U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

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

**REVIEW RESPONSIBILITIES**

**Primary**- Organization responsible for Mechanical Engineering reviews

**Secondary**- None

I. AREAS OF REVIEW

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 requires, in part, that structures, systems, and components (SSCs) important to safety be designed to accommodate the effects of postulated accidents, including appropriate protection against the dynamic effects of postulated pipe ruptures.

Information concerning break and crack location criteria and methods of analysis for evaluating the dynamic effects associated with postulated breaks and cracks in high- and moderate-energy fluid system piping, including "field run" piping inside and outside of containment, should be provided in the applicant's safety analysis report (SAR). This information is reviewed by the staff in accordance with this Standard Review Plan (SRP) section to confirm that there is appropriate protection of SSCs components relied upon for safe reactor shutdown or to mitigate the consequences of a postulated pipe rupture.

The specific areas of review are as follows:

1. The criteria used to define break and crack locations and configurations.

2. The analytical methods used to define the forcing functions, including the jet thrust reaction at the postulated pipe break or crack location and jet impingement loadings on adjacent safety-related SSCs.

3. The dynamic analysis methods used to verify the integrity and operability of mechanical components, component supports, and piping systems, including restraints and other protective devices, under postulated pipe rupture loads.

4. The criteria for defining pipe break and crack locations and configurations.

5. The criteria dealing with special features, such as augmented inservice inspection programs or the use of special protective devices such as pipe-whip restraints, including diagrams showing final configurations, locations, and orientations in relation to break locations in each piping system.

6. The acceptability of the analysis results, including jet thrust and impingement forcing functions, and pipe-whip dynamic effects.

7. The design adequacy of systems, components, and component supports to ensure that the intended design functions will not be impaired to an unacceptable level of integrity or operability as a result of pipe-whip or jet impingement loadings.

8. Inspection, Test, Analysis, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the applicant's proposed information on the ITAAC associated with the SSCs related to this SRP section is reviewed in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria - Design Certification." The staff recognizes that the review of ITAAC is performed after review of the rest of this portion of the application against acceptance criteria contained in this SRP section. Furthermore, the ITAAC are reviewed to assure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

9. COL Action Items and Certification Requirements and Restrictions. COL action items may be identified in the NRC staff's final safety evaluation report (FSER) for each certified design to identify information that COL applicants must address in the application. Additionally, DCs contain requirements and restrictions (e.g., interface requirements) that COL applicants must address in the application. For COL applications referencing a DC, the review performed under this SRP section includes information provided in response to COL action items and certification requirements and restrictions pertaining to this SRP section, as identified in the FSER for the referenced certified design.

Review Interfaces

The listed SRP sections interface with this section as follows:

1. The staff reviews plant arrangements where separation of high-and moderate-energy systems is the method of protection for essential systems and components outside containment in accordance with SRP Section 3.6.1. The reviewer identifies high-and moderate-energy systems outside containment and the essential systems and components that must be protected from postulated pipe rupture in these high-and moderate-energy systems.

2. If an applicant proposes to use leak-before-break technology to exclude the dynamic effects of postulated pipe ruptures from the design basis of plant SSCs, the staff will review the applicant's design and analyses in accordance with SRP Section 3.6.3.

3. The staff reviews for adequacy the loading combinations and other design aspects of protective structures of compartments used to protect essential systems and components in accordance with SRP Sections 3.8.3 and 3.8.4. The organization responsible for inservice inspection and related design provisions of high-and moderate-energy systems, including those associated with the break exclusion regions, reviews the information in accordance with SRP Sections 5.2.4 and 6.6.

4. The staff reviews high-and moderate-energy systems inside containment and the essential systems and components that must be protected from postulated pipe rupture in these high-and moderate-energy systems, such as the emergency core cooling system, in accordance with SRP Section 6.3.

5. The staff reviews the information described for environmental effects of pipe rupture, such as temperature, humidity, and spray-wetting, with respect to the functional performance of essential electrical equipment and instrumentation, in accordance with SRP Section 3.11.

6. The staff reviews to verify that piping systems penetrating the containment barrier are designed with acceptable isolation features to maintain containment integrity in accordance with SRP Section 6.2.4.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

## II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. GDC 4, as it relates to SSCs important to safety being designed to accommodate the dynamic effects associated with postulated pipe rupture.

2. 10 CFR 52.47(b)(1), as it relates to ITAAC (for DC) sufficient to assure that the SSCs in this area of review will operate in accordance with the certification.

3. 10 CFR 52.80(a), as it relates to ITAAC (for COL) sufficient to assure that the SSCs in this area of review have been constructed and will be operated in conformity with the license, the provisions of the Atomic Energy Act, and the Commission's rules and regulations.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for review described in Subsection I of this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

With respect to meeting the relevant requirements of GDC 4:

1. Postulated Pipe Rupture Locations Inside Containment. Acceptable criteria to define postulated pipe rupture locations and configurations inside containment are specified in SRP Section 3.6.2, Appendix A.

2. Postulated Pipe Rupture Locations Outside Containment. Acceptable criteria to define postulated rupture locations and plant layout considerations for protection against postulated pipe ruptures outside containment are specified in SRP Section 3.6.2, Appendix A.

3. Methods of Analysis. Detailed acceptance criteria covering pipe-whip dynamic analysis, including determination of the forcing functions of jet thrust and jet impingement, are included in subsection III, "Review Procedures," of this SRP section. The general bases and assumptions of the analysis are given in SRP Section 3.6.2, Appendix A, subsection 2.C.

Technical Rationale

The technical rationale for application of these requirements and/or SRP acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. Compliance with GDC 4 requires that nuclear power plant SSCs important to safety be designed to accommodate the effects of, and be compatible with, the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These SSCs shall be protected against certain dynamic effects, including pipe-whipping and discharging fluids. Such dynamic effects may be excluded from the design basis if the probability of pipe rupture is shown to be extremely low under conditions consistent with the design basis for piping.

2. Meeting the requirements of GDC 4 provides assurance that safety-related SSCs will be protected from dynamic effects of pipe-whip and discharging fluids that could result from expected environmental conditions, thereby ensuring the ability of these SSCs to perform their intended safety functions.

## III. REVIEW PROCEDURES

The reviewer will select and emphasize material from the procedures described below, as may be appropriate for a particular case.

For each area of review specified in subsection I of this SRP section, the review procedure is identified below. These review procedures are based on the identified SRP acceptance criteria. For deviations from these specific acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives to the SRP criteria provide an acceptable method of complying with the relevant NRC requirements identified in subsection II.

1. The staff reviews the criteria for locations and configurations of breaks in high-energy piping and leakage cracks in moderate-energy piping.

   A. At the Construction Permit (CP) stage, the applicant's criteria for determining break and crack locations are reviewed for conformance with the acceptance criteria referenced in subsection II of this SRP section.

      Exceptions taken by the applicant to the referenced pipe break location and configuration criteria must be identified and the basis clearly justified so that evaluation is possible. Deviations from approved criteria and the justifications provided are reviewed to determine acceptability.

   B. At the OL stage, the following are reviewed to ensure that the pipe break criteria have been properly implemented:

      (i) Sketches showing the locations of the resulting postulated pipe ruptures, including identification of longitudinal and circumferential breaks; structural barriers, if any; restraint locations; and the constrained directions in each restraint.

      (ii) A summary of the data developed to select postulated break locations, including, for each point, the calculated stress intensity, the calculated cumulative usage factor, and the calculated primary plus secondary stress range as delineated in References 2 and 3 and Appendix A of SRP Section 3.6.2.

2. The staff reviews the analyses of pipe motion caused by the dynamic effects of postulated breaks. These analyses should show that pipe motions will not result in unacceptable impact upon, or overstress of, any SSCs important to safety to the extent that essential functions would be impaired or precluded. The analysis methods used should be adequate to determine the resulting loadings in terms of the kinetic energy or momentum induced by the impact of the whipping pipe, if unrestrained, upon a protective barrier or a component important to safety and to determine the dynamic response of the restraints induced by the impact and rebound, if any, of the ruptured pipe.

   An unrestrained whipping pipe should be considered capable of causing circumferential and longitudinal breaks, individually, in impacted pipes of smaller nominal pipe size, and of developing through-wall cracks in equal or larger nominal pipe sizes with thinner wall thickness, except where analytical or experimental, or both, data for the expected range of impact energies demonstrate the capability to withstand the impact without rupture.

At the CP stage, the staff reviews the applicant's criteria, methods, and procedures used or proposed for dynamic analyses by comparing them to the following criteria. At the OL stage, the analyses are reviewed in accordance with these criteria.

A. Dynamic Analysis Criteria. An analysis of the dynamic response of the pipe run or branch should be performed for each longitudinal and circumferential postulated piping break.

The loading condition of a pipe run or branch, prior to the postulated rupture, in terms of internal pressure, temperature, and inertial effects should be used in the evaluation for postulated breaks. For piping pressurized during operation at power, the initial condition should be the greater of the contained energy at hot standby or at 102% power.

In case of a circumferential rupture, the need for a pipe-whip dynamic analysis may be governed by considerations of the available driving energy.

Dynamic analysis methods used for calculating piping and restraint system responses to the jet thrust developed after the postulated rupture should adequately account for the following effects: (a) mass inertia and stiffness properties of the system, (b) impact and rebound, (c) elastic and inelastic deformation of piping and restraints, and (d) support boundary conditions.

If a crushable material, such as honeycomb, is used, the allowable capacity of crushable material should be limited to 80% of its rated energy dissipating capacity as determined by dynamic testing, at loading rates within $\pm$50% of the specified design loading rate. The rated energy dissipating capacity should be taken as not greater than the area under the load-deflection curve as illustrated in Figure 3.6.2-1. The portion of the curve in which the value of load vs. deflection has departed from the essentially horizontal portion should not be used. Pure tension members should be limited to an allowable strain of 50% of the ultimate uniform strain ($X_m$) (see Figure 3.6.2-2(a)). Alternatively, the allowable strain value may be determined as the value of strain associated with 50% of the ultimate uniform energy absorption capacity as determined by dynamic testing at loading rates within $\pm$50% of the specified design loading rate (see Figure 3.6.2-2(b)). The method of dynamic analysis used should be capable of determining the inelastic behavior of the piping and restraint system within these design limits.

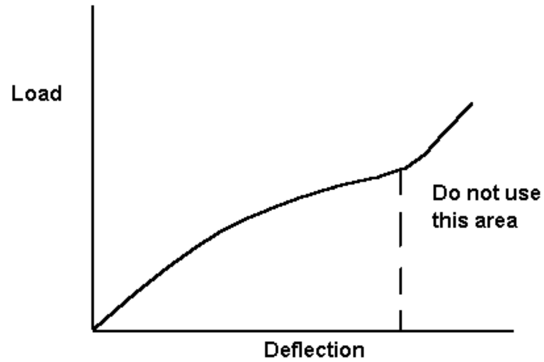


Figure 3.6.2-1 Rated energy dissipating capacity

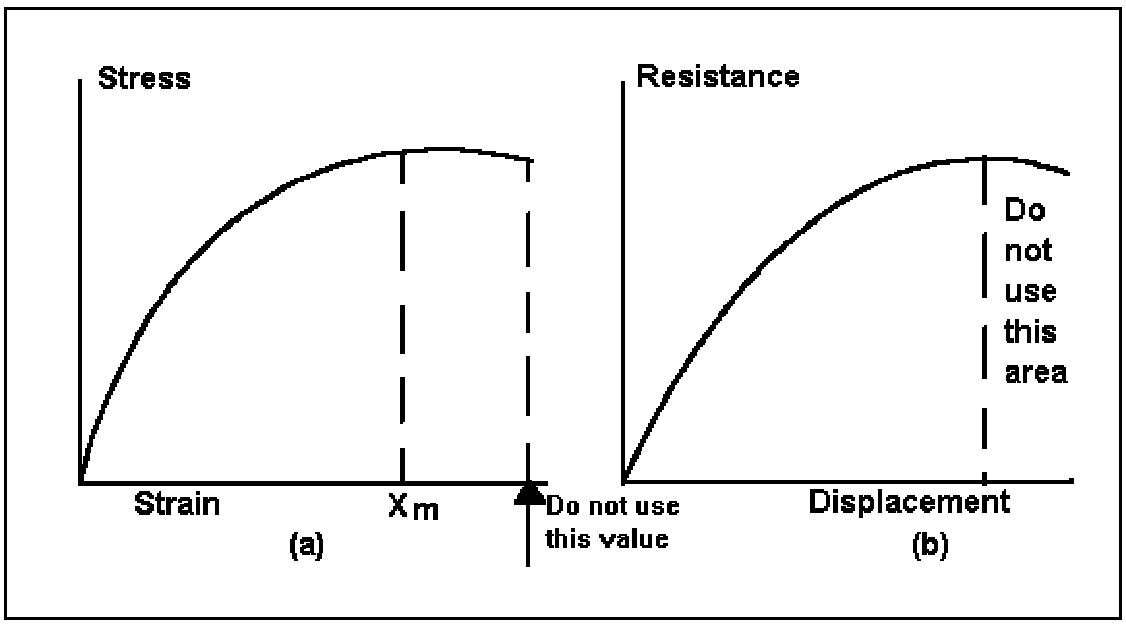


Figure 3.6.2-2 Limitations on pure tension members

A 10% increase of minimum specified design yield strength ($S_y$) may be used in the analysis to account for strain rate effects.

Dynamic analysis methods and procedures presented should include:

(i) A representative mathematical model of the piping system or piping and restraint system.

(ii) The analytical method of solution selected.

(iii) Solutions for the most severe responses among the piping breaks analyzed.

(iv) Solutions with demonstrable accuracy or justifiable conservatism.

The extent of mathematical modeling and analysis should be governed by the method of analysis selected.

B. Dynamic Analysis Models for Piping Systems. Analysis should be conducted of the postulated ruptured pipe and pipe-whip restraint system response to the fluid dynamic force.

Acceptable models for the analysis of ASME Class 1, 2, and 3 piping systems and other nonsafety-class high-energy piping systems include the following:

(i) Lumped Parameter Analysis Model: Lumped mass points are interconnected by springs to take into account inertia and stiffness properties of the system, and time histories of responses are computed by numerical integration, taking into account clearances at restraints and inelastic effects. In the calculation, the maximum possible initial clearance should be used to account for the most adverse dynamic effects of pipe-whip.

(ii) Energy Balance Analysis Model: Kinetic energy generated during the first quarter cycle movement of the rupture pipe and imparted to the piping and restraint system through impact is converted into equivalent strain energy. In the calculation, the maximum possible initial clearance at restraints should be used to account for the most adverse dynamic effects of pipe-whip. Deformations of the pipe and the restraint should be compatible with the level of absorbed energy. The energy absorbed by the pipe deformation may be deducted from the total energy imparted to the system. For applications where pipe rebound may occur upon impact on the restraint, an amplification factor of 1.1 should be used to establish the magnitude of the forcing function in order to determine the maximum reaction force of the restraint beyond the first quarter cycle of response. Amplification factors other than 1.1 may be used if justified by more detailed dynamic analysis.

(iii) Static Analysis Model: The jet thrust force is represented by a conservatively amplified static loading, and the ruptured system is analyzed statically. An amplification factor can be used to establish the magnitude of the forcing function. However, the factor should be based on a conservative value obtained by comparison with factors derived from detailed dynamic analyses performed on comparable systems.

(iv) Other models may be considered if justified.

C. Dynamic Analysis Models for Jet Thrust Justified.

(i) The time-dependent function representing the thrust force caused by jet flow from a postulated pipe break or crack should include the combined effects of the following: the thrust pulse resulting from the sudden pressure drop at the initial moment of pipe rupture; the thrust transient resulting from wave propagation and reflection; and the blowdown thrust resulting from buildup of the discharge flow rate, which may reach steady state if there is a fluid energy reservoir having sufficient capacity to develop a steady jet for a significant interval. Alternatively, a steady state jet thrust function may be used, as outlined in subsection III.2.C(iv), below.

(ii) A rise time not exceeding one millisecond should be used for the initial pulse, unless a combined crack propagation time and break opening time greater than one millisecond can be substantiated by experimental data or analytical theory based on dynamic structural response.

(iii) The time variation of the jet thrust forcing function should be related to the pressure, enthalpy, and volume of fluid in the upstream reservoir and the capability of the reservoir to supply a high energy flow stream to the break area for a significant interval. The shape of the transient function may be modified by considering the break area and the system flow conditions, the piping friction losses, the flow directional changes, and the application of flow-limiting devices.

(iv) The jet thrust force may be represented by a steady state function if the energy balance model or the static model is used in the subsequent pipe motion analysis. In either case, a step function amplified as indicated in subsection III.2.B(ii) or III.2.B(iii), above, is acceptable. The function should have a magnitude not less than

$$T = KpA$$

where

p = system pressure prior to pipe break,
A = pipe break area, and
K = thrust coefficient.

To be acceptable, K values should not be less than 1.26 for steam, saturated water, or stream-water mixtures or 2.0 for subcooled, nonflashing water.

3. The following assumptions in modeling jet impingement forces are consistent with the guidance in the American National Standard Institute (ANSI)/American Nuclear Society (ANS) standard 58.2-1998 currently used by industry. The ANSI/ANS 58.2 standard has been accepted by the NRC. However, based on recent comments from the Advisory Committee on Reactor Safeguards (ACRS) (See Refs.7 and 8), it appears that some assumptions related to jet expansion modeling in the ANSI/ANS 58.2 standard may lead to nonconservative assessments of the jet impingement loads postulated pipe breaks on

neighboring SSCs. The NRC staff is currently assessing the technical adequacy of the information pertaining to dynamic analyses models for jet thrust force and jet impingement load that are included in this SRP Section and ANSI/ANS 58.2. Pending completion of this effort, the NRC staff will review analyses of the jet impingement forces on a case by case basis. These analyses should show that jet impingement loadings on nearby safety related SSCs will not impair or preclude their essential functions.

The assumptions are as follows:

A. The jet area expands uniformly at a half angle, not exceeding 10 degrees.

B. The impinging jet proceeds along a straight path.

C. The total impingement force acting on any cross-sectional area of the jet is time and distance invariant, with a total magnitude equivalent to the jet thrust force as defined in subsection III.2.C(iv), above.

D. The impingement force is uniformly distributed across the cross-sectional area of the jet, and only the portion intercepted by the target is considered.

E. The break opening may be assumed to be a circular orifice of cross-sectional flow area equal to the effective flow area of the break.

F. Jet expansion within a zone of five pipe diameters from the break location is acceptable if substantiated by a valid analysis or testing, i.e., Moody's expansion model (Ref. 9). However, jet expansion is applicable to steam or water-steam mixtures only and should not be applied to cases of saturated water or subcooled water blowdown.

4. Analyses of pipe-break dynamic effects on mechanical components and supports should include the effects of both internal reactor pressure vessel asymmetric pressurization loads and expanded asymmetric compartment pressurization loads, as appropriate, as discussed for pressurized water reactor (PWR) primary systems in Reference 10.

5. For reviews of DC and COL applications under 10 CFR Part 52, the reviewer should follow the above procedures to verify that the design set forth in the safety analysis report (and, if applicable, the site interface requirements) meets the acceptance criteria. For DC applications, the reviewer should identify necessary COL action items. With respect to COL applications, the scope of the review is dependent on whether the COL applicant references a DC, an ESP, or other NRC-approved material, applications, and/or reports.

   After this review, SRP Section 14.3 should be followed for the review of Tier I information for the design, including the postulated site parameters, interface criteria, and ITAAC.

## IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The staff concludes that the applicant has postulated pipe ruptures appropriately, has designed SSCs to accommodate and protect against the associated dynamic effects, and, therefore, has met the relevant requirements of GDC 4. This conclusion is based on the following:

1. The applicant has appropriately identified/postulated proposed pipe rupture locations, and the design of piping restraints and measures to deal with the subsequent dynamic effects of pipe-whip and jet impingement provide adequate protection for the integrity and functionality of the safety-related SSCs.

2. The applicant's provisions for protection against dynamic effects associated with pipe ruptures of the reactor coolant pressure boundary (RCPB) inside containment and the resulting discharging fluid provide adequate assurance that design basis loss-of-coolant accidents will not be aggravated by sequential failures important to safety-related piping, and emergency core cooling system performance will not be degraded by such dynamic effects.

3. The applicant's proposed piping and restraint arrangement and applicable design considerations for high- and moderate-energy fluid systems inside and outside of containment, including the RCPB, provide adequate assurance that the SSCs important to safety that are in close proximity to the postulated pipe rupture will be appropriately protected. The proposed design appropriately mitigates the consequences of pipe ruptures so that the reactor can be safely shut down and maintained in a safe shutdown condition in the event of a postulated rupture of a high- or moderate-energy piping system inside or outside of containment.

For DC and COL reviews, the findings will also summarize (to the extent that the review is not discussed in other SER sections) the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable, and interface requirements and COL action items relevant to this SRP section.

## V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section, unless superceded by a later revision.

For protection against postulated pipe ruptures outside containment, all applicants should demonstrate conformance to criteria as described in Appendix A of SRP Section 3.6.2.
The plants for which construction permit applications were tendered before July 1, 1973, may use design criteria for protection against postulated pipe ruptures outside containment as

described in reference 2 of this SRP. Reference 3 of this SRP emphasizes design criteria for protection against postulated pipe ruptures outside containment via plant arrangement and layouts utilizing the concept of physical separation to the extent practical for those plants for which construction permit applications were tendered after July 1, 1973, and before July 1, 1975.

## VI. REFERENCES


1. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases."

2. Attachment to letter from A. Giambusso, December 1972, "General Information Required for Consideration of the Effects of a Piping System Break Outside Containment," Appendix B to BTP SPLB 3-1 (attached to SRP Section 3.6.1).

3. Letter from J. F. O'Leary, July 12, 1973, and attachment entitled, "Criteria for Determination of Postulated Break and Leakage Locations in High and Moderate Energy Fluid Piping Systems Outside of Containment Structures," Appendix C to BTP SPLB 3-1 (attached to SRP Section 3.6.1).

4. SRP Section 3.6.2, Appendix A, "Postulated Rupture Locations in Fluid System Piping Inside And Outside Containment."

5. Branch Technical Position SPLB 3-1, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment" (attached to SRP Section 3.6.1).

6. ANSI/ANS 58.2-1988, "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture," 1988 Edition.

7. Ransom, V., "Comments on GSI-191 Models for Debris Generation," September 14, 2004, ADAMS ML050830341, ML051320338.

8. Wallis, G., "The ANSI/ANS Standard 58.2-1988: Two Phase Jet Model," September 14, 2004, ADAMS ML050830344.

9. F. J. Moody, "Prediction of Blowdown and Jet Thrust Forces," ASME Paper 69 HT-31, August 6, 1969.

10. NUREG-0609, "Asymmetric Blowdown Loads on PWR Primary Systems" (resolution of Generic Task Action Plan A-2).

## Appendix A

## POSTULATED RUPTURE LOCATIONS IN FLUID SYSTEM PIPING INSIDE AND OUTSIDE CONTAINMENT

### 1. BACKGROUND

This position on pipe rupture postulation is intended to comply with the requirements of 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 4 for the design of nuclear power plant structures, systems and components (SSCs). It is recognized that pipe rupture is a rare event that may only occur under unanticipated conditions, such as those which might be caused by possible design, construction, or operation errors; unanticipated loads; or unanticipated corrosive environments. The staff's observation of actual piping failures has indicated that they generally occur at high stress and fatigue locations, such as at the terminal ends of a piping system at its connection to the nozzles of a component. The criteria of this position are intended to utilize the available piping design information by postulating pipe ruptures at locations having relatively higher potential for failure, such that an adequate and practical level of protection may be achieved.

Subject to certain limitations, GDC 4 allows dynamic effects associated with postulated pipe ruptures to 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 design basis conditions. These analyses are commonly referred to as "leak-before-break" (LBB) analyses. The application of LBB to piping system design is reviewed in accordance with SRP Section 3.6.3.

In the ABWR and System 80+ design certification FSERs, the staff accepted an exemption to 10 CFR 100, Appendix A that the design of all safety-related SSCs consider operating basis earthquake (OBE) loads. In SECY 93-087 (Reference D), the staff recommended that the Commission approve the approach to eliminate the OBE from the design of SSCs.

Furthermore, the Staff concluded that no replacement earthquake loading should be used to establish the postulated pipe rupture and leakage crack locations once the OBE is eliminated from the design and that the criteria for postulating pipe ruptures and leakage cracks in high- and moderate-energy piping systems should be based on factors attributed only to normal and operational transients. However, for establishing pipe breaks and leakage cracks due to fatigue effects, the Staff concluded that calculation of the cumulative usage factor should continue to include seismic cyclic effects.

### 2. BRANCH TECHNICAL POSITION

A. High-Energy Fluid Systems Piping

(i) Fluid Systems Separated From Essential Systems and Components. For the purpose of satisfying the separation provisions of plant arrangement as specified in B.1.a of Branch Technical Position (BTP) SPLB 3-1, a review of the piping layout and plant arrangement drawings should clearly show that the effects of postulated piping breaks at any location are isolated or are physically remote from essential systems and components.[1] At the designer's option, break locations as determined from 2A(iii) of this position may be assumed for this purpose.

(ii) Fluid System Piping in Containment Penetration Areas. Breaks and cracks need not be postulated in those portions of piping from containment wall to and including the inboard or outboard isolation valves, provided they meet the design criteria of the ASME Code, Section III, Subarticle NE-1120, and the following additional design criteria:

(1) The following design stress and fatigue limits should not be exceeded:

For ASME Code, Section III, Class 1 Piping

(a) The maximum stress range between any two load sets (including the zero load set) should not exceed 2.4 $S_m$ and should be calculated[2] by Eq. (10) in ASME Code, Section III, NB-3653.

If the calculated maximum stress range of Eq. (10) exceeds 2.4 $S_m$, the stress ranges calculated by both Eq. (12) and Eq. (13) in Paragraph ASME Code, Section III, NB-3653 should meet the limit of 2.4 $S_m$.

(b) The cumulative usage factor should be less than 0.1.

(c) The maximum stress, as calculated by Eq. (9) in ASME Code, Section III, NB-3652 under the loadings resulting from a postulated piping failure beyond these portions of piping, should not exceed 2.25 $S_m$ and 1.8 $S_y$, except that following a failure outside containment, the pipe between the outboard isolation valve and the first restraint may be permitted higher stresses provided a plastic hinge is not formed and operability of the valves with such stresses is ensured in accordance with the criteria specified in SRP Section 3.9.3. Primary loads include those which are deflection-limited by whip restraints.

For ASME Code, Section III, Class 2 Piping

(d) The maximum stress ranges as calculated by the sum of Eqs.(9) and (10) in Paragraph NC-3653, ASME Code, Section III, considering those loads and conditions thereof for which level A and level B stress limits have been specified in the system's

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[1] Systems and components necessary to shut down the reactor and mitigate the consequences of a postulated pipe rupture without offsite power.

[2] For those loads and conditions for which Level A and Level B stress limits have been specified in the design specification (including the operating basis earthquake).

design specification (i.e., sustained loads, occasional loads, and thermal expansion), including an OBE event, should not exceed $0.8(1.8\ S_h + S_A)$. The $S_h$ and $S_A$ are allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III.

(e) The maximum stress, as calculated by ASME Code, Section III, NC-3653, paragraph Eq. (9) under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping, should not exceed $2.25\ S_h$ and $1.8\ S_y$.

Primary loads include those which are deflection-limited by whip restraints. The exceptions permitted in (c) above may also be applied, provided that when the piping between the outboard isolation valve and the restraint is constructed in accordance with the Power Piping Code ANSI B31.1, the piping should either be of seamless construction with full radiography of all circumferential welds or all longitudinal and circumferential welds should be fully radiographed.

(2) Welded attachments, for pipe supports or other purposes, to these portions of piping should be avoided, except where detailed stress analyses, or tests, are performed to demonstrate compliance with the limits of 2.A(ii)(1).

(3) The number of circumferential and longitudinal piping welds and branch connections should be minimized. Where guard pipes are used, the enclosed portion of <u>fluid system</u> piping should be seamless construction and without circumferential welds unless specific access provisions are made to permit inservice volumetric examination of the longitudinal and circumferential welds.

(4) The length of these portions of piping should be reduced to the minimum length practical.

(5) The design of pipe anchors or restraints (e.g., connections to containment penetrations and pipe-whip restraints) should not need welding directly to the outer surface of the piping (e.g., flued integrally forged pipe fittings may be used), except where such welds are 100% volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the limits of 2.A(ii)(1).

(6) Guard pipes provided for those portions of piping in the containment penetration areas should be constructed in accordance with the criteria of the ASME Code, Section III, Subsection NE, Class MC, where the guard pipe is part of the containment boundary. In addition, the entire guard pipe assembly should be designed to meet the following criteria and tests:

(a) The design pressure and temperature should not be less than the maximum operating pressure and temperature of the enclosed pipe under normal plant conditions.

(b) The Level C stress limits in, ASME Code, Section III, NE-3220 should not be exceeded under the loading associated with containment design pressure and temperature in combination with the safe shutdown earthquake.

(c) Guard pipe assemblies should be subjected to a single pressure test at a pressure not less than its design pressure.

(d) Guard pipe assemblies should not prevent the access necessary to conduct the inservice examination specified in 2.A(ii)(1). Inspection ports, if used, should not be located in that portion of the guard pipe through the annulus of dual barrier containment structures.

(7) A 100% volumetric inservice examination of all pipe welds should be conducted during each inspection interval as defined in ASME Code, Section XI, IWA-2400.

(iii) Postulation of Pipe Breaks in Areas Other Than Containment Penetration

(1) With the exceptions of those portions of piping identified in 2.A(ii), breaks in Class 1 piping (ASME Code, Section III) should be postulated at the following locations in each piping and branch run:

(a) At terminal ends.[3]

(b) At intermediate locations where the maximum stress range[2] as calculated by Eq. (10)and either Eq. (12) or Eq. (13) xceeds 2.4 $S_m$.

(c) At intermediate locations where the cumulative usage factor exceeds 0.1.

As a result of piping reanalysis, the highest stress locations may be shifted; however, the initially determined intermediate break locations need not be changed unless one of the following conditions exists:

[3] This is defined as the extremities of piping runs that connect to structures, components (e.g., vessels, pumps, valves), or pipe anchors that act as rigid constraints to piping motion and thermal expansion. A branch connection to a main piping run is a terminal end of the branch run, except where the branch run is classified as part of a main run in the stress analysis and is shown to have a significant effect on the main run behavior. In piping runs that are maintained pressurized during normal plant conditions for only a portion of the run (i.e., up to the first normally closed valve), a terminal end of such a runs is the piping connection to this closed valve.

(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 necessary in pipe parameters such as major differences in pipe size, wall thickness, and routing.

(2) With the exceptions of those portions of piping identified in 2A(ii), breaks in Class 2 and 3 piping (ASME Code, Section III) should be postulated at the following locations in those portions of each piping and branch run:

(a) At terminal ends.

(b) At intermediate locations selected by one of the following criteria:

(i) At each pipe fitting (e.g., elbow, tee, cross, flange, and nonstandard fitting), welded attachment, and valve. Or, where the piping contains no fittings, welded attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure.

(ii) At each location where stresses are calculated[2] by the sum of Eqs. (9) and (10) in NC/ND-3653 of ASME Code, Section III, to exceed 0.8 times the sum of the stress limits given in NC/ND-3653.

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 redesign of the piping resulting in a change in pipe parameters (diameter, wall thickness, routing) is necessary, or the dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe-whip restraints and jet shields.

(3) Breaks in seismically analyzed non-ASME Class piping are postulated according to the same criteria as for ASME Class 2 and 3 piping above.[4]

(4) Applicable to (1), (2), and (3) above:

If a structure separates a high-energy line from an essential component, that separating structure should be designed to withstand the consequences of the pipe break in the high-energy line which produces the greatest effect at the structure, irrespective of the fact that the above criteria might not need such a break location to be postulated.

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[4] Note that, in addition, breaks in nonseismic (i.e., non-Category I) piping should be taken into account as described in Section II.2.k, "Interaction of Other Piping with Category I Piping," of SRP Section 3.9.2.

(5) Safety-related equipment should be environmentally qualified in accordance with SRP Section 3.11. Appropriate pipe ruptures and leakage cracks (whichever controls) should be included in the design bases for environmental qualification of electrical and mechanical equipment both inside and outside the containment.

(iv) The designer should identify each piping run it considered in order to postulate the break locations pursuant to 2.A(iii) above. In complex systems such as those containing arrangements of headers and parallel piping running between headers, the designer should identify and include all such piping within a designated run in order to postulate the number of breaks pursuant to these criteria.

(v) With the exceptions of those portions of piping identified in 2.A(ii), leakage cracks should be postulated as follows:

(1) For ASME Code, Section III, Class 1 piping, at axial locations where the calculated stress range[2] by Eq. (10) in NB-3653 exceeds 1.2 S(m).

(2) For ASME Code, Section III, Class 2 and 3 or nonsafety-class (not ASME Class 1, 2, or 3) piping, at axial locations where the calculated stress[2] by the sum of Eqs. (9) and (10) in NC/ND-3653 exceeds 0.4 times the sum of the stress limits given in NC/ND-3653.

(3) Nonsafety-class piping that has not been evaluated to obtain stress information should have leakage cracks postulated at axial locations that produce the most severe environmental effects.

B. Moderate-Energy Fluid System Piping

(i) Fluid Systems Separated from Essential Systems and Components. For the purpose of satisfying the separation provisions of plant arrangement as specified in B.1.a of BTP SPLB 3-1, a review of the piping layout and plant arrangement drawings should clearly show that the effects of through-wall leakage cracks at any location in piping designed to seismic and nonseismic standards are isolated or physically remote from essential systems and components.

(ii) Fluid System Piping in Containment Penetration Areas. Leakage cracks need not be postulated in those portions of piping from containment wall to and including the inboard or outboard isolation valves, provided 1) they meet the criteria of the ASME Code, Section III, NE-1120, and 2) the stresses calculated[2] by the sum of Eqs. (9) and (10) in ASME Code, Section III, NC-3653 do not exceed 0.4 times the sum of the stress limits given in NC-3653.

(iii) Fluid Systems in Areas Other Than Containment Penetration.

(1) Leakage cracks should be postulated in piping located adjacent to structures, systems, or components important to safety, except:

(a) Where exempted by 2.B(ii) or 2.B(iv),

(b) For ASME Code, Section III, Class 1 piping, where the stress range calculated[2] by Eq. (10) in NB-3653 is less than 1.2 S(m), and

(c) For ASME Code, Section III, Class 2 or 3 and nonsafety-class piping, where the stresses calculated[2] by the sum of Eqs. (9) and (10) in NC/HD-3653 are less than 0.4 times the sum of the stress limits given in NC/ND-3653.

(2) Leakage cracks, unless the piping system is exempted by (1) above, should be postulated at axial and circumferential locations that result in the most severe environmental consequences.

(3) Leakage cracks should be postulated in fluid system piping designed to nonseismic standards as necessary to satisfy B.3.d of BTP SPLB 3-1.

(iv) Moderate-Energy Fluid Systems in Proximity to High-Energy Fluid Systems. Leakage cracks need not be postulated in moderate-energy fluid system piping located in an area in which a break in high-energy fluid system piping is postulated, provided such leakage cracks would not result in more limiting environmental conditions than the high-energy piping break. Where a postulated leakage crack in the moderate-energy fluid system piping results in more limiting environmental conditions than the break in proximate high-energy fluid system piping, the provisions of 2.B(iii) should be applied.

(v) Fluid Systems Qualifying as High-Energy or Moderate-Energy Systems. Through-wall leakage cracks instead of breaks may be postulated in the piping of those fluid systems [5] that qualify as high-energy fluid systems for only a short operational period but qualify as moderate-energy fluid systems for the major operational period.

C. Type of Breaks and Leakage Cracks in Fluid System Piping

(i) Circumferential Pipe Breaks

The following circumferential breaks should be postulated individually in high-energy fluid system piping at the locations specified in 2.A of this position:

(1) Circumferential breaks should be postulated in fluid system piping and branch runs exceeding a nominal pipe size of 1 inch, except where the maximum stress range[2] exceeds the limits specified in 2.A(iii)(i) and 2A(iii)(ii), but the circumferential stress range is at least 1.5 times the

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[5] The operational period is considered "short" if the fraction of time that the system operates within the pressure-temperature conditions specified for high-energy fluid systems is about 2% of the time that the system operates as a moderate-energy fluid system (e.g., systems such as the reactor decay heat removal system qualify as moderate-energy fluid systems; however, systems such as auxiliary feedwater systems operated during PWR reactor startup, hot standby, or shutdown qualify as high-energy fluid systems).

axial stress range. Instrument lines, as well as 1 inch and less nominal pipe or tubing size, should meet the provisions of Regulatory Guide 1.11.

(2) Where break locations are selected without the benefit of stress calculations, breaks should be postulated at the piping welds to each fitting, valve, or welded attachment.

(3) Circumferential breaks should be assumed to result in pipe severance and separation amounting to at least a one-diameter lateral displacement of the ruptured piping sections unless physically limited by piping restraints, structural members, or piping stiffness as may be demonstrated by inelastic limit analysis (e.g., a plastic hinge in the piping is not developed under loading).

(4) The dynamic force of the jet discharge at the break location should be based on the effective cross-sectional flow area of the pipe and on a calculated fluid pressure as modified by an analytically or experimentally determined thrust coefficient. Limited pipe displacement at the break location, line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs may be taken into account, as applicable, in the reduction of jet discharge.

(5) Pipe whipping should be assumed to occur in the plane defined by the piping geometry and configuration and to initiate pipe movement in the direction of the jet reaction.

(ii) <u>Longitudinal Pipe Breaks</u>

The following longitudinal breaks should be postulated in high-energy fluid system piping at the locations of the circumferential breaks specified in 2C(i):

(1) Longitudinal breaks in <u>fluid system</u> piping and branch runs should be postulated in nominal pipe sizes 4-inch and larger, except where the maximum stress range[2] exceeds the limits specified in 2.A(iii)(1) and 2.A(iii)(2), but the axial stress range is at least 1.5 times the circumferential stress range.

(2) Longitudinal breaks need not be postulated at terminal ends.

(3) Longitudinal breaks should be assumed to result in an axial split without pipe severance. Splits should be oriented (but not concurrently) at two diametrically opposed points on the piping circumference such that the jet reactions cause out-of-plant bending of the piping configuration. Alternatively, a single split may be assumed at the section of highest tensile stress as determined by detailed stress analysis (e.g., finite element analysis).

(4) The dynamic force of the fluid jet discharge should be based on a circular or elliptical (2D x ½D) break area equal to the effective cross-sectional flow area of the pipe at the break location and on a calculated fluid pressure modified by an analytically or experimentally determined thrust

coefficient as determined for a circumferential break at the same location. Line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs may be taken into account, as applicable, in the reduction of jet discharge.

(5) Piping movement should be assumed to occur in the direction of the jet reaction unless limited by structural members, piping restraints, or piping stiffness as demonstrated by inelastic limit analysis.

(iii) Leakage Cracks

Leakage cracks should be postulated at those axial locations specified in 2.A(v) for high-energy fluid system piping and in those piping systems not exempted in 2.B(iii)(1) for moderate-energy fluid system piping.

(1) Leakage cracks need not be postulated in 1-inch and smaller piping.

(2) For high-energy fluid system piping, the leakage cracks should be postulated to be in those circumferential locations that result in the most severe environmental consequences. For moderate-energy fluid system piping, see 2.B(iii)(2).

(3) Fluid flow from a leakage crack should be based on a circular opening of area equal to that of a rectangle one-half pipe diameter in length and one-half pipe wall thickness in width.

(4) The flow from the leakage crack should be assumed to result in an environment that wets all unprotected components within the compartment, with consequent flooding in the compartment and communicating compartments. Flooding effects should be determined on the basis of a conservatively estimated time period necessary to effect corrective actions.

## 3. REFERENCES

A. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases."

B. "Boiler and Pressure Vessel Code," Section III and XI, American Society of Mechanical Engineers.9

C. Regulatory Guide 1.11, "Instrument Lines Penetrating Primary Reactor Containment."

D. SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," April 2, 1993; SRM-93-087 issued on July 21, 1993.

**SRP Section 3.6.2**
Description of Changes

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in (Draft) Revision 2, dated April 1996, of this SRP. See ADAMS accession number ML052070315.

In addition this SRP section was administratively updated in accordance with NRR Office Instruction, LIC-200, Revision 1, "Standard Review Plan (SRP) Process." The revision also adds standard paragraphs to extend application of the updated SRP section to prospective submittals by applicants pursuant to 10 CFR Part 52.

The technical changes are incorporated in Revision 2, dated [Month] 2007:

Review Responsibilities - Reflects changes in review branches resulting from reorganization and branch consolidation. Change is reflected throughout the SRP.

I. AREAS OF REVIEW

None

II. ACCEPTANCE CRITERIA

Renamed Branch Technical Position EMEB 3-1 to Appendix A to this SRP Section.

III. REVIEW PROCEDURES

Added an insert to Section III.3 to alert reviewers to outstanding issues over potential non-conservative assumptions related to jet expansion modeling included in ANSI/ANS 58.2 standard.

IV. EVALUATION FINDINGS

None

V. IMPLEMENTATION

None

VI. REFERENCES

Added references related to documentation associated with ANSI/ANS 58.2 standard including ACRS's comments on the Standard.