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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 831.1 (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."