NUREG-0800
(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

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

REVIEW RESPONSIBILITIES

Primary - Mechanical Engineering Branch (MEB)

Secondary - None

I. AREAS OF REVIEW

General Design Criterion 4 (Ref. 1) requires that structures, systems, and components important to safety shall be designed to accommodate the effects of postulated accidents, including appropriate protection against the dynamic and environmental 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 MEB in accordance with this SRP section, to confirm that requirements for the protection of structures, systems, and components relied upon for safe reactor shutdown or to mitigate the consequences of a postulated pipe rupture are met.

At the construction permit (CP) stage, the staff review covers the following specific areas:

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 structures, systems, and components.

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.

At the operating license (OL) stage, the staff review covers the following specific areas:

1. The implementation of criteria for defining pipe break and crack locations and configurations.

2. The implementation of 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.

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

4. The design adequacy of systems, components, and component supports to assure 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.

In addition, the MEB will coordinate other branches' evaluations that interface with the overall review of the plant protection against postulated pipe rupture as follows:

The Auxiliary Systems Branch (ASB) reviews plant arrangements where separation of high and moderate energy systems is the method of protection for essential systems and components outside containment in SRP Section 3.6.1. The ASB 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. The Structural Engineering Branch (SEB) reviews loading combinations and other design aspects of protective structures of compartments used to protect essential systems and components in SRP Sections 3.8.3 and 3.8.4. The Material Engineering Branch (MTEB) reviews inservice inspection and related design provisions of high- and moderate-energy systems in SRP Sections 5.2.4 and 6.6, including those associated with the break exclusion regions. The Reactor Systems Branch (RSB) identifies 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 SRP Section 6.3. The Equipment Qualification Branch (EQB) reviews the 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 SRP Section 3.11. The Containment Systems Branch (CSB) will verify that piping systems penetrating the containment barrier are designed with acceptable isolation features to maintain containment integrity as part of its primary review responsibility for SRP Section 6.2.4.

For those areas of review identified above as being reviewed as part of the primary review responsibility of another branch, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

MEB acceptance criteria are based on meeting the requirements of General Design Criterion 4, as it relates to structures, systems, and components important to safety being designed to accommodate the dynamic effects of postulated pipe rupture, including postulation of pipe rupture locations; break and crack characteristics; dynamic analysis of pipe whip, and jet impingement loads.

Specific criteria necessary to meet the relevant requirements of GDC 4 are as follows:

1. Postulated Pipe Rupture Locations Inside Containment

   Acceptable criteria to define postulated pipe rupture locations and configurations inside containment are specified in Branch Technical Position (BTP) MEB 3-1 (Ref. 4).

2. Postulated Pipe Rupture Locations Outside Containment

   For protection against postulated pipe ruptures outside containment, BTP MEB 3-1 provide acceptable criteria to define postulated rupture locations and plant layout considerations.

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 BTP MEB 3-1, subsection B.3.

III. REVIEW PROCEDURES

The reviewer will select and emphasize material from this SRP section, as may be appropriate for a particular case.

1. The locations and configurations of breaks in high-energy piping and leakage cracks in moderate energy piping are reviewed.

   a. At the 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:

      (1) 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.

(2) 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 BTP MEB 3-1.

2. Analyses of pipe motion caused by the dynamic effects of postulated breaks are reviewed. These analyses should show that pipe motions will not be such as to result in unacceptable impact upon, or overstress of, any structure, system, or component 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 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 demonstrates 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 criteria which follow. 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 the 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 following the postulated rupture should adequately acccunt 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 shall be limited to 80% of its rated energy dissipating capacity as determined by dynamic testing, at loading

rates within ± 50% of the specified design loading rate. The rated energy dissipating capacity shall 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 shall not be used. Pure tension members shall be limited to an allowable strain of 50% of the ultimate uniform strain (Xm) (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 ± 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.

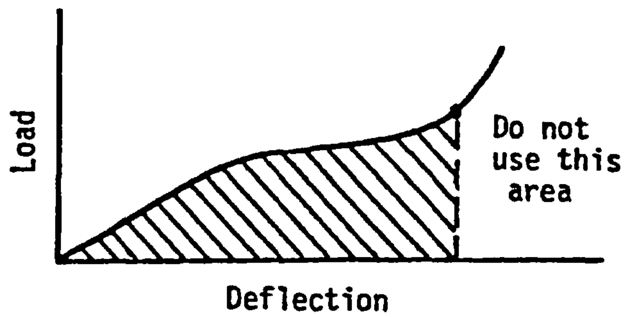

Figure 3.6.2-1 Rated energy dissipating capacity

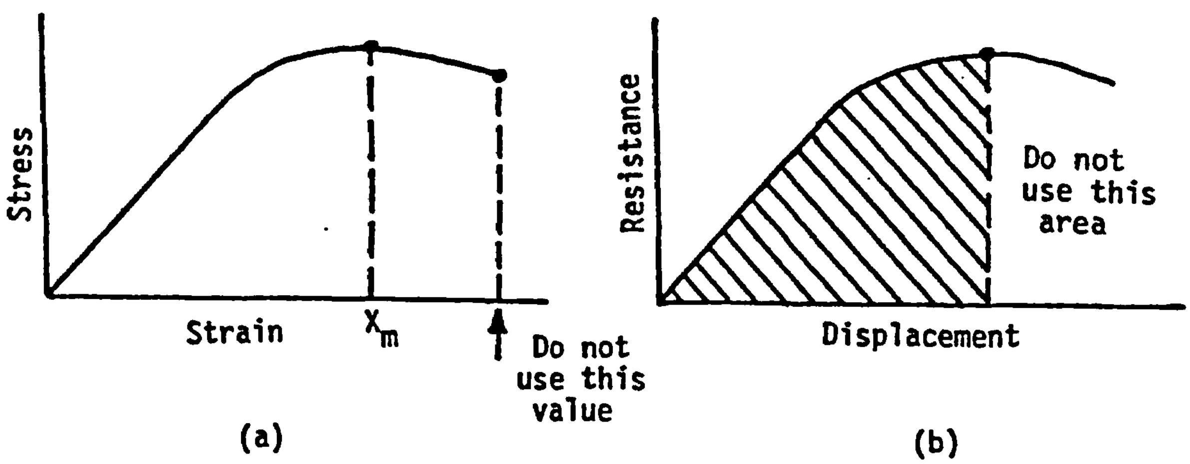

Figure 3.6.2-2 Limitations on pure tension members

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:

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

(2) The analytical method of solution selected.

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

(4) 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:

(1) 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.

(2) 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.

(3) 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.

(4) Other models may be considered if justified.

c. Dynamic Analysis Models for Jet Thrust Justified.

(1) 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(4) below.

(2) 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.

(3) 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.

(4) 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(2) or 2.b(3), 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. Analyses of jet impingement forces are reviewed. These analyses should show that jet impingement loadings on nearby safety-related structures, systems, and components will not be such as to impair or preclude essential functions. Assumptions that are acceptable in modeling jet impingement forces are:

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(4), 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. 6). 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 expand asymmetric compartment pressurization loads, as appropriate, as discussed for PWR primary systems in Reference 7.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and that his review supports conclusions of the following type, to be included in the staff's safety evaluation report:

The staff evaluation concludes that the pipe rupture postulation and the associated effects are adequately considered in the plant design, and therefore are acceptable and meet the requirements of General Design Criterion 4. This conclusion is based on the following:

1. The proposed pipe rupture locations have been adequately assumed and the design of piping restraints and measures to deal with the subsequent dynamic effects of pipe whip and jet impingement provide adequate protection to the integrity and functionality of safety-related structures, systems, and components.

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

3. The proposed piping and restraint arrangement and applicable design considerations for high- and moderate-energy fluid systems inside and outside of containment, including the reactor coolant pressure boundary, will provide adequate assurance that the

structures, systems and components important to safety that are in close proximity to the postulated pipe rupture will be protected. The design will be of a nature to mitigate 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.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

For protection against postulated pipe ruptures outside containment, Reference 2 includes the area of concern in this position and has been used for those plants for which construction permit applications were tendered before July 1, 1973. Reference 3 specifically emphasizes protection via plant arrangement and layouts utilizing the concept of physical separation to the extent practical and has been used for those plants for which construction permit applications were tendered after July 1, 1973 and before July 1, 1975 as specified in Section B.4 of BTP ASB 3-1. BTP MEB 3-1 has been used for all construction permit applications, in lieu of References 2 and 3, since July 1, 1975 and should be used for future applications.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile 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 ASB 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 ASB 3-1 (attached to SRP Section 3.6.1).

4. Branch Technical Position MEB 3-1, "Postulated Rupture Locations in Fluid System Piping Inside And Outside Containment," attached to this SRP section.

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

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

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

BRANCH TECHNICAL POSITION MEB 3-1

POSTULATED RUPTURE LOCATIONS IN FLUID SYSTEM PIPING INSIDE AND OUTSIDE CONTAINMENT

A. BACKGROUND

This position on pipe rupture postulation is intended to comply with the requirements of General Design Criteria 4, of Appendix A to 10 CFR Part 50 for the design of nuclear power plant structures and components. It is recognized that pipe rupture is a rare event which 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. Our observation of actual piping failures have 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 rules 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.

B. BRANCH TECHNICAL POSITION

1. High-Energy Fluid Systems Piping

a. 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) ASB 3-1, a review of the piping layout and plant arrangement drawings should clearly show the effects of postulated piping breaks at any location are isolated or physically remote from essential systems and components.[1] At the designer's option, break locations as determined from B.1.c. of this position may be assumed for this purpose.

b. 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 requirements of the ASME Code, Section III, Subarticle NE-1120 and the following additional design requirements:

(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 by Eq. (10) in Paragraph NB-3653, ASME Code, Section III, for those loads and conditions thereof for

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

which level A and level B stress limits have been specified in the system's Design Specification, including an operating basis earthquake (OBE) event transient. The S_m is design stress intensity as defined in Article NB-3600 of the ASME Code Section III.

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 NB-3653 should meet the limit of 2.4 Sm.

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

(c) The maximum stress, as calculated by Eq. (9) in Paragraph NB-3652 under the loadings resulting from a postulated piping failure beyond these portions of piping should not exceed 2.25S_m 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 assured in accordance with the requirements specified in SRP Section 3.9.3. Primary loads include those which are deflection limited by whip restraints.

<u>For ASME Code, Section III, Class 2 Piping</u>

(d) The maximum stress ranges as calculated by the sum of Eq. (9) and (10) in Paragraph NC-3652, 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 Design Specification (i.e., sustained loads, occasional loads, and thermal expansion) including an OBE event should not exceed 0.8(1.2 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 calulated by Eq. (9) in Paragraph NC-3652 under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping should not exceed 1.8 S_h.

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 (see ASB 3-1 B.2.c(4), the piping shall either be of seamless construction with full radiography of all circumferential welds, or all longitudinal and circumferential welds shall 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 B.1.b(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 fluid system 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 require 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 percent volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the limits of B.1.b(1).

(6) Guard pipes provided for those portions of piping in the containment penetration areas should be constructed in accordance with the rules of Class MC, Subsection NE of the ASME Code, Section III, where the guard pipe is part of the containment boundary. In addition, the entire guard pipe assembly should be designed to meet the following requirements 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 design stress limits of Paragraph NE-3131(c) 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 required to conduct the inservice examination specified in B.1.b.(7). 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 IWA-2400, ASME Code, Section XI.

c. Postulation of Pipe Rupture In Areas Other Than Containment Penetration

(1) With the exceptions of those portions of piping identified in B.1.b, 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.[2]

(b) At intermediate locations where the maximum stress range[3] as calculated by Eq. (10) and either (12) or (13) exceeds 2.4 S_m.

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

(d) If two intermediate locations cannot be determined by (b) and (c) above, two highest stress locations[4] based on Eq. (10) should be selected. If the piping run has only one change or no change of direction, only one intermediate location should be postulated.

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 exist:

(i) Maximum stress ranges or cumulative usage factors exceed the threshold levels in (b) or (c) above.

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

(iii) Breaks at the new highest stress locations are significantly apart from the original locations and result in consequences to safety-related systems requiring additional safety protection.

In such conditions, the newly determined highest stress locations should be the intermediate break locations.

[2]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 which 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 runs is the piping connection to this closed valve.

[3]Stress range under those loads and conditions thereof for which level A and level B stress limits have been specified in the system's Design Specification, including an OBE event per paragraph NB-3653 of the ASME Code, Section III.

[4]Stresses under those loads and conditions thereof for which level A and level B stress limits have been specified in the System's Design Specification, including an OBE event as calculated by Eq. (9) and (10), Paragraph NC/ND-3652 of the ASME Code, Section III.

(2) With the exceptions of those portions of piping identified in B.1.b, 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. 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 the stresses[4] exceed 0.8 $(1.2\ S_h + S_A)$ but at not less than two separated locations chosen on the basis of highest stress.[5] Where the piping consists of a straight run without fittings, welded attachment, or valves, and all stresses are below 0.8 $(1.2\ S_h + S_A)$, a minimum of one location chosen on the basis of highest stress.

As a result of piping reanalysis, the highest stress locations may be shifted; however, the initially determined intermediate break locations may be used unless one of the appropriate conditions of B.1.c(1)(d) exist.

(3) Breaks in nonnuclear class piping should be postulated at the following locations in each piping or branch run:

(a) At terminal ends of the run if located adjacent to the protective structure.

(b) At each intermediate pipe fitting, welded attachment, and valve.

(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 require such a break location to be postulated.

[5]Select two locations with at least 10% difference in stress, or if stresses differ by less than 10%, two locations separated by a change of direction of the pipe run.

d. The designer should identify each piping run he has considered to postulate the break locations required by B.1.c 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 required by these criteria.

e. With the exceptions of those portions of piping identified in B.1.b, leakage cracks should be postulated in ASME Code, Section III, Class 1 piping where the stress range by Eq. (10) of Paragraph NB-3653 exceeds 1.2 S_m, and in Class 2 and 3 or nonsafety class piping where the stress by the sum of Eq. (9) and (10) of Paragraph NC/ND 3652 exceeds 0.4 (1.2 S_h + S_A). Nonsafety class piping which has not been evaluated to obtain similar stress information shall have cracks postulated at locations that result in the most severe environmental consequence.

2. Moderate-Energy Fluid System Piping

a. 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 ASB 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.

b. 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 they meet the requirements of the ASME Code, Section III, Subarticle NE-1120, and are designed such that the maximum stress range does not exceed 0.4 (1.2 S_h + S_A) for ASME Code, Section III, Class 2 piping.

c. Fluid Systems In Areas Other Than Containment Penetration

(1) Through-wall leakage cracks should be postulated in fluid system piping located adjacent to structures, systems or components important to safety, except (1) where exempted by B.2.b and B.2.d, or (2) where the maximum stress range in these portions of Class 1 piping (ASME Code, Section III) is less than 1.2 S_m, and Class 2 or 3 or non-safety class piping is less than 0.4 (1.2 Sh + S_A). The cracks should be postulated to occur individually at locations that result in the maximum effects from fluid spraying and flooding, with the consequent hazards or environmental conditions developed.

(2) Through-wall leakage cracks should be postulated in fluid system piping designed to nonseismic standards as necessary to satisfy B.3.d of BTP ASB 3-1.

d. Moderate-Energy Fluid Systems in Proximity to High-Energy Fluid Systems

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 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 B.2.c should be applied.

e. 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 that qualify as high-energy fluid systems for only short operational periods[6] but qualify as moderate-energy fluid systems for the major operational period.

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

a. Circumferential Pipe Breaks

The following circumferential breaks should be postulated individually in high-energy fluid system piping at the locations specified in B.1 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[3,4] exceeds the limits specified in B.1.c(1) and B.1.c(2) but the circumferential stress range is at least 1.5 times the axial stress range. Instrument lines, one 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. Alternatively, a single break location at the section of maximum stress range may be selected as determined by detailed stress analyses (e.g., finite element analyses) or tests on a pipe fitting.

(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

[6]An 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 percent 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).

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.

b. Longitudinal Pipe Breaks

The following longitudinal breaks should be postulated in high-energy fluid system piping at the locations of the circumferential breaks specified in B.3.a:

(1) Longitudinal breaks in fluid system piping and branch runs should be postulated in nominal pipe sizes 4-inch and larger, except where the maximum stress range[3,4] exceeds the limits specified in B.1.c(1) and B.1.c(2) but the axial stress range is at least 1.5 times the circumferential stress range.

(2) Longitudinal breaks need not be postulated at:

(a) Terminal ends.

(b) At intermediate locations where the criterion for a minimum number of break locations must be satisfied.

(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 causes out-of-plane 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 1/2D) 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.

c. Through-Wall Leakage Cracks

The following through-wall leakage cracks should be postulated in moderate-energy fluid system piping at the locations specified in B.2 of this position:

(1) Cracks should be postulated in moderate-energy fluid system piping and branch runs exceeding a nominal pipe size of 1 inch. These cracks should be postulated individually at locations that result in the most severe environmental consequences.

(2) Fluid flow from a 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.

(3) The flow from the 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 required to effect corrective actions.

C. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Basis."

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

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