory Guide 1.84

** Soil material dampings are provided in Section 2.5.2.

Question 210.38

A) CESSAR-DC Section 3.7.3.3 describes seismic subsystem modeling techniques. No criteria for decoupling subsystems including piping systems are provided. In addition the criteria for the piping mass point spacing, and accordingly the number of mass points and number of degrees of freedom, are not in accordance with SRP 3.7.2. Rev. 2, Subsection II.1.a(iii), criteria.

B) Provide seismic subsystem, including piping, criteria and demonstrate that the number of mass points and degrees of freedom in piping system models are in accordance with SRP 3.7.2, Rev. 2, Subsection II.1.a(iii), criteria.

Response 210.38

A) Where dynamic doupling of subsystems is used, the criteria of SRP 3.7.2, Rev. 2, subsection II.3.b is utilized. Where dynamic analysis methods are used, the criteria of SRP 3.7.2, Rev. 2 subsection II.1.a. (iii) is utilized to determine the number of masses, degrees of freedom and mass point spacing. The description of subsystem modelling techniques in CESSAR-DC Section 3.7.3.3 is reflective of the SRP criteria in that it states that the dynamic model is generated "to accurately evaluate the dynamic behavior of the component."

B) Refer to response to RAI 210.26 (a), which outlines the technical approach to answer the request for additional information on the issue of dynamic analysis modelling. This technical approach will outline dynamic modelling pertinent to both pipe break and seismic analyses of piping systems.

Question 210.40

CESSAR-DC Section 3.7.3.7 states that the seismic response of supports and equipment are not directly included in the seismic analysis of piping initially, but does not address whether or not these responses are included in subsequent analyses, if any.

Provide an explanation of how significant support and equipment responses are to be included in the piping analyses. Specifically address how piping input loadings are developed for flexible equipment and supports (if any).

Response 210.40

In the pre-certification design phase prior to equipment procurement, equipment and piping supports are assumed to be significantly more rigid than the piping itself. Upon completion of the piping analysis and subsequent support design and equipment procurement, support and equipment stiffnesses will be included in the piping analysis if a more accurate representation is warranted.

Question 210.41

CESSAR-DC Section 3.7.3.9 "Multiple Supported Equipment Components with Distinct Inputs" states that when equipment or components are supported at points with different elevations, either the envelope of these elevation response spectra or multiple support excitation is used for the seismic qualification of the equipment. The staff's position is that the multiple support excitation method of analysis is applicable only if used as recommended in NUREG-1061, "Report of the USNRC Piping Review Committee," Volume 4, Sections 2.3 and 2.4. In this position, a support group is defined by supports that have the same time history input. This usually means all supports located on the same floor (or portions of a floor) of a structure. Revise Section 3.7.9.3 and any other applicable section of CESSAR-DC to agree with the above position.

Response 210.41

The following will be added to CESSAR-DC Section 3.7.3.9:

For multiple support excitation, time history analysis method or independent support motion response spectrum method, as described in Reference 10, is used.

NUREG 1061 will be added to the references for Section 3.7 of CESSAR-DC.

RAI 210.41

pipe, the stiffness matrix for the piping system is determined. This includes the effects of torsional, bending, shear, and axial deformations, as well as the local flexibilities of piping curved members. Next, the frequencies and mode shapes for all the significant modes of vibrations are calculated. After the frequency is determined for each mode, the corresponding horizontal and vertical spectral accelerations with appropriate damping are read from the appropriate response spectrum curves. For each mode, the inertia response forces, moments, displacements and accelerations are determined due to excitation in the three directions simultaneously (two horizontal and one vertical). Finally, the stresses are determined by taking the SRSS of the individual components. The relative displacement effects between piping supports are discussed in Section 3.7.3.1.

3.7.3.8.2 Allowable Stresses

Allowable stresses in the piping caused by an earthquake are in accordance with Section III of the ASME Code. Allowable stresses in the earthquake restraint components, such as snubbers, are in accordance with any additional stress limits that may have been established by ASME Code, Section III at the time the restraint components were purchased.

3.7.3.9 Multiple Supported Equipment Components with Distinct Inputs

When the equipment or component is supported at points with different elevations, either the envelope of these elevation response spectra or multiple support excitation is used for the seismic qualification of the equipment.

FOR MULTIPLE SUPPORT EXCITATION, TIME HISTORY ANALYSIS METHOD OR INDEPENDENT SUPPORT MOTION RESPONSE SPECTRUM METHOD, AS DESCRIBED IN REFERENCE 10, IS USED.

3.7.3.10 Use of Constant Vertical Load Factors

In general, Seismic Category I subsystems are analyzed in the vertical direction using the methods specified in Section 3.7.3.1. No vertical static factors are used for subsystems.

3.7.3.11 Torsional Effects of Eccentric Masses

Piping systems are modeled to include projecting masses such as valve motor operators. The actual stiffness of the connecting member is not expected to influence the system appreciably. However, an approximation is made by assuming a member stiffness equal to that of the piping in which the valve is installed.

RAI 210.41

REFERENCES FOR SECTION 3.7

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3. McDonald, C.K., "Seismic Analysis of Vertical PVMPs Enclosed in Liquid Filled Containers", ASME Paper No. 75-PVP-56.
4. Pahl, P.J., "Modal Response on Containment Structures", Seismic Design for Nuclear Power Plants, MIT Press, Cambridge, Mass.
5. Forsberg, K., "Axisymmetrical and Beam-Type Vibrations of These Cylindrical Shells", AJAA Journal, Volume 7, February 1969.
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8. ABB Impell Report No. 01-8503-1784, "Seismic Analysis of the Reactor Building of the System 80+ Certified Design".
9. Impell Corporation, Calculation No. ALWR-2, "SSI Analysis of Case B3.5 with Common Basemat", Job No. 8503-003-1355, Revision 6.
10. U.S. NUCLEAR REGULATORY COMMISSION, "NUREG 1061", REPORT OF THE U.S. NUCLEAR REGULATORY COMMISSION PIPING REVIEW TEAM, APRIL, 1985.

Question 210.44

CESSAR-DC Section 3.7.3.13 provide criteria for the interaction of other piping with Category I piping. These criteria are not totally consistent with criteria in SRP 3.7.3, Rev. 2 Subsection II.8, and SRP 3.9.2, Subsection II.2.K.

Provide justification for the criteria in CESSAR-DC, Section 3.7.3.13 or modify the criteria to be consistent with SRP 3.7.3, Rev. 2, Subsection II.8, and SRP 3.9.2, Subsection II.2.K.

Response 210.44

CESSAR-DC Section 3.7.3.13 will be revised in accordance with SRP 3.7.3 Rev. 2 Subsection II.8.

RAI 210.44

3.7.3.12 Piping Outside Containment Structure

3.7.3.12.1 Buried Piping

Seismic design criteria for buried piping are as follows:

A. Intake structure is designed such that the differential movement between this structure and the earth is negligible and the seismic response spectrum utilized is the ground surface response.

B. Conformance to allowable structural and piping stresses after the line penetrates the Auxiliary Building is assured by the use of expansion joints.

An alternate design method is to use flexible seals as the lines pass through pipe sleeves in the structure.

Important factors considered are the flexibility, supports, and restraints of lines which are virtually anchored in earth but which penetrate a structure. A flexibility analysis of these lines is performed to demonstrate that the piping and structures are not overstressed under the additive differential movement of the earth and structure. I

3.7.3.12.2 Above Ground Piping

Seismic design criteria and methods of accounting for the effects of differential movement of buildings on piping and penetrations are described in Sections 3.7.2.1.2 and 3.7.2.7.

3.7.3.13 Interaction of Other Piping with Category I Piping

The protection of Category I piping from possible adverse effects of other piping during an earthquake is accomplished by several methods. Specifically, these methods are:

A. ~~Category I lines are physically separated from other lines to the extent possible so that failure of a line has no effect on Category I lines.~~

B. All Category I boundary valves are designed to meet seismic criteria. A valve always serves as a pressure boundary and constitutes the seismic to non-seismic boundary. If failure in the non-seismic portion of the system could cause loss of function of the safety system, then an appropriate automatic or remote manual operator would be used if the valve is open during normal reactor operation.

THE INTERACTION OF CATEGORY I LINES WITH NON-CATEGORY I LINES SHALL BE DESIGNED AS DESCRIBED IN CESSAR-DC SECTION 3.6.2.1.4.1.C.

Question 210.49

CESSAR-DC Section 3.9.1.4.1 states that for the evaluation of RCS faulted conditions, the pipe break load analysis procedure considered only those breaks not eliminated by leak-before-break (LBB).

(A) As indicated by a previous question, the LBB procedure has not been approved by the staff for the CESSAR-DC Standard Design and pipe breaks not considered on the basis of LBB must be included in the analysis.

(B) Moreover, CESSAR-DC Section 3.9.1.4.1 states that the branch line breaks analyses were performed using the MDC STRUDL computer code. Explain if the MDC STRUDL code includes ASME Code elbow flexibility factors and if the code was utilized for inelastic methods of analyses.

Response 210.49

(A) Refer to response to RAI 210.13.

(B) The MDC STRUDL code includes ASME code elbow flexibility factors. THe MDC STRUDL code was not utilized for inelastic methods of analysis.

Question 210.54

CESSAR-DC Section 3.9.2.5 indicates that based on LBB arguments, all main RCS loop pipe breaks and all major primary branch line breaks were eliminated from dynamic effects. Consequently, faulted conditions evaluation for the reactor vessel internals and CEDMs were based on 110 percent of SSE loads only.

The use of the 110 percent of SSE loads only for the evaluation of the reactor internals and CEDMs faulted conditions is currently unacceptable. Use of LBB procedures for the CESSAR-DC System 80+Standard Design has not yet been approved by the staff.

Accordingly, faulted conditions evaluations of the reactor internals and CEDMs should include the effects of ruptures currently not considered on the basis of LBB arguments. Revise Section 3.9.2.5 accordingly.

Response 210.54

Refer to response to RAI 210.13.

Question 210.55

CESSAR-DC Table 3.9-2 "Loading Combinations ASME Code Class 1, 2, and 3 Components" shows the level D condition to include component DF in the design loading combination. In footnote a., the description given for load component DF does not clearly indicate that a LOCA is a part of this load component. It is the staff's position that any level D loading combination shall include a LOCA and SSE. Revise the definition of DF in footnote a. to clearly indicate LOCA. Also, revise any other tables in CESSAR-DC which show loading combinations for which this would apply (e.g. Tables 3.9-10, 3.9-11, 3.9-14).

Response 210.55

Table 3.9-2 "Loading Combinations ASME Code Class 1, 2, and 3 Components" shows the level D condition to include component DF in the design loading combinations. DF is defined as systems loadings associated with a postulated pipe rupture for branch line breaks not eliminated by leak before break analysis. This includes LOCA and secondary side pipe breaks not eliminated by leak-before-break.

Table 3.9-2, 3.9-10, 3.9-11, 3.9-12, and 3.9-14 will be revised to clarify that postulated pipe ruptures include LOCA and secondary side pipe breaks not eliminated by leak-before-break.

RAI 210.55

TABLE 3.9-2

LOADING COMBINATIONS ASME CODE CLASS 1, 2, AND 3 COMPONENTS

Condition	Design Loading[(a)] Combination
Design	PD
Level A (Normal)(b)	PO+DW
Level B (Upset)(b)	PO+DW+OBE
Level C (Emergency)	PO+DW+DE
Level D (Faulted)	PO+DW+SSE+DF

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a) Legend:

PD = Design pressure

PO = Operating pressure

DW = Dead weight

OBE = Operating Basis earthquake

SSE = Safe shutdown earthquake

DE = Dynamic system loadings associated with the emergency condition

DF = Dynamic system loadings associated with a postulated pipe rupture for branch line breaks (LOCA and ~~[illegible]~~ secondary side) not eliminated by leak before break analysis.

b) As required by ASME Code Section III, other loads, such as thermal transient, thermal gradient, and anchor point displacement portions of the OBE require consideration in addition to the primary stress producing loads listed.

RAI 210.55

TABLE 3.9-10

LOADING COMBINATIONS FOR ASME SECTION III CLASS 1 PIPING

Service Level	Loading Combination
Design	Design Pressure, Design Temperature, Deadweight
Level A	Level A Transients, Deadweight
Level B	Level B Transients, Deadweight, Operating Basis Earthquake
Level C	Level C Transients, Deadweight
Level D	Level D Transients, Deadweight, Safe Shutdown Earthquake, postulated branch line pipe breaks (LOCA and [illegible]) not eliminated by leak before break

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NOTE: The dynamic loads are combined by the square root of the sum of the squares.

Secondary side

RAI 210.55

TABLE 3.9-11

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA FOR PRESSURIZER SAFETY VALVE PIPING AND SUPPORTS ASME CLASS 1 PORTION

Service Level	Load Combination*
Design	Design Pressure, Weight
Level A	Level A Transients, Weight
Level B	Level B Transients, Weight, OBE, VT**
Level C	Level C Transients, Weight, VT**
Level D	Level D Transients, Weight, SSE, VT**, postulated branch line pipe breaks (LOCA [illegible]) not eliminated by leak-before-break

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* Dynamic loads are combined by the square root of the sum of the squares (SRSS).

** Valve thrust loads (VT) are loads resulting from the rapid acceleration or deceleration of a water mass, noncondensible gases, or both.

E

secondary side

KAI [illegible]

TABLE 3.9-12

LOADING COMBINATIONS FOR ASME SECTION III CLASSES 2 AND 3 PIPING

Service Level	Loading Combination
Level A	Design Pressure, Design Temperature, Deadweight
Level B	Level B Transients Deadweight, Operating Basis Earthquake
Level C	Level C Transients Pressure, Deadweight
Level D	Level D Transients Deadweight, Safe Shutdown Earthquake, or Safe Shutdown Earthquake and ~~Pipe Rupture Load~~s postulated branch line pipe breaks (LOCA and secondary side) not eliminated by leak before break

NOTE: Dynamic loads are combined by the square root of the sum of the squares (SRSS).

RAI 210.35

TABLE 3.9-14

DESIGN LOADING COMBINATIONS FOR ASME CODE, CLASSES 1, 2, AND 3 PIPING SUPPORTS

Service Level	Loading Combination
Level A and Design	DW
Level B	DW + OBE + RV DW + OBE + DU
Testing	DW + DT
Level C	DW + SSE + DE
Level D	DW + SSE + DF

E

Legend:

DW	-	Piping deadweight
OBE	-	Operating Basis Earthquake
SSE	-	Safe Shutdown Earthquake
DT	-	Loads associated with testing
RV	-	Relief Valve
DU	-	Other transient dynamic events associated with the upset plant condition
DE	-	Dynamic events defined as emergency condition
DF	-	Dynamic events defined as a faulted condition including.

NOTE: Dynamic loads are combined by the square root of the sum of the squares (SRSS).

→ postulated pipe ruptures (LOCA and secondary side) not eliminated by leak-before-break

3

Question 210.56

CESSAR-DC Section 3.9.3 states and a number of loading combination tables indicate that pipe ruptures eliminated on the basis of LBB analyses were not considered in the Level D evaluation of ASME Code, Section III, Class 1, 2, and 3 components, component supports and Class CS core support structures. Currently, the staff has not approved the LBB methodology for CE System 80+ Standard Design (reference RAIs 210.13 and 252.03). Accordingly, pipe ruptures eliminated by LBB analyses must be considered and included in the load combination tables.

Response 210.56

Refer to response to RAI 210.13.

Question 210.74

CESSAR-DC Section 3.9.4.3 and Table 3.9-15 do not include LOCA among the loads considered in the CEDM stress analysis and the stress/deformation limits considered for the CEDM pressure housing, respectively.

Include the consideration of the LOCA loading to Section 3.9.4.3 and Table 3.9-15 pending staff approval of LBB procedures for CE System 80+ plants.

In addition, Table 3.9-15 should indicate that dynamic loads will be combined by the SRSS method in accordance with the guidelines of NUREG-0484, Rev. 1, 1980.

Response 210.74

Paragraph 3.9.4.3 and Table 3.9-15 will be revised to include dynamic loads produced by LOCA and secondary side pipe breaks not eliminated by LBB. (Refer also to response to RAI 210.13)

Table 3.9-15 will be revised to indicate that Level D dynamic loads produced by LOCA and secondary side pipe breaks not eliminated by LBB are combined by the SRSS method per NUREG-0484.

Question 210.75

CESSAR-DC Section 3.9.5.2 does not include LOCA among the core support and internal structures loading conditions. In addition, CESSAR-DC Section 3.9.5.3.2 refers to branch line breaks not eliminated by LBB criteria.

Include LOCA among the loads considered in Section 3.9.5.2 and delete reference to LBB criteria in Subsection 3.9.5.3.2 pending staff approval of LBB analyses for System 80+ plant designs.

Response 210.75

Refer to response to RAI 210.13.

*Question 210.90

The proposed resolution to GSI-119.1 concerning pipe rupture requirements indicated that LBB will be applied to certain piping systems including the pressurizer surge line. Also, the response to NRC Question 440.46 (see Enclosure I in your letter LD-91-024, dated May 16, 1991), indicated that measures are taken to ensure design adequacy of the surge line, including appropriate routing and arrangement of the surge line to minimize the effects of thermal stratification and to maintain acceptable stress, fatigue, and deflection levels.

Since LBB application requires staff approval of system specific analyses, verify that LBB analysis is complete and can be utilized to justify that protection against dynamic effects of the postulated pipe break is not needed in the surge line (reference RAI's 210.13 and 252.03). In addition, verify that analysis concerning thermal stratification and striping effects to the surge line is complete. Provide drawings of surge line layout and a summary description of the analysis results to demonstrate compliance with the applicable Code and Standard requirements.

With respect to increasing the SSE loads by a small factor to account for asymmetric blowdown loads associated with a small break LOCA, provide explanations of the magnitude, direction and dynamic nature of the blowdown loads to verify the adequacy of the factor used.

Response 210.90

CESSAR-DC currently provides design requirements, load combination criteria, leak-before-break acceptance criteria and methodology and the design basis to allow preparation of design specifications, piping and support designs and piping stress analyses. LBB analysis of the surge line is not complete. Please see the response to RAIs 210.13 and 252.03. The response to 252.03 outlines the technical approach to answer requests for additional information on the overall LBB issue and how it will be applied to the surge line.

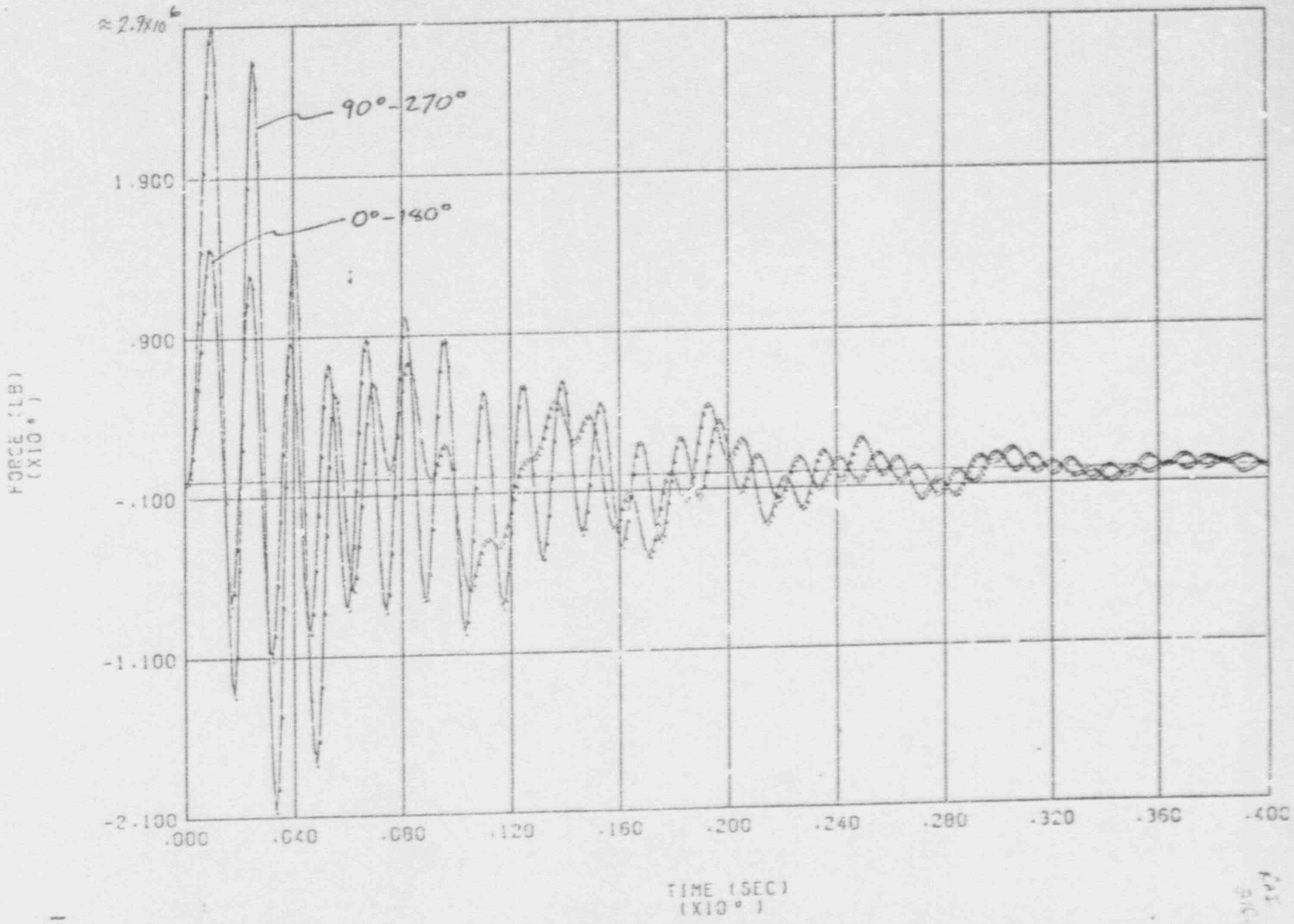
As noted in our response to RAI 252.03, a surge line piping analysis including thermal stratifications and stripping effects will be performed.

A typical small cold leg break LOCA blowdown response is shown in attached Figure 1. Two curves are presented, one

Response 210.90 (Continued)

for the resultant load parallel to the hot legs and the other perpendicular to the hot legs. Also, a study was made to determine the System 80+ internals responses for a 30 inch cold leg break. Table [illegible] shows the resulting peak component shear loads and moments and SSE response loads. The results show in all cases that the combined SRSS design load increases are less than 10 percent since the LOCA loads are all less than 0.46 times the SSE loads, thus verifying the adequacy of the factor used.

SYST 80 LAT LOCA (100 FPIB, BILINEAR)



11

KAI

RAI 210.99

COMBINED SMALL BREAK LOCA AND SSE LOADINGS

COMPONENT	FPIB $30 IN^2$ COLD LEG BREAK (SHEAR/MOMENT)	SSE LOADS (SHEAR/MOMENT)	SRSS OF SSE + LOCA (SHEAR/MOMENT)	SRSS/SSE (SHEAR/MOMENT)
CORE SUPPORT BARREL				
-UPPER FLANGE	.425E6/.162E8	.235E7/.125E9	.239E7/.126E9	1.02/1.01
-CENTER CYLINDER	.228E6/.255E8	.117E7/.774E8	.119E7/.815E8	1.02/1.05
- LOWER FLANGE	.136E6/.721E7	.107E7/.588E8	.108E7/.592E8	1.01/1.01
LOWER SUPPORT STRUCTURE	.118E6/.671E7	.106E7/.729E8	.107E7/.732E8	1.01/1.00
CORE SHROUD	.122E6/.584E7	.92E6/.575E8	.928E6/.578E8	1.01/1.01
UPPER GUIDE STRUCTURE				
-UPPER FLANGE	.208E6/.986E7	.21E7/.129E9	.211E7/.129E9	1.00/1.00
-LOWER FLANGE	.172E6/.962E7	.46E6/.335E8	.473E6/.349E8	1.03/1.04
-UPPER PACKAGE/UGS ℄	.152E6/.235E6	N/A/.172E8	—/.172E8	N/A/1.00

Question 210.91

For USI A-2 concerning integrity of reactor internals and vessel supports under rapidly occurring internal and external asymmetric pressure transient loading induced by a break of the primary coolant piping, your resolution indicated that the LBB methodology is used. Thus the resultant LOCA loads on the primary system component are no longer significant. Since LBB application requires staff approval of system specific analysis, clarify your intention either to submit LBB analysis, or to perform LOCA analysis for the primary system components based on a break of the primary coolant piping.

Response 210.91

Refer to response to RAI 210.13.

Question 210.92

For USI A-1, provide a list of systems for which you have incorporated water hammer loads in piping designs. Verify that for these systems, you have the following detailed information documented for ensuring design adequacy of piping and supports: (a) detail piping and support layout drawings, (b) calculation packages or stress reports to show definition of loads and calculation details for verifying that the analytical approach used and analysis results obtained are in compliance with applicable Codes and licensing requirements, and (c) operating procedures, technical specifications or administration controls that are applicable to prevent or minimize the occurrence of water hammer in those systems.

Response 210.92

The USI A-1 response in CESSAR-DC discusses systems which are susceptible to water hammer, and design features to minimize water hammer. CESSAR-DC contains design criteria which will be used to preclude destructive water hammer including:

- 90 degrees downward vertical elbow at each steam generator feedwater nozzle. This feature minimizes the amount of horizontal piping susceptible to steam void formation.
- Continuously rising feedwater (FW) and emergency feedwater (EFW) inside containment. Also, all FW and EFW lines have check valves inside containment. These piping layout criteria, along with the feedwater ring outlet design in the steam generators maintain the piping full during low flow conditions and prevent column separation during transients.
- Adequate filling and venting provisions to minimize voids in piping.
- Steam piping arrangement and drain system design to preclude condensation-induced water hammer during normal operation and startup.
- Water hammer consideration in specifying valve operating times.
- Preoperational testing to ensure no unacceptable water hammer in the FW and EFW systems during startup, normal operation and transients.

The detailed design (piping and support layout drawings, stress reports, operating procedures, etc.) will depend on vendor-supplied information. It is the position of ABB-CE as presented to the Staff at the meeting of November 26 that this detailed information is (1) not required for certification, (2) depends on plant-specific details not finalized at the certifications stage, and (3) is subject to revision until specific details of piping and other plant design are finalized.

Prevention of water hammer will also be addressed in the System 80+ Distribution Systems Guide, which was discussed during the November 26 meeting. This guide will provide an integrated approach for optimizing the layout and detailed detailed design of piping, HVAC, cable trays and conduits. The purpose of this guide is to facilitate a final design which meets all safety criteria and which optimizes plant operation and maintenance. A detailed outline of the guide is currently being prepared. Design considerations and guidance in preventing destructive water hammer will be one of the major topics of this document.

The Distribution Systems Guide will be included on the docket and will be available for audit by the Staff.

(See also 210.8 Question and Answer)

Question 210.93

Verify that the following information is available and properly documented for resolution of USI A-13 concerning snubber operability assurance: (a) detail piping layout drawings to show number, types and locations of snubbers in all Seismic Category I systems, and (b) procedures of snubber operability assurance program. If such information is not available, the schedule to complete such information should be provided.

Response 210.93

A. It is the position of C-E, as presented to the Staff at the meeting of November 26, that piping layout and plant arrangement drawings that provide number, types, and locations of snubbers in seismic Category I piping represents detailed information that is (1) not required for certification, (2) depends on plant-specific details not finalized at the certification stage and (3) is subject to revision until specific details of piping and other plant design are finalized. It was also agreed at that meeting that a Distribution Systems Design Guide would be prepared to ensure that the final design would be completed consistent with the design basis and methodology in CESSAR-DC.

   The issue is considered to be a question of the level of detail necessary for ALWR certification. See response to NRC RAI 210.12 for C-E's position on level of detail.

B. This issue is considered to be a question of the level of detail necessary for ALWR certification as responded to in part a. above. Assurance of snubber operability for the System 80+ Standard Design will be provided by specification, qualification testing, and/or production testing with guidelines and procedures established in parallel with industry standards. Refer to CESSAR-DC, Appendix A and the response to RAI 210.89 for the resolution to USI A-13: Snubber Operability Assurance.

Question 220.50

Section 3.8.3.1 and Section 3.6 - It is stated that "The secondary shield wall... protects the steel containment vessel from internal missiles." Are there potential sources of missiles and high energy line breaks between the secondary shield wall and steel containment, between the steel containment and the shield building, and between the steel containment and the operating floor and refueling cavity walls?

Response 220.50

There are high energy lines between the secondary shield wall and steel containment, and between the steel containment and the shield building. High energy lines to be considered for high energy line breaks are listed in CESSAR-DC, Tables 3.6-3 and 3.6-4, which include these areas. Tables 3.6-3 and 3.6-4 will be updated in the next amendment to CESSAR-DC.

Some high energy lines in containment will be analyzed to demonstrate leak-before-break (LBB) to eliminate them from consideration for high energy line break potential. For the remainder of the high energy lines in containment, protection of safety-related components and equipment from high energy line breaks and missiles will be provided by separation, guard pipes, shields, whip restraints, etc. Postulated missiles from equipment in containment are listed in CESSAR-DC, Table 3.5.1.

There are no lines to be considered for high energy line breaks in the area between the steel containment and the operating floor and refueling cavity walls.

High energy lines between the steel containment and the shield building will be enclosed in guard pipes. There are no postulated missiles from equipment between the steel containment and the shield building.

Question 252.03

Section 3.6.3 Leak-Before-Break Evaluation Procedure

The application of Leak-Before-Break (LBB) to piping systems is permitted in GDC-4 in Appendix A to 10 CFR Part 50, published in Federal Register, Volume 52, No. 207, Rules and Regulations, Pages 41288 to 41295, October 27, 1987. GDC-4 states, in part, that, "....dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping."

The analyses referred to in GDC-4 should be based on specific plant data, such as piping geometry, material specifications, piping loads, and pipe support locations. The staff must review and approved the LBB analysis for specific piping systems before dynamic effects can be excluded from the design basis. The staff does not pre-approve the LBB procedure. The staff requires the following:

- The LBB analysis must include a deterministic fracture mechanics evaluation. The acceptance criteria for the LBB analysis are delineated in NUREG-1061, Volume 3, "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee, Evaluation of Potential for Pipe Break."

- The LBB analysis must evaluate the potential for water hammer, corrosion, fatigue, erosion, environmental conditions, indirect failure mechanisms and other degradation sources which could lead to pipe rupture. The effectiveness of any mitigating measures should be supported with actual data.

- The LBB analysis must show from the results of a fracture mechanics analysis that a substantial range of stable pipe crack sizes can exist for an extended period which provides detectable leaks and that the fluid systems piping will not rupture under these conditions consistent with the design basis for the piping.

The staff has the following comments on the LBB procedures in Section 3.6.3; however, response to the comments is not necessary. They are provided for future references:

In Section 3.6.3.3.1, CE indicated that the LBB analysis will be used for the main steam line. The future applicant that references the System 80+ design needs to submit the LBB analysis for review.

Section 3.6.3.1.6 referred to in Section 3.6.3.4 does not exist in CESSAR-DC.

Response 252.03

As presented to the Staff at the meeting of November 26, leak before break (LBB) evaluations represent detailed information that (1) is not required for certification, (2) depends on plant-specific details not finalized at the certification stage and (3) is subject to revision until specific details of piping and other plant design are finalized.

CESSAR-DC currently provides acceptance criteria and analysis methodology for LBB evaluations. It also provides some of the information needed for LBB evaluations, such as pipe sizes, P&IDs, and building and RCS seismic response information. Specific plant data, which is necessary for the deterministic fracture mechanics evaluations that the Staff requests, are not currently available.

In lieu of LBB evaluations based on detailed piping design and specific plant data, C-E offers the following technical approach which was outlined during the November 26th meeting.

1. Preparation of a Distribution Systems Guide.

   This guide will provide an integrated approach for optimizing the layout and detailed design of piping, HVAC, cable trays and conduits. The purpose of the guide is to facilitate a final design which meets all safety criteria and which optimizes plant operation and maintenance. A detailed outline of the guide is currently being prepared. Design considerations and guidance in LBB evaluation will be one of the major topics of the document. The general outline for the section on LBB is as follows:

Leak Before Break (LBB)

Plant and Piping Design Considerations

LBB Acceptance Criteria

Analysis

The LBB section of the guide will include consideration of leak detection systems, pipe sizes and material properties, system transients, steps to minimize stratified flow, water hammer and steam hammer, potential for pipe degradation sources, LBB acceptance criteria, the analytical process, and evaluation of analytical results.

2. Preparation of a set of sample piping layouts and analyses, which will include a preliminary LBB evaluation of the surge line.

The purpose of preparing these samples is to demonstrate the use of the guide in performing detailed design of distribution systems. The surge line was specifically chosen to be the sample piping system for demonstration of LBB because the evaluation will demonstrate LBB methodology and use of the guide for a tributary pipe and specifically demonstrate that the surge line thermal flow stratification issue is satisfied.

The samples will use best available information. Where detailed information is not available, design parameters will be assumed based on experience or previous designs. The sample layouts and analyses using the guide are intended to demonstrate that the information currently in CESSAR-DC and further developed in the guide supports the safety review by the Staff and provides additional assurance that plant design safety criteria will be met.

It is C-E's position that the above information will preclude the necessity for including in the design basis the dynamic effects of postulated ruptures of pipes for which CESSAR-DC states that LBB is demonstrated.

The reference to Section 3.6.3.1.6 will be deleted from Section 3.6.3.4 of CESSAR-DC.

RAI 252.03

failure from the effects of corrosion, water hammer or low- and high-cycle fatigue, or degradation or failure of the piping from indirect causes.

3.6.3.2 Leakage Crack Location

A survey of the piping is performed to determine the locations of highest stress loading and coincident poorest material properties. All base metal, weld materials, heat affected zones in the vicinity of the terminal ends, and all intermediate elbow locations are considered.

3.6.3.3 Leak Detection

There are two major aspects to leak rate based on crack detection in addition to the crack opening size; leak detection capability, and flow rate correlation for leakage through a crack.

3.6.3.3.1 Leak Detection System

A leak detection system is recommended by Regulatory Guide 1.45, Reference 8, capable of detecting a leakage rate of ~~less than~~ 1.0 gpm or less from the primary system. NUREG-1061, Volume 3, recommends a safety margin of ten on the leak detection system. Diverse measurement means are provided, including water inventory monitoring, sump level and flow monitoring, and measurement of airborne radioactive particulates or gases (see Section 5.2.5). Leak detection system requirements to support the LBB analysis for main steam line piping are met by a combination of humidity detectors, air coolers, radioactive airborne activity sensors and sump flow and level meters.

3.6.3.3.2 Flow Rate Correlation

The other major aspect of crack detection based on the leak rate, namely the flow rate correlation for leakage through a given crack size, cannot be predicted precisely. Variables such as surface roughness of the side walls of the crack, the nonparallel relationship of the side walls due to th elongated crack shape, and possibly zigzag tearing of the material during crack formation all introduce uncertainties in defining an exact flow rate correlation.

The leakage rate required to be detectable is 1.0 gpm. The licensing guidelines (NUREG 1061, Volume 3) recommend a factor of 10 on that leakage rate, for conservatism; therefore, a crack length which leaks a maximum of 10 gpm at normal operating conditions is selected as the design leakage crack. Increased accuracy and sensitivity of the leak detection system are utilized, where possible, to reduce the size of the design leakage crack to one which leaks less than 10 gpm. Using recent work by EPRI (Reference 10), the leakage rate per square inch of leak area in the 10 gpm leakage rate range is computed to be approximately 250

1.6

gpm per square inch for the primary system for the range of pipe sizes of interest. The crack opening area corresponding to the 10 gpm rate is found to be 0.04 square inch. This crack opening area is used to determine the length of the detectable crack for stability evaluation.

3.6.3.4 Screening of Leakage Crack Sizes Using EPRI/GE Estimation Scheme

Prior to detailed calculations of through-wall leakage cracks and corresponding margins on loads and crack sizes, a preliminary scoping evaluation is performed. In this part, all possible locations in the piping evaluated are screened to identify the most critical candidates for detailed study. The screening study is performed using the EPRI/GE estimation scheme (Reference 11) for the determination of crack opening areas using elastic plastic fracture mechanics methods, and the C-E developed JEST computer program for the leakage rates through cracks.

This estimation procedure is used to compare the severity of hypothesized flaws in all piping locations in order to reduce the number of cases to be subjected to detailed analysis. The procedure also provides an estimate of the leakage crack length for input to the detailed finite-element analysis, ~~discussed in Section 3.6.3.1.6.~~

3.6.3.5 Material Properties

For the main coolant loop, the hot and cold leg piping material is SA516 Gr70. All hot- and cold-leg pipe-to-pipe welds and the pipe-to-reactor vessel, steam generator and reactor coolant pump safe end welds are carbon steel. All main loop component nozzles are SA508 CL 2 or 3 carbon steel or SA541 CL 1, 2 or 3. The surge line is SA351 GR CF8M stainless steel, resulting in bimetallic safe end welds. The shutdown cooling line and the direct vessel safety injection line are both Type 304 stainless steel. The main steam line is SA516 Gr70.

The detailed analysis of cracks in pipe welds requires consideration of the properties of the pipe and the weld materials. Previous work by C-E has shown that a conservative bounding analysis results when the material stress-strain properties of the base metal (lower yield) and the fracture properties of the weld (lower toughness) are used for the entire structure, (Reference 12). This material representation is used for all analyses. The tensile (stress-strain) curves and the J_D vs. Δa curves are required for each material type.

Question 252.15

USI 15 Radiation Effects on Reactor Vessel Supports

In the Resolution section, CE states that irradiation effects are addressed in the fracture analysis of the supports. NRC needs to approve this analysis before the issue is resolved. CE also states that "the conservatism of this analysis is further enhanced by the adoption of the leak-before-break (LBB) method in the System 80+ Design Basis." CE cannot adopt the LBB method without the staff approval.

CE also needs to provide the fracture toughness data of the reactor vessel supports in Section 5.4.14.2.

Response 252.15

Refer to response to RAI 210.13 concerning request for information on LBB.

Section 5.4.14.3 of CESSAR-DC states that the structural integrity of RCS support components is ensured during fabrication. Fracture toughness data for reactor vessel supports will be made available during the construction stage.