U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 3-3

PROTECTION AGAINST POSTULATED PIPING FAILURES IN FLUID SYSTEMS OUTSIDE CONTAINMENT

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of cooling water systems

Secondary - None

A. BACKGROUND

General Design Criterion (GDC) 4, "Environmental and Dynamic Effects Design Bases," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that structures, systems, and components important to safety “be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents.” Guidance on acceptable design approaches to meet GDC 4 for existing plants and for plants for which applications for construction permits (CP) 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 Branch Technical Position (BTP).

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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 ensure 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) 3-4.

General Design Criterion (GDC) 2, "Design Bases for Protections Against Natural Phenomena," requires that SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes. The BTP 3-4 does not consider full-circumferential breaks in moderate-energy piping, only through-the-wall cracks. Full circumferential breaks in non-seismic piping should be considered in addition to all breaks postulated in BTP 3-4.

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 3-4 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.

Past applications for CP & Operating Licenses (OL) contained plant layouts where safety-related equipment or structures were 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, BTP 3-3 is intended to give clear 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

[1]Underlined terms are defined in Branch Technical Position 3-4

fluid system piping such that the environmental effects of any postulated piping failure therein cannot impair the integrity or operability of essential systems and components. The following considerations should also be made:

(1) Even though portions of the main steam and feedwater lines meet the break exclusion requirements of item 2.A(ii) of BTP 3-4, they should be separated from essential equipment. Designers are cautioned to avoid concentrating essential equipment in the break exclusion zone. Essential equipment must be protected from the environmental effects of an assumed nonmechanistic longitudinal break of the main steam and feedwater lines. Each assumed nonmechanistic 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 designing or testing essential systems and components to withstand the environmental effects associated with postulated piping failures.

2. Design Features

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

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

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 design basis earthquake within the respective design load limits for structures.

c. Fluid system piping in containment penetration areas should be designed to meet the break exclusion provisions contained in item 2.A(ii) of BTP 3-4.

d. Piping classification as recommended by RG 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 3-4 and postulated to include full-circumferential ruptures of non-seismic moderate energy piping (since BTP 3-4 only applies during normal conditions, not seismic events). Each longitudinal or circumferential break or leakage crack 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 BTP 3-4 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. Also, offsite power should be assumed unavailable following seismic events.

(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 (e.g., one required to operate during normal plant conditions as well as to shut down the reactor and mitigate the consequences of the postulated piping failure), single active failures of components in the other train or trains of that system or other systems necessary to mitigate the consequences of the piping failure and shut down the reactor, need

not be assumed provided the systems are designed to seismic Category I standards, are powered from both offsite and onsite sources, and are 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. For breaks in non-seismic piping systems, only seismically-qualified systems should be assumed to be available to mitigate the consequences of the failure since a seismic event may have caused the pipe break.

c. The environmental effects of a postulated piping failure 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.

e. The considerations related to the leak-before-break approach should conform with the provisions of SRP Section 3.6.3.

4. Implementation

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

b. Designs of plants for which CP 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 CP 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 CP 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 OL 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 Dynamic Effects Design Bases."

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, “Design Bases for Protection Against Natural Phenomena.”

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

4. 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.

5. Letter from J. F. O'Leary, Director of Licensing, to applicants, reactor vendors, 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

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 95 °C (200 °F), or

b. Maximum operating pressure exceeds 1900 kPa (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 95 °C (200 °F) or less, and

b. Maximum operating pressure is 1900 kPa (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 seismically-designed moderate energy fluid system piping postulated according to the provisions BTP 3-4. Also, full circumferential breaks in non-seismic moderate energy piping should be considered (since these breaks are not considered in BTP 3-4 because it only applies during normal operation, not seismic events).

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.

APPENDIX B

This appendix consists of the attachment to the letters sent by A. Giambusso, Deputy Director for Reactor Projects, Directorate of Licensing, in December 1972 to applicants and licensees on the subject of postulated piping failures outside containment. The attachment provided guidance on measures to be taken and on information to be submitted. An errata sheet for the attachment was sent in January 1973 to recipients of the original letters. The attachment as given here has been corrected for the errata.

General Information Required for Consideration of the Effects of a Piping System Break Outside Containment

The following is a general list of information required for AEC review of the effects of a piping system break outside containment, including the double-ended rupture of the largest pipe in the main steam and feedwater systems, and for AEC review of any proposed design changes that may be found necessary. Since piping layouts are substantially different from plant to plant, applicants and licensees should determine on an individual plant basis the applicability of each of the following items for inclusion in their submittals.

1. The systems (or portions of systems) for which protection against pipe whip is required should be identified. Protection from pipe whip need not be provided if any of the following conditions will exist:

    a. Both of the following piping system conditions are met:

        1. the service temperature is less than 200°F; and

        2. the design pressure is 275 psig or less; or

    b. The piping is physically separated (or isolated) from structures, systems, or components important to safety by protective barriers, or restrained from whipping by plant design features, such as concrete encasement; or

    c. Following a single break, the unrestrained pipe movement of either end of the ruptured pipe in any possible direction about a plastic hinge formed at the nearest pipe whip restraint cannot impact any structure, system, or component important to safety; or

    d. The internal energy level[1] associated with the whipping pipe can be demonstrated to be insufficient to impair the safety function of any structure, system or component to an unacceptable level.

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[1]Footnotes are collected at the end of this appendix.

2. Design basis break locations should be selected in accordance with the following pipe whip protection criteria: however, where pipes carrying high energy fluids are routed in the vicinity of structures and systems necessary for safe shutdown of the nuclear plant, supplemental protection of those structures and systems shall be provided to cope with the environmental effects (including the effects of jet impingement) of a single postulated open crack at the most adverse location(s) with regard to those essential structures and systems, the length of the crack being chosen not to exceed the critical crack size. The critical crack size is taken to be 1/2 the pipe diameter in length and 1/2 the wall thickness in width.

   The criteria used to determine the design basis piping break locations in the piping systems should be equivalent to the following:

   a. ASME Section III Code Class I piping[2] breaks should be postulated to occur at the following locations in each piping run[3] or branch run:

      1. The terminal ends;

      2. Any intermediate locations between terminal ends where the primary plus secondary stress intensities S (circumferential or longitudinal) derived on an elastically calculated basis under the loadings associated with one-half safe shutdown earthquake and operational plant conditions[4] exceeds 2.0 S_m[5] for ferritic steel, and 2.4 S_m for austenitic steel;

      3. Any intermediate locations between terminal ends where the cumulative usage factor (U)[6] derived from the piping fatigue analysis and based on all normal, upset, and testing plant conditions exceeds 0.1; and

      4. At intermediate locations in addition to those determined by (1) and (2) above, selected on a reasonable basis as necessary to provide protection. As a minimum, there should be two intermediate locations for each piping run or branch run.

   b. ASME Section III Code Class 2 and 3 piping breaks should be postulated to occur at the following locations in each piping run or branch run:

      1. The terminal ends;

      2. Any intermediate locations between terminal ends where either the circumferential or longitudinal stresses derived on an elastically calculated basis under the loadings associated with seismic events and operational plant conditions exceed 0.8 (S_h+ S_A)[7] or the expansion stresses exceed 0.8 S_A; and

      3. Intermediate locations in addition to these determined by (2) above, selected on a reasonable basis as necessary to provide protection. As a minimum, there should be two intermediate locations for each piping run or branch run.

3. The criteria used to determine the pipe break orientation at the break locations as specified under (2) above should be equivalent to the following:

a. Longitudinal[8] breaks in piping runs and branch runs, 4 inches nominal pipe size and larger, and/or

b. Circumferential[9] breaks in piping runs and branch runs exceeding 1 inch nominal pipe size.

4. A summary should be provided of the dynamic analyses applicable to the design of Category I piping and associated supports which determine the resulting loadings as a result of a postulated pipe break including:

   a. The locations and number of design basis breaks on which the dynamic analyses are based.

   b. The postulated rupture orientation, such as a circumferential and/or longitudinal break(s), for each postulated design basis break location.

   c. A description of the forcing functions used for the pipe whip dynamic analyses, including the direction, rise time, magnitude, duration, and initial conditions that adequately represent the jet stream dynamics and the system pressure difference.

   d. Diagrams of mathematical models used for the dynamic analysis.

   e. A summary of the analyses which demonstrates that unrestrained motion of ruptured lines will not damage to an unacceptable degree, structures, systems, or components important to safety, such as the control room.

5. A description should be provided of the measures, as applicable, to protect against pipe whip, blowdown jet and reactive forces, including:

   a. Pipe restraint design to prevent whip impact;

   b. Protective provisions for structures, systems, and components required for safety against pipe whip and blowdown jet and reactive forces;

   c. Separation of redundant features;

   d. Provisions to separate physically piping and other components of redundant features; and

   e. A description of the typical pipe whip restraints and a summary of number and location of all restraints in each system.

6. The procedures that will be used to evaluate the structural adequacy of Category I structures and to design new seismic Category I structures should be provided including:

   a. The method of evaluating stresses, e.g., the working stress method and/or the ultimate strength method that will be used;

   b. The allowable design stresses and/or strains; and

c. The load factors and the load combinations.

7. The structural design loads, including the pressure and temperature transients, the dead, live and equipment loads and the pipe and equipment static, thermal, and dynamic reactions should be provided.

8. Seismic Category I structural elements such as floors, interior walls, exterior walls, building penetrations and the buildings as a whole should be analyzed for eventual reversal of loads due to the postulated accident.

9. If new openings are to be provided in existing structures, the capabilities of the modified structures to carry the design loads should be demonstrated.

10. Verification that failure of any structure, including non-seismic Category I structures, caused by the accident, will not cause failure of any other structure in a manner to adversely affect:

    a. Mitigation of the consequences of the accidents; and

    b. Capability to bring the unit(s) to a cold shutdown condition.

11. Verification that rupture of a pipe carrying high energy fluid will not directly or indirectly result in:

    a. Loss of required redundancy in any portion of the protection system (as defined in IEEE-279), Class IE electric system (as defined in IEEE-308), engineered safety feature equipment, cable penetrations, or their interconnecting cables required to mitigate the consequences of that accident and place the reactor(s) in a cold shutdown condition; or

    b. Environmentally induced failures caused by a leak or rupture of the pipe which would not of itself result in protective action but does disable protection functions. In this regard, a loss of redundancy is permitted; but a loss of function is not permitted. For such situations, plant shutdown is required.

12. Assurance should be provided that the control room will be habitable and its equipment functional after a steam line or feedwater line break or that the capability for shutdown and cooldown on the unit(s) will be available in another habitable area.

13. Environmental qualification should be demonstrated by test for that electrical equipment required to function in the steam-air environment resulting from a high energy line break. The information required for our review should include the following:

    a. Identification of all electrical equipment necessary to meet requirements of (11) above. The time after the accident in which they are required to operate should be given.

    b. The test conditions and the results of test data showing that the systems will perform their intended function in the environment resulting from the postulated accident and time interval of the accident. Environmental conditions used for the tests should be selected from a conservative evaluation of accident conditions.

c. The results of a study of steam systems identifying locations where barriers will be required to prevent steam jet impingement from disabling a protection system. The design criteria for the barriers should be stated and the capability of the equipment to survive within the protected environment should be described.

d. An evaluation of the capability for safety-related electrical equipment in the control room to function in the environment that may exist following a pipe break accident should be provided. Environmental conditions used for the evaluation should be selected from conservative calculations of accident conditions.

e. An evaluation to assure that the onsite power distribution system and onsite sources (diesels and batteries) will remain operable throughout the event.

14. Design diagrams and drawings of the steam and feedwater lines including branch lines showing the routing from containment to the turbine building should be provided. The drawings should show elevations and include the location relative to the piping runs of safety-related equipment including ventilation equipment, intakes, and ducts.

15. A discussion should be provided of the potential for flooding of safety-related equipment in the event of failure of a feedwater line or any other line carrying high energy fluid.

16. A description should be provided of the quality control and inspection programs that will be required or have been utilized for piping systems outside containment.

17. If leak detection equipment is to be used in the proposed modifications, a discussion of its capabilities should be provided.

18. A summary should be provided of the emergency procedures that would be followed after a pipe break accident, including the automatic and manual operations required to place the reactor unit(s) in a cold shutdown condition. The estimated times following the accident for all equipment and personnel operational actions should be included in the procedure summary.

19. A description should be provided of the seismic and quality classification of the high energy fluid piping systems including the steam and feedwater piping that run near structures, systems, or components important to safety.

20. A description should be provided of the assumptions, methods, and results of analyses, including steam generator blowdown, used to calculate the pressure and temperature transients in compartments, pipe tunnels, intermediate buildings, and the turbine building following a pipe rupture in these areas. The equipment assumed to function in the analyses should be identified and the capability of systems required to function to meet a single active component failure should be described.

21. A description should be provided of the methods or analyses performed to demonstrate that there will be no adverse effects on the primary and/or secondary containment structures due to a pipe rupture outside these structures.

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[1] The internal fluid energy level associated with the pipe break reaction may take into account

any line restrictions (e.g., flow limiter) between the pressure source and break location, and the effects of either single-ended or double-ended flow conditions, as applicable. The energy level in a whipping pipe may be considered as insufficient to rupture an impacted pipe of equal or greater nominal pipe size and equal or heavier wall thickness.

[2] Piping is a pressure retaining component consisting of straight or curved pipe and pipe fittings (e.g., elbows, tees, and reducers).

[3] A piping run interconnects components such as pressure vessels, pumps, and rigidly fixed valves that may act to restrain pipe movement beyond that required for design thermal displacement. A branch run differs from a piping run only in that it originates at a piping intersection, as a branch of the main pipe run.

[4] Operational plant conditions include normal reactor operation, upset conditions (e.g., anticipated operational occurrences) and testing conditions.

[5] S_m is the design stress intensity as specified in Section III of the ASME Boiler and Pressure Vessel Code, "Nuclear Plant Components."

[6] S_A is the cumulative usage factor as specified in Section III of the ASME Boiler and Pressure Vessel Code, Nuclear Power Plant Components."

[7] S_h is the stress calculated by the rules of NC-3600 and ND-3600 for Class 2 and 3 components, respectively, of the ASME Code Section III Winter 1972 Addenda. S_A is the allowable stress range for expansion stress calculated by the rules of NC-3600 of the ASME Code, Section III, or the USA Standard Code for Pressure Piping, ANSI B31.1.0-1967.

[8] Longitudinal breaks are parallel to the pipe axis and oriented at any point around the pipe circumference. The break area is equal to the effective cross-sectional flow area upstream of the break location. Dynamic forces resulting from such breaks are assumed to cause lateral pipe movements in the direction normal to the pipe axis.

[9] Circumferential breaks are perpendicular to the pipe axis, and the break area is equivalent to the internal cross-sectional area of the ruptured pipe. Dynamic forces resulting from such breaks are assumed to separate the piping axially, and cause whipping in any direction normal to the pipe axis.

APPENDIX C

This appendix consists of the letter and attachment sent by J. F. O'Leary, Director of Licensing, to applicants, reactor vendors, and architect-engineers on the subject of postulated piping failures outside containment. The letter was dated July 12, 1973.

Late last year, the Atomic Energy Commission's Regulatory staff requested those utilities that operate nuclear power plants, have applied for operating licenses, or have plants whose construction permit review was essentially complete, to assess the effects and consequences of a postulated rupture of piping containing high-energy fluids and located outside of the containment structure. These requests were issued by Mr. A. Giambusso, Deputy Director for Reactor Projects, Directorate of Licensing, in letters, most of which were dated in December 1972.

Because these plants were either in operation or in advanced stages of engineering design and construction, the request included guidance for corrective modifications that could be implemented by in-situ measures. Such modifications included relocation or rerouting of piping, installation of impingement barriers and encapsulation sleeves around high-stressed piping regions, provisions for venting of compartments subject to pressurization, addition of piping restraints, and strengthening of structural components of buildings.

From our review of responses submitted to the Regulatory staff, and from discussions with architect-engineering firms, we have learned that some of these organizations have inferred that the criteria contained in Mr. A. Giambusso's letter pertaining to corrective modifications for plants in advanced stages of construction and operation are applicable for the design of high-energy fluid systems outside the containment in new designs of nuclear power plants. It was not our intent that the criteria for corrective plant modifications be applied to new power plants that are in the initial design stages. We believe that a more direct approach, involving a rearrangement of the physical plant layout with a view to relocation of essential safety systems and components is appropriate for the new plants.

For the present, pending issuance of a planned AEC Regulatory Guide "Protection Against Postulated Events and Accidents Outside Containment," an acceptable implementation of Criterion 4 of the Commission's General Design Criteria listed in Appendix A of 10 CFR Part 50, as applied to new plants with respect to the design of structures, systems and components important to safety and located outside of containment is as follows:

I. PIPING SYSTEMS CONTAINING HIGH-ENERGY FLUIDS* DURING NORMAL REACTOR OPERATION

a. The piping systems are isolated by adequate physical separation and remotely located from safety systems and components that are required to shut down the reactor safely and maintain the plant in a cold shutdown condition.

b. Where isolation by remote location is impracticable, systems containing high-energy fluids, or portions of the systems, are enclosed within the structures suitably designed to protect adjoining safely systems and components required

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*Refer to Appendix A for identification of high-energy fluid systems.

to shut down the reactor safely and maintain the plant in a cold shutdown condition from postulated pipe failures within the enclosure.

c. Where both isolation by remote location (as specified in I.a) and enclosure in protective structures (as specified in I.b) are impracticable, systems containing high-energy fluids, or portions of the systems, are provided with restraints and protective measures such that the operability and integrity of structures, safety systems and components that are required to shut down condition are not impaired.

d. Protective enclosures for the piping systems containing high-energy fluids are designed as Seismic Category I structures to withstand the combined effects of a postulated pipe break, the dynamic effects of pipe whipping, the jet impingement forces, and the compartment pressurization as a consequence of discharging fluids in combination with the specified seismic event of the Safe Shutdown Earthquake and normal operating loads.

e. Piping systems containing high-energy fluids are designed so that the effects of a single postulated pipe break cannot, in turn, cause failures of other pipes or components with unacceptable consequences.

In addition, any systems, or portions of systems, that are designed to mitigate the consequences of a postulated pipe failure, and to place the reactor in the cold shutdown condition, are provided with design features that will assure the performance of their safety function, assuming a single active component failure.

f. For a postulated pipe failure, the escape of steam, water, and heat from structures enclosing the high-energy fluid containing piping does not preclude: 1) the accessibility to surrounding areas important to the safe control of reactor operations, 2) the habitability of the control room, 3) the ability of instrumentation, electric power supplies, and components and controls to initiate, actuate and complete a safety action. In this regard, a loss of redundancy is permissible but not the loss of function.

g. The criteria for determination of postulated break locations are contained in the attached Appendix A, "Criteria for Determination of Postulated Pipe Break or Leakage Locations in Fluid Piping Systems Outside Containments."

II. PIPING SYSTEMS CONTAINING MODERATE-ENERGY FLUIDS[**] DURING REACTOR OPERATION

a. Piping systems containing moderate-energy fluids are designed to comply with the criteria applied to high-energy fluid piping systems as listed under I., above, except that the piping is postulated to develop a limited-size through-wall leakage crack instead of a pipe break.

[**] Refer to Appendix A for identification of moderate-energy fluid systems.

b. For each postulated leakage, design measures are included that provide protection from the effects of the resulting water spray and flooding to the same extent required to satisfy criterion I(e).

c. The criteria for determination of postulated leakage locations are contained in Appendix A.

The measures taken for the protection of structures, systems and components important to safety should not preclude the conduct of inservice examinations of ASME Class 2 and 3 pressure-retaining components as required by the rules of ASME Boiler and Pressure Vessel Code - Section XI, "Inservice Inspection of Nuclear Power Plant Components."

Although compliance with the design criteria listed above should be accomplished by plant arrangement and layouts utilizing the separation concept to the extent practicable, special consideration will be necessary to provide adequate protection where interconnection is unavoidable between high-energy fluid containing piping and piping of systems important to safety.

We are prepared to discuss with you these guidelines for the design of new nuclear power plants with regard to protection required against postulated breaks of high and moderate energy piping outside of containment, particularly for those plants with construction permit applications currently under consideration.

Sincerely,

John F. O'Leary, Director
Directorate of Licensing

Enclosure:
Appendix A

APPENDIX A TO J. F. O'LEARY LETTER OF JULY 12, 1972

CRITERIA FOR DETERMINATION OF POSTULATED BREAK AND LEAKAGE LOCATIONS IN HIGH[1] AND MODERATE[2] ENERGY FLUID PIPING SYSTEMS OUTSIDE OF CONTAINMENT STRUCTURES[c]

A. High-Energy Fluid Systems

1. For piping systems that by plant arrangement and layout are isolated by remote location for structures, systems, and components important to safety[3], pipe breaks[4] need not be postulated provided the requirements of A.4 are satisfied.

2. For piping systems that are enclosed in suitably designed concrete structures or compartments to protect structures, systems, and components important to safety, pipe break should be postulated at the following locations in each piping or branch run within the protective structure:

   a. the terminal ends[9] of the piping or branch run (except as exempted by the provisions of A.4), if located within the protective structure or compartment, and

   b. each fitting (i.e., elbow, tee, cross, non-standard fitting), and

   c. a minimum of one break selected in each piping or branch run within the protective structure or compartment at a location that results in the maximum loading from the impact of the postulated ruptured pipe and jet discharge force on wall, floor, and roof of the structure or compartment, including internal pressurization, and taking into account any piping restraints provided to limit pipe motions.

3. For portions of piping systems that can neither be isolated as specified in A.1, nor enclosed in protective structures as specified in A.2, pipe breaks should be postulated at the following locations in each piping or branch run within the confines of the structures or compartments that enclose or adjoin areas containing systems and components important to safety:

   a. the terminal ends[9] of piping or branch run (except as exempted by A.4), if located within the boundary of the confining structure or each compartment within the structure; and

   b. any intermediate location within the boundary of the confining structure or each compartment within the structure where the stresses[5] under the loadings associated with specified seismic events[6] and operational plant conditions[7] exceed 0.8 $(S_h + S_A)$[8] or, in lieu of these calculated stress-related locations, at each fitting (i.e., elbow, tree, cross, non-standard fitting); and

   c. a minimum of two separated locations within the boundary of the confining structure of each compartment within the structure in piping or branch runs exceeding twenty pipe diameters in length; a minimum of one location in piping or branch runs twenty pipe-diameters or less in length except that no intermediate locations need to be postulated in branch runs that are three pipe-diameters or less in length. Intermediate break locations should be selected such that the maximum pipe whip and jet impingement will result, assuming for this purpose an unrestrained ruptured pipe.

4. For those portions of the piping passing through primary containment penetrations and extending to the first outside isolation valve, pipe breaks need not be postulated provided such piping is conservatively reinforced and restrained beyond the valve such that, in the event of a postulated pipe break outside containment, the transmitted pipe loads will neither impair the operability of the valve nor the integrity of the piping or the containment penetration. (A terminal end of such piping is considered to originate at this restraint location.)

B. Moderate-Energy Fluid Systems

1. For piping systems that by plant arrangement and layout are isolated and physically separated and remotely located from systems and components important to safety, through-wall leakage cracks need not be postulated.

2. For piping systems that are located in the same areas as high-energy fluid systems which, by the criteria of A.1 to A.3 have postulated pipe break locations, through-wall leakage cracks need not be postulated.

3. For piping systems that are located in areas containing systems and components important to safety, but where no high-energy fluid systems are present, through-wall leakage cracks should be postulated at the most adverse location to determine the protection needed to withstand the effects of the resulting water spray and flooding.

C. Size and Types of Pipe Breaks and Cracks

1. The following types of breaks should be postulated at the locations specified by the criteria listed under A. High-Energy Fluid Systems:

   a. longitudinal breaks in piping runs and branch runs with nominal pipe sizes of 4 inches and larger,

   b. circumferential breaks in piping runs and branch runs exceeding a nominal pipe size of 1 inch.

2. The following leakage cracks are postulated at the locations specified by the criteria listed under B. Moderate-Energy Fluid Systems:

   a. through-wall leakage cracks in piping and branch runs exceeding a nominal pipe size of 1 inch, where the crack opening is assumed as 1/2 the pipe diameter in length and 1/2 the pipe wall thickness in width.

FOOTNOTES

[1] High-energy systems include those systems where either of the following conditions are met:

(a) the maximum operating temperature exceeds 200°F, and
(b) the maximum operating pressure exceeds 275 psig.

[2] Moderate energy systems include those systems where both of the following conditions are met:

(a) the maximum operating temperature is 200°F or less, and
(b) the maximum operating pressure is 275 psig or less.

[3] Structures, systems, and components important to safety, as specified herein refer to those plant features required to shut down the reactor safely and maintain the plant in the cold shutdown condition.

[4] Break in piping means (a) a complete circumferential pipe severance and, (b) a longitudinal split opening an area equal to the pipe area, but without pipe severance. Such breaks are assumed to occur at each specified break location, but not concurrently.

[5] Either circumferential or longitudinal stresses derived on an elastically-calculated basis.

[6] Specified seismic events are earthquakes that produce at least 50 percent of the vibratory motion of the Safe Shutdown Earthquake (SSE).

[7] Operational plant conditions include normal reactor operation, upset conditions, (e.g., anticipated operational occurrences) and testing conditions.

[8] S_h is the allowable stress at maximum temperature, and S_A is the allowable stress range for expansion stresses for Class 2 and 3 piping as permitted by the rules of ASME Code Section III.

[9] Terminal ends of pipe runs originate at points of maximum constraint (e.g., connections to vessels, pumps, valves, fittings that are rigidly anchored to structures). Terminal ends of branch runs originate at pipe intersections and components that act as rigid constraints.

[10] These criteria are intended for the purpose of designing piping restraints and do not preclude consideration of other aspects of the AEC General Design Criteria, such as single failure criteria and other additional protective measures required to provide protection against environmental conditions incident to postulated accidents.