3.6 Protection Against Dynamic Effects Associated with the Postulated Rupture of Piping

This Section discusses the structures, systems, components and equipment in the Lungmen Nuclear Power Station (NPS).

Subsections 3.6.1 and 3.6.2 describe the design bases and protective measures which ensure that the containment, essential systems, components and equipment, and other essential structures are adequately protected from the consequences associated with a postulated rupture of high-energy piping or crack of moderate-energy piping both inside and outside the containment.

Before delineating the criteria and assumptions used to evaluate the consequences of piping failures inside and outside of the containment, it is necessary to define a pipe break event and a postulated piping failure:

Pipe break event: Any single postulated piping failure occurring during normal plant operation and any subsequent piping failure and/or equipment failure that occurs as a direct consequence of the postulated piping failure.

Postulated Piping Failure: Longitudinal or circumferential break or rupture postulated in high-energy fluid system piping or throughwall leakage crack postulated in moderate-energy fluid system piping. The terms used in this definition are explained in Subsection 3.6.2.

Structures, systems, components, and equipment that are required to shut down the reactor and mitigate the consequences of a postulated piping failure, without offsite power, are defined as essential and are designed to Seismic Category I requirements.

The dynamic effects that may result from a postulated rupture of high-energy piping include (1) missile generation, (2) pipe whipping, (3) pipe break reaction forces, (4) jet impingement forces, (5)compartment, subcompartment and cavity pressurizations, (6) decompression waves within the ruptured pipes. There are also seven types of loads identified with a loss-of-coolant accident (LOCA) shown on Table 3.9-2.

3.6.1 Postulated Piping Failures in Fluid Systems Inside and Outside of Containment

This subsection sets forth the design bases, description, and safety evaluation for determining the effects of postulated piping failures in fluid systems both inside and outside the containment, and for including necessary protective measures.

3.6.1.1 Design Bases

3.6.1.1.1 Criteria

Pipe break event protection conforms to 10CFR50 Appendix A, General Design Criterion 4, Environmental and Missile Design Bases. The design bases for this protection are in compliance with NRC Branch Technical Positions (BTP) ASB 3-1 and MEB 3-1 included in Subsections 3.6.1 and 3.6.2, respectively, of NUREG-0800 (Standard Review Plan (SRP)), except for the following:

(1) MEB 3-1, B.1.b(1)(a) Footnote 2 should read, "For those loads and conditions in which Level A and Level B stress limits have been specified in the Design Specification (excluding earthquake loads)."

(2) MEB 3-1, B.1.b(1)(d) should read, "The maximum stress as calculated by the sum of Equations (9) and (10) in Paragraph NC-3653, ASME Code, Section III, considering those loads and conditions thereof for which Level A and Level B stress limits have been specified in the system's Design Specification (i.e., sustained loads, occasional loads, and thermal expansion) excluding earthquake loads should not exceed 0.8 (1.8 Sh + SA)."

(3) MEB 3-1, B.1.C(1)(b) should read, "At intermediate locations where the maximum stress range as calculated by Equation (10) exceeds 2.4 Sm, and the stress range calculated by either Equation (12) or Equation (13) in Paragraph NB-3653 exceeds 2.4 Sm."

MEB 3-1 describes an acceptable basis for selecting the design locations and orientations of postulated breaks and cracks in fluid systems piping. Standard Review Plan Sections 3.6.1 and 3.6.2 describe acceptable measures that could be taken for protection against the breaks and cracks and for restraint against pipe whip that may result from breaks.

The design of the containment structure, component arrangement, pipe runs, pipe whip restraints and compartmentalization is done in consonance with the acknowledgment of protection against dynamic effects associated with a pipe break event. Analytically sized and positioned pipe whip restraints are engineered to preclude damage based on the pipe break evaluation.

3.6.1.1.2 Objectives

Protection against pipe break event dynamic effects is provided to fulfill the following objectives:

(1) Assure that the reactor can be shut down safely and maintained in a safe cold shutdown condition and that the consequences of the postulated piping failure are mitigated to acceptable limits without offsite power.

(2) Assure that containment integrity is maintained.

(3) Assure that the radiological doses of a postulated piping failure remain below the limits of 10CFR100.

3.6.1.1.3 Assumptions

The following assumptions are used to determine the protection requirements:

(1) Pipe break events may occur during normal plant conditions (i.e., reactor startup, operation at power, normal hot standby* or reactor cooldown to cold shutdown conditions but excluding test modes).

(2) A pipe break event may occur simultaneously with a seismic event; however, a seismic event does not initiate a pipe break event. This applies to Seismic Category I and non-Seismic Category I piping.

(3) A Single Active Component Failure (SACF) is assumed in systems used to mitigate consequences of the postulated piping failure and to shut down the reactor, except as noted in item (4) below. A SACF is a 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, or electrical malfunction but not the loss of component structural integrity. The direct consequences of a SACF are considered to be a part of the single active failure. The single active component failure is assumed to occur in addition to the postulated piping failure and any direct consequences of the piping failure.

(4) 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 active failure of components in the other train or trains of that system only are not 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-related systems (e.g., the Residual Heat Removal System (RHR)).

(5) If a pipe break event involves a failure of non-Seismic Category I piping, the pipe break event must not result in failure of essential systems, components, and equipment to shut down the reactor and mitigate the consequences of the pipe break event considering a SACF in accordance with items (3) and (4) above.

(6) If loss of offsite power is a direct consequence of the pipe break event (e.g., trip of the turbine-generator producing a power surge, which, in turn, trips the main breaker), then a loss of offsite power occurs in a mechanistic time sequence with a SACF. Otherwise, offsite power is assumed available with a SACF.

(7) Pipe whip shall be considered capable of causing circumferential and longitudinal breaks, individually, in impacted pipes of smaller nominal pipe size, irrespective of pipe wall thickness, and developing through-wall cracks in equal or larger nominal pipe sizes with equal or thinner wall thickness. Analytical or experimental data, or both, for the expected range of impact energies may be used to demonstrate the capability to withstand the impact without rupture; however, loss of function due to reduced flow in the impacted pipe should be considered.

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

(9) Although a pipe break event outside the containment may require a cold shutdown, up to eight hours in hot standby (within Reactor Core Isolation Cooling System (RCIC) capability) is allowed in order for plant personnel to assess the situation and make repairs.

(10) Pipe whip, with rapid motion of a pipe resulting from a postulated pipe break, occurs in the plane determined by the piping geometry and causes movement in the direction of the jet reaction. If unrestrained, a whipping pipe with a constant energy source forms a plastic hinge and rotates about the nearest rigid restraint, anchor, or wall penetration. If unrestrained, a whipping pipe without a constant energy source (i.e., a break at a closed valve with only one side subject to pressure) is not capable of forming a plastic hinge and rotating provided its movement can be defined and evaluated.

(11) The fluid internal energy associated with the pipe break reaction can take into account any line restrictions (e.g., flow limiter) between the pressure source and break location and absence of energy reservoirs, as applicable.

(12) All walls, doors, floors, and penetrations which serve as divisional boundaries will be designed to withstand the worst case pressurizations associated with the postulated pipe failures inside primary containment.

All structural divisional separation walls will maintain their structural integrity after a postulated failure outside primary containment and within secondary containment. Divisional separation doors, penetration and floors are not required to maintain their structural integrity. Justification for divisional separation integrity is addressed in Subsections 3.4.1, 6.2.3 and 9.5.1.

3.6.1.1.4 Approach

To comply with the objectives previously described, the essential systems, components, and equipment are identified. The essential systems, components, and equipment, or portions thereof, are identified in Table 3.6-1 for piping failures postulated inside the containment and in Table 3.6-2 for outside the containment.

3.6.1.2 Description

High-energy lines are defined in Subsection 3.6.2.1.1 are listed in Table 3.6-3 for inside the containment and in Table 3.6-4 for outside the containment. Moderate-energy lines are defined in Subsection 3.6.2.1.2 and are defined in Table 3.6-5 for inside and Table 3.6-6 for outside the containment. Pressure response analyses are performed for the subcompartments containing high-energy piping. A detailed discussion of the line breaks selected, vent paths, room volumes, analytical methods, pressure results, etc., is provided in Section 6.2 for primary containment subcompartments.

The effects of pipe whip, jet impingement, spraying, and flooding on required function of essential systems, components, and equipment, or portions thereof, inside and outside the containment are considered.

The control room is protected from high-energy line breaks. As such, there are no effects upon the habitability of the control room by a piping failure in the control building or elsewhere either from pipe whip, jet impingement, or transport of steam. Further discussion on control room habitability systems is provided in Section 6.4.

3.6.1.3 Safety Evaluation

3.6.1.3.1 General

An analysis of pipe break events is performed to identify those essential systems, components, and equipment that provide protective actions required to mitigate, to acceptable limits, the consequences of the pipe break event.

Pipe break events involving high-energy fluid systems are evaluated for the effects of pipe whip, jet impingement, flooding, room pressurization, and other environmental effects such as temperature. Pipe break events involving moderate-energy fluid systems are evaluated for wetting from spray, flooding, and other environmental effects.

By means of the design features such as separation, barriers, and pipe whip restraints, a discussion of which follows, adequate protection is provided against the effects of pipe break events for essential items to an extent that their ability to shut down the plant safely or mitigate the consequences of the postulated pipe failure would not be impaired.

3.6.1.3.2 Protection Methods

3.6.1.3.2.1 General

The direct effects associated with a particular postulated break or crack must be mechanistically consistent with the failure. Thus, actual pipe dimensions, piping layouts, material properties (in accordance with SRP 3.6.2), and equipment arrangements are considered in defining the following specific measure for protection against actual pipe movement and other associated consequences of postulated failures:

1. Protection against the dynamic effects of pipe failures is provided in the form of pipe whip restraints, equipment shields, and physical separation of piping, equipment, and instrumentation.
2. The precise method chosen depends largely upon limitations placed on the designer such as accessibility, maintenance, and proximity to other pipes.

3.6.1.3.2.2 Separation

Each plant arrangement provides physical separation to the extent practicable to maintain the independence of redundant essential systems (including their auxiliaries) in order to prevent the loss of safety function due to any single pipe break event. Redundant trains (e.g., A and B trains) and divisions are located in separate compartments to the extent possible. Physical separation between redundant essential systems with their related auxiliary supporting features, therefore, is the basic protective measure incorporated in the design to protect against the dynamic effects of a pipe break anywhere in high energy piping.

However, due to the complexities of several divisions being adjacent to high-energy lines in the drywell and Reactor Building steam tunnel, specific break locations are determined in accordance with Subsection 3.6.2.1.4.3 for possible spatial separation. Care is taken to avoid concentrating essential equipment in the break exclusion zone allowed per Subsection 3.6.2.1.4.2. If spatial separation requirements (distance and/or arrangement described below) cannot be met based on the postulation of specific breaks, then barriers, enclosures, shields, or restraints are provided. These methods of protection are discussed in Subsections 3.6.1.3.2.3 and 3.6.1.3.2.4.

For other areas where physical separation is not practical, the following high-energy line-separation analysis (HELSA) evaluation is done to determine which high-energy lines meet the spatial separation requirement and which lines require further protection:

(1) For the HELSA evaluation, no particular break points are identified. Cubicles or areas through which the high-energy lines pass are examined in total. Breaks are postulated at any point in the piping system.

(2) Essential systems, components, and equipment at a distance greater than 9.14m from any high-energy piping are considered as meeting spatial separation requirements. No damage is assumed to occur due to jet impingement since the impingement, force becomes negligible beyond 9.14m. Likewise, a 9.14m evaluation zone is established for pipe breaks to assure protection against potential damage from a whipping pipe. Assurance that 9.14m represents the maximum free length is made in the piping layout.

(3) Essential systems, components, and equipment at a distance less than 9.14m from any high-energy piping are evaluated to see if damage could occur to more than one essential division, preventing safe shutdown of the plant. If damage occurred to only one division of a redundant system, the requirement for redundant separation is met. Other redundant divisions are available for safe shutdown of the plant and no further evaluation is performed.

(4) If damage could occur to more than one division of a redundant essential system within 9.14m of any high-energy piping, then other protection measures in the form of barriers, shields, or enclosures (Subsection 3.6.1.3.2.3) or pipe whip restraints (Subsection 3.6.1.3.2.4) are used as described above.

3.6.1.3.2.3 Barriers, Shields, and Enclosures

Protection requirements are met through the protection afforded by the walls, floors, columns, abutments, and foundations in many cases. Where adequate protection is not already present due to spatial separation or existing plant features, additional barriers, deflectors, or shields are identified as necessary to meet the functional protection requirements.

Barriers or shields that are identified as necessary by the use of specific break locations in the drywell are designed for the specific loads associated with the particular break location.

The steam tunnel is made of reinforced concrete 2m thick. A steam tunnel subcompartment analysis was performed for the postulated rupture of a main steamline and for a feedwater line (Subsection 6.2.3.3.1.3). The calculated peak pressure from a main steamline break was found to be 58.84 kPaG. The calculated peak pressure from a feedwater line break was found to be 26.48 kPaG. The steam tunnel is designed for the effects of an SSE coincident with HELB inside the steam tunnel. Under this conservative load combination, no failure in any portion of the steam tunnel was found to occur; therefore, a HELB inside the steam tunnel will not effect control room habitability.

The main steam isolation valves (MSIVs) and the feedwater isolation and check valves located inside the tunnel shall be designed for the effects of a line break. The details of how the MSIV and feedwater isolation and check valves functional capabilities are protected against the effects of these postulated pipe failures will be provided in the FSAR.

Barriers or shields that are identified as necessary by the HELSA evaluation (i.e., based on no specific break locations) are designed for worst-case loads. The closest high-energy pipe location and resultant loads are used to size the barriers.

3.6.1.3.2.4 Pipe Whip Restraints

Pipe whip restraints are used where pipe break protection requirements could not be satisfied using spatial separation, barriers, shields, or enclosures alone. Restraints are located based on the specific break locations determined in accordance with Subsections 3.6.2.1.4.3 and 3.6.2.1.4.4. After the restraints are located, the piping and essential systems are evaluated for jet impingement and pipe whip. For those cases where jet impingement damage could still occur, barriers, shields, or enclosures are utilized.

The design criteria for restraints are given in Subsection 3.6.2.3.3.

3.6.1.3.3 Specific Protection Measures

(1) Nonessential systems and system components are not required for the safe shutdown of either reactor, nor are they required for the limitation of the offsite release in the event of a pipe rupture. However, while none of this equipment is needed during or following a pipe break event, pipe whip protection is considered where a resulting failure of a nonessential system or component could initiate or escalate the pipe break event in an essential system or component, or in another nonessential system whose failure could affect an essential system.

(2) For high-energy piping systems penetrating through the containment, isolation valves are located as close to the containment as possible.

(3) The pressure, water level, and flow sensor instrumentation for those essential systems, which are required to function following a pipe rupture, are protected.

(4) High-energy fluid system pipe whip restraints and protective measures are designed so that a postulated break in one pipe could not, in turn, lead to a 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.

(5) For any postulated pipe rupture, the structural integrity of the containment structure is maintained. In addition, for those postulated ruptures classified as a loss of reactor coolant, the design leaktightness of the containment fission product barrier is maintained.

(6) Safety/relief valves (SRVs) and the Reactor Core Isolation Cooling (RCIC) System steamline are located and restrained so that a pipe failure would not prevent depressurization.

(7) Separation is provided to preserve the independence of the low-pressure flooder (LPFL) systems.

(8) Protection for the FMCRD scram insert lines is not required since the motor operation of the FMCRD can adequately insert the control rods even with a complete loss of insert lines (Subsection 3.6.2.1.6.1).

(9) The escape of steam, water, combustible or corrosive fluids, gases, and heat in the event of a pipe rupture do not preclude:

    (a) Accessibility to any areas required to cope with the postulated pipe rupture

    (b) Habitability of the control room

    (c) The ability of essential instrumentation, electric power supplies, components, and controls to perform their safety-related function

3.6.2 Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping

Information concerning break and crack location criteria and methods of analysis for dynamic effects is presented in this subsection and is supplemented in Appendix 3L. The location criteria and methods of analysis are needed to evaluate the dynamic effects associated with postulated breaks and cracks in high- and moderate-energy fluid system piping inside and outside of the primary containment. This information provides the basis for the requirements for the protection of essential structures, systems, and components defined in the introduction of Section 3.6.

3.6.2.1 Criteria Used to Define Break and Crack Location and Configuration

The following subsections establish the criteria for the location and configuration of postulated breaks and cracks.

3.6.2.1.1 Definition of High-Energy Fluid Systems

High-energy fluid systems are defined to be those systems or portions of systems that, during normal plant conditions (as defined in Subsection 3.6.1.1.3 (1)), are either in operation or are maintained pressurized under conditions where either or both of the following are met:

(1) Maximum operating temperature exceeds 93°C.

(2) Maximum operating pressure exceeds 1902.5 kPaG.

Table 3.6-3 lists the high-energy lines inside containment, and Table 3.6-4 lists the high-energy lines outside the containment.

3.6.2.1.2 Definition of Moderate-Energy Fluid Systems

Moderate-energy fluid systems are defined to be those systems or portions of systems that, during normal plant conditions (as defined in Subsection 3.6.1.1.3 (1)), are either in operation or are maintained pressurized (above atmospheric pressure) under conditions where both of the following are met:

(1) Maximum operating temperature is 93°C or less.

(2) Maximum operating pressure is 1902.5 kPaG or less.

Piping systems are classified as moderate-energy systems when they operate as high-energy piping for only short operational periods in performing their system function but, for the major operational period, qualify as moderate-energy fluid systems. An operational period is considered short if the total fraction of time that the system operates within the pressure-temperature conditions specified for high-energy fluid systems is less than 2% of the total time that the system operates as a moderate-energy fluid system. Table 3.6-5 lists the moderate-energy lines inside containment, and Table 3.6-6 lists the moderate-energy lines outside containment.

3.6.2.1.3 Postulated Pipe Breaks and Cracks

A postulated pipe break is defined as a sudden gross failure of the pressure boundary either in the form of a complete circumferential severance (guillotine break) or a sudden longitudinal split without pipe severance, and is postulated for high-energy fluid systems only. For a moderate-energy fluid system, pipe failures are limited to postulation of cracks in piping and branch runs. These cracks affect the surrounding environmental conditions only and do not result in whipping of the cracked pipe. High-energy fluid systems are also postulated to have cracks for conservative environmental conditions in a confined area where high- and moderate-energy fluid systems are located.

The following high-energy piping systems (or portions of systems) are considered as potential candidates for a postulated pipe break during normal plant conditions and are analyzed for potential damage resulting from dynamic effects:

(1) All piping which is part of the reactor coolant pressure boundary and subject to reactor pressure continuously during station operation.

(2) All piping which is beyond the second isolation valve but subject to reactor pressure continuously during station operation.

(3) All other piping systems or portions of piping systems considered high-energy systems.

Portions of piping systems that are isolated from the source of the high-energy fluid during normal plant conditions are exempted from consideration of postulated pipe breaks. This includes portions of piping systems beyond a normally closed valve. Pump and valve bodies are also exempted from consideration of pipe break because of their greater wall thickness.

3.6.2.1.4 Locations of Postulated Pipe Breaks

Postulated pipe break locations are selected as follows:

3.6.2.1.4.1 Piping Meeting Separation Requirements

Based on the HELSA evaluation described in Subsection 3.6.1.3.2.2, the high-energy lines which meet the spatial separation requirements are generally not identified with particular break points. Breaks are postulated at all possible points in such high-energy piping systems. However, in some systems break points are particularly specified per the following subsections if special protection devices such as barriers or restraints are provided.

3.6.2.1.4.2 Piping in Containment Penetration Areas

No pipe breaks or cracks are postulated in those portions of piping from containment wall to and including the inboard or outboard isolation valves which meet the following requirement in addition to the requirement of ASME Code Section III, Subarticle NE-1120:

(1) The following design stress and fatigue limits of (a) through (e) are not exceeded.

For ASME Code Section III, Class 1 Piping

(a) The maximum stress range between any two loads sets (including the zero load set) does not exceed 2.4 Sm, and is calculated† by Eq. (10) in NB-3653, ASME Code, Section III.

If the calculated maximum stress range of Eq. (10) exceeds 2.4 Sm, the stress ranges calculated by both Eq. (12) and Eq. (13) in Paragraph NB-3653 meet the limit of 2.4 Sm.

(b) The cumulative usage factor is less than 0.1.

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

For ASME Code Section III, Class 2 Piping

(d) The maximum stress, as calculated by the sum of Equations (9) and (10) in Paragraph NC-3653, ASME Code Section III, considering those loads and conditions thereof for which Level A and Level B stress limits are specified in the system's Design Specification (i.e., sustained loads, occasional loads, and thermal expansion) does not exceed 0.8(1.8 Sh + SA). The Sh and SA are allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of ASME Code Section III.

(e) The maximum stress, as calculated by Eq. (9) in NC-3653, under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping does not exceed the lesser of 2.25 Sh and 1.8 Sy.

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

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

(3) The number of circumferential and longitudinal piping welds and branch connections are minimized. Where penetration sleeves are used, the enclosed portion of fluid system piping is seamless construction and without circumferential welds unless specific access provisions are made to permit inservice volumetric examination of longitudinal and circumferential welds.

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

(5) The design of pipe anchors or restraints (e.g., connections to containment penetrations and pipe whip restraints) does 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% volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the limits of Item (1).

(6) Sleeves provided for those portions of piping in the containment penetration areas are constructed in accordance with the rules of Class MC, Subsection NE of ASME Code Section III, where the sleeve is part of the containment boundary. In addition, the entire sleeve assembly is designed to meet the following requirements and tests:

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

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

   (c) The assemblies are subjected to a single pressure test at a pressure not less than its design pressure.

   (d) The assemblies do not prevent the access required to conduct the inservice examination specified in Item (7).

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

3.6.2.1.4.3 ASME Code Section III Class 1 Piping in Areas Other Than Containment Penetration

With the exception of those portions of piping identified in Subsection 3.6.2.1.4.2, breaks in ASME Code Section III Class 1 Piping are postulated at the locations identified in (1), (2), and (3) in each piping and branch run.

(1) At terminal ends‡.

(2) At intermediate locations where the maximum stress range as calculated by Eq. (10) exceeds 2.4 Sm, and

The stress range calculated by either Eq. (12) or Eq. (13) in Paragraph NB-3653 exceeds 2.4 Sm.

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

As a result of piping re-analysis due to differences between the design configuration and the as-built configuration, the highest stress or cumulative usage factor locations may be shifted; however, the initially determined intermediate break locations need not be changed unless one of the following conditions exists:

(a) The dynamic effects from the new (as-built) intermediate break locations are not mitigated by the original pipe whip restraints and jet shields.

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

3.6.2.1.4.4 ASME Code Section III Class 2 and 3 Piping in Areas Other Than Containment Penetration

With the exception of those portions of piping identified in Subsection 3.6.2.1.4.2, breaks in ASME Code Section III, Class 2 and 3 Piping are postulated at the following locations in those portions of each piping and branch run:

(1) At terminal ends (Subsection 3.6.2.1.4.3, Paragraph (1)).

(2) At intermediate locations selected by one of the criteria below.

  (a) 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.

  (b) At each location where stresses calculated (Subsection 3.6.2.1.4.2, Paragraph (1) (d)) by the sum of Eqs. (9) and (10) in NC/ND-3653, ASME Code Section III, exceed 0.8 times the sum of the stress limits given in NC/ND- 3653.

As a result of piping re-analysis due to differences between the design configuration and the as-built configuration, the highest stress locations may be shifted; however, the initially determined intermediate break locations may be used unless a redesign of the piping resulting in a change in the pipe parameters (diameter, wall thickness, routing) is required, or the dynamic effects from the new (as-built) intermediate break location are not mitigated by the original pipe whip restraints and jet shields.

3.6.2.1.4.5 Non-ASME Class Piping

Breaks in seismically analyzed non-ASME Class (not ASME Class 1, 2 or 3) piping are postulated according to the same requirements for ASME Class 2 and 3 piping above. Separation and interaction requirements between seismically analyzed and non-seismically analyzed piping are met as described in Subsection 3.7.3.13.

3.6.2.1.4.6 Separating Structure with High-Energy Lines

If a structure separates a high-energy line from an essential component, the separating structure is designed to withstand the consequences of the pipe break in the high-energy line at locations that the aforementioned criteria require to be postulated. However, as noted in Subsection

3.6.1.3.2.3, some structures that are identified as necessary by the HELSA evaluation (i.e., based on no specific break locations) are designed for worst-case loads.

3.6.2.1.5 Locations of Postulated Pipe Cracks

Postulated pipe crack locations are selected as follows:

3.6.2.1.5.1 Piping Meeting Separation Requirements

Based on the HELSA evaluation described in Subsection 3.6.1.3.2.2, the high- or moderate-energy lines which meet the separation requirements are not identified with particular crack locations. Cracks are postulated at all possible points that are necessary to demonstrate adequacy of separation or other means of protections provided for essential structures, systems and components.

3.6.2.1.5.2 High-Energy Piping

With the exception of those portions of piping identified in Subsection 3.6.2.1.4.2, leakage cracks are postulated for the most severe environmental effects as follows:

(1) For ASME Code Section III, Class 1 piping, at axial locations where the calculated stress range [Subsection 3.6.2.1.4.2, Paragraph (1)(a)] by Equation (10) in NB-3653 exceeds 1.2 Sm.

(2) For ASME Code Section III Class 2 and 3 or non-ASME class piping, at axial locations where the calculated stress [Subsection 3.6.2.1.4.4, Paragraph (2)(b)] by the sum of Equations (9) and (10) in NC/ND-3653 exceeds 0.4 times the sum of the stress limits given in NC/ND-3653.

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

3.6.2.1.5.3 Moderate-Energy Piping

3.6.2.1.5.3.1 Piping in Containment Penetration Areas

Leakage cracks are not postulated in those portions of piping from containment wall to and including the inboard or outboard isolation valves, provided they meet the requirements of ASME Code Section III, NE-1120, and the stresses calculated (Subsection 3.6.2.1.4.4, Paragraph (2)(b)) by the sum of Equations (9) and (10) in ASME Code Section III, NC-3653 do not exceed 0.4 times the sum of the stress limits given in NC-3653.

3.6.2.1.5.3.2 Piping in Areas Other Than Containment Penetration

(1) Leakage cracks are postulated in piping located adjacent to essential structures, systems or components, except for (a), (b), and (c) below.

(a) Where exempted by Subsections 3.6.2.1.5.3.1 and 3.6.2.1.5.4.

(b) For ASME Code Section III, Class 1 piping the stress range calculated by Eq. (10) in NB-3653 is less than 1.2 Sm.

(c) For ASME Code Section III Class 2 or 3 and non-ASME class piping, the stresses calculated [Subsection 3.6.2.1.4.4, Paragraph (2) (b)] by the sum of Equations (9) and (10) in NC/ND-3653 are less than 0.4 times the sum of the stress limits given in NC/ND-3653.

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

(3) Leakage cracks are postulated in fluid system piping designed to nonseismic standards as necessary to meet the environmental protection requirements of Subsection 3.6.1.1.3.

3.6.2.1.5.4 Moderate-Energy Piping in Proximity to High-Energy Piping

Moderate-energy fluid system piping or portions thereof that are located within a compartment of confined area involving considerations for a postulated break in high-energy fluid system piping are acceptable without postulation of throughwall leakage cracks except where a postulated leakage crack in the moderate-energy fluid system piping results in more severe environmental conditions than the break in the proximate high-energy fluid system piping, in which case the provisions of Subsection 3.6.2.1.5.3 are applied.

3.6.2.1.6 Types of Breaks and Cracks to be Postulated

3.6.2.1.6.1 Pipe Breaks

The following types of breaks are postulated in high-energy fluid system piping at the locations identified by the criteria specified in Subsection 3.6.2.1.4.

(1) No breaks are postulated in piping having a nominal diameter less than or equal to 25mm. Instrument lines 25mm and less nominal pipe or tubing size meet the provision of Regulation Guide 1.11 (Table 3.2-1). Additionally, the 32mm hydraulic control unit fast scram lines do not require special protection measure because of the following reasons:

(a) The piping to the control rod drives from the hydraulic control units (HCUs) are located in the containment under reactor vessel, and in the Reactor

Building (RB) away from other safety-related equipment; therefore, should a line fail, it would not affect any safety-related equipment but only impact on other HCU lines. As discussed in Subsection 3.6.1.1.3, Paragraph (7), a whipping pipe will only rupture an impacted pipe of smaller nominal pipe size or cause a throughwall crack in the same nominal pipe size but with thinner wall thickness.

(b) The total amount of energy contained in the 32mm nominal pipe size piping between normally closed scram insert valve on the HCU module and the ball-check valve in the control rod housing is small. In the event of a rupture of this line, the ball-check valve will close to prevent reactor vessel flow out of the break.

(c) Even if a number of the HCU lines ruptured, the control rod insertion function would not be impaired, since the electrical motor of the Fine Motion Control Rod Drive (FMCRD) would drive in the control rods.

(2) Longitudinal breaks are postulated only in piping having a nominal diameter equal to or greater than 100mm.

(3) Circumferential breaks are only assumed at all terminal ends.

(4) At each of the intermediate postulated break locations identified to exceed the stress and usage factor limits of the criteria in Subsections 3.6.2.1.4.3 and 3.6.2.1.4.4, consideration is given to the occurrence of either a longitudinal or circumferential break. Examination of the state of stress in the vicinity of the postulated break location is used to identify the most probable type of break. If the maximum stress range in the longitudinal direction is greater than 1.5 times the maximum stress range in the circumferential direction, only the circumferential break is postulated. Conversely, if the maximum stress range in the circumferential direction is greater than 1.5 times the stress range in the longitudinal direction, only the longitudinal break is postulated. If no significant difference between the circumferential and longitudinal stresses is determined, then both types of breaks are considered.

(5) Where breaks are postulated to occur at each intermediate pipe fitting, weld attachment, or valve without the benefit of stress calculations, only circumferential breaks are postulated.

(6) For both longitudinal and circumferential breaks, after assessing the contribution of upstream piping flexibility, pipe whip is assumed to occur in the plane defined by the piping geometry and configuration for circumferential breaks, and out of plane for longitudinal breaks and to cause piping movement in the direction of the jet reactions. Structural members, piping restraints, or piping stiffness as demonstrated by inelastic limit analysis are considered in determining the piping movement limit

(alternatively, circumferential breaks are assumed to result in pipe severance and separation amounting to at least a one-diameter lateral displacement of the ruptured piping sections).

(7) For a circumferential break, the dynamic force of the jet discharged at the break location is based upon 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 are used, as applicable, in the reduction of the jet discharge.

(8) Longitudinal breaks in the form of axial split without pipe severance are postulated in the center of the piping at two diametrically opposed points (but not concurrently) located so that the reaction force is perpendicular to the plane of the piping configuration and produces out-of-plane bending. Alternatively, a single split is assumed at the section of highest tensile stress as determined by detailed stress analysis (e.g., finite element analysis).

(9) The dynamic force of the fluid jet discharge is 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.

3.6.2.1.6.2 Pipe Cracks

The following criteria are used to postulate throughwall leakage cracks in high- or moderate-energy fluid systems or portions of systems:

(1) Cracks are postulated in moderate-energy fluid system piping and branch runs exceeding a nominal pipe size of 25mm.

(2) At axial locations determined per Subsection 3.6.2.1.5, the postulated cracks are oriented circumferentially to result in the most severe environmental consequences.

(3) Crack openings are assumed as a circular orifice of area equal to that of a rectangle having dimensions one-half-pipe-diameter in length and one-half-pipe-wall thickness in width.

(4) The flow from the crack opening is assumed to result in an environment that wets all unprotected components within the compartment, with consequent flooding in the compartment and communicating compartments, based on a conservatively estimated time period to effect corrective actions.

3.6.2.2 Analytic Methods to Define Blowdown Forcing Functions and Response Models

3.6.2.2.1 Analytic Methods to Define Blowdown Forcing Functions

The rupture of a pressurized pipe causes the flow characteristics of the system to change, creating reaction forces which can dynamically excite the piping system. The reaction forces are a function of time and space and depend upon the fluid state within the pipe prior to rupture, break flow area, frictional losses, plant system characteristics, piping system, and other factors.

The thrust time-histories acting at the break location and on the segments of the ruptured piping system shall be defined according to the following:

(1) Pipe segment forces are defined by the generalized equations in Paragraph 6.2 and Appendix A of ANS 58.2.

(2) Pipe segment forces are further defined according to the methods and procedures in The Thermal-Hydraulics of a Boiling Water Nuclear Reactor, by R.T. Lahey, Jr. and F.J. Moody. (Reference 3.6-7)

(3) Thrust forces acting at the rupture point are determined according to the simplified methods contained in Appendix B of ANS 58.2, and are assumed to occur at 102%.

When the pipe rupture analysis requires a complete-system dynamic analysis, as defined in Paragraph 6.3.1 of ANS 58.2, the pipe segment time-histories are calculated by a computer program such as MS-BRK in compliance with (1) and (2) above.

All thrust time-history calculations shall be based on the postulated rupture descriptions contained in Paragraph 4.2 of ANS 58.2.

When the pipe rupture analysis is performed by a simplified analysis with a portion of the pipe system, as defined in Paragraph 6.3.2 of ANS 58.2, the thrust time-histories acting at the break locations may be calculated manually in compliance with (3) above.

3.6.2.2.2 Pipe Whip Dynamic Response Analyses

An analysis shall be conducted of the postulated ruptured piping and pipe whip restraint system response to the fluid dynamic forces specified in Subsection 3.6.2.2.1 in accordance with the requirements of Paragraph 6.3 of ANS 58.2. The analysis shall be in sufficient detail to evaluate the potential for pipe whip, determine potential jet impingement targets, establish the pipe whip restraint and associated structural loads and demonstrate that following dynamic event the system would be capable of supporting fluid forces at steady state flow conditions.

The alternative analytical approaches described in Paragraphs 6.3.1 through 6.3.5 of ANS 58.2 are acceptable approaches for piping response calculation. Criteria for an acceptable design are:

(1) The piping stresses between the isolation valves are within the allowable limits specified in SRP 3.6.2 and BTP MEB 3-1, Paragraph B.1.b.

(2) The pipe whip restraint loads and displacements due to postulated break are within the allowable limits specified in SRP 3.6.2.

(3) Calculated loads or stresses for safety-related valves or equipment to which the ruptured piping is attached do not exceed the operability limits specified in Subsection 3.9.3.

Appendix 3L provides an acceptable procedure for evaluation of the piping-pipe whip restraint system due to the dynamic effect of fluid forces resulting from postulated pipe ruptures. The procedure in Appendix 3L covers the analytical approach for (1) a complete system dynamic analysis as defined in Paragraph 6.3.1 of ANS 58.2 using the ANSYS computer program, and (2) a simplified dynamic analysis as defined in Paragraph 6.3.2 of ANS 58.2 using the PDA computer program.

3.6.2.3 Dynamic Analysis Methods to Verify Integrity and Operability

3.6.2.3.1 Jet Impingement Analyses and Effects on Safety-Related Components

The methods used to evaluate the jet effects resulting from the postulated breaks of high-energy piping are described in Appendices C and D of ANS 58.2 and presented in this subsection.

The criteria used for evaluating the effects of fluid jets on essential structures, systems, and components are as follows:

(1) Essential structures, systems, and components are not impaired so as to preclude essential functions. For any given postulated pipe break and consequent jet, those essential structures, systems, and components needed to safely shut down the plant are identified.

(2) Essential structures, systems, and components which are not necessary to safely shut down the plant for a given break are not protected from the consequences of the fluid jet.

(3) Safe shutdown of the plant due to postulated pipe ruptures within the RCPB is not aggravated by sequential failures of safety-related piping and the required emergency cooling system performance is maintained.

(4) Offsite dose limits specified in 10CFR100 are complied with.

(5) Postulated breaks resulting in jet impingement loads are assumed to occur in high-energy lines at full (102%) power operation of the plant.

(6) Throughwall leakage cracks are postulated in moderate-energy lines and are assumed to result in wetting and spraying of essential structures, systems, and components.

(7) Reflected jets are considered only when there is an obvious reflecting surface (such as a flat plate) which directs the jet onto an essential equipment. Only the first reflection is considered in evaluating potential targets.

(8) Potential targets in the jet path are considered at the calculated final position of the broken end of the ruptured pipe. This selection of potential targets is considered adequate due to the large number of breaks analyzed and the protection provided from the effects of these postulated breaks.

The analytical methods used to determine which targets will be impinged upon by a fluid jet and the corresponding jet impingement load include:

(1) The direction of the fluid jet is based on the arrested position of the pipe during steady-state blowdown.

(2) The impinging jet proceeds along a straight path.

(3) The total impingement force acting on any cross-sectional area of the jet is time and distance invariant with a total magnitude equivalent to the steady-state fluid blowdown force given in Subsection 3.6.2.2.1 and with jet characteristics shown in Figure 3.6-1.

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

(5) The break opening is assumed to be a circular orifice of cross-sectional flow area equal to the effective flow area of the break.

(6) The jet impingement force is equal to the steady-state value of the fluid blowdown force calculated by the methods described in Subsection 3.6.2.2.1.

(7) The distance of jet travel is divided into two or three regions. Region 1 (Figure 3.6-1) extends from the break to the asymptotic area. Within this region, the discharging fluid flashes and undergoes expansion from the break area pressure to the atmospheric pressure. In Region 2 the jet expands further. For partial-separation circumferential breaks, the area increases as the jet expands. In Region 3, the jet expands at a half angle of 10° (Figures 3.6-1).

(8) The analytical model for estimating the asymptotic jet area for subcooled water and saturated water assumes a constant jet area. For fluids discharging from a break which are below the saturation temperature at the corresponding room pressure or have a pressure at the break area equal to the room pressure, the free expansion does not occur.

(9) The distance downstream from the break where the asymptotic area is reached (Region 3, Figure 3.6-1) is calculated for circumferential and longitudinal breaks.

(10) Both longitudinal and fully separated circumferential breaks are treated similarly. The value of friction loss used in the blowdown calculation is used for jet impingement also.

(11) Circumferential breaks with partial (i.e., h<D/2) separation between the two ends of the broken pipe not significantly offset (i.e., no more than one pipe wall thickness lateral displacement) are more difficult to quantify. For these cases, the following assumptions are made:

  (a) The jet is uniformly distributed around the periphery.

  (b) The jet cross section at any cut through the pipe axis has the configuration depicted in Figure 3.6-1b and the jet regions are as therein delineated.

  (c) The jet force F_j = total blowdown F.

  (d) The pressure at any point intersected by the jet is:

$$P_j = \frac{F_j}{A_j} \qquad (3.6\text{-}1)$$

  where:

  A_j = The cylindrical surface area of the jet at a radius equal to the distance from the centerline to the target, calculated in accordance with ANS-58.2, Appendix C.

  (e) The pressure of the jet is then multiplied by the area of the target submerged within the jet.

(12) Target loads are determined using the following procedures:

  (a) For both the fully separated circumferential break and the longitudinal break, the jet is studied by determining target locations vs. asymptotic distance and the target shape factor and load are calculated in accordance with ANS-58.2, Appendices C and D.

(b) For circumferential break with limited separation, the jet is analyzed by using the equations of ANS 58.2, Appendices C and D and determining respective target and asymptotic locations

(c) After determination of the total area of the jet at the target, the jet pressure is calculated by:

$$P_1 = \frac{F_j}{A_x} \tag{3.6-2}$$

where:

P_1 = Incident pressure

A_x = Area of the expanded jet at the target intersection.

Target shape factors are included in accordance with ANS-58.2. If the effective target area (A_{te}) is less than the expanded jet area ($A_te \le A_x$), the target is fully submerged in the jet and the impingement load is equal to (P_1) (A_{te}). If the effective target area is greater than the expanded jet area ($A_{te} > A_x$), the target intercepts the entire jet and the impingement load is equal to (P_1) (A_x) = F_j. The effective target area (A_{te}) for various geometries follows.

(1) Flat Surface—For a case where a target with physical area At is oriented at angle q with respect to the jet axis and with no flow reversal, the effective target area Ate equals At.

(2) Pipe Surface—As the jet hits the convex surface of the pipe, its forward momentum is decreased rather than stopped; therefore, the jet impingement load on the impacted area is expected to be reduced. For conservatism, no credit is taken for this reduction and the pipe is assumed to be impacted with the full impingement load. The effective target area A_{te} is:

$$A_{te} = (D_A)\,(D) \tag{3.6-3}$$

where

D_A = Diameter of the jet at the target interface, and

D = Pipe OD of target pipe for a fully submerged pipe.

When the target (pipe) is larger than the area of the jet, the effective target area equals the expanded jet area

$$A_{te} = A_x \tag{3.6-4}$$

(3) For all cases, the jet area (Ax) is assumed to be uniform and the load is uniformly distributed on the impinged target area Ate.

3.6.2.3.2 Pipe Whip Effects on Essential Components

This subsection provides the criteria and methods used to evaluate the effects of pipe displacements on essential structures, systems, and components following a postulated pipe rupture.

Pipe whip (displacement) effects on essential structures, systems, and components can be placed in two categories: (1) pipe displacement effects on components (nozzles, valves, tees, etc.) which are in the same piping run that the break occurs in, and (2) pipe whip or controlled displacements onto external components such as building structure, other piping systems, cable trays, and conduits, etc.

3.6.2.3.2.1 Pipe Displacement Effects on Components in the Same Piping Run

The criteria for determining the effects of pipe displacements on inline components are as follows:

(1) Components such as vessel safe ends and valves which are attached to the broken piping system and do not serve a safety function or failure of which would not further escalate the consequences of the accident need not be designed to meet ASME Code Section III-imposed limits for essential components under faulted loading.

(2) If these components are required for safe shutdown or serve to protect the structural integrity of an essential component, limits to meet the ASME Code requirements for faulted conditions and limits to ensure required operability are met.

The methods used to calculate the pipe whip loads on piping components in the same run as the postulated break are described in Section 3.6.2.2.2.

3.6.2.3.2.2 Pipe Displacement Effects on Essential Structures, Other Systems, and Components

The criteria and methods used to calculate the effects of pipe whip on external components consist of the following:

(1) The effects on essential structures and barriers are evaluated in accordance with the barrier design procedures given in Subsection 3.5.3.

(2) If the whipping pipe impacts a pipe of equal or greater nominal pipe diameter and equal or greater wall thickness, the whipping pipe does not rupture the impacted pipe. Otherwise, the impacted pipe is assumed to be ruptured.

(3) If the whipping pipe impacts other components (valve actuators, cable trays, conduits, etc.), it is assumed that the impacted component is unavailable to mitigate the consequences of the pipe break event.

(4) Damage of unrestrained whipping pipe on essential structures, components, and systems other than the ruptured one is prevented by either separating high-energy systems from the essential systems or providing pipe whip restraints.

3.6.2.3.3 Design Criteria and Load Combinations for Pipe Whip Restraint

The loading combinations and design criteria for pipe whip restraints are dependent on the type of restraint and the function it performs. Some restraints in the Lungmen NPS are designed to perform a dual function of supporting the pipe during operating conditions and also of controlling the motion of the pipe following a postulated rupture. However, most pipe whip restraints in the units of the Lungmen NPS are single purpose restraints designed to control the motion of a broken pipe.

Figure 3.6-3 illustrates some acceptable pipe whip restraint designs. These designs include:

(1) The U-bar restraint—This is a single purpose, energy absorbing restraint designed for once-in-a-lifetime loading. The gap between the pipe and the restraint is relatively large to permit free thermal expansion of the pipe and does not provide support to maintain structural integrity of the pipe during any of the plant operating conditions. Most of the restraints used in the Lungmen NPS plant on large ASME Class 1 piping are U-bar restraints with stainless steel U-bars. This restraint is further defined in this Subsection and serves as the basis for the Appendix 3L procedure for evaluation of postulated ruptures in high-energy pipes. Although piping integrity does not depend on this single purpose pipe whip restraint, the restraint shall be designed to remain functional following an earthquake up to and including the SSE (Subsection 3.2.1). This pipe whip restraint is further illustrated in Figure 3.6-2.

(2) Restraints with Crushable Material—Pipe whip restraints with crushable material have the same design basis as the U-bar restraint. It is a single purpose, energy absorbing restraint with sufficient gap between the pipe and the restraint to allow free thermal expansion of the pipe. Restraints with crushable pads may not have lateral load capability so they must be provided in every direction in which the jet thrust from the ruptured pipe may occur. Figure 3.6-3 illustrates several acceptable pipe whip restraint designs using crushable material: the crushable ring, the honeycomb restraint, and the frame with a series of crushable rings.

(3) Rigid Restraints—Rigid pipe whip restraints are dual purpose, essentially elastic restraints that take the form of seismic guides, struts, and structural frames. Since rigid restraints are attached to the pipe or are separated from the pipe by very small gaps, they carry loads caused by thermal expansion, dead weight, seismic and other

dynamic events during plant operation. Rigid restraints therefore serve a pressure integrity function and are considered as pipe supports that must meet the requirements of ASME III, Subsection NF. They are modeled as spring elements in the static and dynamic analysis of the piping. Following a postulated pipe rupture these restraints carry the load from the jet thrust and control motion of a broken pipe. These restraints are designed to stop the pipe without exceeding ASME III, Subsection NF, Level D limits. The seismic guide provided on the main steam and feedwater pipe serves as a rigid pipe whip restraint performing a dual function.

The specific design objectives of pipe whip restraints are:

(1) Single purpose restraints shall in no way increase the reactor coolant pressure boundary stresses by their presence during any normal mode of reactor operation.

(2) The restraint system shall function to stop the movement of a ruptured pipe without allowing damage to critical components or missile development.

(3) The restraints should permit inservice inspection of the process piping.

For the purpose of design, the pipe whip restraints are designed for the following dynamic loads:

(1) Blowdown thrust of the pipe section that impacts the restraint.

(2) Dynamic inertia loads of the moving pipe section which is accelerated by the blowdown thrust and subsequent impact of the restraint.

(3) Non-linear design characteristics of the pipe whip restraints are included and verified by the pipe whip dynamic analysis described in Subsection 3.6.2.2.2 and Appendix 3L.

(4) Since single purpose pipe whip restraints are not contacted during normal plant operation, the postulated pipe rupture event is the only design loading condition.

(5) For unruptured pipe, dual purpose pipe whip restraints act as ASME III, Subsection NF pipe supports and must meet the Code requirements for service loads and load combinations for unruptured pipe specified in the design specification and summarized in Table 3.9-2. Following postulated pipe rupture, the restraint stress must not exceed ASME III, Subsection NF, Level D limits for pipe rupture loads acting in combination with loading for which service Level A limits are specified.

Strain rate effects and other material property variations have been considered in the design of the pipe whip restraints. The material properties utilized in the design have included one or more of the following methods:

(1) Code minimum or specification yield and ultimate strength values for the affected components and structures are used for both the dynamic and steady-state events,

(2) Not more than a 10% increase in minimum code or specification strength values is used when designing components or structures for the dynamic event, and code minimum or specification yield and ultimate strength values are used for the steady-state loads,

(3) Representative or actual test data values are used in the design of components and structures including justifiable elevated strain rate-affected stress limits in excess of 10%, or

(4) Representative or actual test data are used for any affected component(s) and the minimum code or specification values are used for the structures for the dynamic and the steady-state events.

3.6.2.4 Guard Pipe Assembly Design

The primary containment for each unit of the Lungmen NPS does not require guard pipes.

3.6.2.5 Material to be Supplied for the Operating License Review

The following shall be provided:

(1) A summary of the dynamic analyses applicable to high-energy piping systems in accordance with Subsection 3.6.2.5 of Regulatory Guide 1.70. This shall include:

    (a) Sketches of applicable piping systems showing the location, size and orientation of postulated pipe breaks and the location of pipe whip restraints and jet impingement barriers.

    (b) A summary of the data developed to select postulated break locations including calculated stress intensities, cumulative usage factors and stress ranges as delineated in BTP MEB 3-1, as modified by Subsection 3.6.1.1.1.

(2) For failure in the moderate-energy piping systems listed in Tables 3.6-5 and 3.6-6, descriptions showing how safety-related systems are protected from the resulting jets, flooding and other adverse environmental effects.

(3) Identification of protective measures provided against the effects of postulated pipe failures for protection of each of the systems listed in Tables 3.6-1 and 3.6-2.

(4) The details of how the MSIV functional capability is protected against the effects of postulated pipe failures.

(5) Typical examples, if any, where protection for safety-related systems and components against the dynamic effects of pipe failures include their enclosure in suitably designed structures or compartments (including any additional drainage system or equipment environmental qualification needs).

(6) The details of how the feedwater line check and feedwater isolation valves functional capabilities are protected against the effects of postulated pipe failures.

(7) An inspection of the as-built high-energy pipe break mitigation features shall be performed. The pipe break analysis report will document the results of the as-built inspection of the high-energy pipe break mitigation features (see Subsection 3.6.4, for a summary of the as-built inspection requirements).

(8) High-energy line separation analysis (HELSA) will be performed to determine which high-energy lines meet the spatial separation requirements and which lines require further protection (see Subsection 3.6.1.3.2.2, for a summary of the HELSA requirements).

3.6.3 Not used

3.6.4 As-Built Inspection of High-Energy Pipe Break Mitigation Features

An as-built inspection of the high-energy pipe break mitigation features shall be performed. The as-built inspection shall confirm that systems, structures and components, that are required to be functional during and following an SSE, are protected against the dynamic effects associated with high-energy pipe breaks. An as-built inspection of pipe whip restraints, jet shields, structural barriers and physical separation distances shall be performed.

For pipe whip restraints and jet shields, the location, orientation, size and clearances to allow for thermal expansion shall be inspected. The locations of structures, identified as a pipe break mitigation feature, shall be inspected. Where physical separation is considered to be a pipe break mitigation feature, the assumed separation distance shall be confirmed during the inspection.

3.6.5 References

3.6-1 Modification of General Design Criterion 4 Requirements for Protection Against Dynamic Effects of Postulated Pipe Rupture, Federal Register, Volume 52, No. 207, Rules and Regulations, Pages 41288 to 41295, October 27, 1987

3.6-2 RELAP 3, A Computer Program for Reactor Blowdown Analysis, IN-1321, issued June 1970, Reactor Technology TID-4500.

3.6-3 ANSI/ANS-58.2, Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture.

3.6-4 NUREG-1061, Volume 3, Evaluation of Potential for Pipe Breaks, Report of the U.S. NRC Piping Review Committee, November 1984.

3.6-5 Lahey, R.T. and Moody, F.J., Thermal Hydraulics of a Boiling Water Nuclear Reactor, American Nuclear Society, 1977.

Table 3.6-1 Essential Systems, Components, and Equipment[*] for Postulated Pipe Failures Inside Containment

1. Reactor Coolant Pressure Boundary (up to and including the outboard isolation valves)
2. Containment Isolation System and Containment Boundary (including liner plate)
3. Reactor Protection System (SCRAM SIGNALS)
4. Emergency Core Cooling Systems[†] (For LOCA events only)

   One of the following combinations is available (Table 6.3-3):

   (a) HPCF (B and C) + RCIC + RHR-LPFL (B and C) + ADS
   (b) HPCF (B and C) + RHR-LPFL (A and B and C) + ADS
   (c) HPCF (B or C) + RCIC + RHR-LPFL (A and either of B or C) + ADS
5. Core Cooling Systems (other than LOCA events)

   (a) HPCF (B or C) or RCIC
   (b) RHR-LPFL (A or B or C) + ADS
   (c) RHR shutdown cooling mode (two loops)
   (d) RHR suppression pool cooling mode (three loops)
6. Control Rod Drive (scram/rod insertion)
7. Flow Restrictors (passive)
8. Atmospheric Control (for LOCA event only)
9. Standby Gas Treatment[‡] (for LOCA event only)
10. Control Room Environmental[‡]
11. The following equipment/systems or portions thereof required to assure the proper operation of those essential items listed in items 1 through 10:

    (a) Class 1E electrical systems, AC and DC (including diesel generator system[‡], 6900, 480 and 120VAC, and 125VDC emergency buses[‡], motor control centers[‡], switchgear[‡], batteries[‡] and distribution systems)
    (b) Reactor Building Cooling Water[‡] to the following:

        1. Room coolers
        2. Pump coolers
        3. Diesel generator jacket coolers
        4. Electrical switchgear coolers

    (c) Environmental Systems[‡] (HVAC)
    (d) Instrumentation (including post-LOCA monitoring)
    (e) Fire Protection System[‡]
    (f) HVAC Emergency Cooling Water System[‡]
    (g) Process Sampling System[‡]

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[*] The essential items listed in this table are protected in accordance with Subsection 3.6.1 consistent with the particular pipe break evaluated.

[†] See Section 6.3 for detailed discussion of emergency core cooling capabilities.

[‡] Located outside containment but listed for completeness of essential shutdown requirements.

Table 3.6-2 Essential Systems, Components, and Equipment* for Postulated Pipe Failures Outside Containment

1. Containment Isolation System and Containment Boundary.
2. Reactor Protection System (SCRAM signals)
3. Core Cooling Systems:
    - (a) HPCF (B or C) or RCIC
    - (b) RHR-LPFL (A or B or C) + ADS
    - (c) RHR shutdown cooling mode (two loops)
    - (d) RHR suppression pool cooling mode (three loops)
4. Flow Restrictors
5. Control Room Habitability
6. Spent Fuel Pool Cooling
7. Standby Gas Treatment
8. The following equipment/systems or portions thereof required to assure the proper operation of those essential items listed in items 1 through 7:
    - (a) Class 1E electrical systems, AC and DC (including diesel generator system, 6900, 480 and 120VAC, and 125VDC emergency buses, motor control centers, switchgear, batteries, auxiliary shutdown control panel, and distribution systems).
    - (b) Reactor Building Cooling water to the following:
        - (1) Room coolers
        - (2) Pump coolers (motors and seals)
        - (3) Diesel generator auxiliary system coolers
        - (4) Electrical switchgear coolers
        - (5) RHR heat exchangers
        - (6) FPC heat exchangers
        - (7) HECW refrigerators
    - (c) HVAC
    - (d) Instrumentation (including post accident monitoring)
    - (e) Fire Water System
    - (f) HVAC Emergency Cooling Water System
    - (g) Process Sampling System

* The essential items listed in this table are protected in accordance with Subsection 3.6.1 consistent with the particular pipe break evaluated.

Table 3.6-3 High-Energy Piping Inside Containment

Piping System
Main steam
Main steam drains
Steam supply to RCIC
Feedwater
Recirculation motor cooling
HPCF (RPV to first check valve)
RHR-LPFL (RPV to first check valve)
RHR (Suction from RPV to first normally closed gate valve)
Reactor Water Cleanup (suction from RHR and RPV drain supply to RPV head spray from first inlet valve)
RPV head spray (RPV to first check valve)
RPV vent (RPV to first closed valve)
Standby Liquid Control (from HPCF to first check valve)
CRD (Scram/rod insertion)
RPV bottom head drain lines (RPV to first closed valves)
Miscellaneous 80mm and smaller piping

Table 3.6-4 High-Energy Piping Outside Containment

Piping System*
Main Steam
Main Steam Drains
Feedwater
Steam supply to RCIC Turbine
CRD (to and from HCU)
RHR (injection to feedwater from nearest check valves in the RHR lines)
Reactor Water Cleanup (to Feedwater lines and to first inlet valve to RPV head spray)
Reactor Water Cleanup (pumps suction and discharge)

* Fluid systems operating at high-energy levels less than 2% of the total time that the system operates as a moderate-energy fluid system are not included. These systems are classified moderate-energy systems, (e.g., HPCF, RCIC, and SLC).

Table 3.6-5 Moderate-Energy Piping Inside Containment

Residual Heat Removal System
Radioactive Waste System
Instrument/Service Air System
HVAC Cooling Water System
Reactor Building Cooling Water System

Table 3.6-6 Moderate-Energy Piping Outside Containment

Residual Heat Removal System (Piping beyond outermost isolation valve)
High Pressure Core Flooder System (Piping beyond outermost isolation valve)
Reactor Core Isolation Cooling System (Suction line from condensate storage pool beyond second shutoff valve, vacuum pump discharge line from vacuum pump to containment isolation valve)
Control Rod Drive System (Piping up to pump suction)
Standby Liquid Control System (Piping beyond injection valves)
Suppression Pool Cleanup System (Beyond containment isolation valve)
Fuel Pool Cooling and Cleanup System
Radioactive Waste System (Beyond isolation valve)
Instrument/Service Air System (Beyond isolation valve)
HVAC Cooling Water System
Makeup Water System (Condensate)
Reactor Building Cooling Water System
Turbine Building Cooling Water System
Atmospheric Control System (Beyond shutoff valve)

Table 3.6-7 Additional Criteria for Integrated Leakage Rate Test

(1) Those portions of fluids systems that are part of the reactor coolant pressure boundary, that are open directly to the primary reactor containment atmosphere under post-accident conditions and become an extension of the boundary of the primary reactor containment, shall be opened or vented to the containment atmosphere prior to or during the Type A test. Portions of closed systems inside containment that penetrate primary containment and are not relied upon for containment isolation purposes following a LOCA shall be vented to the containment atmosphere.

(2) All vented systems shall be drained of water to the extent necessary to ensure exposure of the system primary containment isolation valves to the containment air test pressure.

(3) Those portions of fluid systems that penetrate primary containment, that are external to containment and are not designed to provide a containment isolation barrier, shall be vented to the outside atmosphere as applicable, to assure that full post-accident differential pressure is maintained across the containment isolation barrier.

(4) Systems that are required to maintain the plant in a safe condition during the Type A test shall be operable in their normal mode and are not vented.

(5) Systems that are normally filled with water and operating under post-LOCA conditions need not be vented.

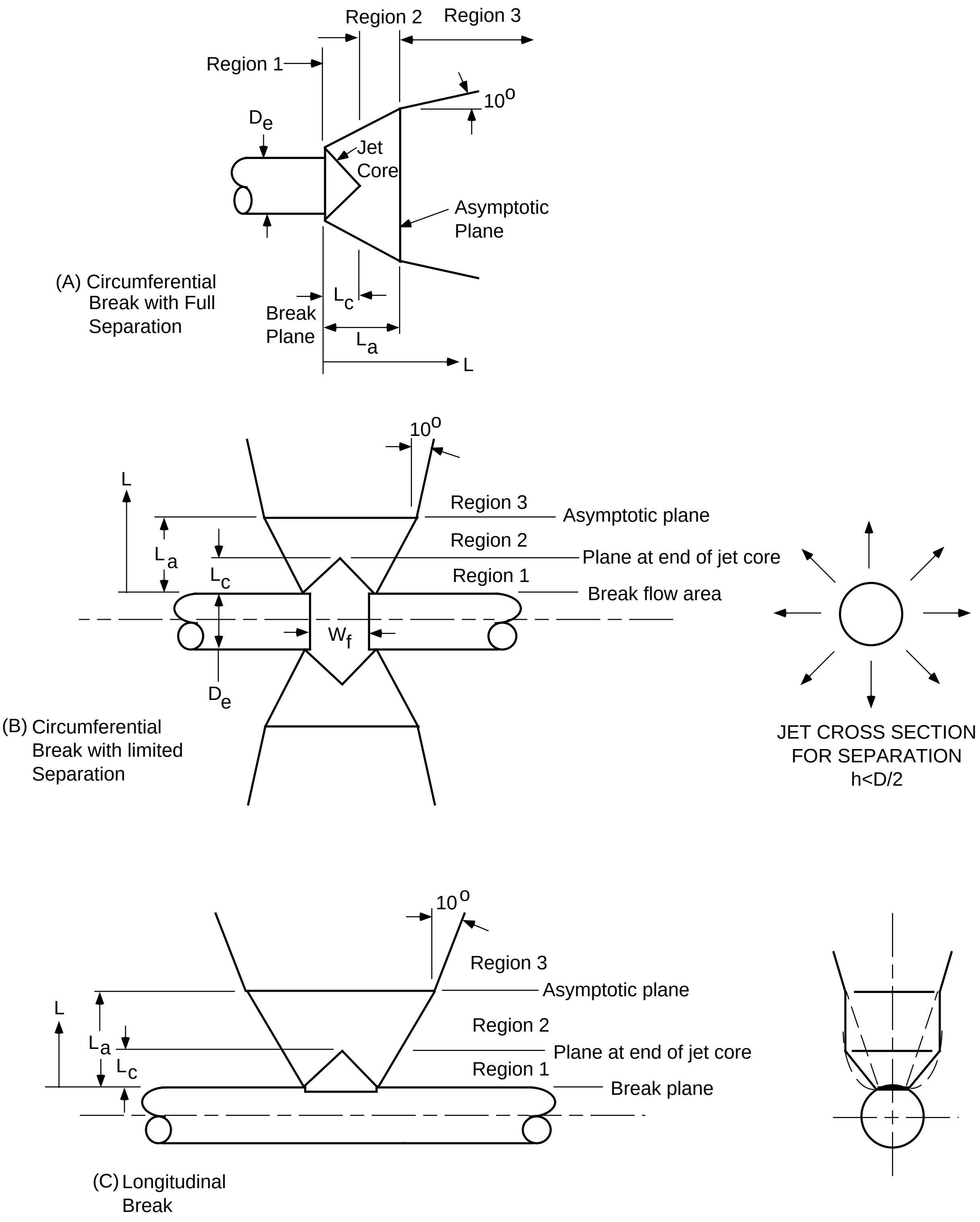


Figure 3.6-1 Jet Characteristics

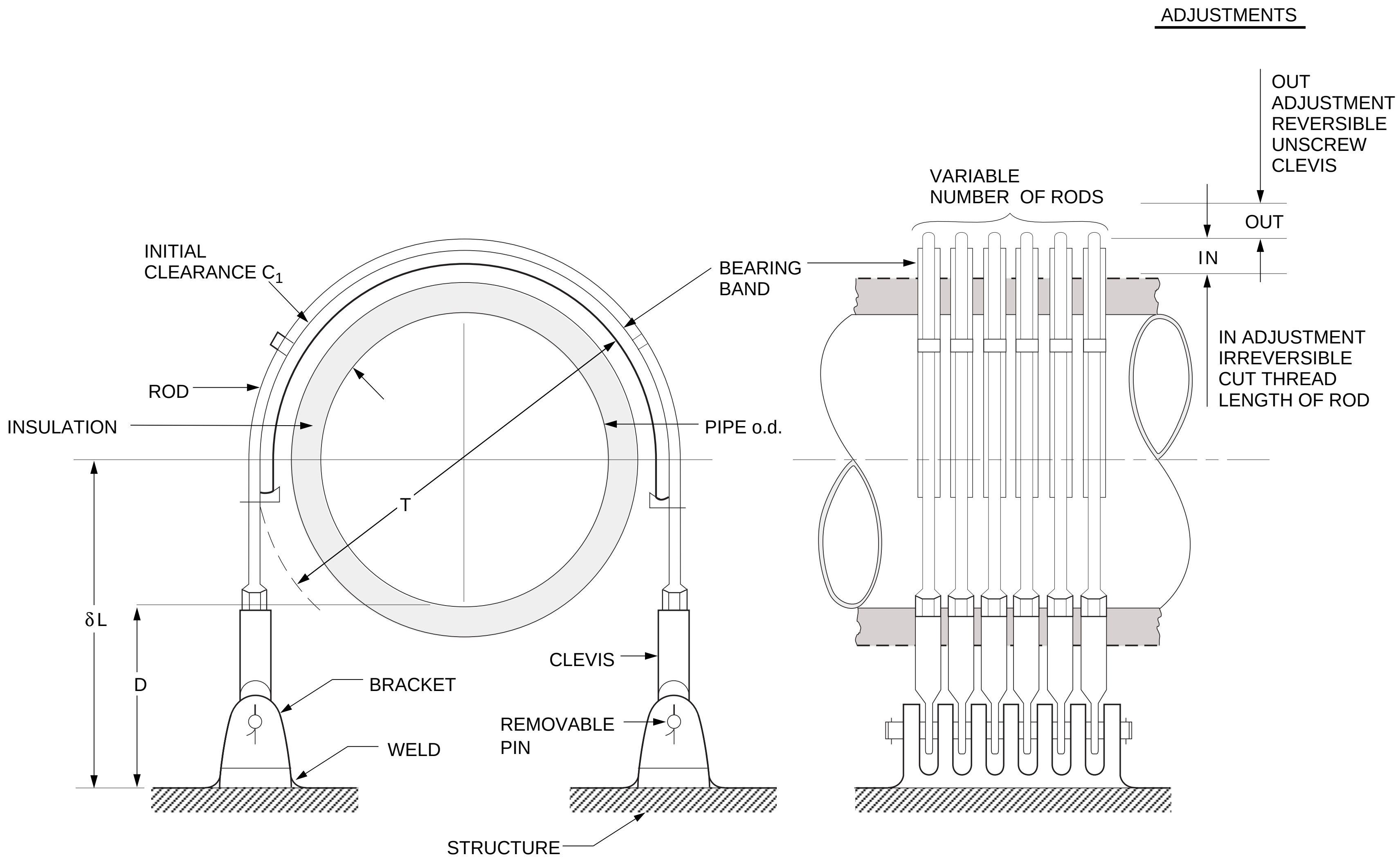


Figure 3.6-2 Typical Pipe Whip Restraint Configuration

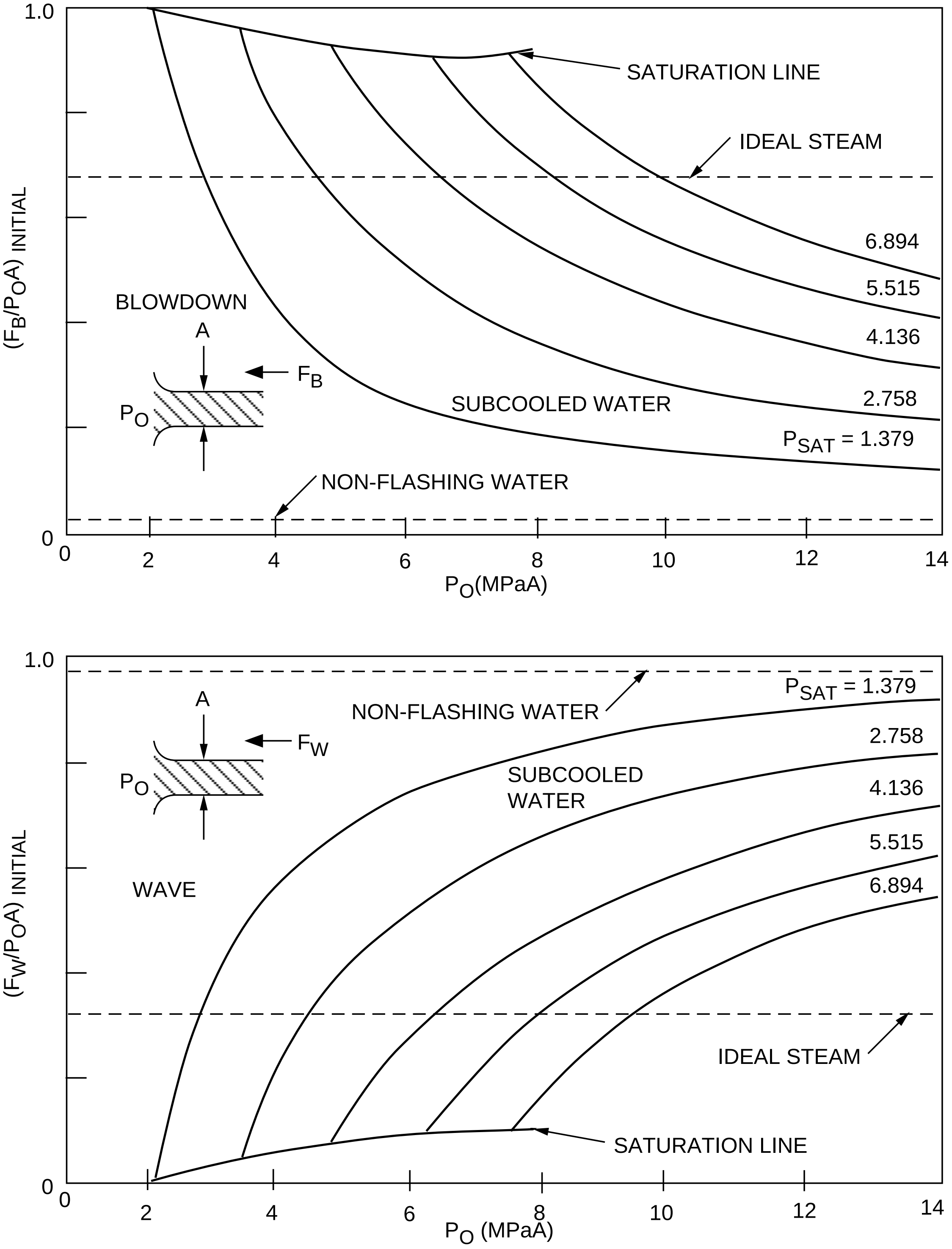
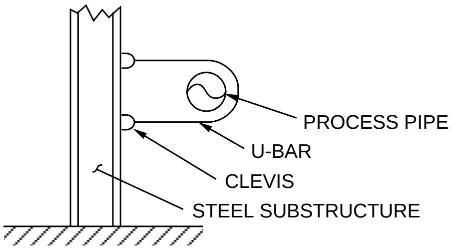
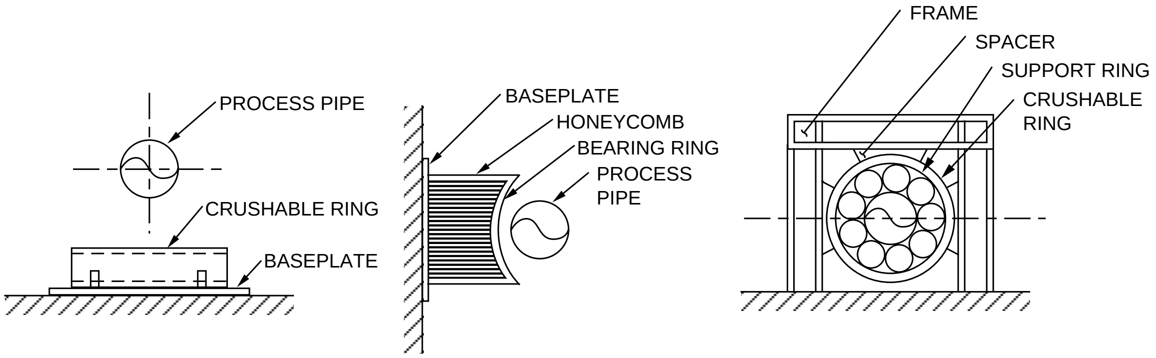


Figure 3.6-3 Initial Blowdown and Wave Forces

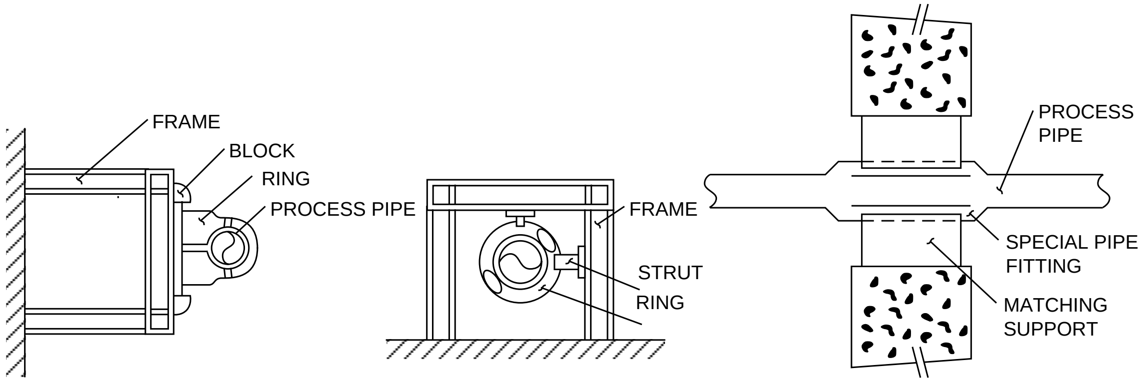


(1) U-BAR PIPE WHIP RESTRAINT



A – CRUSHABLE RING **B – HONEYCOMB** **C – FRAME WITH SERIES OF RINGS**

(2) RESTRAINTS WITH CRUSHABLE MATERIAL



A – ELASTIC RING **B – RING WITH STRUT** **C – FIVE WAY RESTRAINT**

(3) RIGID RESTRAINTS

Figure 3.6-4. Acceptable Types of Pipe Whip Restraints

Figure 3.6-4 Acceptable Types of Pipe Whip Restraints