BRANCH TECHNICAL POSITION ASB 3-1
(FORMERLY BTB APCSB 3-1)

PROTECTION AGAINST POSTULATED PIPING FAILURES IN FLUID SYSTEMS OUTSIDE CONTAINMENT

A. BACKGROUND

General Design Criterion 4, "Environmental and Missile Design Bases," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that systems and components important to safety "...shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit." Guidance on acceptable design approaches to meet General Design Criterion 4 for existing plants and for plants for which applications for construction permits were then under review was provided in letters to applicants and licensees from A. Giambusso, Deputy Director of Licensing for Reactor Projects, most of which were dated in December 1972. The guidance document from these letters is attached as Appendix B to this position. Similar interim guidance for new plants was provided in a letter to applicants, prospective applicants, reactor vendors, and architect-engineers from J. F. O'Leary, Director of Licensing, dated July 12, 1973. This document is attached as Appendix C to this position.

Reviews of nuclear power plant designs have indicated that the functional or structural integrity of systems and components required for safe shutdown of the reactor and maintenance of cold shutdown conditions could be endangered by fluid system piping failures at locations outside containment. The staff has evolved an acceptable approach for the design, including the arrangement, of fluid systems located outside of containment to assure that the plant can be safely shut down in the event of piping failures outside containment. This approach is set forth in this position and in the companion branch technical position BTP MEB 3-1 attached to SRP Section 3.6.2.

It is the intent of this design approach that postulated piping failures in fluid systems should not cause a loss of function of essential safety-related systems and that nuclear plants should be able to withstand postulated failures of any fluid system piping outside containment, taking into account the direct results of such failure and the further failure of any single active component, with acceptable offsite consequences.

The detailed provisions of the position below and of BTP MEB 3-1 are intended to implement this intent with due consideration of the special nature of certain dual purpose systems and the need to define and to limit to a finite number the types and locations of piping failures to be analyzed. Although various measures for the protection of safety-related systems and components are outlined in this position, the preferred method of protection is based upon separation and isolation by plant arrangement.

Recent applications for CP licenses contain plant layouts where safety-related equipment or structures appear to be located near the main steam and feedwater high energy lines on the basis of utilization of the "break exclusion" design basis in these lines. In consideration of the large magnitude of potential energy stored in these (main steam and feed) systems during normal plant operation, we are revising BTP ASB 3-1 to give clearer guidance on acceptable methods for protecting essential equipment from the effects of postulated failures in these systems.

B. BRANCH TECHNICAL POSITION

1. Plant Arrangement

Protection of essential systems and components[1/] against postulated piping failures in high or moderate energy fluid systems that operate during normal plant conditions and that are located outside of containment, should be provided by items a., b., or c. below in order of their preference.

a. Plant arrangements should separate fluid system piping from essential systems and components. Separation should be achieved by plant physical layouts that provide sufficient distances between essential systems and components and fluid system piping such that the full dynamic effects of any postulated piping failure therein (e.g., pipe whip, jet impingement, and the environmental conditions resulting from the escape of contained fluids as appropriate to high or moderate energy fluid system piping) cannot impair the integrity or operability of essential systems and components.

(1) Even though portions of the main steam and feedwater lines meet the break exclusion requirements of item B.1.6 of BTP MEB 3-1, they should be separated from essential equipment. In order for essential equipment to be properly separated, the essential equipment must be protected from the jet impingement and environmental effects of an assumed longitudinal break of the main steam and feedwater lines. Each assumed longitudinal break should have a cross sectional area of at least one square foot and should be postulated to occur at a location that has the greatest effect on essential equipment.

(2) The main steam and feedwater lines should not be routed around or in the vicinity of the control room.

b. Fluid system piping or portions thereof not satisfying the provisions of item B.1.a should be enclosed within structures or compartments designed to protect nearby essential systems and components. Alternatively, essential systems and components may be enclosed within structures or compartments designed to withstand the effects of postulated piping failures in nearby fluid systems.

c. Plant arrangements or system features that do not satisfy the provisions of either item B.1.a or item B.1.b should be limited to those for which the above provisions are impractical because of the stage of design or construction of the plant; because the plant design is based upon that of an earlier plant accepted by the staff as a base plant under the Commission's standardization and replication policy; or for other substantive reasons such as particular design features of the fluid systems. Such cases may arise, for example, (1) at interconnections between fluid systems and essential systems and components, or (2) in fluid systems having dual functions (i.e., required to operate during normal plant conditions as well as to shut down the reactor). In these cases, redundant design features that are separated or otherwise protected from postulated piping failures, or additional protection, should be provided so that the effects of postulated piping failures are shown by the analyses and guidelines of Section B.3 to be acceptable. Additional protection may be provided by restraints and barriers or by designing or testing essential systems and components to withstand the effects associated with postulated piping failures.

If a case should arise as a result of overriding engineering considerations, where adequate separation by physical distance or adequate separation by a combination of distance and barriers cannot be reasonably attained, and so justified to the staff, restraints may be used to assist in obtaining a finding of adequate separation by distance or barriers when designed as follows:

(1) The use of a restraint should not affect the responses of the piping systems when subjected to the loads resulting from normal and upset plant and system operating conditions.

(a) Care should be exercised to ensure that the system stresses due to normal and upset transients, thermal growth, and inertial effects and differential anchor motions associated with seismic events are not adversely affected by the restraints.

(b) A program should be developed to ensure that the system stresses due to long term changes in the system and its supports and restraints, such as due to pipe relaxation and differential settling, will not be adversely affected by the restraints.

(c) Details of the methods used to obtain these assurances should be submitted to the staff for review.

(2) The restraint and its supporting structures should be designed so that they will not prevent the inservice inspection of any pipe welds.

2. Design Features

a. Essential systems and components should be designed to meet the seismic design requirements of Regulatory Guide 1.29.

b. Protective structures or compartments, fluid system piping restraints, and other protective measures should be designed in accordance with the following:

(1) Protective structures or compartments needed to implement Section B.1 should be designed to seismic Category I

requirements. The protective structures should be designed to withstand the effects of a postulated piping failure (i.e., pipe whip, jet impingement, pressurization of compartments, water spray, and flooding, as appropriate) in combination with loadings associated with the operating basis earthquake and safe shutdown earthquake within the respective design load limits for structures. Piping restraints, if used, may be taken into account to limit effects of the postulated piping failure.

(2) High-energy fluid system piping restraints and protective measures should be designed such that a postulated break in one pipe cannot, in turn, lead to rupture of other nearby pipes or components if the secondary rupture could result in consequences that would be considered unacceptable for the initial postulated break. An unrestrained whipping pipe should be considered capable of rendering damage as defined in Subsection III.2. of SRP Section 3.6.

c. Fluid system piping in containment penetration areas should be designed to meet the break exclusion provisions contained in item B.1.b of BTP MEB 3-1.

d. Piping classification as required by Regulatory Guide 1.26 should be maintained without change until beyond the outboard restraint. If the restraint is located at the isolation valve, a classification change at the valve interface is acceptable.

3. Analyses and Effects of Postulated Piping Failures

a. To show that the plant arrangement and design features provide the necessary protection of essential systems and components, piping failures should be postulated in accordance with BTP MEB 3-1, attached to SRP Section 3.6.2. In applying the provisions of BTP MEB 3-1, each longitudinal or circumferential break in high-energy fluid system piping or leakage crack in moderate-energy fluid system piping should be considered separately as a single postulated initial event occurring during normal plant conditions. An analysis should be made of the effects of each such event, taking into account the provisions of BTP MEB 3-1 and of the system and component operability considerations of item B.3.b. below. The effects of each postulated piping failure should be shown to result in offsite consequences within the guidelines of 10 CFR Part 100 and to meet the provisions of items B.3.c and d below.

b. In analyzing the effects of postulated piping failures, the following assumptions should be made with regard to the operability of systems and components:

(1) Offsite power should be assumed to be unavailable if a trip of the turbine-generator system or reactor protection system is a direct consequence of the postulated piping failure.

(2) A single active component failure should be assumed in systems used to mitigate consequences of the postulated piping failure and to shut down the reactor, except as noted in item B.3.b.(3) below. The single active component failure is assumed to occur in addition to the postulated piping failure and any direct consequences of the piping failure, such as unit trip and loss of offsite power.

(3) Where the postulated piping failure is assumed to occur in one of two or more redundant trains of a dual-purpose moderate-energy essential system, i.e., one required to operate during normal plant conditions as well as to shut down the reactor and mitigate the consequences of the piping failure, single failures of components in the other train or trains of that system only, need not be assumed provided the system is designed to seismic Category I standards, is powered from both offsite and onsite sources, and is constructed, operated, and inspected to quality assurance, testing, and inservice inspection standards appropriate for nuclear safety systems. Examples of systems that may, in some plant designs, qualify as dual-purpose essential systems are service water systems, component cooling systems, and residual heat removal systems.

(4) All available systems, including those actuated by operator actions, may be employed to mitigate the consequences of a postulated piping failure. In judging the availability of systems, account should be taken of the postulated failure and its direct consequences such as unit trip and loss of offsite power, and of the assumed single active component failure and its direct consequences. The feasibility of carrying out operator actions should be judged on the basis of ample time and adequate access to equipment being available for the proposed actions.

c. The effects of a postulated piping failure, including environmental conditions resulting from the escape of contained fluids, should not preclude habitability of the control room or access to surrounding areas important to the safe control of reactor operations needed to cope with the consequences of the piping failure.

d. The functional capability of essential systems and components should be maintained after a failure of piping not designed to seismic Category I standards, assuming a concurrent single active failure.

4. Implementation

a. Designs of plants for which construction permit applications are tendered after July 1, 1975 should conform to the provisions of this position.

b. Designs of plants for which construction permit applications are tendered after July 1, 1973 and before July 1, 1975 should conform to the provisions of either (a) the letter of July 12, 1973 from J. F. O'Leary, Appendix C to this position, or (b) this position, at the option of the applicants.

c. Designs of plants for which construction permit applications were tendered before July 1, 1973 and operating licenses are issued after July 1, 1975 should follow the guidance provided in the December 1972 letter from A. Giambusso, Appendix B to this position and provide analyses of moderate energy lines made in conformance with Section B.3 of this position, as part of the operating license application for these plants to demonstrate that acceptable protection against the effects of piping failures outside containment has been provided. Alternately, this position may be used in its entirety as an acceptable basis for this finding.

   For plants in this category for which construction permits are not issued as of February 1, 1975, a commitment by the applicant to either (a) follow the guidance of Appendix B and submit Section B.3 analyses of moderate energy lines with the plant final safety analysis report (FSAR), or (b) conform the plant design to the provisions of this position, should provide an acceptable basis for issuance of the construction permit with regard to effects of piping failures outside containment.

d. Designs of plants for which operating licenses are issued before July 1, 1975 are considered acceptable with regard to effects of piping failures outside containment on the basis of the analyses made and measures taken by applicants and licensees in response to the December 1972 letter from A. Giambusso, and the staff review and acceptance of these analyses and measures.

   For plants in this category for which the staff review and acceptance of protection against the effects of piping failures outside containment is not substantially complete as of February 1, 1975, a commitment by the applicant to carry out analyses according to Section B.3 of this position, to submit them for staff review, and to carry out any system modifications found necessary before extended operation of the plant at power levels above one-half the license power level, should provide an acceptable basis for issuance of the operating license.

C. REFERENCES

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

2. Regulatory Guide 1.29, "Seismic Design Classification."

3. Letter from A. Giambusso, Deputy Director for Reactor Projects, Directorate of Licensing, to applicants and licensees, December 1972, and attachment entitled "General Information Required for Consideration of the Effects of a Piping System Break Outside Containment." The corrected attachment is Appendix B to this position.

4. Letter from J. F. O'Leary, Director of Licensing, to applicants, reactor venders, and architect-engineers, July 12, 1972, and attachment entitled "Criteria for Determination of Postulated Break and Leakage Locations in High and Moderate Energy Fluid Piping Systems Outside of Containment Structures." The letter and attachment is Appendix C to this position.

APPENDIX A
BRANCH TECHNICAL POSITION ASB 3-1
DEFINITIONS

Essential Systems and Components. Systems and components required to shut down the reactor and mitigate the consequences of a postulated piping failure, without offsite power.

Fluid Systems. High and moderate energy fluid systems that are subject to the postulation of piping failures outside containment against which protection of essential systems and components is needed.

High-Energy Fluid Systems. Fluid systems that, during normal plant conditions, are either in operation or maintained pressurized under conditions where either or both of the following are met:

a. maximum operating temperature exceeds 200°F, or

b. maximum operating pressure exceeds 275 psig.

Moderate-Energy Fluid Systems. Fluid systems that, during normal plant conditions, are either in operation or maintained pressurized (above atmospheric pressure) under conditions where both of the following are met:

a. maximum operating temperature is 200°F or less, and

b. maximum operating pressure is 275 psig or less

Normal Plant Conditions. Plant operating conditions during reactor startup, operation at power, hot standby, or reactor cooldown to cold shutdown condition.

Upset Plant Conditions. Plant operating conditions during system transients that may occur with moderate frequency during plant service life and are anticipated operational occurrences, but not during system testing.

Postulated Piping Failures. Longitudinal and circumferential breaks in high-energy fluid system piping and through-wall leakage cracks in moderate-energy fluid system piping postulated according to the provisions of BTP MEB 3-1, attached to SRP Section 3.6.2.

Single Active Component Failure. Malfunction or loss of function of a component of electrical or fluid systems. The failure of an active component of a fluid system is considered to be a loss of component function as a result of mechanical, hydraulic, pneumatic, or electrical malfunction, but not the loss of component structural integrity. The direct consequences of a single active component failure are considered to be part of the single failure.

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 S_m.

(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."