3.6 PROTECTION AGAINST DYNAMIC EFFECTS ASSOCIATED WITH THE POSTULATED RUPTURE OF PIPING

This section describes protection against dynamic effects associated with postulated rupture of piping both inside and outside containment.

3.6.1 POSTULATED PIPING FAILURES IN FLUID SYSTEMS

3.6.1.1 Design Bases

The underlined terms in this section are defined in Subsection 3.6.3. The ASME Boiler and Pressure Vessel Code, 1971 and the Addenda through Winter 1972 are referred to as the Code in the text.

In the design of nuclear safety systems, it is necessary to ensure that all components which are required for the safe shutdown of the plant will not fail as a result of a failure in a high energy or a moderate energy piping system. The separation criteria and a listing of separation techniques, for nuclear safety systems are given in Subsections 3.12.2.1 and 3.12.2.2, respectively.

Pipe breaks are postulated to occur in all high energy fluid system piping (or portion of system) in accordance with the criteria stated in Subsection 3.6.2.

Pipe cracks are postulated to occur in all moderate energy fluid system piping in accordance with the criteria stated in Subsection 3.6.2.1.2.

The failure of piping containing high energy fluid may lead to damage of surrounding systems and equipment. The effects of such a failure including pipe whip, fluid jet impingement, flooding, compartment pressurization, and environmental effects require special consideration to ensure the following:

a) The ability to shut down the reactor safely and maintain it in a safe shutdown condition

b) Containment integrity

c) A pipe break which is not a loss of reactor coolant must not cause a loss of reactor coolant

d) Resultant doses are below the guideline values of 10CFR 50.67.

A design basis for Susquehanna SES is that a postulated pipe break inside the containment (up to and including a rupture of the recirculation piping), in conjunction with the SSE, plus a single failure will not prevent the plant from accomplishing the above. For outside the containment, the single failure is qualified per NRC Branch Technical Position APCSB BTP 3-1, paragraph B.3.b.3. No credit is taken for non-seismic system in plant shutdown following a SSE, with the exception of the components and piping systems described in Subsection 6.7.

Components which are required to operate for a safe shutdown of the plant are protected from the below listed effects of postulated pipe failures, unless it can be demonstrated that the function of the safety equipment is not impaired.

Pipe Whip

Pipe whip is assumed to be one consequence of a guillotine failure of a high energy pipe. Cracks in moderate energy systems do not cause pipe whip. Pipe whip is an unrestrained pipe movement of either end of the ruptured pipe in any direction about a plastic hinge formed at the nearest pipe whip restraint.

A whipping pipe is assumed to rupture an impacted pipe of smaller nominal pipe size, and of the same nominal size with smaller wall thickness. A whipping pipe is assumed to have sufficient energy to cause the failure of impacted electrical cable ways and instrumentation unless the equipment can be shown to be sufficiently strengthened or protected. High energy piping is located away from the essential safety system wherever practical. Otherwise, pipe whip restraints are located on the piping to prevent pipe whip.

Jet Impingement

Jet impingement loads (due to pipe failures) on equipment and safety systems are considered. Protection against the jet impingement is provided either by separation by adding additional supports, or by the addition of barriers and enclosures.

Environmental

Pipe failures in high and moderate energy lines will release fluid which can increase temperature, pressure, and humidity in the vicinity of the pipe failure and also in remote areas that communicate with the local atmosphere. Safety equipment required after the pipe failure may be exposed to abnormal conditions which can degrade the capability of the equipment to perform its function.

Safety related equipment is qualified to meet the postulated environmental conditions.

Piping systems whose failure might generate hazardous environmental condition are located in compartments which are capable of being isolated from required safety systems. Isolation, where necessary, of compartments which enclose high energy lines is provided by maintaining normally closed accessways and providing automatic isolation of other communication paths, such as ventilation ductwork. Compartments are designed to withstand internal pressurization or are provided with vent capability to the atmosphere.

Pressure rise analysis and verification of structural adequacy of enclosures used to provide protection are discussed in Subsections 6.2.3, 3.8.1, 3.8.2, 3.8.3, and 3.8.4. Transportation of a steam environment which could affect the habitability of the control room has been discussed in Subsection 6.4.2.4.

An additional environmental consequence of pipe failure is radiation. Safety equipment is designed to tolerate the integrated exposure resulting from normal plant operations. Safety equipment inside the containment is designed for the additional exposure resulting from a DBA.

Water Spray

Water alone is a hazard to certain equipment, particularly electric equipment. Safety equipment is protected from water sprays by barriers or by enclosure of the equipment. In most cases, spatial separation is adequate to prevent spray from reaching the equipment.

Flooding

Any significant failure of a steam or fluid system may result in flooding. The flooding rate and the total fluid volume released are computed based on the break configuration, the service of the system, and the time required to isolate the system.

For compartments containing safety equipment, design features are provided to permit rapid detection and isolation of flooding due to major line breaks, except where it can be demonstrated that flooding will not affect the performance of the equipment or its redundant counterpart.

Because of the high degree of separation in Susquehanna SES, failure of ECCS equipment due to flooding will always be limited to one division of equipment. All non-safety grade piping in ECCS and other safety-related areas whose failure could potentially reduce the function of a safety-related plant feature to an unacceptable safety level, have been analyzed for the effects of a seismic event. This analysis is performed consistent with Regulatory Guide 1.29 paragraph C.2. A single failure is postulated and system availability is consistent with BTP APCSB 3-1, B.3.b.

If the initiating event is a break in a primary reactor coolant line, with subsequent leakage in an ECCS equipment room, isolation of the ECCS equipment room is required to prevent the depletion of the suppression pool inventory thus ensuring that long-term cooling capacity is adequate. This is discussed in Subsection 6.3.6.

If the initiating event is a pipe break in an ECCS equipment room, isolation is not required for long-term cooling adequacy. However, the room will be isolated and the equipment in the room declared inoperative, consistent with the requirements of the Technical Specifications.

Refer to Section 3.4 for additional information regarding flood protection from postulated piping failures inside the Reactor Building.

3.6.1.2 Description

A listing of high energy fluid system piping is provided in Table 3.6-1. A listing of moderate energy fluid piping systems is provided in Table 3.6-1a. Proximity of the essential systems and components in relation to the high and moderate energy fluid system piping is reviewed and the essential systems and components are either relocated to achieve separation, protection against the effects of pipe failure is provided, or it can be shown that the effects of pipe failure could be withstood. Tables 3.6-2 and 3.6-3 show those safety components in close proximity to high energy fluid system piping which required jet impingement protection. The method used to protect each component is also shown.

Some of the high energy fluid system piping is separated from all essential systems and components. These piping systems are listed in Table 3.6-1 designated by Note 1.

Descriptions of some typical high energy fluid system piping are provided below.

3.6.1.2.1 Main Steam System

Separation

The main steamlines inside the containment are routed, wherever possible, away from safety related equipment. Two steamlines, A and B, are connected to the north side of the reactor vessel and the other two steamlines, C and D, are connected to the opposite side of the vessel.

To avoid failing all the main steam ADS safety relief valves by a single rupture of a main steam pipe, the ADS valves are divided so that three ADS valves are connected to the A and B lines, and the remaining ADS valves are connected to the C and D lines.

To avoid failing both the RCIC and HPCI steam supply lines by a single rupture of a main steam pipe, the RCIC is connected to main steamline C and the HPCI is connected to main steamline B.

Besides those areas identified in Tables 3.6-2 and 3.6-3, the main steam lines are separated by adequate distance from safety-related components. The following design features have been incorporated into the main steamlines to ensure the core cooling capability over the entire range of operating and postulated accident conditions.

1) A flow restrictor (venturi) is located in each main steamline just upstream of the inboard isolation valve. The purpose is to limit the flow of steam and therefore the loss of reactor coolant from the reactor vessel in the event of a postulated break in this line, outside the primary containment.

2) The safety/relief valves protect the main steamlines from abnormal pressure. The safety/relief valves, besides protecting the steamlines against over-pressurization, precipitate the initiation of the LPCI mode of the RHR system for smaller pipeline breaks by rapidly depressurizing the reactor vessel.

3) Separate main steam loops supply high pressure steam to run the turbine driven pumps of RCIC and HPCI systems. Should steam power not be available to drive the reactor feedwater pumps during shutdown, part of the residual steam will be used to drive the turbine in the RCIC system which supplies makeup water to the reactor from the condensate storage tanks or the suppression pool.

In addition, the following design features are incorporated into the design to ensure isolation valve operability and the leaktight integrity of the containment:

a) The piping between the containment isolation valves is designed to meet "no break" criteria stress limits of Subsection 3.6.2.1.1.

b) Moment limiting restraints are placed upstream of inside containment isolation valves and downstream of outside containment isolation valves for HPCI, RCIC, feedwater outside containment, main steam drain, main steam and RWCU pipes.

c) Plate barriers are provided to protect the inboard main steam isolation valve operators from a high energy pipe break of the feedwater lines. In addition, the main steam isolation valve limit switch support brackets are reinforced to address the jet impingement effects from a high energy break of the recirculation nozzles. The actuator springs are capable of closing the main steam isolation valves under jet impingement conditions without pneumatic assist, see Section 5.4.5.2.

Pipe Break Locations and Pipe Whip Restraints

The postulated pipe break locations and the type of the break are determined based on the criteria given in Subsection 3.6.2. Figures 3.6-1A, 3.6-1B, 3.6-1C and 3.6-1D shows the locations of postulated pipe breaks and pipe whip restraints. The main steamlines are restrained inside the primary containment to prevent the main steam pipe whip. The main steamlines in the turbine building are separated from essential systems and components.

Verification of the Safe Shutdown of the Plant

1) The routing of main steam piping, locations of pipe whip restraints, and the protective measures described in Table 3.6-2 ensure that the emergency core cooling systems are not adversely affected by a postulated pipe break in the main steam lines.

2) Subsequent to any postulated pipe break in the main steamlines, containment isolation is achieved by closure of either or both of the isolation valves and the safe shutdown of the plant is accomplished by the emergency core cooling systems.

3.6.1.2.2 Feedwater System

Separation

The feedwater spargers are connected to opposite sides of the reactor vessel. The sparger restricts the rate of loss of reactor water level in the event of a postulated pipe break inside the primary containment. The spargers are then connected into two feedwater loops, which run in parallel through the primary containment and which are reasonably separated from safety related components.

Pipe whip restraints are provided inside the primary containment to prevent one feedwater pipe from damaging the other as a result of pipe break.

The two feedwater lines extend outside the primary containment before they connect to a common header. Restraints are also provided outside the containment. Bumpers are provided at the end of the header, before it enters the turbine building.

The HPCI return line taps into one of the feedwater lines and the RCIC taps into the other. The RWCU return line taps into both feedwater lines.

The feedwater piping in the turbine building is separated from essential systems and components.

The following design features have been incorporated into the design of feedwater lines to ensure isolation valve operability and the leaktight integrity of the containment:

a) The piping between the containment isolation valves is designed to meet the "no break" criteria stress limits of Subsection 3.6.2.

b) Moment limiting restraints are placed upstream of two outside containment isolation valves to protect against the pipe break beyond the restraints. Inside containment check valves on one feedwater line are protected against the pipe break postulated in the other feedwater line. The containment penetration flued head is designed to withstand pipe break loads.

Pipe Break Locations and Pipe Whip Restraints

The postulated pipe break locations and the type of the break are determined based on the criteria given in Subsection 3.6.2. The Figure 3.6-2 shows the locations of postulated pipe breaks and pipe whip restraints. The feedwater lines are restrained inside the primary containment to prevent pipe whip.

Verification of Safe Shutdown of the Plant

1) For any postulated pipe break in the feedwater piping inside or outside the primary containment, isolation of the reactor and the containment from the external environment is provided by the two containment isolation valves located outside primary containment. The outermost containment isolation valve provides positive closure by virtue of being a stop check valve.

   For a feedwater line break inside containment, the operability of the containment valve inside containment is not credited as providing containment isolation, as described in Section 6.2.4, for this event.

2) The two feedwater lines are restrained to prevent pipe whip damage. The HPCI, which is a high pressure emergency core cooling system, taps into one feedwater loop while the RCIC taps into the other loop to ensure adequate core cooling. In addition to the HPCI and the RCIC, the ADS relief valves and the RHR system, which are not in this area, are also available for core cooling.

3.6.1.2.3 High Pressure Coolant Injection (HPCI) System

Separation

The steam supply line to the HPCI turbine taps off main steamline B, inside the primary containment. The piping is routed, wherever possible, away from safety related components which are required for the safe shutdown of the plant.

For small line pipe breaks, the HPCI system functions as a redundant system to the combination of ADS and LPCI (mode of RHR) system. The routing of this pipe ensures that any postulated pipe break does not disable the ADS function.

Proximity of the essential systems and components in relation to the HPCI lines were reviewed and the findings listed in Tables 3.6-2 and 3.6-3.

Pipe Break Locations and Pipe Whip Restraints

The postulated pipe break locations and the type of the break are determined based on the criteria given in Subsection 3.6.2.

Figure 3.6-3 shows the locations of postulated pipe breaks and pipe whip restraints. Pipe whip restraints are provided for the high energy portions of this system.

Verification of the Safe Shutdown of the Plant

Postulated pipe breaks in this line affect neither the primary containment integrity nor the systems required to bring the reactor to a safe shutdown condition.

If a pipe break does occur in the HPCI line, the reactor and the primary containment are isolated from the external environment by isolation valves. The other emergency core cooling systems, ADS and LPCI (RHR), would be used to bring the reactor to a safe shutdown.

3.6.1.2.4 Reactor Core Isolation Cooling (RCIC) System

Separation

The steam supply line to the RCIC turbine taps off main steamline C, inside the primary containment. The piping is routed, wherever possible, away from safety related components which are required for the safe shutdown of the plant. Proximity of the essential systems and components in relation to the RCIC lines were reviewed and the findings listed in Tables 3.6-2 and 3.6-3.

Pipe Break Locations and Pipe Whip Restraints

The postulated pipe break locations and the types of breaks are determined based on the criteria given in Subsection 3.6.2.

Figure 3.6-4 shows the location of postulated pipe breaks and pipe whip restraints. Pipe whip restraints are provided for the high energy portions of this system.

Verification of the Safe Shutdown of the Plant

Postulated pipe breaks in this line neither affect the primary containment integrity nor the systems required to bring the reactor to a safe shutdown condition.

If a pipe break does occur in the RCIC line, the reactor and the primary containment are isolated from the external environment by isolation valves. Shutdown of the plant is achieved by the emergency core cooling systems.

3.6.1.3 Safety Evaluation

The analysis of postulated line failure and the resulting addition of restraint features into the design has ensured that failure in any single high energy fluid system piping in the plant will not result in unacceptable damage to any other safety-related system or component.

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

Information concerning break and crack location criteria and methods of analysis is presented in this section. 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 primary containment. This information confirms that the requirements for the protection of structures, systems, and components relied upon for safe reactor shutdown or to mitigate the consequences of a postulated pipe break have been met.

The analyses to determine the postulated break and crack locations are based on the original plant life of 40 years. The locations determined by those analyses and the criteria specified in this section are identified in Tables 3.6-6 through 3.6-15. A fatigue monitoring program tracks the fatigue (cumulative usage) at all critical piping locations. When a monitored location exceeds the cumulative usage predicted by the original design fatigue analysis, the affected piping system is evaluated to determine if any additional break and crack locations must be postulated. Any new locations that are postulated are accommodated by appropriate pipe break restraints, barriers, and shields.

3.6.2.1 Criteria Used To Determine Pipe Break and Crack Locations and Their Configurations

Pipe failures are postulated in high and moderate energy fluid systems piping that are not separated from essential systems and components based on the criteria given in this section. The types of failures considered at those locations are also discussed in this section.

3.6.2.1.1 High Energy Fluid System Piping Other than Recirculation System Piping

Fluid System Piping Between Containment Isolation Valves

Pipe breaks are not postulated in these portions of high energy fluid system piping provided the following additional design requirements are met:

1) The following design stress and fatigue limits are satisfied:

For ASME Code, Section III Class 1 piping:

a) The primary plus secondary stress intensity range, Sn, calculated for normal and upset conditions by equation (10) of Paragraph NB-3653, does not exceed 2.4 Sm. Or,

b) The range of stress intensity, Sn, calculated for normal and upset conditions by equation (10) does not exceed 3.0 Sm, and the cumulative fatigue usage factor associated with normal, upset and testing conditions is less than 0.10. Or,

c) The range of stress intensity, Sn, calculated for normal and upset conditions by equation (10) exceeds 3.0 Sm, but the stress intensity ranges computed by equations (12) and (13) are less than 2.4 Sm. In addition, the fatigue usage factor associated with normal, upset and testing conditions is less than 0.10. And,

d) The loading resulting from a postulated pipe break beyond these portions of the piping

    1) Does not cause the primary stress intensity, as calculated by equation (9) of Paragraph NB-3652 to exceed 2.25 Sm.

2) A plastic hinge is not formed and the operability of the isolation valve is assured.

For ASME Code, Section III Class 2 and 3 piping:

e) The maximum stress ranges as calculated by the sum of equations (9) and (10) in Paragraph NC-3652, for normal and upset conditions does not exceed $0.8(1.2S_h + S_A)$.

f) The maximum stress, as calculated by equation (9) in Paragraph NC-3652 under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of piping does not exceed 1.8S. Higher stresses are allowed provided that the valve operability is not impaired.

2) The piping is restrained reasonably close to the valve, such that occurrence of a pipe break inside or outside containment beyond these restraints will impair neither operability of the valve nor the integrity of the containment penetration. Terminal ends of the piping runs extending beyond these portions of high energy piping are considered to originate at a point adjacent to these restraints.

3) Welded pipe support attachments to those portions of piping penetrating containment are avoided to eliminate stress concentrations.

4) The number of piping circumferential and longitudinal welds and branch connections is minimized.

5) The length of piping run is minimized, consistent with requirements to keep stress levels low and provide access for in-service inspection.

6) The design at points of pipe fixity, e.g., pipe anchors or welded connections at containment penetrations, do not require welding directly to the outer surface of the piping (e.g., flued, integrally forged pipe fittings are acceptable designs), except where such welds are 100 percent volumetrically examinable in service and a detailed stress analysis is performed to demonstrate compliance with the limits of 1) above.

7) To the extent described in Subsection 6.6.8, the in-service examination completed during each inspection interval will provide 100 percent volumetric examination of circumferential and longitudinal pipe welds within these portions of piping. See paragraphs 5.2.4.7 and 6.6.8.

Fluid System Piping Other Than That Between Containment Isolation Valves

Pipe breaks are postulated to occur at terminal ends, and at all intermediate break locations determined by one of the following two criteria:

a) At each location of potential high stress such as pipe fittings (elbows, tees, reducers, etc.), valves, flanges, and welded attachments

b) At each location where the following stress and fatigue limits are not met:

For ASME Code, Section III, Class 1 Piping under normal and upset conditions,

1) The primary plus secondary stress intensity range, Sn, as calculated by equation (10) of Paragraph NB-3653, does not exceed 2.4 Sm, or

2) The stress intensity range, Sn, as calculated by equation (10) of Paragraph NB-3653 exceeds 2.4 Sm, but is less than 3.0 Sm, and the cumulative fatigue usage factor is less than 0.10, or

3) The stress intensity range, Sn, calculated by equation (10) exceeds 3.0 Sm, but the ranges of stresses computed by equations (12) and (13) of subparagraph NB-3653 are less than 2.4 Sm and the fatigue usage factor is less than 0.10.

For ASME Code, Section III, Class 1 piping:

4) In the event that at least two intermediate pipe break locations cannot be determined by the above stress and fatigue usage criteria, a minimum of two locations of highest stress as calculated by equation (10) in Paragraph NB-3653, and which are separated by a change of direction in the pipe run, are selected.

For ASME Code, Section III, Class 2 and 3 piping:

5) The maximum range of stress, as calculated by the sum of equations (9) and (10) in Paragraph NC-3652, for normal and upset plant conditions, does not exceed 0.8 (1.2 S_h + S_A).

6) If two intermediate break locations cannot be determined by the above stress and fatigue usage criteria, a minimum of two locations of highest stress, as calculated by the sum of equations (9) and (10) in Paragraph NC-3652, and which are separated by a change in direction of the pipe run, are selected.

For piping not designed to seismic Category I standards:

7) Criteria for ASME Code, Class 2 and 3 piping was used if all necessary analyses are made. Otherwise, longitudinal and circumferential breaks in non-Category I piping are postulated in accordance with (a) above. All breaks or cracks were assumed to occur at the worst location. Only one pipe break at a time is postulated to occur concurrent with the SSE.

For all classes of pipe:

8) When the above stress and fatigue criteria result in less than two intermediate break locations, a minimum of two separated locations are chosen based on highest stress. Where the piping consists of a straight run without fittings, welded attachments, or valves, a minimum of one location is chosen. The two locations chosen are with at least 10 percent difference in stress, or separated by a change of direction of pipe run if stress differs by less than 10 percent.

For high energy piping in the Reactor Building, shown in Figures 3.6-17-1, 3.6-17-2 and 3.6-17-3, pipe breaks are postulated to occur at terminal ends, and at all intermediate break locations determined by criterion "a" above. Alternatively, criterion “b” may be used if intermediate breaks

become too numerous and/or it becomes necessary to minimize the number of whip restraints required. Both circumferential and longitudinal breaks are postulated at each of the intermediate break locations, whereas only circumferential breaks are postulated at the terminal ends. Additionally, NRC Generic Letter 87-11 is used on a case-by-case basis for identifying high energy pipe breaks.

Protection in the areas shown on Figures 3.6-17-1, 3.6-17-2 and 3.6-17-3, is a combination of separation, barriers, and pipe whip restraints. The CRD system high energy piping as noted on Figure 3.6-17-1 required no restraints due to separation and barrier location.

3.6.2.1.2 Moderate Energy Fluid System Piping Other than Recirculation Piping System

1) Through-wall leakage crack locations are postulated in moderate energy piping located in areas containing systems important to safety. Orientation of the crack is such as to result in the most adverse water spray and flooding conditions.

2) Through-wall leakage crack locations are postulated in fluid system piping located within, or outside and adjacent to, protective structures designed to protect essential systems and components except in seismic Category I systems where exempted by (3), (4), or where the maximum stress range in these portions of Class 2 or 3 piping or non-nuclear piping as calculated by the sum of equations (9) and (10) in Paragraph NC-3652 is less than $0.4(1.2S_h + S_A)$, or where the maximum stress intensity range of Class I piping, as calculated by equation (9) of NB-3652, is less than 0.6 Sm.

The cracks are postulated to occur individually at locations that result in the maximum effects from fluid spraying and flooding, with the consequent hazards on environmental conditions developed.

3) No through-wall leakage crack locations are postulated in moderate energy piping systems in areas where high energy piping system break locations are postulated, except where a postulated leakage crack in the moderate energy fluid system piping results in more severe environmental conditions than the break in proximate high energy fluid system piping.

4) Through-wall cracks are not postulated in portions of seismic Category I moderate energy piping between containment isolation valves, provided they meet the requirements of Subarticle NE-1120 of the Code and they are designed so that the maximum stress, for ASME Code, Section III, Class I piping, as calculated by equation (9) of Paragraph NB-3652, does not exceed 0.6 Sm, and the maximum stress range for Class 2, 3 or non-nuclear piping, as calculated by the sum of equations (9) and (10) of Paragraph NC-3652, does not exceed $0.4\ (1.2S_h + S_A)$.

5) For moderate energy piping not designed to seismic Category I standards, through-wall leakage cracks are postulated at locations that result in maximum effects from fluid spray and flooding.

3.6.2.1.3 Types of Breaks and Leakage Cracks in Fluid System Piping Other than Recirculation Piping System

Circumferential Pipe Break

A circumferential break is assumed to result in severance of a high energy pipe, perpendicular to the pipe axis, and separation amounting to at least a one-diameter lateral displacement of the ruptured piping section unless physically limited by piping restraints, structural members, or piping stiffness.

Circumferential breaks are postulated in high energy fluid system piping of nominal pipe size greater than 1 in. at the locations determined by the criteria given in Subsection 3.6.2.1.1, except where it can be shown that the maximum stress is in the circumferential direction and is at least 1.5 times the longitudinal stress, in which case only a longitudinal break is postulated.

Longitudinal Pipe Break

A longitudinal pipe break is an axial split parallel to pipe axis without pipe severance. Break opening area is assumed to be equal to the effective cross-sectional flow area of the pipe at the break location and length of the break is assumed to be twice the inside diameter of the pipe. The orientation of the break is assumed to be such that the jet reaction force causes out-of-plane bending of the piping configuration.

Longitudinal pipe breaks are postulated in high energy fluid system piping of nominal size 4 in. and larger at the break locations determined by the criteria given in Subsection 3.6.2.1.1 with the following exceptions:

1) Longitudinal pipe breaks are not postulated at

   a) Terminal ends provided the piping at the terminal ends contains no longitudinal pipe welds

   b) Intermediate break location where the criterion for a minimum number of break locations must be satisfied

   c) Where it can be shown that the maximum stress is in longitudinal direction and is at least 1.5 times the circumferential stress. In this case only circumferential break needs to be postulated.

Through Wall Leakage Cracks

A through-wall leakage crack is a crack opening in a moderate energy pipe assumed as a circular orifice of cross-sectional flow area equal to one-half the pipe inside diameter times one-half the pipe wall thickness. The crack may occur at any orientation about the circumference of the pipe and is postulated to occur in moderate energy piping larger than 1 in. nominal pipe diameter.

3.6.2.1.4 Criteria for Recirculation System Piping (NSSS Supply)

3.6.2.1.4.1 Definition of High Energy Fluid System

See Subsection 3.6.3.

3.6.2.1.4.2 Definition of Moderate Energy Fluid System

There are no moderate energy lines in the recirculation system piping.

3.6.2.1.4.3 Postulated Pipe Breaks

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 as development of a sudden longitudinal, uncontrolled crack (longitudinal split) and is postulated for high energy fluid system only.

A high-energy piping system break is not postulated to be simultaneous with a moderate energy piping system crack nor is any pipe break or crack outside the containment postulated concurrently with a postulated pipe break inside the containment.

3.6.2.1.4.4 Exemptions from Pipe Whip Protection Requirements

Protection from pipe whip need not be provided if any one of the following conditions exist:

(1) Piping which is classified as moderate energy piping.

(2) Following a single postulated pipe break, piping for which the unrestrained movement of either end of the ruptured pipe in any feasible direction about a plastic hinge, formed within the piping, cannot impact any structure, system or component important to safety.

(3) Piping for which the internal energy level associated with whipping is insufficient to impair the safety function of any structure, system, or component to an unacceptable level. Any line restrictions (e.g., flow limiters) between the pressure source and break location, and the effects of either a single-ended or double-ended flow condition are accounted for, in the determination of the internal fluid energy level associated with the postulated pipe break reaction. The energy level in a whipping pipe will be considered as insufficient to rupture an impacted pipe of equal or greater nominal pipe size and equal or heavier wall thickness.

All other effects from pipe breaks, such as jet impingement, pressure, temperature, humidity, wetting of all exposed equipment and flooding have been considered for those breaks exempted by the above criteria.

3.6.2.1.4.5 Location for Postulated Pipe Breaks

Postulated pipe break locations are selected in accordance with Regulatory Guide 1.46, NRC Branch Technical Position APCSB 3-1, Appendix B and as expanded in NRC Branch Technical Position MEB 3-1. For ASME Section III, Class 1 piping systems which are classified as high energy, the postulated break locations are:

(1) The terminal ends of the pressurized portions of the run.

(2) At intermediate locations between the terminal ends where the maximum stress range between any two load sets (including zero load set) according to Subarticle NB-3600 ASME Code Section III for upset plant conditions and an independent OBE event transient, exceeds the following:

(a) If the stress range calculated using Equation (10) of the Code exceeds 2.4 Sm but is not greater than 3 Sm, no breaks will be postulated unless the cumulative usage factor exceeds 0.1.

(b) The stress ranges, as calculated by Equations (12) or (13) of the Code, exceed 2.4 Sm or if the cumulative usage factor exceeds 0.1 when equation (10) exceeds 3 Sm.

(3) In the event that two or more intermediate locations cannot be determined by stress or usage factor limits, a total of two intermediate locations shall be identified on a reasonable basis (a) for each piping run or branch run.

(a) Reasonable basis shall be one or more of the following:

(1) Fitting locations

(2) Highest stress or usage factor locations

Where more than two such intermediate locations are possible using the application of the above reasonable basis, those two locations possessing the greatest damage potential will be used. A break at each end of a fitting may be classified as two discrete break locations where the stress analysis is sufficiently detailed to differentiate stresses at each postulated break.

3.6.2.1.4.6 Types of Breaks to be Postulated in Fluid System Piping

The following types of breaks are postulated in high energy fluid system piping:

(1) No breaks need be postulated in piping having a nominal diameter less than or equal to one inch.

(2) Circumferential breaks are postulated only in piping exceeding a one inch nominal pipe diameter.

(3) Longitudinal splits are postulated only in piping having a nominal diameter, equal to or greater than 4 inches.

(4) Circumferential breaks are to be assumed at all terminal ends and at intermediate locations identified by the criteria in Subsection 3.6.2.1.4.5. At each of the intermediate postulated break locations identified to exceed the stress and usage factor limits of the criteria in Subsection 3.6.2.1.4.5 either a circumferential or a longitudinal break, or both, shall be postulated per the following:

a. Circumferential breaks shall be postulated at fitting joints and;

b. Longitudinal breaks shall be postulated in the center of the fitting at two diametrically opposed points (but not concurrently) located so that the reaction force is perpendicular to the plane of the piping and produces out-of-plane bending.

c. Consideration shall be 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 may be 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 may be postulated, and conversely if maximum stress range in the circumferential direction is greater than 1.5 the stress range in the longitudinal direction, only the longitudinal break may be postulated. If no significant difference between the circumferential and longitudinal stresses is determined, then both types of breaks shall be considered.

d. At intermediate locations chosen to satisfy the minimum break location criteria, only circumferential breaks shall be postulated.

(5) For design purposes, a longitudinal break area shall be assumed to be the equivalent of one circumferential pipe area unless analytical methods representing test results can conservatively reduce forces based on a mechanistic approach.

(6) For both longitudinal and circumferential breaks, after assessing the contribution of upstream piping flexibilities, pipe whipping 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 pipe movement in the direction of the jet reaction.

(7) For a circumferential break, the dynamic force of the jet discharge at the break location will be 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. Justifiable line restrictions, flow limiters, and the absence of energy reservoirs shall be used, as applicable, in the reduction of the jet discharge.

3.6.2.1.5 High Energy Fluid Systems With and Without Sufficient Capacity to Develop a Jet Stream

Some of the high energy fluid system piping do not have any flow during plant normal and upset operating conditions. These lines have either a check valve or a normally closed valve in the system. Only that portion of the piping between the RPV and the check valve of the normally closed valve, is considered to be high energy system.

For a postulated pipe break in the high energy portion of the system, that portion of the piping towards the normally closed valve, is considered not to have fluid energy reservoir with sufficient capacity to cause pipe whip. Table 3.6-13 lists these systems and the reservoirs with and without sufficient capacity to develop a jet stream.

3.6.2.2 Analytical Models to Define Forcing Functions and Response Models

3.6.2.2.1 For Piping Other than Recirculation Piping System

Analyses are performed for the pipe failure postulated in Subsection 3.6.2.1. Analysis of jet thrust forces which result in the event of a pipe rupture are described in Section 2.2 of Reference 3.6-2. Fluid jet impingement forces are discussed in Section 2.3 of Reference 3.6-2. Impulsive loading and impact combined with impulsive loading are described in Sections 3.2 and 3.3 respectively of Reference 3.6-2. Alternatively, nonlinear time history dynamic analyses are performed. The forcing function used in piping dynamic analysis is obtained using Reference 3.6-1 and Reference 3.6-7. A typical forcing function and the piping system model used for the dynamic response analysis is provided on Figure 3.6-12 and Figure 3.6-12a.

A typical piping system model used in the dynamic analysis is provided on Figure 3.6-11A.

Protection against the pipe whip is accomplished by restraining the motion of the pipe after pipe break. The pipe whip restraints are designed with energy absorbing components, i.e., crushable honeycomb, in the direction of the pipe whip. Crushable honeycomb limits the reaction load in the whip restraint in most cases to about 80% of the design yield load for the restraint and absorbs the energy to greatly reduce the tendency of the pipe to rebound after impact.[1]

When the required energy absorption is too great to be entirely accomplished by the honeycomb, the plastic deformation capability of the whip restraint itself is taken into account. The structural steel whip restraint is permitted to have plastic deformation that results in ductility ratio no greater than 20.[2] For structural steel subjected to shock and impact loading, ductility ratio of 20 is an acceptable practice (Reference 3.6-9). Reference 3.6-8 was used in determining the response of the piping system under pipe break loads.

The criteria for the dynamic analyses are as follows:

1) An analysis of the piping system is performed for each longitudinal and circumferential postulated rupture at the break locations determined in accordance with the criteria of Subsection 3.6.2.1.

2) The loading condition of a piping system prior to postulated rupture in terms of internal pressure, temperature, and stress state is that condition associated with reactor operating at 100 percent power.

3) For a circumferential rupture, pipe whip dynamic analyses are performed only for that end (or ends) of the pipe or branch that is connected to a contained fluid energy reservoir having sufficient capacity to develop a jet stream.

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[1] Energy absorption capacity of the honeycomb associated with crushing up to 60% of its original height is used in the design calculations. The load deflection curve in this region is relatively flat.

[2] Ductility ratio is defined as plastic strain (deformation) divided by the strain (deformation, at yield strength of the material.

4) Dynamic analytic methods used for calculating the piping and piping/restraint system response to the pipe break forces adequately account for the effects of:

   a) Translational masses (and rotational masses for major components) and stiffness properties of the piping system, restraint system, major components, and support walls

   b) Transient forcing function(s) acting on the piping system

   c) Elastic and inelastic deformation of piping and/or restraint

   d) The design clearance between the pipe and the restraint.

5) A 10 percent increase of minimum specified design yield strength (Sy) is used to account for strain rate effects in inelastic nonlinear analyses.

Figures 3.6-1A to 3.6-8E show the pipe break locations and pipe break restraint locations and Tables 3.6-6a, 3.6-6b, 3.6-6c, 3.6-6d, 3.6-6e, 3.6-6f, 3.6-6g, 3.6-6h, 3.6-7, 3.6-7a, 3.6-8, 3.6-8a, 3.6-9, 3.6-9a, 3.6-10, 3.6-10a, 3.6-11, 3.6-11a, 3.6-12a, 3.6-12a.1, 3.6-12a.2, 3.6-12a.3, 3.6-12a.4, 3.6-12a.5, 3.6-12a.6, 3.6-12a.7, 3.6-12b, 3.6-12b.1, 3.6-12b.2, 3.6-12b.3, 3.6-12b.4, 3.6-12c.1, 3.6-12d.1, 3.6-12d.3, 3.6-12e.1, 3.6-12e.2, and 3.6-12e.3. 3.6-13 show the summary of the analysis of main steam, feedwater water, HPCI, RCIC, CORE SPRAY, RHR SUPPLY and RHR Return Lines, Head Vent Line, Head Spray, STANDBY LIQUID CONTROL, and MSIV Drain Lines.

These figures and tables indicate the breaks for which dynamic analysis was performed and the type of the break assumed.

3.6.2.2.2 Analytic Methods to Define Blowdown Forcing Functions and Response Models for Recirculation Piping System (NSSS Supply)

3.6.2.2.2.1 Analytical 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 fluid state within the pipe prior to rupture, break flow area, frictional losses, plant system characteristics, piping system, and other factors. The methods used to calculate the reaction forces for recirculation piping system are presented in the following sections.

The criteria used for calculation of fluid blowdown forcing functions includes:

(1) 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 unless physically limited by piping restraints, structural members, or piping stiffness as is demonstrated by the inelastic pipe whip analysis (Subsection 3.6.2.2.2.2).

(2) The dynamic force of the jet discharge at the break location are based on the effective cross-sectional flow area of the pipe and on a calculated fluid pressure as modified by an analytically or experimentally determined thrust coefficient. Limited pipe displacement at

the break location, line restrictions, flow limiters, positive pump-controlled flow, and the absence of energy reservoirs are taken into account, as applicable, in the reduction of jet discharge.

(3) A rise time not exceeding one millisecond is used for the initial pulse.

Blowdown forcing functions are determined by either of two methods given in (1) and (2) below:

(1) The predicted blowdown forces on pipes fed by a pressure vessel can be described by transient and steady state forcing functions. The forcing functions used are based on methods described in Reference 3.6-6. These are simply described as follows:

a. The transient forcing functions at points along the pipe, result from the propagation of waves (wave thrust) along the pipe, and from the reaction force due to the momentum of the fluid leaving the end of the pipe (blowdown thrust).

b. The waves cause various sections of the pipe to be loaded with time-dependent forces. It is assumed that the pipe is one-dimensional, in that there is no attenuation or reflection of the pressure waves at bends, elbows, and the like. Following the rupture, a decompression wave is assumed to travel from the break at a speed equal to the local speed of sound within the fluid. Wave reflections will occur at the break end, changes in direction of piping, and the pressure vessel until a steady flow condition is established. Vessel and free space conditions are used as boundary conditions. The blowdown thrust causes a reaction force perpendicular to the pipe break.

c. The initial blowdown force on the pipe is taken as the sum of the wave and blowdown thrusts and is equal to the vessel pressure (P_o) times the break area (A). After the initial decompression period (i.e., the time it takes for a wave to reach the first change in direction), the force is assumed to drop off to the value of the blowdown thrust (i.e., 0.7 P_oA).

d. Time histories of transient pressure, flow rate, and other thermodynamic properties of the fluid can be used to calculate the blowdown force on the pipe using the following equation:

$$F = \left[(P - P_a) + \frac{\rho u^2}{2g} \right] A$$

Where

F	=	Blowdown Force
P	=	Pressure at exit plane
P_a	=	Ambient pressure
u	=	Velocity at exit plane
ρ	=	Density at exit plane
A	=	Area of break
g	=	Gravitational constant

e. Following the transient period a steady-state period is assumed to exist. Steady-state blowdown forces are calculated including frictional effects. For saturated steam, these effects reduce the blowdown forces from the theoretical maximum of 1.26 P_oA. The method of accounting for these effects is presented in Reference 3.6-3. For subcooled water, a reduction from the theoretical maximum of 2.0 P_oA is found through the use of Bernoulli's and standard equations such as Darcy's equation, which account for friction.

(2) The following is an alternate method for calculating blowdown forcing functions.

The computer code RELAP3 (Ref. 3.6-4) is used to obtain exit plane thermodynamic states for postulated ruptures. Specifically, RELAP3 supplies exit pressure, specific volume and mass rate. From these data the blowdown reaction load is calculated using the following relation:

$$\frac{T}{A_e} = P_E - P_{00} + \frac{G_E^2 \ \overline{V}_E}{g_c}$$

$$R = -\frac{T}{A_e} \ x \ A_{te}$$

Where

$\frac{T}{A_e}$	=	Thrust Per unit Break Area – Lb/ft^2
P_E	=	Exit Pressure – Lb/ft^2
P_{00}	=	Receiver Pressure – Lb/ft^2
G_E	=	Exit Mass Flux – $Lb/Sec\text{-}ft^2$
$\overline{V}_E$	=	Exit Specific Volume – ft^3/Lb
g_c	=	Gravitational Constant – 32.174 $Ft\text{-}Lb_m/sec^2\text{-}Lb_f$
R	=	Reaction Force on the Pipe – Lb
A_{te}	=	Effective Target Area – ft^2

3.6.2.2.2.2 Pipe Whip Dynamic Response Analysis for Recirculation Piping System

The prediction of time-dependent and steady-thrust reaction loads caused by blowdown of sub-cooled, saturated, and two-phase fluid from a ruptured pipe is used in design and evaluation of dynamic effects of pipe breaks. A detailed discussion of the analytical methods employed to compute these blowdown loads is given in Subsection 3.6.2.2.2.1. Analytical methods used to account for this loading are discussed below.

The criteria used for performing the pipe whip dynamic response analyses include:

(1) A pipe whip analysis is performed for each postulated pipe break. However, a given analysis can be used for more than one postulated break location if the blowdown forcing function, piping and restraint system geometry and piping and restraint system properties are conservative for other break locations.

(2) The analysis includes the dynamic response of the pipe in question, and the pipe whip restraints which transmit loading to the structures.

(3) The analytical model adequately represents the mass/inertia and stiffness properties of the system.

(4) Pipe whipping is assumed to occur in the plane defined by the piping geometry and configuration, and to cause pipe movement in the direction of the jet reaction.

(5) Piping within the broken loop is no longer considered part of the RCPB. Plastic deformation in the pipe is considered as a potential energy absorber. Limits of strain are imposed which are similar to strain levels allowed in restraint plastic members. Piping systems are designed so that plastic instability does not occur in the pipe at the design dynamic and static loads unless damage studies are performed which show the consequences does not result in direct damage to any essential system or component.

(6) Components such as vessel safe ends and valves which are attached to the broken piping system and do not serve a safety function or whose failure would not further escalate the consequences of the accident, are not designed to meet ASME Code imposed limits for essential components under faulted loading. However, if these components are required for safe shutdown, or serve a safety function to protect the structural integrity of an essential component, limits to meet the Code requirements for faulted conditions and limits ensure operability if required will be met.

The pipe whip analysis was performed using the PDA computer program (Reference 3.6-5). PDA is a computer program used to determine the response of a pipe subjected to the thrust force occurring after a pipe break. The program treats the situation in terms of generic pipe break configuration, which involves a straight, uniform pipe fixed at one end and subjected to a time-dependent thrust-force at the other end. A typical restraint used to reduce the resulting deformation is also included at a location between the two ends. Nonlinear and time-independent stress-strain relations are used for the pipe and the restraint. Similar to the plastic-hinge concept, bending of the pipe is assumed to occur only at the fixed end and at the location supported by the restraint.

Shear deformation is also neglected. The pipe bending moment-deflection (or rotation) relation used for these locations is obtained from a static nonlinear cantilever beam analysis. Using the moment-rotation relation, nonlinear equations of motion of the pipe are formulated using an energy consideration and the equations are numerically integrated in small time steps to yield time-history information of the deformed pipe.

A comprehensive verification has been performed to demonstrate the conservatisms inherent in the PDA pipe whip computer program and the analytical methods utilized. This is described in

Reference 3.6-6. Part of this verification program included an independent analysis by Nuclear Services Corporation, under contract to the General Electric Company, of the recirculation piping system for the 1969 Standard Plant Design. The recirculation piping system was chosen for study due to its complex piping arrangement and assorted pipe sizes. The NSC analysis included elastic-plastic pipe properties, elastic-plastic restraint properties and gaps between the restraint and pipe and is documented in Reference 3.6-6. The piping/restraint system geometry and properties and fluid blowdown forces were the same in both analyses. However, a linear approximation was made by NSC for the restraint load - deflection curve supplied by GE. This approximation is demonstrated in Figure 3.6-15. The effect of this approximation is to give lower energy absorption of a given restraint deflection. Typically, this yields higher restraint deflections and lower restraint to structure loads than the GE analysis. The deflection limit used by NSC is the design deflection at one-half of the ultimate uniform strain for the GE restraint design. The restraint properties used for both analyses are provided in Table 3.6-4.

A comparison of the NSC analysis with the PDA analysis, as presented in Table 3.6-5 and Figure 3.6-16, shows that PDA predicts higher loads in 15 of the 18 restraints analyzed. This is due to the NSC model including energy absorbing effects in secondary pipe elements and structural members. However, PDA predicts higher restraint deflections in 50% of the restraints. The higher deflections predicted by NSC for the lower loads are caused by the linear approximation used for the force - deflection curve rather than by differences in computer techniques. This comparison demonstrates that the simplified modeling system used in PDA is adequate for pipe rupture loading, restraint performance and pipe movement predictions within the meaningful design requirements for these low probability postulated accidents.

3.6.2.3 Dynamic Analysis Methods to Verify Integrity and Operability

3.6.2.3.1 For Piping Other than Recirculation Piping System

Pipe whip restraints and compensating struts are used to control pipe whipping during a postulated rupture of the pipe. Barriers are used to protect components against jet impingement.

Compensating struts are mechanical snubbers used to perform the following functions:

a. Permit unrestrained thermal motion of the pipe.

b. Restrain pipe motion under seismic and other dynamic loads, and

c. Resist sustained loads resulting from a pipe break.

The pipe whip restraints used to protect the mechanical components are designed either as a part of the normal restraint system or as independent restraints. The independent restraints are designed solely to control movement of the pipe following pipe break and function only during pipe break. A typical pipe whip restraint of this type is shown in Figure 3.6-10.

Pipe whip restraints are placed near the isolation valves whose operability is required. These pipe whip restraints are an integral part of the normal pipe support system and are designed to pipe break loads. A typical pipe whip restraint arrangement to protect the isolation valve is shown in Figure 3.6-11.

A time-history dynamic analysis of the piping near isolation valves is performed for the pipe break loads and stresses in the pipe and loads on the restraints are determined. The stress in the pipe at the isolation valve is maintained below yield strength of the material to ensure valve operability. Since the section modulus of the valve is much greater than that of the pipe, the stress in the valve body would be below yield strength of the valve. Therefore, the deformations in the valve body would be small and would be in the elastic range such that binding of the valve internals cannot occur.

3.6.2.3.1.1 Design Loading Combinations

The design loading combinations applied in the design of the restraints for equipment and piping are categorized with respect to the plant operating conditions which are identified as normal, upset, emergency, and faulted as described in Table 3.9-1.

3.6.2.3.1.2 Design Stress Limits

Integral Restraints - when restraints for equipment piping are designed as an integral part of the normal support system, the design loading combinations for normal, upset, emergency, and faulted conditions are applicable. In evaluating the supports and restraints for ASME, Section III, Classes 1, 2, and 3 piping, the design stress limits applied in evaluating loading combinations for normal, upset, emergency, and faulted (except for pipe rupture) conditions are those given in Table 3.9-11. After rupture of the supported pipe occurs, the piping system is no longer within the jurisdiction of ASME Section III because the pressure boundary has been breached. The restraints are evaluated for pipe rupture loads as described in Subsection 3.6.2.2.1.

Independent Restraints - when restraints are designed solely to control movement following a postulated pipe rupture and to function independently of the normal support system, only the design pipe rupture loads are applicable.

To ensure that restraints do function independently of the normal support system, the motions of the intact pipe due to all normal and upset plant conditions and the vibratory motion of the SSE are calculated and used to specify a minimum clearance between the pipe and the restraint. Wherever possible, gaps between pipes and restraints are maximized to avoid possible contact during plant operation. Where a particular location requires minimizing a gap, special features are provided to permit adjustment of the gap size during hot functional testing.

The restraints are evaluated for the pipe rupture loads as described in Subsection 3.6.2.2.1.

3.6.2.3.2 Dynamic Analysis Methods to Verify Integrity and Operability for Recirculation Piping System (NSSS Supply)

3.6.2.3.2.1 Jet Impingement Analyses and Effects on Safety Related Components Resulting from Postulated Ruptures of the Recirculation Piping System

The methods used to evaluate the jet effects resulting from the postulated breaks of recirculation piping are same as those discussed in Subsection 3.6.2.3.1.

3.6.2.3.2.2 Pipe Whip Effects Following a Postulated Rupture of the Recirculation System Piping

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

(1) Pipe displacement effects on components in same piping run.

   a. The criteria which is used for determining the effects of pipe displacements on in-line components is as follows:

      (i) Components such as vessel safe ends and valves which are attached to the broken piping system and do not serve a safety function or whose failure 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.

      (ii) If these components are required for safe shutdown, or serve a safety function to protect the structural integrity of an essential component, limits to meet the Code requirements for faulted conditions and limits to ensure operability, if required, will be met.

   b. The methods used to calculate the pipe whip loads on piping components in the same run as the postulated break are described in Subsection 3.6.2.2.2.2.

(2) Pipe displacement effects on structures, other systems and components.

   a. Pipe displacement effects on structures are as follows:

The drywell floor and the reactor pedestal support pipe whip restraints for the 28 in. diameter recirculation loop piping. A description of the loading on these structures due to a postulated rupture of a 28 in. diameter recirculation loop pipe is given in Subsection 3.8.3.3.2.1.

The reactor shield wall supports pipe whip restraints for the 12 in. and 22 in. diameter recirculation loop piping. The equivalent static loads on the reactor shield wall due to a postulated rupture of a recirculation loop pipe are specified by G.E. and are as follows:

Pipe Diameter (in.)	Equivalent Static Load (kips)
12	270
22	630

3.6.2.3.2.3 Loading Combinations and Design Criteria for Recirculation Piping Pipe Whip Restraints

Pipe whip restraints, as differentiated from piping supports, are designed to function and carry load for an extremely low probability gross failure in a piping system carrying high energy fluid. The piping integrity does not usually depend on the pipe whip restraints for any loading combination. When the piping integrity is lost because of a postulated break, the pipe whip restraint acts to limit the movement of the broken pipe to an acceptable distance. The pipe whip restraints (i.e., those devices which serve only to control the movement of a ruptured pipe following gross failure) will be subjected to once in a lifetime loading. For the purpose of design, the pipe break event is considered to be a faulted plant condition, and other unbroken pipe, its restraints, and structure to which the restraint is attached, are analyzed and designed accordingly.

The pipe whip restraint devices designed, tested, fabricated and installed by GE for the recirculation loop piping, utilize energy absorbing wire rope cable restraints. The wire rope cable restraint uses a low clearance design with a frame attached to a support and carbon steel wire ropes restraining the pipe. The low clearances between the cable restraints and the pipe prevent the pipe from building up a large amount of kinetic energy. Thus, the cables have to absorb only a limited quantity of energy, and resist large forces. A conceptual sketch for the restraints is shown in Figure 3.6-13. However, the restraints do have some clearance between them and the process pipe to allow for installation of some normal pipe insulation, and thermal movements during plant operation.

The specific design objectives for the restraints are:

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

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

(3) The restraints should provide minimum hindrance to in-service inspection of the process piping.

For the purposes 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 on the restraint;

(3) Design characteristics of the pipe whip restraints are included and verified by the pipe whip dynamic analysis described in Subsection 3.6.2.2.2.2; and

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

As previously described, the recirculation loop pipe whip restraints are composed of two parts, the cable and the restraint frame. Both parts of the restraining device function as load carry members, and will deflect under load. The load configurations for a cable restraint are shown in

Figure 3.6-13. The components of the restraints are categorized as Type I and II, as described below:

Type I - radial load-carrying members - these members composed of cables will absorb energy loaded in the direction perpendicular to the restraint base by elastic, and plastic deformations (Figure 3.6-13 Item a)

Type II - tangential load-carry members - these members composed of restraint frames will absorb energy loaded in the direction parallel to the base by plastic deformation. (Figure 3.6-13 Item b)

Each of these components is constructed of a different material in order to fulfill different design objectives. The design requirements and design limits for each component are therefore different. They are specified as below:

(1) Type I - Carbon steel wire ropes.

For carbon steel wire ropes, the maximum acceptable load was

- 90 percent of the load carrying capacity of the cable in the restraint configuration. This limit takes into consideration efficiency reduction experienced when a cable is wrapped around a pipe. This means that the design load is limited to about 75 percent of a minimum certified load carrying capacity of the cable in tension.

(2) Type 2 - Restraint Frames

Design limits for the ASTM A36 restraint frames is as follows:

(i) Design Load

The load bearing member is primarily a cantilever beam with an extra support (the diagonal plate) at approximately midspan. At loads approaching the plastic moment capability of the beam, the plastic hinge forms at section determined from an elastic structural analysis. The maximum design load and the ultimate load are calculated based on plastic moment capability, Mp, of this section, with the diagonal plate stressed uniformly at the minimum ultimate stress.

(ii) Design Deflection

The design and ultimate deflection are calculated assuming the beam remains straight and rotates about a point on the upper surface of the beam. The maximum design deflection at the load point is calculated assuming the diagonal plate undergoes 10 percent elongation. The ultimate deflection of the beam is based on a 20 percent ultimate elongation of the diagonal plate.

3.6.2.4 Guard Pipe Assembly Design Criteria

Guard pipe assembly design is not used in this plant.

3.6.2.5 Material To Be Submitted for Operating License Review

3.6.2.5.1 For Piping Other than Recirculation Piping System

The following paragraphs indicate how the criteria for protection against dynamic effects associated with postulated piping features are implemented.

1) The criteria given in Subsection 3.6.2.1 have been adhered to in locating the pipe failure locations and type of the failure. These locations are shown on Figures 3.6-1 to 3.6-8e.

2) Protective devices such as pipe whip restraints and the barriers are used. A typical pipe break restraint is shown in Figure 3.6-10. The in-service inspection requirements are implemented as discussed in Section 6.6.

3) Analytical methods to analyze the effects of pipe break are discussed in Subsections 3.6.2.2 and 3.6.2.3. Summary of the results are shown on Tables 3.6-6a, 3.6-6b, 3.6-6c, 3.6-6d, 3.6-6e, 3.6-6f, 3.6-6g, 3.6-6h, 3.6-7, 3.6-7a, 3.6-8, 3.6-8a, 3.6-9, 3.6-9a, 3.6-10, 3.6-10a, 3.6-11, 3.6-11a, 3.6-12a, 3.6-12a.1, 3.6-12a.2, 3.6-12a.3, 3.6-12a.4, 3.6-12a.5, 3.6-12a.6, 3.6-12a.7, 3.6-12b, 3.6-12b.1, 3.6-13.

4) All safety related systems and components have been protected from the effects of pipe whip and their design intended function will not be impaired to an unacceptable level.

3.6.2.5.2 Implementation of Criteria for Pipe Break and Crack Location and Orientation for Recirculation Piping System (NSSS Supply)

3.6.2.5.2.l Postulated Pipe Breaks in Recirculation Piping System - Inside Containment

The criteria for selection of postulated pipe breaks in the recirculation piping system, inside containment, are provided in Subsection 3.6.2.l.4. The postulated pipe break locations and types selected in accordance with these criteria are shown in Figure 3.6-14. Conformance with these criteria is demonstrated in Tables 3.6-14 and 3.6-15.

3.6.2.5.2.2 Implementation of Special Protection Criteria

The pipe whip restraints provided for the recirculation piping system are also shown in Figure 3.6-14. Using the analysis methods of Subsection 3.6.2.2.2.2, this system of restraints has been found to prevent unrestrained pipe whip resulting from a postulated rupture at any of the identified break locations.

3.6.2.5.2.3 Jet Effects for Postulated Ruptures of Recirculation System Piping

Jet effects from postulated breaks in the recirculation piping have been reviewed and modifications made as part of the jet impingement review program.

3.6.3 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.

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

a) Maximum operating temperature exceeds 200°F

b) Maximum operating pressure exceeds 275 psig

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

a) Maximum operating temperature is 200°F or less

b) Maximum operating pressure is 275 psig or less.

A system that operates within pressure-temperature conditions specified for a high energy fluid system, for less than 2 percent of the time the system operates as a moderate energy fluid system, is considered a moderate energy fluid system.

Normal Plant Conditions - Plant operating conditions during reactor startup, operation at power, or reactor cooldown to cold shutdown condition, but excluding test modes.

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.

Sh and Sa - Allowable stresses at maximum (hot) temperature and allowable stress range for thermal expansion, respectively, as defined in Article NC-3600 of the ASME Code, Section III.

Sm - Design stress intensity as defined in Article NB-3600 of the ASME Code, Section III.

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.

Terminal Ends - Extremities of piping runs that connect to structures, components (e.g., vessels, pumps, valves), or pipe anchors that act as rigid constraints to piping thermal expansion. A branch connection to a main piping run is a terminal end of the branch run, except when all three of the following conditions are in effect:

1) The branch nominal size is at least half that of the main run;

2) The intersection is not rigidly constrained to the building structure; and

3) The branch and main runs are included together in the same piping stress analysis model.

In piping runs which are maintained pressurized during normal plant conditions for only a portion of the run (i.e., up to the first normally closed valve), a terminal end of such runs is the piping connection to this closed valve.

3.6.4 REFERENCES

3.6-1 F.J. Moody, Fluid Reactions and Impingement Loads, Structural Design of Nuclear Plant Facilities, Vol. 1, (1973).

3.6-2 "Design for Pipe Break Effects," BN-TOP-2A, Bechtel Power Corporation.

3.6-3 GE Spec. No. 22A2625 - "System Criteria and Applications for Protection Against the Dynamic Effects of Pipe Break."

3.6-4 Relap 3 - A Computer Program for Reactor Blowdown Analysis IN-1321, issued June 1970, Reactor Technology TID-4500.

3.6-5 GE Report NEDE-10813 - "PDA - Pipe Dynamic Analysis Program for Pipe Rupture Movement." (Proprietary Filing)

3.6-6 Nuclear Services Corporation Report No. GEN-02-02, "Final Report Pipe Rupture Analysis of Recirculation System for 1969 Standard Plant Design."

3.6-7 Relap 4 - A computer program for transient Thermal Hydraulic analysis of Nuclear Reactors and Related Systems, ANCR-NUREG-1335, issued in September, 1976.

3.6-8 PIPRUP - A computer program for pipe Rupture Analysis, developed by nuclear services corporation (1977), Campbell, Ca.

3.6-9 "Design of Structures for Missile Impact," BC-TOP-9A, Revision 2, Bechtel Power Corporation, September 1974.

3.6-10 "COTTAP-4 (Compartment Transient Temperature Analysis Program)," EC-034-1019, Revision 0, Pennsylvania Power and Light Company, November, 1999.

TABLE 3.6-1

HIGH ENERGY FLUID SYSTEM PIPING

P&ID No.	Title	Description
M-101[(1)]	Main Steam	From nuclear boiler to the turbines, high pressure turbines to moisture/separator, to low pressure turbines. Main steam flow sensing line.
M-106[(1)]	Feedwater	From condensate demineralizers to feedwater heaters, to RF pumps, from RFP to nuclear boiler.
M-105[(1)]	Condensate	From condensate pump discharge to steam jet air ejector condenser, to steam packing exhausters, to condensate filters and to condensate demineralizers. From condensate demineralizer to control valves.
M-116[(1)]	Condensate Demineralizer	From condensate filters to condensate demineralizer to drain coolers.
M-141[(2)]	Nuclear Boiler	Main steam lines from reactor vessel to outside containment. From feedwater lines to reactor vessel. Main steam drains from the main steam lines to the condenser. Head vent line from the RPV head to the main steam "A" line.
M-142	Nuclear Boiler Instrumentation	Reactor Pressure Vessel pressure and level sensing lines, jet pump flow sensing lines and core delta ρ sensing lines.
M-143	Reactor Recirculation	Recirculation piping. From CRD to recirc. pump seal. Recirc flow sensing line.
M-144 M-145	Reactor Water Cleanup	From recirculation piping to cleanup pumps, through regenerative and non-regenerative heat exchangers, through cleanup Filter Demineralizer to feedwater.
M-146[(2)] & M-147	Control Rod Drive	From CRD pump discharge, to hydraulic control units, to control rod drives, to reactor vessel.

TABLE 3.6-1

HIGH ENERGY FLUID SYSTEM PIPING

P&ID No.	Title	Description
M-148	Standby Liquid Control	From isolation valve inside containment to reactor vessel.
M-149 & M-150	Reactor Core Isolation	From main steam to RCIC turbine stop valve, and drain pot. From RCIC Injection valve to feedwater line.
M-151	Residual Heat Removal	From recirc. piping to RHR inboard isolation valves, reactor vessel head spray, RHR flow sensing line.
M-152	Core Spray	From reactor vessel to inboard isolation valves.
M-155	High Pressure Coolant Injection	From main steam line to HPCI turbine stop valve, and drain pot. From HPCI Injection valve to feedwater line.

(1) High energy fluid system piping on these P&ID's are located in the Turbine Building. The components located in the Turbine Building (including safety related components) are not the essential systems and components that are required to operate to achieve safe shutdown following a high energy fluid system pipe break in the Turbine Building.

(2) High energy fluid system piping on these P&ID's are partially located in the Turbine Building.

Table 3.6-1A
MODERATE ENERGY FLUID SYSTEM PIPING
(LOCATED IN SAFETY-RELATED STRUCTURES)

Security-Related Information
Table Withheld Under 10 CFR 2.390

Table 3.6-2
SAFETY COMPONENTS IN CLOSE PROXIMITY TO
HIGH ENERGY FLUID SYSTEM PIPING
(REQUIRING JET IMPINGEMENT PROTECTION) – PRIMARY CONTAINMENT

Security-Related Information
Table Withheld Under 10 CFR 2.390

Table 3.6-3
SAFETY COMPONENTS IN CLOSE PROXIMITY TO
HIGH ENERGY FLUID SYSTEM PIPING
(REQUIRING JET IMPINGEMENT PROTECTION) – REACTOR BUILDING

Security-Related Information
Table Withheld Under 10 CFR 2.390

TABLE 3.6-4

RESTRAINT DATA

General Restraint Data for 1 Bar of a Restraint

$F = C_2 (\Delta \text{restraint})^n$

Where Δrestraint = δpipe - Total clearance

Pipe Size (In)	Rest Load Direction	C_2	n	Limit ΔRestraint	Initial Clearance	Effective Clearance	Total Clearance
12	0°	27,733	.24	6.129	4	1.941	5.941
12	90°	14,795	.401	9.063	4	12.247	16.247
16	0°	109,265	.24	6.278	4	1.934	5.934
16	90°	62,599	.377	8.978	4	12.187	16.187
24	0°	102,228	.24	8.222	4	1.984	5.084
24	90°	55,531	.375	11.972	4	13.685	17.685
24	38° *	109,888	.24	5.588	4	5.698	9.698
24	52° *	109,835	.24	5.473	4	8.462	12.462

*Applies to Restraint RCR 3 only.

TABLE 3.6-5

COMPARISON OF PDA AND NSC CODE

Break Indent (Figure 3.6-15)	Restraint Indent (Figure 3.6-15)	No. of Bars PDA	No. of Bars NSC	Load (kips) PDA	Load (kips) NSC	Restraint Deflection (in.) PDA	Restraint Deflection (in.) NSC	% of Design Restraint Deflection PDA	% of Design Restraint Deflection NSC	Pipe Deflection (in.) PDS	Pipe Deflection (in.) NSC
$RC1_J$	RCR1	5	5	803.2	788.3	6.57	7.926	79.93%	96.4%	17.72	15.58
$RC2_{LL}$	RCR1	5	5	766.4	458.4	14.99	7.495	125 %	62.6%	35.83	24.52
$RC3_{LL}$	RCR2	6	6	747.0	639.7	2.27	3.73	27.65%	45.35%	17.16	20.11
$RC3_{LL}$	RCR2	6	6	796.6	780.3	10.22	10.54	57.8 %	59.6 %	41.48	43.0
$RC4_{LL}$	RHR3	5	5	846.0	838.4	7.64	8.05	92.95%	97.98%	18.87	16.43
$RC4_{LL}$	RCR3	8	8	1319.0	1073.9	5.43	4.62	99.23%	76.85%	23.38	17.25
$RC4C_V$	RCR3	8	8	1260.7	1275.0	4.49	5.58	80.37%	99.89%	22.56	18.73
$PC6A_V$	RCR3	8	8	928.5	722.5	1.22	1.77	22.46%	31.7 %	23.68	95.39
$RC7_J$	RCR7	6	6	953.3	80.61	6.28	5.76	76.4 %	70.12%	16.46	21.63
$RC8_{LL}$	RCR6 RCR7	4 6	4 6	599.0 895.0	0 0	8.28 8.16	0 0	112.46% 110.76%	0 0	26.76 29.316	8.39
$RC9C_V$	RCR6	4	4	575.8	520.16	4.16	5.53	50.63%	67.33%	13.2	14.56
$RC9_{LL}$	RCR8	6	6	830.2	546.8	11.408	6.815	95.29%	56.9 %	36.612	26.24
RC11A	RCR8	6	6	818.3	493.6	10.98	5.99	91.72%	50.07%	31.404	23.71
PC13	RCR10	4	4	668.0	478.4	5.87	3.66	93.5 %	58.39%	13.37	10.44
PC16	RCR11	4	4	687.4	518.4	6.59	4.38	105 %	69.86%	15.37	10.22
$RC14C_V$	RCR20	8	8	285.0	309.6	2.83	5.88	46.3 %	95.92%	15.45	13.96
$RC14_{LL}$	RCR20	8	8	116.3	129.9	0.96	3.36	10.5 %	37.1 %	22.13	23.56

TABLE 3.6-6a

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 1 - LINE "A"

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
8 (butt weld)	18.59	.0015	43.4	A
541 (sweepolet)	62.80	.2111	43.4	C
542 (sweepolet)	59.76	.0740	43.4	C
543 (sweepolet)	63.32	.1076	43.4	C
544 (sweepolet)	57.19	.0621	43.4	C
545 (sweepolet)	56.17	.0577	43.4	C
27 (tapered transition joint)	30.57	.0111	43.4	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1A for Node Locations

Table 3.6-6b

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 1 – LINE "B"

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
402 (tapered transition joint)	29.119	.0098	43.4	A
441 (sweepolet)	59.481	.0672	43.4	C
442 (sweepolet)	60.690	.0757	43.4	C
443 (sweepolet)	61.386	.0309	43.4	C
257 (butt weld)	19.783	.0016	43.4	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1B for Node Locations

Table 3.6-6c

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 1 – LINE “C”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
508 (butt weld)	17.886	.0014	43.4	A
528 (sweepolet)	56.121	.0524	43.4	C
536 (sweepolet)	61.449	.0772	43.4	C
620 (sweepolet)	64.425	.0648	43.4	C
660 (tapered transition joint)	28.867	.0093	43.4	A

NOTES:
A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1C for Node Locations

Table 3.6-6d

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 1 – LINE “D”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
762 (butt weld)	18.267	.0015	43.4	A
782 (sweepolet)	68.242	.4155	43.4	C
850 (sweepolet)	63.177	.2956	43.4	C
860 (sweepolet)	59.512	.1696	43.4	C
870 (sweepolet)	57.465	.0948	43.4	C
880 (sweepolet)	55.616	.1348	43.4	C
778 (tapered transition joint)	30.683	.0117	43.4	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1D for Node Locations

Table 3.6-6e

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE "A"

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
8 (butt weld)	19.238	.0016	43.40	A
590 (sweepolet)	64.090	.1969	43.40	C
690 (sweepolet)	60.334	.1168	43.40	C
790 (sweepolet)	65.379	.1286	43.40	C
890 (sweepolet)	58.256	.0561	43.40	C
990 (sweepolet)	56.421	.0607	43.40	C
27 (tapered transition joint)	30.693	.0112	43.40	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1A for Node Locations

Table 3.6-6f

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE “B”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
108 (tapered transition joint)	28.353	.0034	43.40	A
930 (sweepolet)	65.257	.4452	43.40	C
920 (sweepolet)	62.391	.1790	43.40	C
910 (sweepolet)	58.614	.0958	43.40	C
20 (butt weld)	19.960	.0014	43.40	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1B for Node Locations

Table 3.6-6g

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE "C"

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
508 (butt weld)	17.636	.0013	43.40	A
528 (sweepolet)	55.447	.0624	43.40	C
536 (sweepolet)	61.708	.0831	43.40	C
701 (sweepolet)	58.315	.0583	43.40	C
750 (tapered transition joint)	29.933	.0046	43.40	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1C for Node Locations

Table 3.6-6h

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE “D”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
25 (butt weld)	18.724	.0015	43.40	A
75 (sweetpolet)	72.150	.6341	43.40	C
90 (sweetpolet)	65.942	.3880	43.40	C
105 (sweetpolet)	62.784	.2499	43.40	C
110 (sweetpolet)	56.323	.1737	43.40	C
120 (sweetpolet)	57.233	.1774	43.40	C
210 (tapered transition joint)	31.635	.0324	43.40	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-1D for Node Locations

Table 3.6-7

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE “D”

Loop “A”/Loop “B” Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
125 (tapered transition joint)	56.999	.6134	42.48	A
122 (elbow)	53.188	.1755	42.48	C
118 (elbow)	41.663	.1647	42.48	C
80 (tapered transition joint)	67.405	.9087	42.48	A
82 (elbow)	61.362	.1924	42.48	C
85 (elbow)	55.739	.1656	42.48	C
75 (tee)	115.915	.9489	42.48	C
40 (tapered transition joint)	72.600	.8174	42.48	A
42 (elbow)	65.367	.1708	42.48	C
45 (elbow)	59.112	.1773	42.48	C
35 (tee)	106.302	.6353	42.48	C
25 (tapered transition joint)	61.194	.1240	42.48	C
20 (tapered transition joint)	49.151	.0868	42.48	C**

Table 3.6-7

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

MAIN STEAM LINE INSIDE CONTAINMENT
UNIT 2 – LINE "D"

Loop "A"/Loop "B" Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
12 (tapered transition joint)	50.854	.0974	42.48	C**
10 (tapered transition joint)	50.307	.0932	42.48	A

NOTES:

A. Terminal End Break
B. Breakers determined by "Minimum Break Locations" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-2 for Node Locations
* Highest values of either Loop "A" or "B".
** These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-7a

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

FEEDWATER LINE INSIDE CONTAINMENT*
UNIT 2

Loop "A"/Loop "B" Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
450/125 (tapered transition joint)	55.682	.5767	42.48	A
443/122 (elbow)	52.425	.1754	42.48	C
425/118 (elbow)	40.867	.1658	42.48	C
202/80 (tapered transition joint)	70.954	.8845	42.48	A
200/82 (elbow)	63.855	.1850	42.48	C
192/86 (elbow)	48.417	.1653	42.48	C
75/75 (tee)	107.204	.9594	42.48	C
370/40 (tapered transition joint)	67.737	.9769	42.48	A
360/42 (elbow)	52.935	.1681	42.48	C
345/46 (elbow)	58.002	.1781	42.48	C
50/35 (tee)	87.447	.5927	42.48	C
35/25 (tapered transition joint)	61.124	.1027	42.48	C**
30/20 (tapered transition joint)	48.564	.0836	42.48	C**
20/12 (tapered transition joint)	50.389	.0934	42.48	C**

Table 3.6-7a

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

FEEDWATER LINE INSIDE CONTAINMENT*
UNIT 2

Loop “A”/Loop “B” Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
15/10 (tapered transition joint)	50.508	.0939	42.48	A**

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-2 for Node Locations
* Highest values of either Loop “A” or “B”.
** These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

Table 3.6-8

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

HPCI STEAM SUPPLY LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
405 (tapered transition)	45.754	.1209	42.10	A
411 (elbow)	66.674	.0836	42.10	B
425 (elbow)	50.053	.0292	42.10	B
431 (butt weld)	17.964	.0009	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-3 for Node Locations

Table 3.6-8a

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HPCI STEAM SUPPLY LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
304 (tapered transition joint)	57.878	.1835	42.10	A
310 (elbow)	66.600	.0911	42.10	B
327 (elbow)	60.766	.0823	42.10	B
341 (butt weld)	21.087	.0015	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-3 for Node Locations

Table 3.6-9

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

RCIC STEAM SUPPLY LINE INSIDE CONTAINMENT UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
643 (tapered transition joint)	78.272	.3638	42.10	A
644 (elbow)	56.466	.0081	42.10	B
652 (elbow)	39.408	.0139	42.10	C*
671 (butt weld)	15.679	.0002	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-4 for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-9a

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RCIC STEAM SUPPLY LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
643 (tapered transition joint)	75.972	.4869	42.10	A
644 (elbow)	57.592	.0077	42.10	B
652 (elbow)	64.182	.1046	42.10	C
676 (butt weld)	13.258	.0000	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-4 for Node Locations

TABLE 3.6-10

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

CORE SPRAY LINE INSIDE CONTAINMENT*
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
10 (Tapered Transition Joint))	63.84	0.0843	40.02	A
15 (Reducer)	65.04	0.0831	40.02	C**
20 (Elbow Beginning - Butt Weld)	59.13	0.0209	40.02	C**
25 (Tapered Transition Joint)	41.14	0.0018	40.02	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-5 for Node Locations
* Highest values of either Loop "A" or "B".
** These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

TABLE 3.6-10a

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

CORE SPRAY LINE INSIDE CONTAINMENT
UNIT 2

Node*	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
10 (Tapered Transition Joint)	64.11	0.0912	40.02	A
15 (Reducer)	67.09	0.1093	40.02	C
20 (Elbow)	57.09	0.0210	40.02	C**
25 (Tapered Transition Joint)	40.29	0.0015	40.02	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-5 for Node Locations
* Highest values of either Loop "A" or "B".
** These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

TABLE 3.6-11

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

RHR SUPPLY LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
636 (butt weld)	33.52	.0008	40.20	A
636 (elbow end)	33.44	.0162	40.20	C
639 (tapered transition joint)	52.16	.0555	40.20	C
645 (tapered transition joint)	53.40	.0696	40.20	C
648 (tapered transition joint)	51.50	.0515	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-6 for Node Locations

TABLE 3.6-11a

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

RHR SUPPLY LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
435 (butt weld)	33.39	.008	40.20	A
435 (end of elbow)	52.22	.0156	40.20	C*
445 (tapered transition joint)	50.75	.0466	40.20	C*
465 (tapered transition joint)	53.56	.0779	40.20	C
485 (tapered transition joint)	51.53	.052	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-6 for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

Table 3.6-12a

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RHR RETURN LINE INSIDE CONTAINMENT
UNIT 1 – LOOP “A”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
125 (tapered transition joint)	54.04	.114	40.20	A
132 (tapered transition joint)	48.15	.068*	40.20	B
143 (tapered transition joint)	48.52	.066*	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined **by** “Minimum Break Location” Criteria
C. Breaks determined **by** Stress Requirement
D. See Figure 3.6-7 for Node Locations

Envelope Value Represents Maximum Values at Similar Components And/Or Node Locations in Both Loops.

Table 3.6-12a.1

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

REACTOR WATER CLEAN UP LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
173 (butt weld)	42.23	.0123	42.864	C*
222 (tapered transition joint)	41.41	.0052	34.27	A
318 (tapered transition joint)	36.68	.0039	34.27	A
802 (butt weld)	51.18	.0687	34.27	A
808 (reducer)	54.38	.0251	34.27	C
822 (socket weld)	23.65	.0002	34.27	C
804 (tee)	77.98	.6140	34.27	C
842 (elbow)	60.16	.0272	34.27	C

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1 for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-12a.2

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

REACTOR WATER CLEAN UP LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
5 (butt weld)	10.52	.0053	42.864	A
59 (tee)	38.78	.0158	34.27	C*
504 (butt weld)	40.04	.0365	34.27	C*
61 (butt weld)	43.11	.0208	34.27	C*
710 (socket weld)	37.12	.0026	34.27	A
153 (curb)	13.64	.0012	42.864	A
80 (tee)	47.96	.0486	42.864	C*

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1,3-6-8A.2, 3.6-8A.3 for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-12a.3

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

REACTOR WATER CLEAN UP LINE INSIDE CONTAINMENT UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
846 (elbow)	65.08	.0468	34.27	C
301 (butt weld)	40.36	.0040	34.27	A
320 (elbow)	48.08	.0013	34.27	C*
330 (elbow)	47.33	.0012	34.27	C*
335 (tee)	53.43	.0278	34.27	C*
340 (reducer)	49.09	.0072	34.27	C
352 (socket weld)	31.22	.0007	34.27	A
850 (elbow)	53.78	.0090	34.27	C

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1, for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-12a.4

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

REACTOR WATER CLEAN-UP LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
432 (butt weld)	40.71	.0043	34.27	A
435 (tee)	55.31	.0283	34.27	C
441 (reducer)	51.76	.0118	34.27	C
460 (socket weld)	27.01	.0002	34.27	A
510 (elbow)	47.28	.0012	34.27	C*
535 (elbow)	46.20	.0010	34.27	C*
551 (tapered transition joint)	64.07	.4768	34.27	A
610 (butt weld)	51.57	.0917	34.27	A
615 (tee)	86.601	.794	34.27	C
705 (elbow)	64.52	.1002	34.27	C
695 (elbow)	59.63	.0226	34.27	C
715 (elbow)	54.54	.0074	34.27	C

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1, for Node Locations
* These locations can be considered arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

Table 3.6-12a.5

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

REACTOR WATER CLEAN-UP LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
735 (tapered transition)	72.27	.9975	34.27	A
619 (reducer)	72.67	.6331	34.27	C
635 (socket weld)	21.83	.0001	34.27	C

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1 for Node Locations

Table 3.6-12a.6

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RHR RETURN LINE INSIDE CONTAINMENT
UNIT 2 – LOOP “A”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi)	Remarks
640 (tapered transition joint)	54.31	,1179	40.20	A
655 (tapered transition joint)	49.30	.068*	40.20	B
680 (tapered transition joint)	49.49	.066*	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-7 for Node Locations

Envelope Value Represents Maximum Values at Similar Components And/Or Node Locations in Both Loops.

Table 3.6-12a.7

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

REACTOR WATER CLEAN-UP LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
248 (butt weld)	38.33	0.0059	42.864	B
5 (butt weld)	23.90	0.0104	42.864	A
102 (tree)	48.81	0.0623	34.27	B
101 (butt weld)	42.46	0.0385	34.27	B
515 (socket weld)	24.07	0.0003	34.27	A
154 (curve end)	13.88	0.0013	42.864	A
235 (tee)	46.50	0.0460	42.864	B
55 (tee)	48.51	0.0291	34.27	C*
281 (reducer)	42.75	0.0092	42.864	B

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8A.1,3-6-8A.4, 3.6-8A.5 for Node Locations
* These locations can be considered arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained above.

Table 3.6-12b

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RHR RETURN LINE INSIDE CONTAINMENT
UNIT 1 – LOOP “B”

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi)	Remarks
684 (tapered transition ioint)	52.82	.088	40.20	A
690 (tapered transition joint)	50.01	.068*	40.20	B
698 (tapered transition joint)	49.13	.066*	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined **by** “Minimum Break Location” Criteria
C. Breaks determined **by** Stress Requirement
D. See Figure 3.6-8 for Node Locations

Envelope Value Represents Maximum Values at Similar Components And/Or Node Locations in Both Loops.

TABLE 3.6-12b.1

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HEAD VENT LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
117 (red)	22.97	0.0	33.60	A
145 (taper transition joint)	27.89	.0025	42.10	A
254 (socket weld)	36.77	.1239	42.10	C
256 (socket weld)	30.85	.0824	42.10	C*
260 (socket weld)	28.94	.0666	42.10	A
358 (socket weld)	23.79	.0504	42.10	C*
365 (straight pipe)	13.64	0.0	42.10	A
408 (socket weld)	51.34	.0565	42.10	C*

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8B for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

TABLE 3.6-12b.2

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HEAD VENT LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
410 (socket weld)	55.96	.0846	42.10	C*
420 (socket weld)	54.09	.0682	42.10	A
613 (reducer)	24.31	.0001	33.60	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8B for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

Table 3.6-12b.3

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RHR RETURN LINE INSIDE CONTAINMENT
UNIT 2 – LOOP "B"

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi)	Remarks
815 (tapered transition joint)	53.28	,0941	40.20	A
840 (tapered transition joint)	49.73	.068*	40.20	B
860 (tapered transition joint)	49.08	.066*	40.20	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8 for Node Locations

Envelope Value Represents Maximum Values at Similar Components And/Or Node Locations in Both Loops.

TABLE 3.6-12b.4

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HEAD VENT LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
422 (red)	24.87	.0001	33.60	A
7 (tapered transition joint)	28.30	.0028	42.10	A
618 (reducer)	25.08	.0001	33.60	A
260 (socket weld)	17.67	.0098	42.10	A
363 (straight pipe)	21.08	.0001	42.10	A
716 (socket weld)	46.13	.0358	42.10	A
251 (socket weld)	24.33	.0161	42.10	C*
249 (socket weld)	35.70	.0873	42.10	C*
358 (socket weld)	23.45	.1063	42.10	C
708 (socket weld)	47.24	.0370	42.10	C*
712 (socket weld)	51.47	.0420	42.10	C*

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8B for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2; however, original break classification is retained.

TABLE 3.6-12c

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HEAD SPRAY LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
5 (taper transition joint)	69.34	.4376	39.76	A
12 (taper transition joint)	58.71	.1162	39.76	C
14 (taper transition joint)	56.12	.0798	39.76	C*
15 (taper transition joint)	52.65	.0482	39.76	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8C for Node Locations
* These locations can be considered as arbitrary breaks based on criteria given in Section 3.6.2, however, original break classification is retained above.

TABLE 3.6-12c.1

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

HEAD SPRAY LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
7 (tapered transition joint)	87.95	.9195	39.76	A
12 (tapered transition joint)	62.47	.2222	39.76	C
14 (tapered transition joint)	58.66	.1361	39.76	C
30 (tapered transition joint)	54.56	.0672	39.76	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8C for Node Locations

TABLE 3.6-12d.1

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

STANDBY LIQUID CONTROL LINE INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
32 (socket weld)	37.36	.0087	34.080	B
25 (socket weld)	43.98	.0678	34.080	A
230 (anchor)	10.72	0.0	34.080	A
71 (socket weld)	31.95	.0055	34.080	B
50 (socket weld)	33.37	.0056	34.080	A
192 (socket weld)	37.57	.0075	34.080	B
203 (socket weld)	34.33	.0060	34.080	B

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8D for Node Locations

TABLE 3.6-12d.3

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

STANDBY LIQUID CONTROL LINE INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
32 (socket weld)	36.63	.0081	34.080	B
25 (socket weld)	46.68	.1245	34.080	A
230 (anchor)	8.98	0.0	34.080	A
71 (socket weld)	32.76	.0049	34.080	B
50 (socket weld)	33.37	.0056	34.080	A
192 (socket weld)	37.57	.0075	34.080	B
203 (socket weld)	34.33	.0060	34.080	B

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8D for Node Locations

TABLE 3.6-12e.1

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

MSIV DRAIN LINES INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
113 (socket weld)	53.05	.0487	42.10	A
112 (elbow)	52.44	.0038	42.10	B
35 (tee)	27.23	.0039	42.10	A
41 (tee)	34.33	.0059	42.10	B
43 (elbow)	34.50	.0008	42.10	B
66 (elbow)	43.83	.0066	42.10	B
51 (socket weld)	45.84	.0337	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8E for Node Locations

TABLE 3.6-12e.2

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

MSIV DRAIN LINES INSIDE CONTAINMENT
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
67 (socket weld)	40.52	.0157	42.10	A
93 (elbow)	35.42	.0067	42.10	B
95 (elbow)	36.03	.0071	42.10	B
99 (socket weld)	42.08	.0298	42.10	A
106 (elbow)	37.99	.0012	42.10	B

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8E for Node Locations

TABLE 3.6-12e.3

SUMMARY OF STRESS IN HIGH ENERGY ASME CLASS 1 PIPING

MSIV DRAIN LINES INSIDE CONTAINMENT
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
113 (socket weld)	53.05	.0487	42.10	A
112 (elbow)	52.44	.0038	42.10	B
106 (elbow)	37.99	.0012	42.10	B
93 (elbow)	35.42	.0067	42.10	B
95 (elbow)	36.03	.0071	42.10	B
99 (socket weld)	42.08	.0298	42.10	A
35 (tee)	27.23	.0039	42.10	A
41 (tee)	34.33	.0059	42.10	B
43 (elbow)	34.50	.0008	42.10	B
51 (socket weld)	45.84	.0337	42.10	A
66 (elbow)	43.83	.0066	42.10	B
67 (socket weld)	40.52	.0157	42.10	A

NOTES:

A. Terminal End Break
B. Breaks determined by "Minimum Break Location" Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-8E for Node Locations

TABLE 3.6-13

HIGH ENERGY FLUID SYSTEMS

WITH AND WITHOUT SUFFICIENT CAPACITY TO DEVELOP A JET STREAM

System	Reservoir Without Sufficient Capacity To Develop Jet Stream	Reservoir With Sufficient Capacity To Develop Jet Stream
Core Spray Inside Containment.	Between the postulated pipe break and the normally closed valve (Check Valve).	Between the postulated pipe break and the RPV.
Steam Supply To HPCI Turbine, Outside Containment.	Between the postulated pipe break and the normally closed valve HV1F001.	Between the postulated pipe and the RPV.
Steam Supply To RCIC Turbine, Outside Containment.	Between the postulated pipe break and the normally closed valve HV F045.	Between the postulated pipe break and the RPV.
Other High Energy Systems.	None.	All.

Table 3.6-14

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RECIRCULATION PIPING SYSTEM – LOOP “A”
UNIT 1

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
S1 (tapered transition joint)	46.53	.0061	40.02	A
F1 (sweepolet)	63.42*	.144*	40.02	C
F3 (sweepolet)	63.42*	.144*	40.02	C
F5 (cross)	69.85*	.199*	40.02	C
F7 (sweepolet)	63.42*	.144*	40.02	C
F9 (sweepolet)	63.42*	.144*	40.02	C
F2 (tapered transition joint)	46.93*	.039*	40.02	A
F4 (tapered transition joint)	46.93*	.039*	40.02	A
F6 (tapered transition joint)	46.93*	.039*	40.02	A
F8 (tapered transition joint)	46.93*	.039*	40.02	A
F10 (tapered transition joint)	46.93*	.039*	40.02	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-14 for Node Locations
* Envelope Value Represents Maximum Values at Similar Components and/or Node Locations in Both Loops.

Table 3.6-14

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RECIRCULATION PIPING SYSTEM – LOOP “B”
UNIT 1

S1 (tapered transition joint)	49.77	.0073	40.02	A
F1 (sweepolet)	63.42*	.144*	40.02	C
F3 (sweepolet)	63.42*	.144*	40.02	C
F5 (cross)	74.46	.199	40.02	C
F7 (sweepolet)	63.46	.144	40.02	C
F9 (sweepolet)	63.42*	.144	40.02	C
F2 (tapered transition joint)	46.93*	.039*	40.02	A
F4 (tapered transition joint)	46.93*	.039*	40.02	A
F6 (tapered transition joint)	46.93*	.039*	40.02	A
F8 (tapered transition joint)	46.93*	.039*	40.02	A
F10 (tapered transition joint)	46.93*	.039*	40.02	A
S2LL (tee)	74.99	.192	40.02	C

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-14 for Node Locations
* Envelope Value Represents Maximum Values at Similar Components and/or Node Locations in Both Loops.

Table 3.6-15

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RECIRCULATION PIPING SYSTEM – LOOP “A”
UNIT 2

Node	Stress (ksi) (Eq. 10)	Cumulative Factor	Usage Pipe Break Stress Limit (ksi) (2.4 Sm)	Remarks
425 (tapered transition joint)	46.63	.006	40.02	A
15 (sweepolet)	63.42*	.144*	40.02	C
45 (sweepolet)	63.88	.144*	40.02	C
70 (cross)	73.53	.199*	40.02	C
95 (sweepolet)	63.42	.144*	40.02	C
125 (sweepolet)	63.42*	.144*	40.02	C
155 (tapered transition joint)	46.93*	.039*	40.02	A
175 (tapered transition joint)	46.93*	.039*	40.02	A
200 (tapered transition joint)	46.93*	.039*	40.02	A
220 (tapered transition joint)	46.93*	.039*	40.02	A
240 (tapered transition joint)	46.93*	.039*	40.02	A

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-14 for Node Locations
* Envelope Value Represents Maximum Values at Similar Components and/or Node Locations in Both Loops

Table 3.6-15

SUMMARY OF STRESS IN HIGH ENERGY
ASME CLASS 1 PIPING

RECIRCULATION PIPING SYSTEM – LOOP “B”
UNIT 2

135 (sweepolet)	63.42*	.144*	40.02	C
105 (cross)	72.75	.199*	40.02	C
55 (sweepolet)	63.42	.144*	40.02	C
641 (tapered transition joint)	46.93*	.039*	40.02	A
626 (tapered transition joint)	46.93*	.039*	40.02	A
195 (tapered transition joint)	46.93*	.039*	40.02	A
59 (tapered transition joint)	46.93*	.039*	40.02	A
19 (tapered transition joint)	46.93*	.039*	40.02	A
400 (tee)	64.16	.0576	40.02	C
15 (sweepolet)	63.42*	.144*	40.02	C
425 (tapered transition joint)	46.49	.0069	40.02	A
150 (sweepolet)	63.42*	.144*	40.02	C

NOTES:

A. Terminal End Break
B. Breaks determined by “Minimum Break Location” Criteria
C. Breaks determined by Stress Requirement
D. See Figure 3.6-14 for Node Locations

* Envelope Value Represents Maximum Values at Similar Components and/or Node Locations in Both Loops.

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
MAIN STEAM LINE 'A'
FIGURE 3.6-1A

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
MAIN STEAM LINE 'B' FIGURE 3.6-1B

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
MAIN STEAM LINE 'C'
FIGURE 3.6-1C

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
MAIN STEAM LINE 'D' FIGURE 3.6-1D

Security-Related Information
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SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
FEEDWATER SYSTEM FIGURE 3.6-2

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
HPCI STEAM SUPPLY
FIGURE 3.6-3

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
RCIC STEAM SUPPLY
FIGURE 3.6-4

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CORE SPRAY
FIGURE 3.6-5

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
RHR SUPPLY FIGURE 3.6-6

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
RHR RETURN LOOP 'A'
FIGURE 3.6-7

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

RHR RETURN LOOP 'B'

FIGURE 3.6-8

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
REACTOR WATER CLEANUP
FIGURE 3.6-8A.1

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
UNIT 1 REACTOR WATER CLEANUP FIGURE 3.6-8A.2

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
UNIT 2 REACTOR WATER CLEANUP FIGURE 3.6-8A.3

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
UNIT 1 REACTOR WATER CLEANUP FIGURE 3.6-8A.4

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
UNIT 1 REACTOR WATER CLEANUP FIGURE 3.6-8A.5

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
REACTOR VESSEL HEAD VENT
FIGURE 3.6-8B

Security-Related Information
Figure Withheld Under 10 CFR 2.390

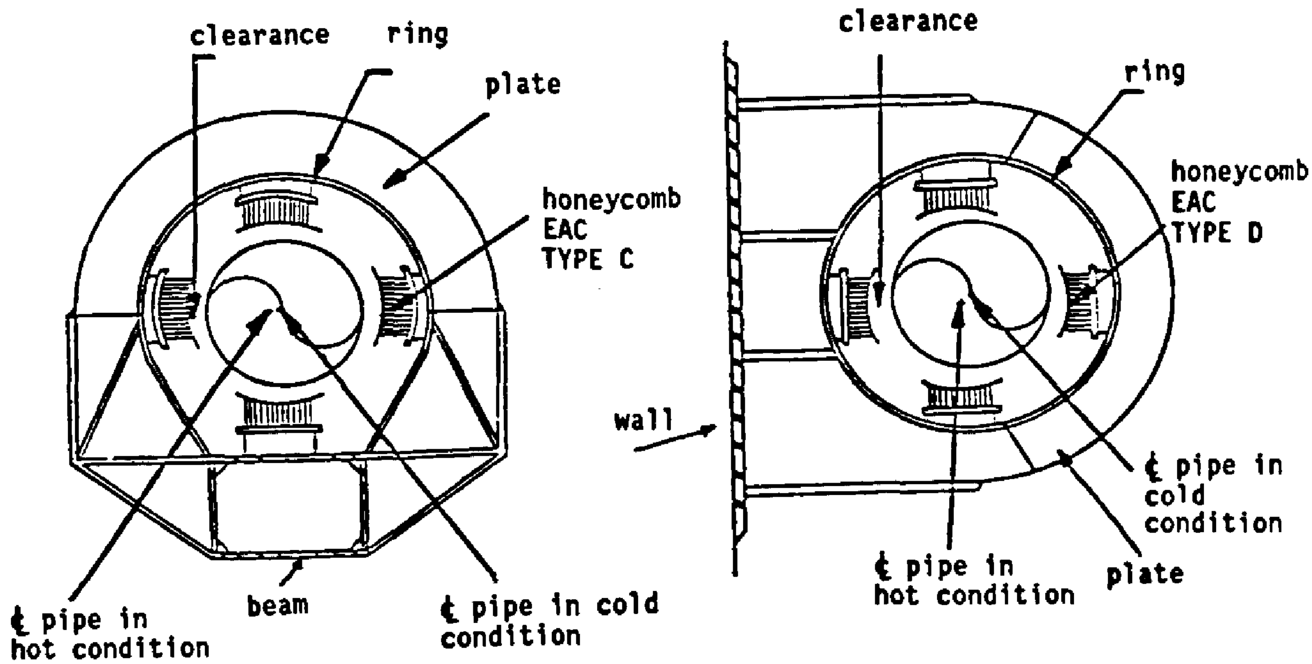
SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
HEAD SPRAY
FIGURE 3.6-8C

Security-Related Information
Figure Withheld Under 10 CFR 2.390

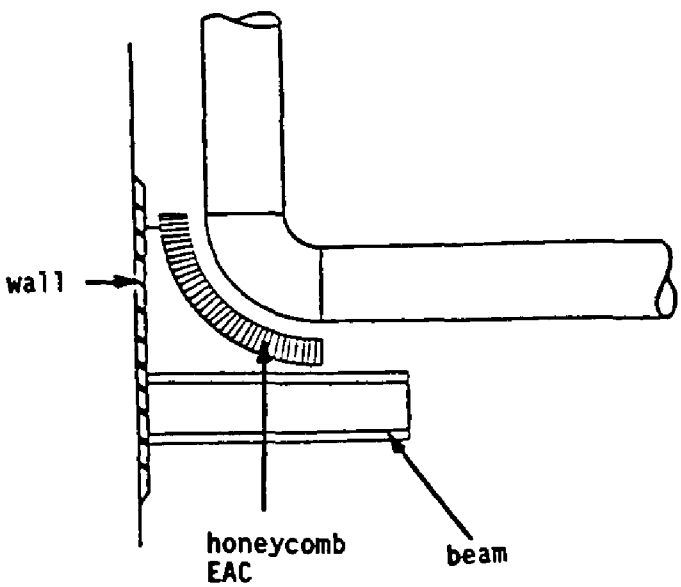
SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
STANDBY LIQUID CONTROL
FIGURE 3.6-8D

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
MSIV DRAINS
FIGURE 3.6-8E



a) Pipe whip restraints with honeycomb (EAC) and clearance all around the pipe



b) Bumpers

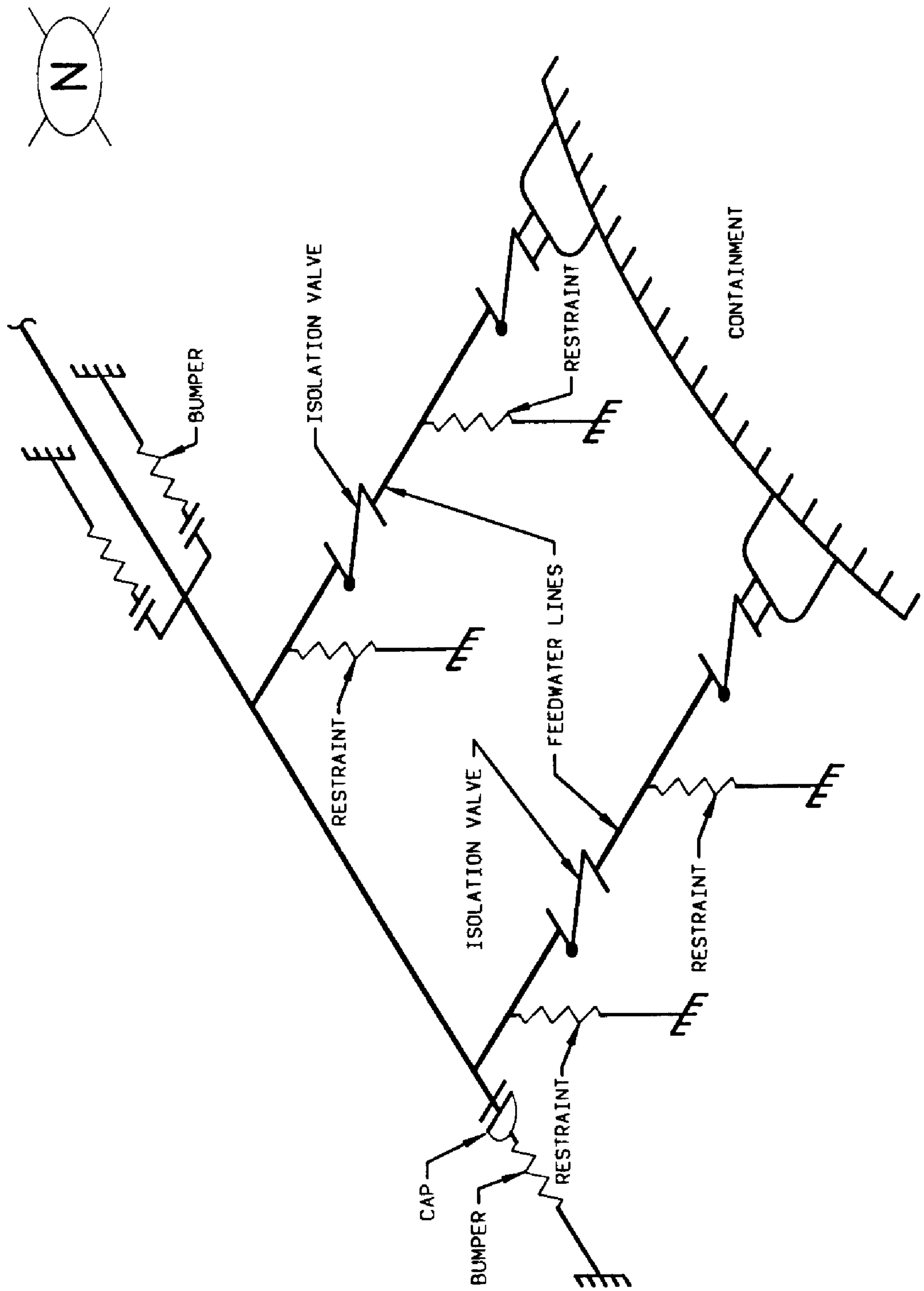
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

TYPICAL PIPE
WHIP RESTRAINTS

FIGURE 3.6-10, Rev. 47

Auto-Cad Figure Fsar 3_6_10.dwg



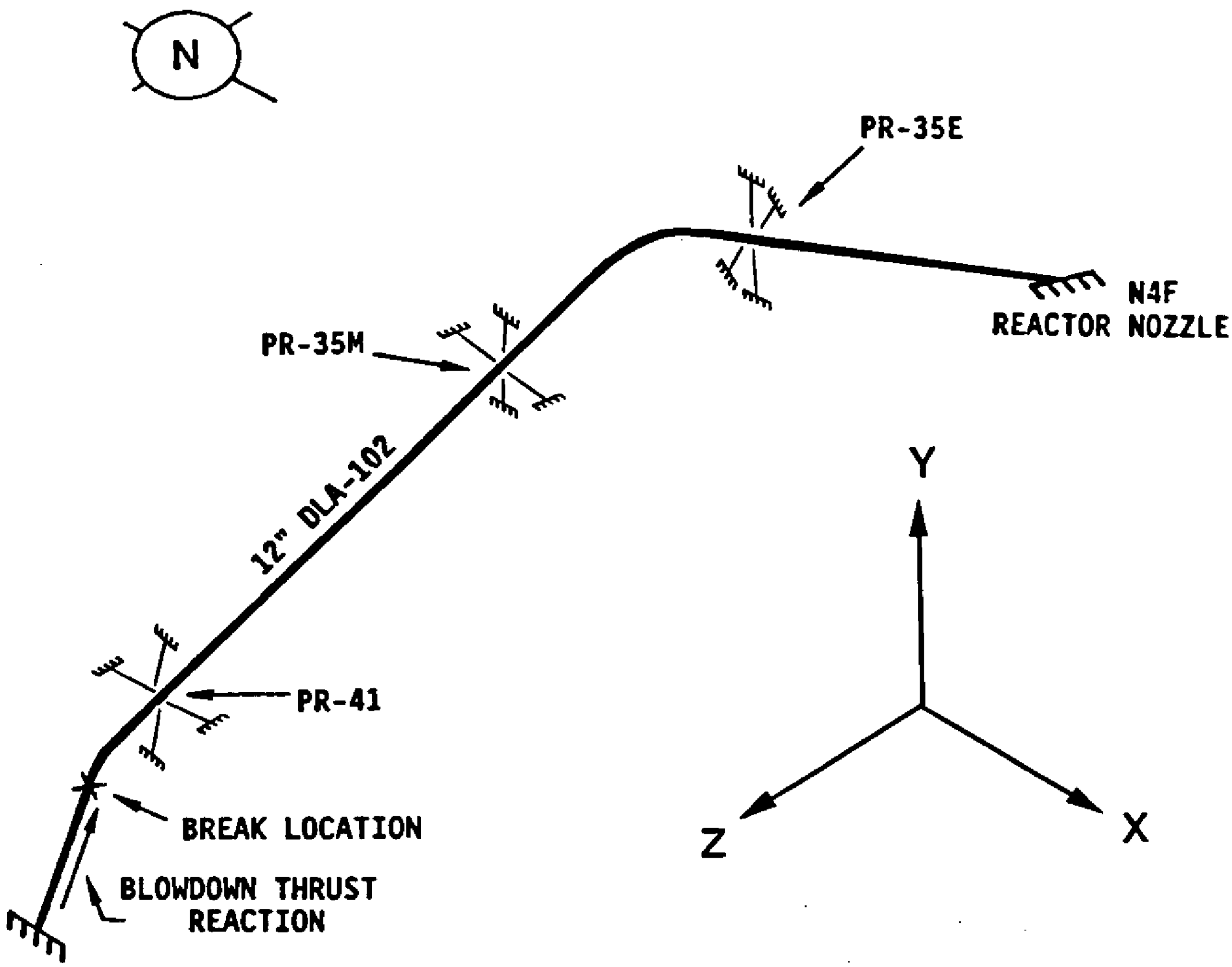
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

PIPE WHIP RESTRAINT
ARRANGEMENT TO PROTECT
FEEDWATER OUTSIDE
CONTAINMENT ISOLATION VALVES

FIGURE 3.6-11, Rev. 47

Auto-Cad Figure Fsar 3_6_11.dwg



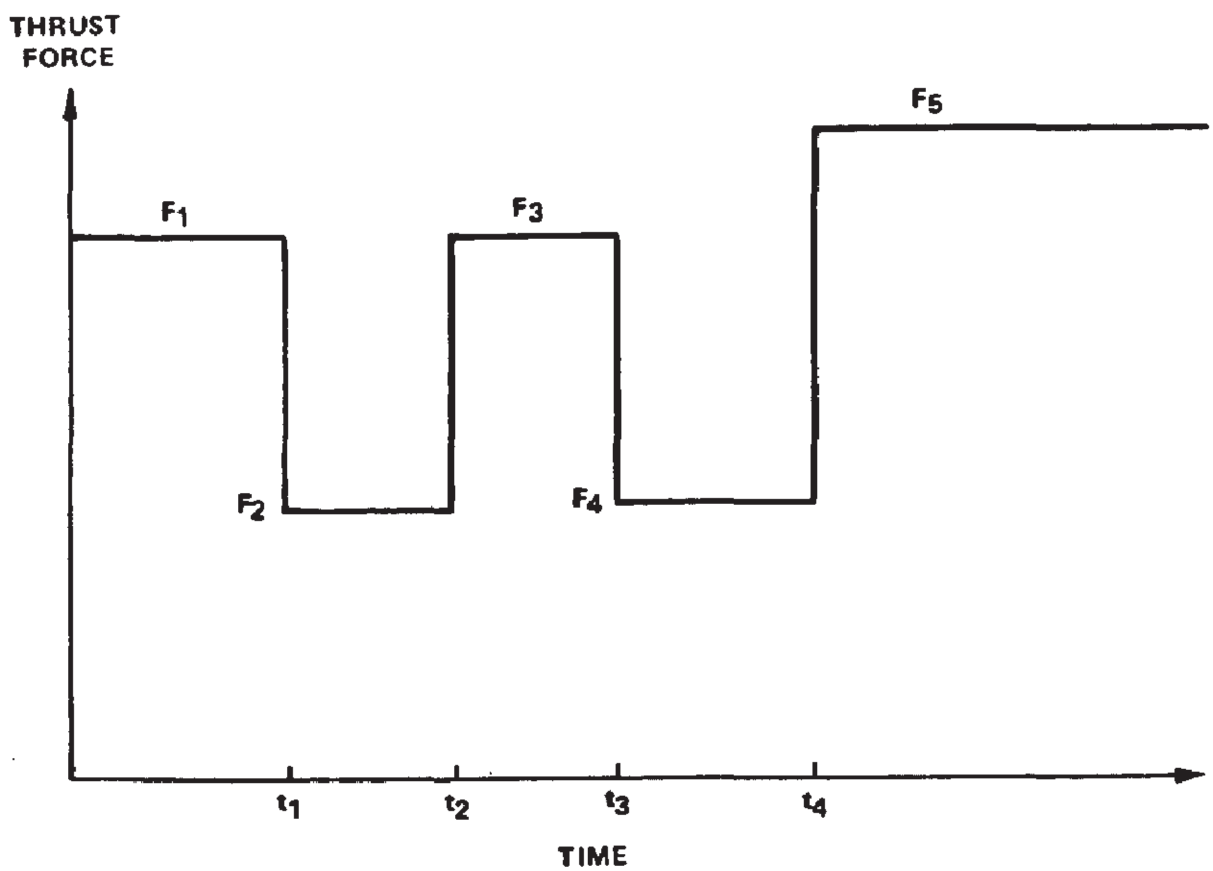
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

MAIN FEEDWATER LINE
PIPERUP MATHEMATICAL MODEL

FIGURE 3.6-11A, Rev. 47

Auto-Cad Figure Fsar 3_6_11A.dwg



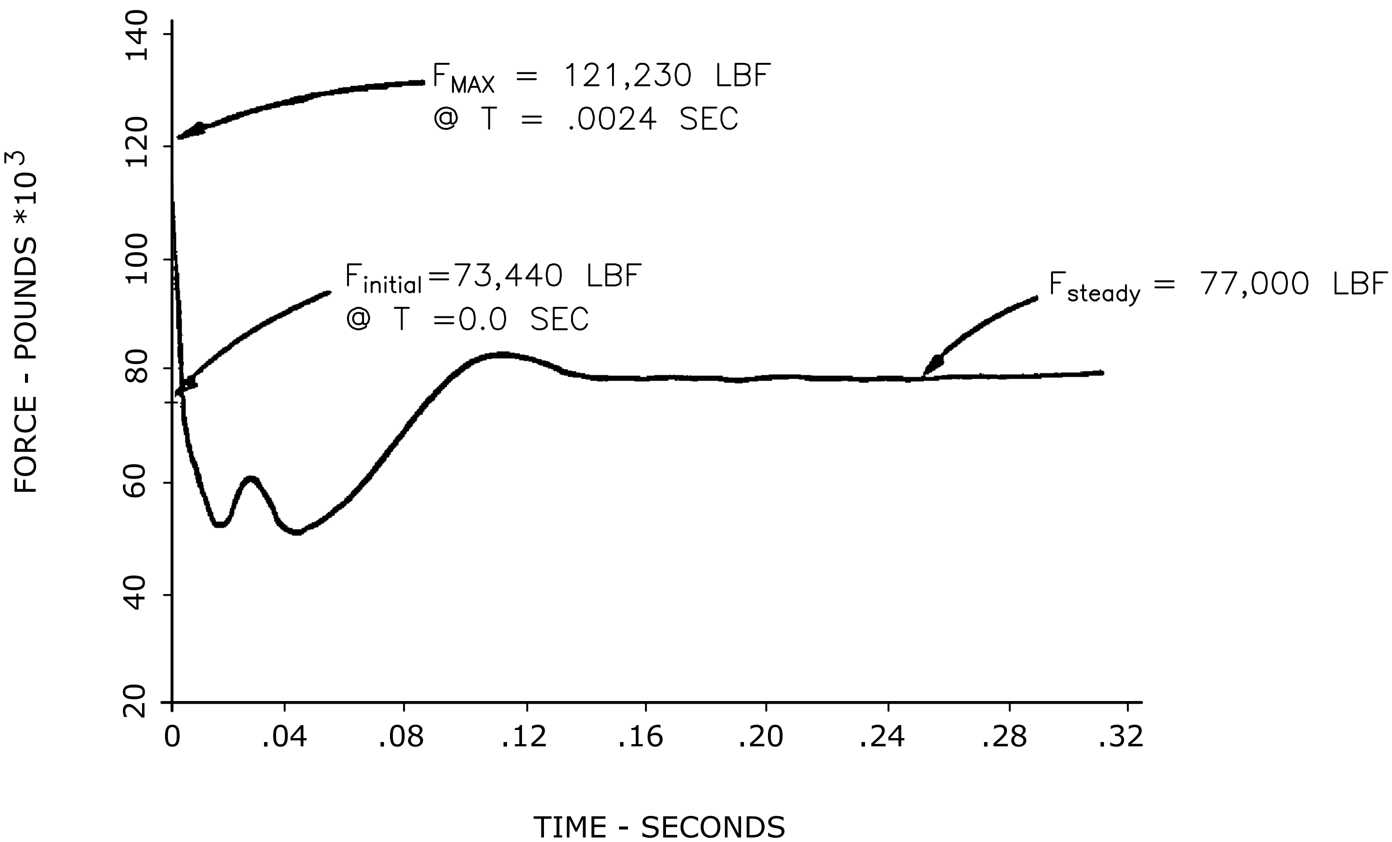
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

FORCING FUNCTIONS MODEL
ASSOCIATED WITH PIPE WHIP
DYNAMIC ANALYSIS

FIGURE 3.6-12, Rev. 47

Auto-Cad Figure Fsar 3_6_12.dwg

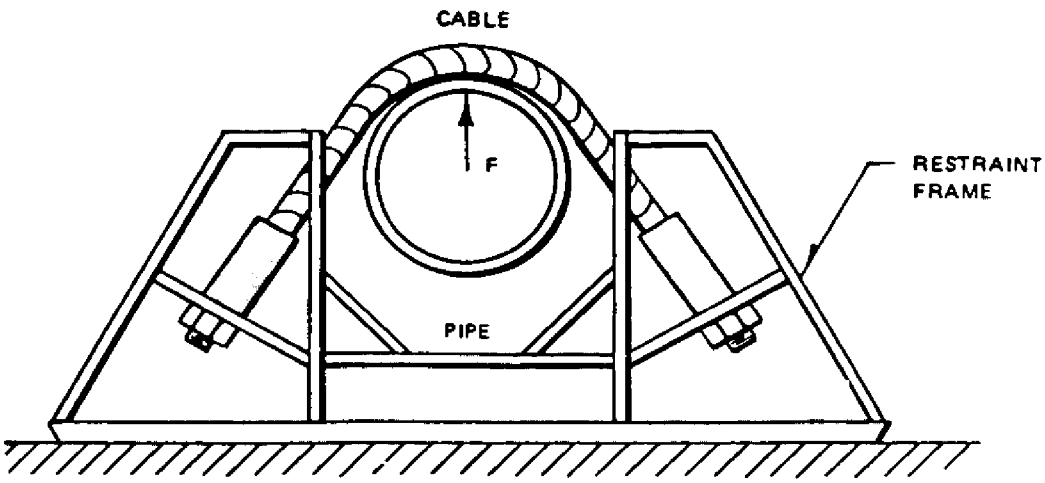


HPCI INSIDE CONTATINMENT PIPE BREAK FORCING FUNCITON REACTOR SIDE

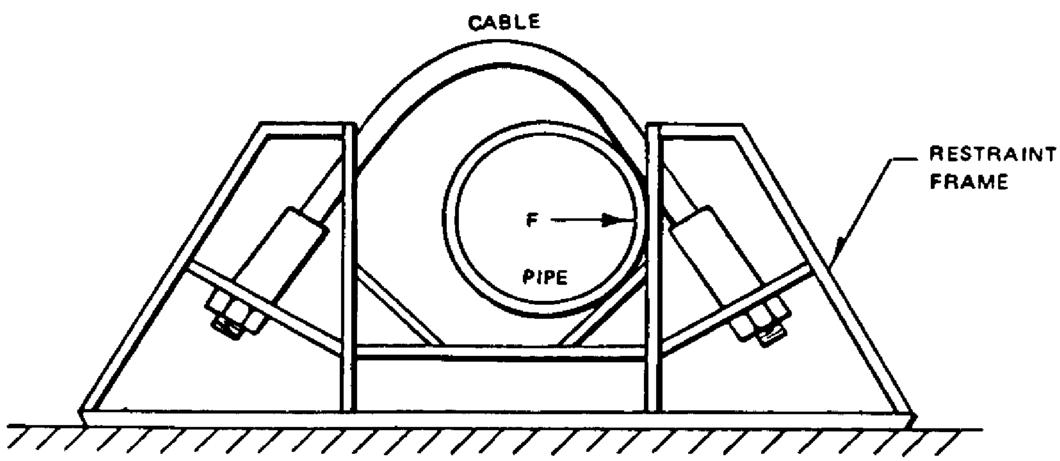
FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
FORCING FUNCTIONS MODEL ASSOCIATED WITH PIPE WHIP DYNAMIC ANALYSIS FIGURE 3.6-12A, Rev. 47

Auto-Cad Figure Fsar 3_6_12A.dwg



(a) LOAD APPLIED PERPENDICULAR TO RESTRAINT BASE AGAINST CABLES



(b) LOAD APPLIED PARALLEL TO FRAME BASE AGAINST ONE SIDE OF RESTRAINT FRAME

FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

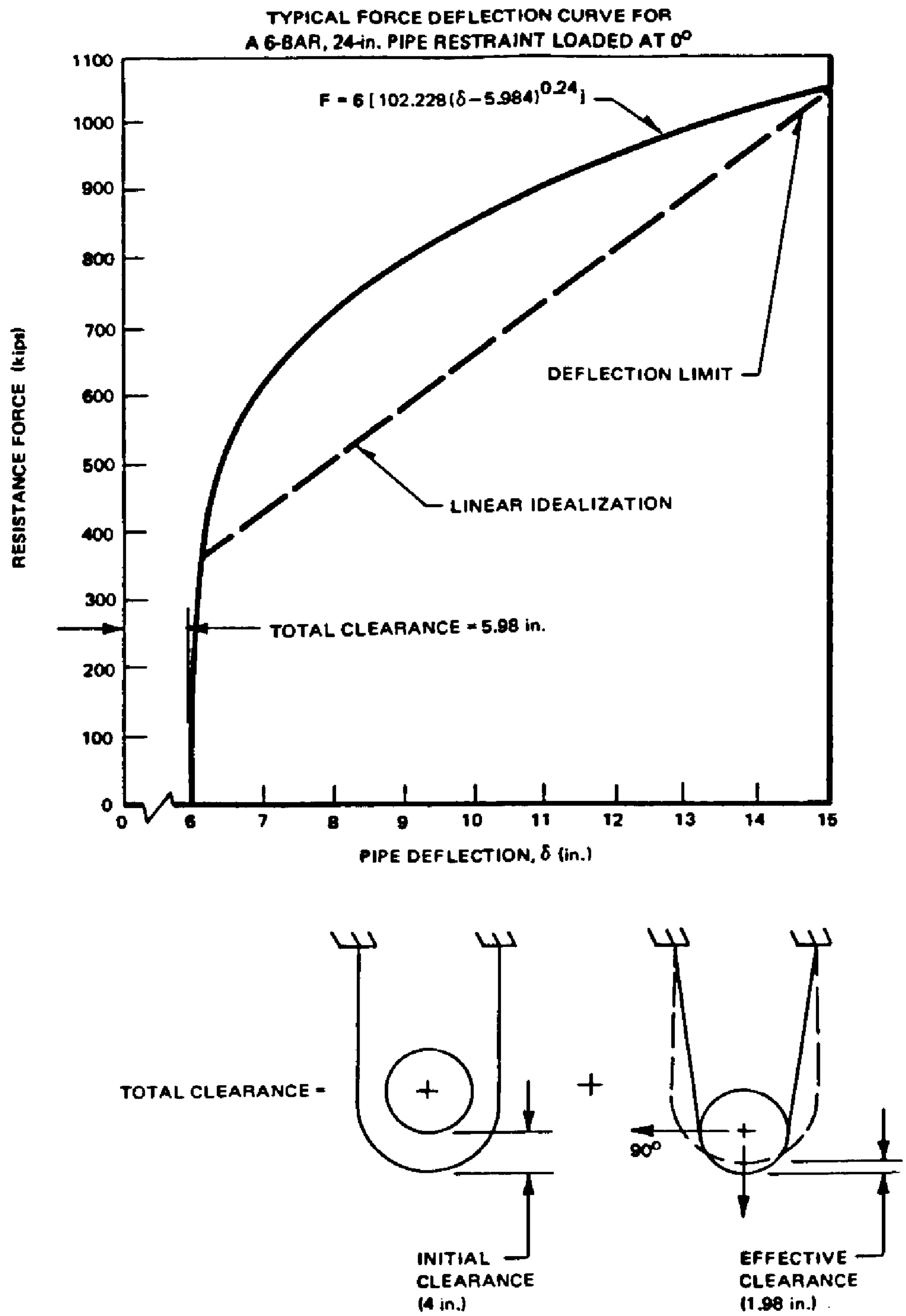
TYPICAL PIPE WHIP
RESTRAINT CONFIGURATION

FIGURE 3.6-13, Rev. 47

Auto-Cad Figure Fsar 3_6_13.dwg

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
RECIRCULATION SYSTEM POSTULATED BREAK LOCATIONS AND RESTRAINT LOCATIONS (LOOP A AND B SAME, UNLESS OTHERWISE SPECIFIED) FIGURE 3.6-14



FSAR REV.65

SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

TYPICAL RESTRAINT FORCE
DEFLECTION CURVE

FIGURE 3.6-15, Rev. 47

Auto-Cad Figure Fsar 3_6_15.dwg

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
BREAK LOCATIONS AND RESTRAINTS ANALYZED PDA VERIFICATION PROGRAM FIGURE 3.6-16

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
PIPE BREAK PROTECTION FOR HIGH ENERGY PIPING IN THE REACTOR BUILDING FIGURE 3.6-17-1

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
PIPE BREAK PROTECTION FOR HIGH ENERGY PIPING IN THE REACTOR BUILDING FIGURE 3.6-17-2

Security-Related Information
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
PIPE BREAK PROTECTION FOR HIGH ENERGY PIPING IN THE REACTOR BUILDING FIGURE 3.6-17-3

APPENDIX 3.6A

PIPE BREAK OUTSIDE CONTAINMENT SUMMARY OF ANALYSIS AND RESULTS

PART I - ANALYSIS FOR SPACES OTHER THAN MAIN STEAM TUNNEL

In addition to the analysis provided in Table 3.6-3, compartments containing high energy lines were analyzed to determine the peak pressures and temperatures that might result from breaks in these lines. For the HPCI, RCIC and RWCU pipe breaks outside primary containment, a concurrent LOOP and single failure is assumed to occur, which is consistent with the response time testing (ATT) assumption. The analysis was done, in part, to verify structural integrity. Duration of the blowdown was not a factor in the pressure transient since adequate vent area was provided, and pressure peaked quickly then declined to a lower steady state value. The blowout panels are designed to release at design pressure of approximately 0.5 psig. The structures and safe shutdown equipment are adequate to withstand the peak pressures and temperatures indicated by the analysis.

The valves which would be used to terminate the blowdown are indicated. In general, however, it is unnecessary to qualify equipment for the pipe break environment because the safeguards systems are separated into compartments which are vented directly to the atmosphere and high energy breaks affect only a single space. The plant can be safely shutdown using equipment not affected by the high energy line break.

The following information for each compartment was utilized with the analytical techniques described in Reference 3.6-10 of the FSAR to determine the pressures and temperatures resulting from high energy line breaks outside containment.

ANALYSIS FOR HPCI PENETRATION ROOM (UNIT 1)

Pipe Break Data

Location:	HPCI Penetration Room (I-202, I-204, I-205)
Line Identification/Size:	DBB-114/10"

Isolation Valve Designation and Location: HV-E41-1F003 located in the HPCI Penetration Room

Blowdown Data:

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.0	2074.	1190.2
0.1	2074.	1190.2
0.1	1501.	1190.2
0.18	1501.	1190.2
0.18	464.	1190.2
13.0	464.	1190.2
63.0	0	1190.2

Compartment Volume: 87,680. ft^3

Vent Area: 69.6 ft^2 (3 circular panels, each with a flow area of 23.2 ft^2)
Vent Loss Coefficient: 1.95
L/A: 0.97 ft^{-1}

Results (BDIDs Closed):

Peak Pressure:	1.95 psig
Peak Temperature:	295.6°F

Results (BDIDs Open, HPCI Steam Supply Break):

Peak HPCI Penetration Room Pressure:	1.84 psig
Peak HPCI Penetration Room Temperature:	294.4ºF
Peak RBCCW Heat Exchanger Area (I-203) Pressure:	0.38 psig
Peak RBCCW Heat Exchanger Area (I-203) Temperature:	105.0ºF
Peak 683' Equipment Area (I-200) Pressure:	0.50 psig
Peak 683' Equipment Area (I-200) Temperature:	106.6ºF

Results (BDIDs Open, RCIC Steam Supply Break, 4"-DBB-109):

Note: Break is isolated by isolation valve HV-E51-1F008

Peak HPCI Penetration Room Pressure:	1.26 psig
Peak HPCI Penetration Room Temperature:	151.0ºF
Peak RBCCW Heat Exchanger Area (I-203) Pressure:	1.09 psig
Peak RBCCW Heat Exchanger Area (I-203) Temperature:	112.4ºF
Peak 683' Equipment Area (I-200) Pressure:	1.25 psig
Peak 683' Equipment Area (I-200) Temperature:	114.0ºF

ANALYSIS FOR HPCI PUMP ROOM (UNIT 1)

Pipe Break Data

Location:	HPCI Pump Room (I-11)
Line Identification/Size:	DBB-114/10"

Isolation Valve Designation and Location: HV-E41-1F003 located in the HPCI Penetration Room

Blowdown Data:

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.0	2074.	1190.2
0.076	2074.	1190.2
0.076	1037.	1190.2
.218	1037.	1190.2
.218	314.	1190.2
13.0	314.	1190.2
63.0	0	1190.2

Compartment Volume: 27,883 ft^3

Vent Area: 60 sq ft
Vent Loss Coefficient: 2.63
L/A: 0.39 ft^{-1}

Results (Duct Closed):

Peak Pressure: 3.55 psig
Peak Temperature: 303.3°F

Results (Duct Open):

Peak HPCI Pump Room Pressure: 3.30 psig
Peak HPCI Pump Room Temperature: 303.1ºF
Peak 670' General Access Area (I-102) Pressure: 0.67 psig
Peak 670' General Access Area (I-102) Temperature: 108.4ºF
Peak "B" Core Spray Room (I-10) Pressure: 0.40 psig
Peak "B" Core Spray Room (I-10) Temperature: 109.0ºF

ANALYSIS FOR RCIC PUMP ROOM (UNIT 1)

Pipe Break Data

Location: RCIC Pump Room (I-12)
Line Identification/Size: DBB-109/4"

Isolation Valve Designation and Location: HV-E51-1F008 located in the HPCI Penetration Room

Blowdown Data:

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.0	314.0	1190.2
0.021	314.0	1190.2
0.021	157.0	1190.2
0.278	157.0	1190.2
0.278	30.1	1190.2
13.0	30.1	1190.2
33.0	0	1190.2

Compartment Volume: 18,129 ft^3

Vent Area: 46.0 sq ft
Vent Loss Coefficient: 2.67
L/A: 0.43 ft^{-1}

Results (BDIDS Closed):

Peak Pressure: 1.17psig
Peak Temperature: 220.0°F

Results (BDIDs Open):

Peak RCIC Pump Room Pressure: 0.99 psig
Peak RCIC Pump Room Temperature: 219.8ºF
Peak 670' General Access Area (I-102) Pressure: 0.09 psig
Peak 670' General Access Area (I-102) Temperature: 101.1ºF

ANALYSIS FOR RHR ROOM A (UNIT 1)

Pipe Break Data

Location: RHR Room A (I-14)
Line Identification/Size: HBB-110/24"

Isolation Valve Designation and Location: HV-E11-1F008 located in the HPCI Penetration Room

Compartment Volume: 48,554 cu ft

Vent Area: 85 sq ft

Results: Peak Pressure: 0.93 psig
Peak Temperature: 215.12°F

ANALYSIS FOR RHR ROOM B (UNIT 1)

Pipe Break Data

Location: RHR Room B (I-13)
Line Identification/Size: HBB-110/24"

Isolation Valve Designation and Location: HV-E11-1F008 located in the HPCI Penetration Room

Compartment Volume: 60,000 cu ft

Vent Area: 85 sq ft

Results: Peak Pressure: 0.93 psig
Peak Temperature: 215.12°F

Due to the removal of the steam condensing mode of RHR, the only high energy piping which would cause room pressurization during normal plant operation in both RHR Pump Rooms is during the initial stages of the shutdown cooling mode of RHR. Per BTP MEB 3-1, when RHR is placed in shutdown cooling, the piping is classified as a moderate-energy fluid system and only a pipe crack (not break) is postulated.

ANALYSIS FOR REACTOR WATER CLEANUP SYSTEM (RWCS) PENETRATION ROOM, PUMP ROOMS, AND HEAT EXCHANGER ROOMS (UNIT 1)

Pipe Break Data

Various break locations were analyzed to determine the maximum pressure and temperature which develop in each room.

Isolation Valve Designation and Location: HV-G33-F004 in RWCS Penetration Room

Blowdown Data:

Penetration Room (I-501)

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.00	4570.0	518.5
0.07	4570.0	518.5
0.07	3030.0	518.5
0.14	3030.0	518.5
0.14	1155.0	518.5
0.84	1155.0	518.5
0.84	410.0	518.5
20.00	410.0	518.5
50.00	0.0	518.5

Pump Rooms (I-502,503)

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.00	1990.0	518.5
0.10	1990.0	518.5
0.10	1640.0	518.5
0.21	1640.0	518.5
0.21	1055.0	518.5
1.10	1055.0	518.5
1.10	410.0	518.5
20.00	410.0	518.5
50.00	0.0	518.5

Heat Exchanger Rooms (I-504,505)

t (sec)	m (lbm/sec)	h (BTU/lbm)
0.00	2420.0	518.5
0.08	2420.0	518.5
0.08	1855.0	518.5
0.30	1855.0	518.5
0.30	1055.0	518.5
0.50	1055.0	518.5
0.50	410.0	518.5
20.00	410.0	518.5
50.00	0.0	518.5

Compartment Volumes:

Arch. Room No.	Volume (Cu. Ft.)
I-501	6940
I-502 & 503	6350
I-504 & 505	12229

Intercompartment Flow Path Data:

Flow Path	Area (Ft²)	Loss Coefficient	L/A (ft^{-1})
I-501 to ATM	46.4 (2 circular panels, each with a flow area of 23.2 ft^{-2})	1.81	1.25
I-501 to I-503	60.0	1.00	0.1181
I-503 to I-504	60.0	1.00	0.0749

Results

Architectural Room Number	Peak Pressure (psig)	Peak Temperature (ºF)
I-500	0.21	102.7
I-501	3.76	215.1
I-502	2.73	213.1
I-503	2.73	213.1
I-504	3.18	213.0
I-505	3.18	213.0

Note: To provide a bounding case, a larger enthalpy condition was coupled with a larger mass flow rate. A break in the RWCU Heat Exchanger Room with the BDIDs open results in the most severe environment in the 749' general access area (I-500); therefore, the results for this area are presented. All other values are the result of breaks with the BDIDs in the closed position.

Analysis for Compartment Pressurization in Unit 2 is identical to Unit 1, with the exception of breaks in the HPCI and RCIC Rooms. These analyses are presented below.

ANALYSIS FOR RCIC PUMP ROOM (UNIT 2)

Pipe Break Data

Location: RCIC Pump Room (II-12)
Line Identification/Size: DBB-209/4"

Isolation Valve Designation and Location: HV-E51-2F008 located in HCPI Penetration Room

Blowdown Data:

t (sec)	m (lbm/sec)	h (BTU/lbm)
0	314.0	1190.2
0.021	314.0	1190.2
0.021	157.0	1190.2
0.278	157.0	1190.2
0.278	30.1	1190.2
13.0	30.1	1190.2
33.0	0.0	1190.2

Compartment Volumes:

RCIC 18,129 ft^3
HPCI 27.883 ft^3
Tunnel 3,312 cu ft

Flow Path	Area (Ft^2)	Loss Coefficient	L/A (ft^{-1})
RCIC to Tunnel	25	0.88	0.341
Tunnel to HPCI	72	0.50	0.3551
Tunnel to ATM	45	5.33	0.3914

Results (BDIDs Closed):

Room	Peak Pressure (PSIG)	Peak Temperature. (°F)
RCIC	1.56	218.3
HPCI	1.50	112.8
Tunnel	1.63	195.5

Results (BDIDs Open):

Room	Peak Pressure (psig)	Peak Temperature (ºF)
RCIC	1.27	215.7
HPCI	1.27	113.3
Connecting Tunnel	1.40	185.2
670' General Access Area (II-102)	1.26	117.0

Note: A break in the RCIC pump room results in a change in environment to the HPCI pump room via connection of the tunnel to both rooms. Therefore, peak pressures are shown for all three compartments.

ANALYSIS FOR HPCI PUMP ROOM (UNIT 2)

Pipe Break Data

Location: HPCI Pump Room (II-11)
Line Identification/Size: DBB-214/10"

Isolation Valve Designation and Location: HV-E41-2F003 located in the HPCI Penetration Room

Blowdown Data:

t (sec)	m (lbm/sec)	h (BTU/lbm)
0	2074.	1190.2
0.06	2074.	1190.2
0.06	1037.	1190.2
0.223	1037.	1190.2
0.223	308.	1190.2
13.0	308.	1190.2
63.0	0	1190.2

Compartment Volumes:

HPCI	27.883 ft^3
RCIC	18,129 ft^3
Tunnel	3,312 cu ft

Flow Path	Area (Ft^2)	Loss Coefficient	L/A (ft^{-1})
HPCI to Tunnel	72	0.50	0.3551
Tunnel to RCIC	25	0.88	0.341
Tunnel to ATM	45	5.33	0.3914

Results (BDIDs Closed):

Room	**Peak Pressure (psig)**	**Peak Temperature (°F)**
HPCI	3.71	304.2
RCIC	3.29	133.3
Tunnel	3.50	304.7

Results (BDIDs Open):

Room	Peak Pressure (psig)	Peak Temperature (ºF)
RCIC	2.59	128.5
HPCI	3.16	303.6
Connecting Tunnel	2.97	303.6
670' General Access Area (II-102)	1.39	120.3

Note: A break in the HPCI pump room results in a change in environment to the RCIC pump room via connection of the tunnel to both rooms. Therefore, peak pressures are shown for all three compartments.

PART II - ANALYSIS OF MAIN STEAM LINE BREAKS IN THE MAIN STEAM LINE TUNNEL

Subcompartment differential pressure analysis was performed for the Reactor and Turbine Building main steamline tunnel. The blowout panels in the reactor building steam tunnel are designed to release at design pressure of approximately 0.5 psig. Two break locations were chosen to render the design of each portion of the tunnel (viz. - Reactor and Turbine Building sides) conservative. They are:

Case A. MSLB in the Reactor Building.
(24" DBB-103 at the elbow on El. 719'-8")

Case B. MSLB in the Turbine Building.
(24" DBB-103 at El. 719'-6", 1st elbow in the Turbine Building)

The pressure and temperature response of these areas to the postulated pipe breaks are predicted using COTTAP 4 for the Reactor Building Main Steam Tunnel and the analytical model described in Appendix 6B with the changes described below for the Turbine Building Main Steam Tunnel. COTTAP 4 uses a similar analytical model as the model discussed in this section and Appendix 6B. Any differences between COTTAP 4 and the models presented in this section and Appendix 6B were reviewed and determined to have an insignificant or conservative effect on the peak pressures and peak temperatures. The Appendix 6B model ignores "momentum effects" within a subcompartment. For most cases considered, this is justified as the momentum effects are insignificant relative to the absolute pressure peaks. However, momentum effects are important to conservatively predicting pressures resulting from the main steam tunnel case. Therefore, for this study, the momentum equation

$$\frac{\partial}{\partial t}(\rho\vec{u}) + \vec{\nabla}(\rho\vec{u}\vec{u}) = -\vec{\nabla}p + \vec{\nabla}\,\vec{\vec{\tau}} + \rho\vec{g}$$

is "one-dimensionalized" and solved in the following manner:

$$\left(\frac{1}{g_c\,A(x)}\right)\frac{\partial}{\partial t}\left[A(x)\ G(x,t)\right] = -\left(\frac{1}{g_c\,A(x)}\right)\frac{\partial}{\partial x}\left[\frac{A(x)\,G^2(x,t)}{\rho(x,t)}\right] - \frac{\partial \mathrm{p(x,t)}}{\partial \mathrm{x}} - \frac{1}{A(x)}\frac{\partial F(x,t)}{\partial x} \qquad (1)$$

Where G = Δv

Where the F(x,t) term includes shear forces and non-one-dimensional momentum change effects. Its integral over a flow path is evaluated by means of empirically determined flow coefficients (see Appendix 6B).

Equation (1) is now integrated from midpoint to midpoint of two adjoining compartments assuming uncompressible flow, but with a uniquely determined fluid density. The density of the flow mixture is evaluated in a way which assures that, as flow approaches steady state conditions, the density and the computed mass flux approach the values obtained from the compressible steady state equations in Appendix 6B.

Using this assumption and integrating term by term, we obtain:

First term:

$$\frac{1}{g_c}\int_{x_1}^{x_2}\frac{1}{\mathrm{A(x)}}\frac{\partial}{\partial t}\left[A(x)\,G(x,t)\right]dx = \frac{1}{\mathrm{g_c}}\frac{\partial}{\partial t}W(t)\int_{x_1}^{x_2}\frac{\mathrm{dx}}{\mathrm{A(x)}} = \frac{1}{\mathrm{g_c}}\frac{\mathrm{dW(t)}}{\mathrm{dt}}\sum_i\left(L_i/A_i\right) \qquad (1a)$$

Where the integral of (dx/A(x)) is evaluated sequentially for constant area segments between X_1 and X_2. Li thus represents the length of segment i.

Second term:

$$-\frac{1}{g_c}\int_{x_1}^{x_2}\frac{1}{\mathrm{A(x)}}\frac{\partial}{\partial x}\left[\frac{A(x)\,G^2(x,t)}{\rho(x,t)}\right]dx=-\frac{W^2(t)}{g_c\rho}\int_{x_1}^{x_2}\left(\frac{1}{A(x)}\right)\frac{\mathrm{d}}{\mathrm{dx}}\left(\frac{1}{\mathrm{A(x)}}\right)\mathrm{dx}=-\frac{W^2(t)}{2g_c\rho}\left[\frac{1}{A_2^2}-\frac{1}{A_1^2}\right] \quad (1b)$$

Where the Δ in the above expression remains to be defined.

Third term:

$$-\int_{x_1}^{x_2}\frac{\partial p(x,t)}{\partial x}dx=-\left[P_2-P_1\right] \quad (1c)$$

It should be noted that the above pressures are static values and to match the units of Equation (1) are, at this point, given in terms of 1b/ft^2.

Fourth term:

$$-\int_{x_1}^{x_2}\frac{1}{A(x)}\frac{\partial F(x,t)}{\partial x}\,dx=-Ki\,\frac{V_T^2}{2g_c}\rho \qquad (1d)$$

Where i = +1 if W ≥ 0 and i = -1 if W < 0.

The above equation is not really a proper integration, but just a replacement of this integral by the appropriate empirical correlation. The coefficient K is a properly summed coefficient for the flow path from x_1 to x_2 and can include friction terms. The velocity V^2_T depends on the empirical correlation used, but is usually taken as the "throat" velocity. This is assumed to be the case, then Equation (1d) becomes:

$$-\frac{KiV_T^2}{2g_c}\rho\left(\frac{\rho A_T^2}{\rho A_T^2}\right)=-Ki\,\frac{W^2(t)}{2g_c A_T^2\rho} \qquad (1e)$$

Where A^2_T is the junction flow area.

Before collecting all the integrated terms, it is preferable to convert the static pressures of Equation 1c into stagnation pressures.

$$P^*_{stat(i)}=P^*_{stag(i)}-\frac{\rho V(i)^2}{2g_c}=\mathrm{P}^*_{\mathrm{stag(i)}}-\frac{W^2(t)}{2g_c\rho A_i^2} \qquad (1f)$$

Summing the expressions obtained by Equations (1b) to (1e) and using (1f) we get:

$$\frac{1}{g_c}\frac{dW(t)}{dt}\sum_i\left(\frac{L_i}{A_i}\right)=\mathrm{P}_1^*-\mathrm{P}_2^*-\frac{\mathrm{KiW}^2(t)}{2g_c\rho A_T^2} \qquad (1g)$$

Where the starred pressures imply stagnation values.

Now the flow rate of the previous time step is used to evaluate a finite-difference approximation of the time derivative:

$$\frac{dW(t)}{dt}=\frac{W(t)-W(t-\Delta t)}{\Delta t} \qquad (2)$$

In a given time interval, W(t-Dt) is known, thus Equation (1g) is a quadratic in W(t). Writing it in the customary quadratic form we have:

$$\frac{Ki}{2\rho g_c A_T^2} W^2(t) + \frac{\sum_i \left(L_i \big/ A_i \right)}{g_c \Delta t} W(t) - \left\{ \frac{\sum_i \left(L_i \big/ A_i \right)}{g_c \Delta t} W(t - \Delta t) + \mathrm{P}_1^* - P_2^* \right\} = 0 \qquad (3)$$

and substituting the compressible flow equation for W. The resulting ratio is:

$$\frac{\rho}{\rho_2} = \left(\frac{k}{k-1} \right) \left[\frac{1}{1 - \frac{P_2}{P_1}} \right] \left[\left(\frac{P_2}{P_1} \right)^{1/k} - \left(\frac{P_2}{P_1} \right) \right] \qquad (4)$$

In the limit as $(P_2/P_1) \rightarrow 1$, Equation 4 approaches a value of one as required and the P_2/P_1 ratio stays below one for all other values of p_2/p_1 and for all positive k. Δ is thus smaller than the arithmetic mean of the densities and smaller than the downstream density itself. This assures a conservatively minimized flow rate for a given pressure gradient. This also holds true when the inertial effects (time dependent momentum equation) are included. Table 3.6A-1 shows representative mass flux values calculated by density Δ_2, and the proper compressible flow compatible density Δ is used. As seen for all cases, the use of r results in minimum and thus conservative flow rates.

The calculational sequence can now be summarized.

1. After compartment state functions have been obtained, a first estimate of W(t) is evaluated using the compressible flow equation.

2. The estimate of W(t) is used in Equation 3b to evaluate the fluid density.

3. Utilizing the flow rate from the previous time step and the calculated Δ, Equation (3) is solved to obtain W(t).

During each time step, the junction flow rate is chosen as the smaller of the flow rate resulting from the one-dimensional momentum equation or the flow rate resulting from the selected steady state compressible flow correlation. (Appendix 6B.)

Schematic drawings showing the nodalization of the steam tunnel for Case A and Case B are given in Figures 3.6A-1 and 3.6A-5, respectively. Blow out panel locations are shown in Figure 3.6A-2. Volumes, flow areas, flow coefficients, L/A's and blowdown rates for the models are presented in Tables 3.6A-2 through 3.6A-6. As indicated in Figure 3.6A-1, for Case A, the main steam tunnel is subdivided into a total of eighteen volumes to model the effect of obstructions such as pipe restraints and blow out panels. For Case B, in Figure 3.6A-5, a ten volume model is used since the one-way blowout panels completely block the flow path to reactor building side, leaving it unpressurized. The overall flow diagrams for both Cases A and B are presented in Figures 3.6A-3 and 3.6A-6.

The blowdown data for the postulated double end guillotine mainsteam line break is shown in Table 3.6A-4. This blowdown is done in a way similar to ANS 176 standard (draft, now known as ANSI/ANS 58.2-1980), as discussed below, but system friction is accounted for to reduce the calculated mass and energy releases to reasonable levels while maintaining a degree of conservatism. Other criteria are addressed as follows:

1. Full double-end break area Moody flow for steam blowdown immediately after pipe break.

2. Choking Moody flow occurs first at the break, then moves up to choke at flow restrictors.

3. Frictional loss of valves is not included.

4. Level swell (4% quality blowdown) occurs at 1 sec.

5. Steam isolation valves close in 5 seconds with a 0.6 second instrument and signal delay time. A linear ramp in flow area is used to model this closure.

The computational method of this double-end guillotine mainsteam line break is shown in Fig. 3.6A-8.

In Figure 3.6A-8, flow from the RPV to the break location is "forward flow," while the flow from the turbine to the break location is "reverse flow."

Let L_1 = The distance from flow restrictors to break location.

L_2 = The distance from reactor pressure vessel nozzle to the flow restrictors.

L_3 = The distance from flow restrictor to the turbine crosstie.

L_4 = The shortest distance from the MSL crosstie back to the break location.

(A) Calculation of mass and energy release rates from the forward direction.

let

A_p	=	The cross-sectional flow area of the break, ft^2.
A_v	=	The throat area of the flow restrictor, ft^2.
P_o	=	No-load system pressure, PSIA.
X	=	Steam quality.
h	=	Enthalpy of fluid, BTU/lbm.
N	=	Number of lines.
c	=	Sonic speed for steam.
f	=	Frictional factor.
D	=	Diameter of the pipe system.

1. At $O \le T \le L_1/C$ sec.

$$\dot{W}_{1F} = \left(G_{M1}A_p - \dot{W}_{2F}\right)\left(1 - T/\left(L_1/C\right)\right) + \dot{W}_{2F}$$

Where G_{M1} = Moody specific flowrate (lbm/sec*ft^2) based on P_0 = 1050 PSIA and h = 1190.0 BTU/lbm.

This ramp-down in flow rate simulates the increasing system resistance downstream of the decompression wave front.

2. $At = L_1 / C \le T \le \frac{2*(1.1*L_1)}{0.9*C}\text{sec}$ (Time for choking at flow restrictor)

$$\dot{W}_{2F} = G_{M2} * A_p$$

Where G_{M2} = Moody specific flow rate based on p = 1050 psia and h = 1190 BTU/lbm with $\frac{fl_1}{D}$.

3. $At\,\frac{2*(1.1*L_1)}{0.9*C} \le T \le 1.0\,\text{sec}$ (Time for level swell)

$W_{3f} = G_{M3} * A_v$

Where G_{M3} = Moody specific flow rate based on p = 1050 psia and h = 1190 BTU/lbm with $\frac{fl_1}{D}$.

(B) Calculation of mass and energy release rates from the reverse direction.

1. At $O \le T \le L_4/C$ sec.

$$W_{1R} = (G_{M1} * A_p - W_{2R})(1 - T/(L_4/C)) + W_{2R}$$

This ramp-down in flow rate simulates the increasing system resistance downstream of the decompression wave front.

2. $At\,L_4 / C \le T \le \frac{2*(L_3 + L_4)}{C}\text{sec}$ (Time for choking at the flow restrictors)

$$\dot{W}_{2R} = G_{M2R} * A_V * N$$

Where G_{M2R} = Moody specific flow rate based on h = 1190 BTU/lbm with $f\,\frac{(L_3 + L_4)}{D}$

3. $At\,\frac{2*(L_3 + L_4)}{C} \le T \le 1.00\,\text{sec}$ (Time for level swell)

$$\dot{W}_{3R} = \dot{W}_{3R}(\text{A LINE}) + \dot{W}_{3R}(\text{B LINE}) + \dot{W}_{3R}(\text{C LINE})$$
$$= \text{A}_\text{V}\left[G_{M3R}(A) + G_{M3R}(B) + G_{M3R}(C)\right]$$

Where G_{M3R} (A), G_{M3R} (B) and G_{M3R} (C) are the Moody specific flow rates for lines A, B, C based on P_o = 1050 PSIA and h = 1190 BTU/lbm with fL_2/D for each line.

(C) Calculation of mass and energy release rates from the swell phenomenon.

1. At 1.0 ≤ T ≤ 4.35 sec. (Time for choking at the valve)

$$\dot{W}_S = \dot{W}_S(A) + \dot{W}_S(B) + \dot{W}_S(C) + \dot{W}_S(D)$$
$$A_V\left[G_{MA}(A) + G_{MS}(B) + G_{MS}(C) + G_{MS}(D)\right]$$

Where G_{M2} (A), G_{M2} (B), G_{M2} (C), G_{M2} (D) are the Moody specific flow rates for lines A, B, C, D based on h =572 BTU/LBM (4% quality) and fL_2/D for each line.

2. At T = 5.6 sec. (Time for valve completely closed)

$$\dot{W}_3 = 0.0\,\text{lbm/sec}$$

(D) Calculation of the total mass and energy release rates.

The total flow rate is obtained by adding up the forward flow and reverse flow at each time sequence by superpositioning of the two curves (forward and reverse). Then after 1.0 second, the total flow rate will be just the flow rate calculated from swell on section (C).

The pressure transients of this analysis for Cases A (with BDIDs closed) and B are plotted in Figures 3.6A-4 and 3.6A-7. It can be seen that the maximum pressure for Case A in the Reactor Building is 23.1 PSIA and for Case B in the Turbine Building is 37.1 PSIA. The peak temperature for Case A is 303.0°F and for Case B is 325.0°F. For Case A in which the BDIDs are open, the peak pressure in the reactor building steam tunnel is 23.0 psia and the peak temperature is 303.0ºF. The open BDIDs will allow the transport of the reactor building main steam tunnel environment to the 719’ elevation general access area and the valve access area on elevation 749’. The peak pressure for the 719’ general access area is 15.0 psia and the peak temperature for this area is 104.5ºF, the peak pressure in the valve access area on elevation 749’ is 15.2 psia and the peak temperature is 111.7º.

The following essential equipment is located with the steam tunnels on Susquehanna SES:

Main Steam Isolation Valves (MSIV's) and Piping
Feedwater Check Valves and Piping
HPCI Piping
RCIC Piping
Leak Detection Instrumentation

Pipe breaks in the remaining portion of the main steam piping between the reactor building and the turbine building will not impact essential equipment since breaks in these areas are completely vented to the turbine building.

Waterflooding in either the turbine building or reactor building portion of the tunnel will drain to the turbine building without damage to the structure.

All of the terms in the coefficients of Equation 3 can be evaluated except for the as yet undefined fluid density, ρ. As stated in the assumptions, ρ will be evaluated in such a way that, under steady state conditions, Equation (3) and the compressible flow equations of Appendix 6B will yield identical results for W(t). Under steady state conditions W(t) = W(t-Δt) and Equation (3) reduces to:

$$\frac{K}{2g_c \rho A_T^2} W^2 - \Delta\rho^* = 0 \qquad (3a)$$

which yields

$$\rho = \frac{W^2 K}{2g_c A_T^2 \Delta\rho^*} \qquad (3b)$$

where the W^2 can be obtained from the steady state compressible flow equations in Appendix 6B.

Under steady state conditions, the above value of ρ which is used in the momentum equation has a straightforward definition -- it is the density which has to be used in the steady state incompressible flow equation in order to reproduce correct steady state compressible flow rates. To achieve this, the density includes an implied correction factor which compensates for the energy required in compressible flow to accelerate the expanding fluid. Because of this correction, ρ will, in fact, be smaller than the downstream density, ρ_2, calculated by the isentropic expansion relationship. This can be shown by dividing Equation (3b) by

$$\rho_2 = \rho_1 \left(\frac{P_2}{P_1} \right)^{1/k} \qquad (4)$$

TABLE 3.6A-1

COMPARISON OF FLOW RATES COMPUTED FROM THE TIME DEPENDENT MOMENTUM EQUATION

	$\frac{G_m(i-1)}{G_{comp}}$	$G_{mi}(\rho)$	$G_{mi}(\rho_{au})$	$G_{mi}(\rho_c)$	$\frac{G_{mi}(\rho_{au})}{G_{mi}(\rho)}$
k = 1.08	1.0 (Steady State)	43.44	44.69	44.69	1.029
	.5 (Flow Acceleration)	24.10	24.50	24.31	1.017
	1.2 (Flow Deceleration)	50.86	52.55	51.76	1.033
$\frac{P_2}{P_1}$ = .6					
k = .5	1.0	28.94	31.12	30.14	1.076
	.5	16.75	17.18	17.18	1.025
	1.2	33.55	36.44	35.13	1.086
k = 1.2	1.0	45.01	6.17	45.63	1.026
	.5	24.98	25.26	25.09	1.015
	1.2	52.73	54.29	53.56	1.030

ρ = Compressible flow mean density (Equation 4m)
ρ_1 = Upstream node density
ρ_2 = Downstream node density
ρ_{au} = $\rho_1 + \rho_2$

TABLE 3.6A-2

CASE A
STEAM TUNNEL COMPARTMENT VOLUMES

NODE	VOL (FT^3)	NODE	VOL (FT^3)
1	7326.7	10	1.0E15
2	1.0E15	11	10922.3
3	9911.9	12	27723.5
4	11148.8	13	5911.8
5	1.0E15	14	6803.9
6	900000.	15	2183.1
7	54000.	16	13994.1
8	54000.	17	1911.3
9	2.3E6	18	1932.6

TABLE 3.6A-3

STEAM TUNNEL FLOW AREAS, COEFFICIENTS AND L/A

PATH	AREA (FT^2)	LOSS COEFFICIENTS	L/A (FT^1)
1-3	614.7	0.13	.0151
1-11	125.0	0.60	.0480
3-4	612.7	0.25	.0146
4-12	459.0	0.27	.0717
6-7	390.0	2.19	.0415
6-8	390.0	2.19	.0398
7-9	980.0	2.19	.0623
8-9	980.0	2.19	.0722
9-10	6000.0	1.87	.0087
11-13	111.6	0.27	.3380
11-14	52.5	1.30	.0239
12-2	420.0	1.50	.0032
13-14	98.5	0.77	.0318
13-15	110.1	0.28	.1580
14-5	140.0	1.50	.0090
15-14	35.1	1.25	.0617
15-17	132.5	0.14	.0810
16-6	300.0	0.56	.0313
17-14	33.3	1.25	.0643
17-18	108.5	0.30	.0781
18-14	32.7	1.25	.0652
18-16	137.7	0.65	.0711

TABLE 3.6A-4

MASS FLOW RATES FOR CASE A

T (SEC)	M (lbm/SEC)	h (BTU/lbm)
0.000	10376.0	1190.0
0.051	7710.6	1190.0
0.125	4067.6	1190.0
0.131	3956.0	1190.0
0.590	3956.0	1190.0
0.590	4670.0	1190.0
1.000	4670.0	1190.0
1.000	16948.0	572.0
4.350	16948.0	572.0
4.500	14914.2	572.0
5.000	8135.0	572.0
5.600	0.0	572.0

MASS FLOW RATES FOR CASE B

T (SEC)	M (lbm/SEC)	h (BTU/lbm)
0.000	11852.0	1190.0
0.045	8681.5	1190.0
0.111	6907.6	1190.0
.0130	3499.0	1190.0
0.630	3499.0	1190.0
0.630	4142.0	1190.0
1.000	4142.0	1190.0
1.000	16948.0	572.0
4.350	16948.0	572.0
4.500	14340.6	572.0
5.000	7822.1	572.0
5.600	0.0	572.0

TABLE 3.6A-5

CASE B
STEAM TUNNEL COMPARTMENT VOLUMES

NODE	VOL (FT^3)	NODE	VOL (FT^3)
1	10922.3	6	900000.
2	5913.7	7	54000.
3	6227.0	8	54000.
4	13994.1	9	2.3E6
5	6803.9	10	1.7E9

TABLE 3.6A-6

STEAM TUNNEL FLOW AREAS, COEFFICIENTS AND L/A FOR CASE B

PATH	AREA (FT^2)	COEFFICIENTS	L/A (FT^{-1})
1-2	111.6	.89	.338
1-5	52.5	.66	.0239
2-3	110.1	.89	.236
2-5	98.5	.70	.0318
3-4	137.7	.78	.0711
3-5	101.1	.70	.0252
4-6	300.00	.80	.0313
5-10	210.0	.87	.009
6-7	390.0	.56	.0415
6-8	390.0	.56	.0398
7-9	980.0	.56	.0623
8-9	980.0	.56	.0722
9-10	6000.0	.59	.0087

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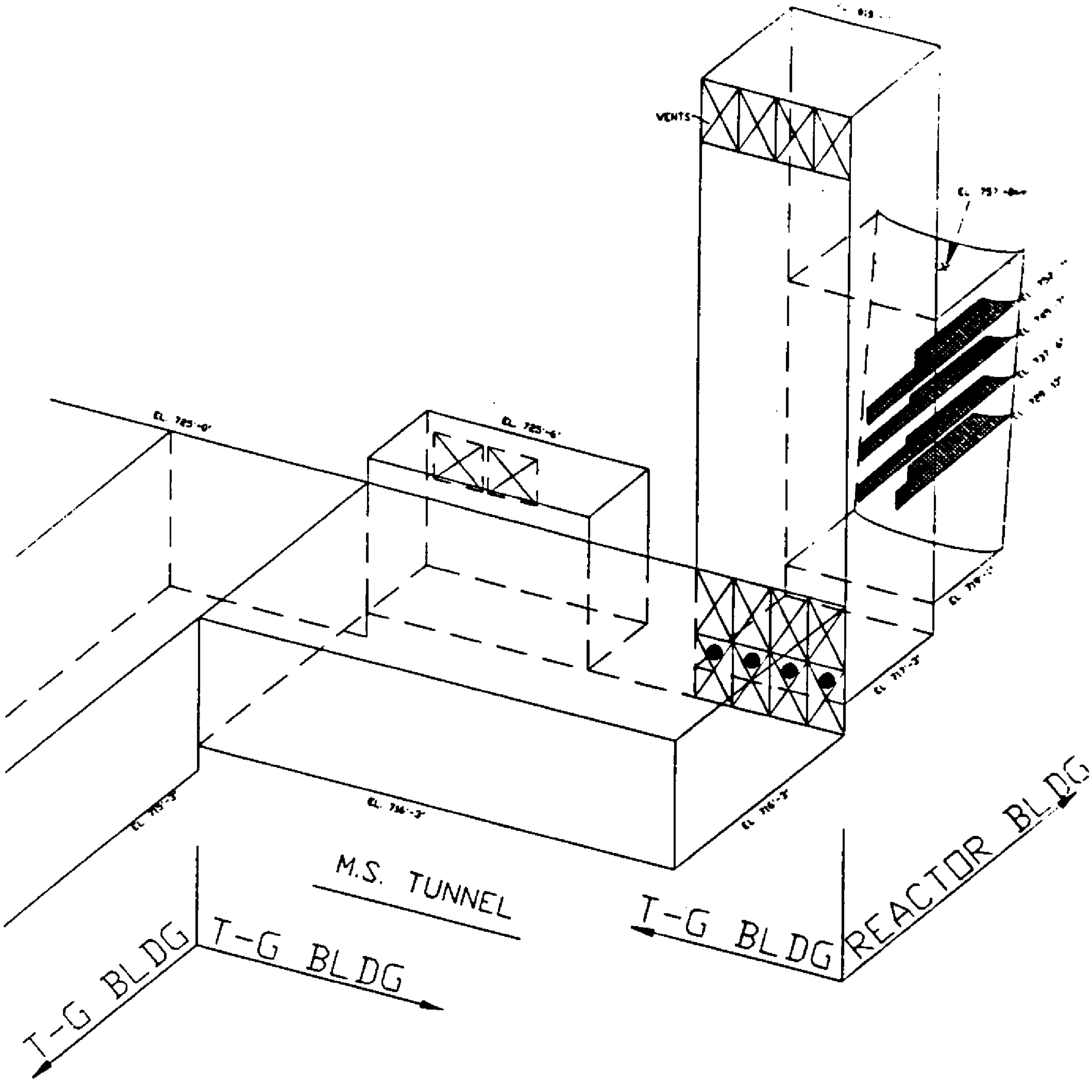
Figure Withheld Under 10 CFR 2.390

SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CASE A MSLB IN REACTOR BUILDING
FIGURE 3.6A-1



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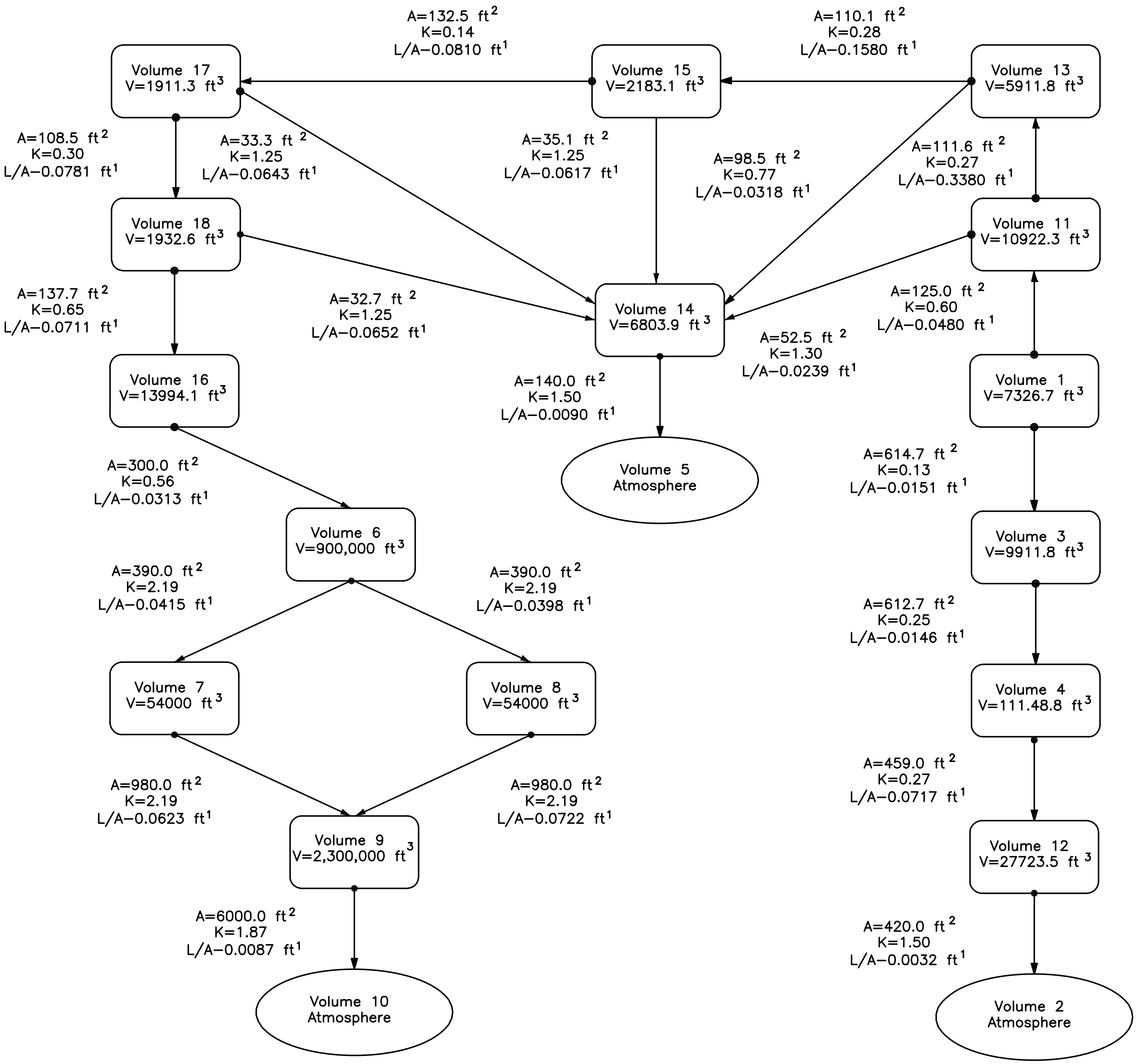
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

PANEL AND PLATFORM
LOCATIONS

FIGURE 3.6A-2, Rev. 47

Auto-Cad Figure Fsar 3_6A_2.dwg



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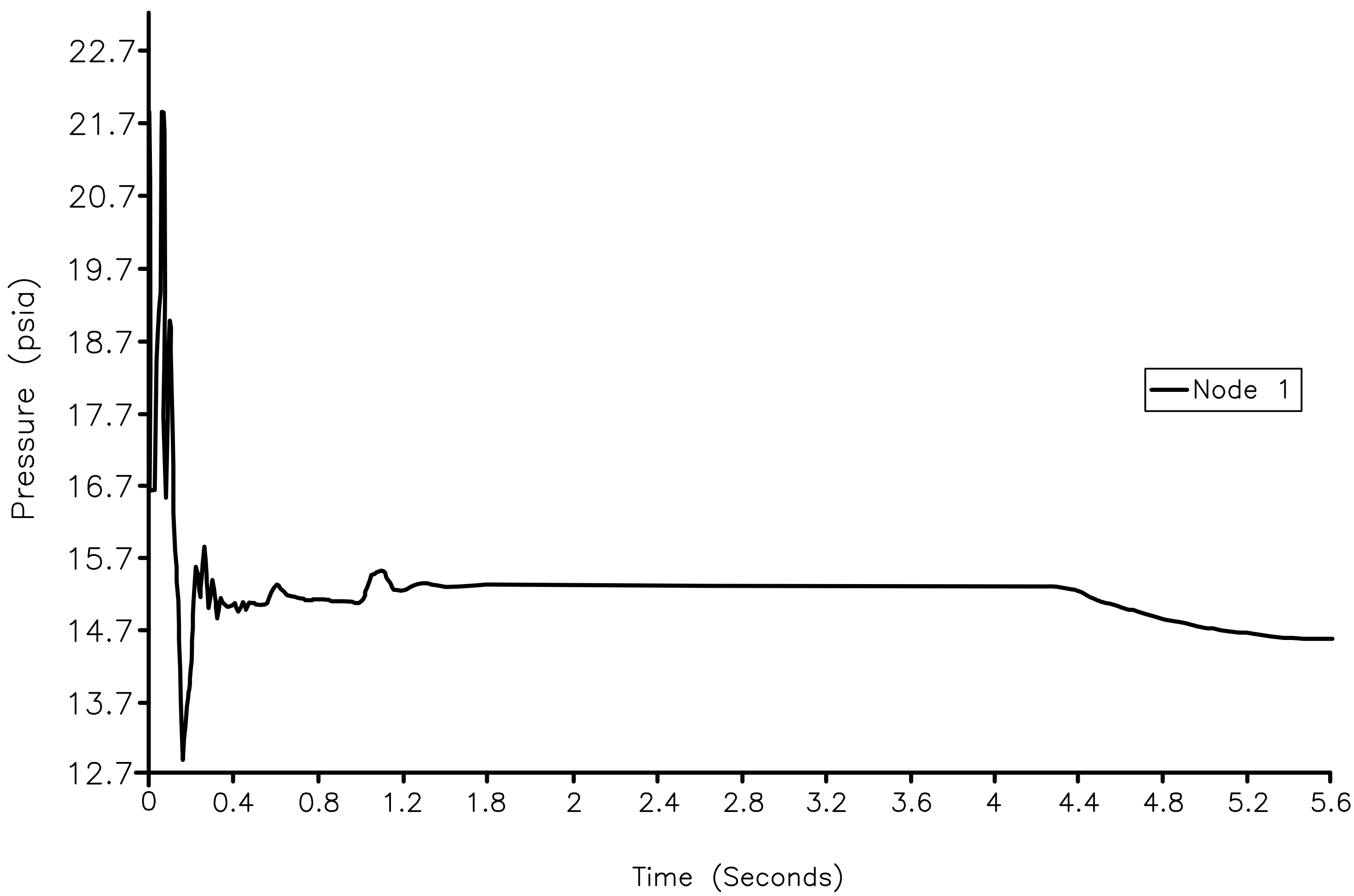
CASE A VOLUME FLOWS

FIGURE 3.6A-3, Rev. 48

Auto-Cad Figure Fsar 3_6A_3.dwg

RB Steam HELB Pressure Response for Worst Node



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SUSQUEHANNA STEAM ELECTRIC STATION
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CASE A PRESSURE TRANSIENT

FIGURE 3.6A-4, Rev. 48

Auto-Cad Figure Fsar 3_6A_4.dwg

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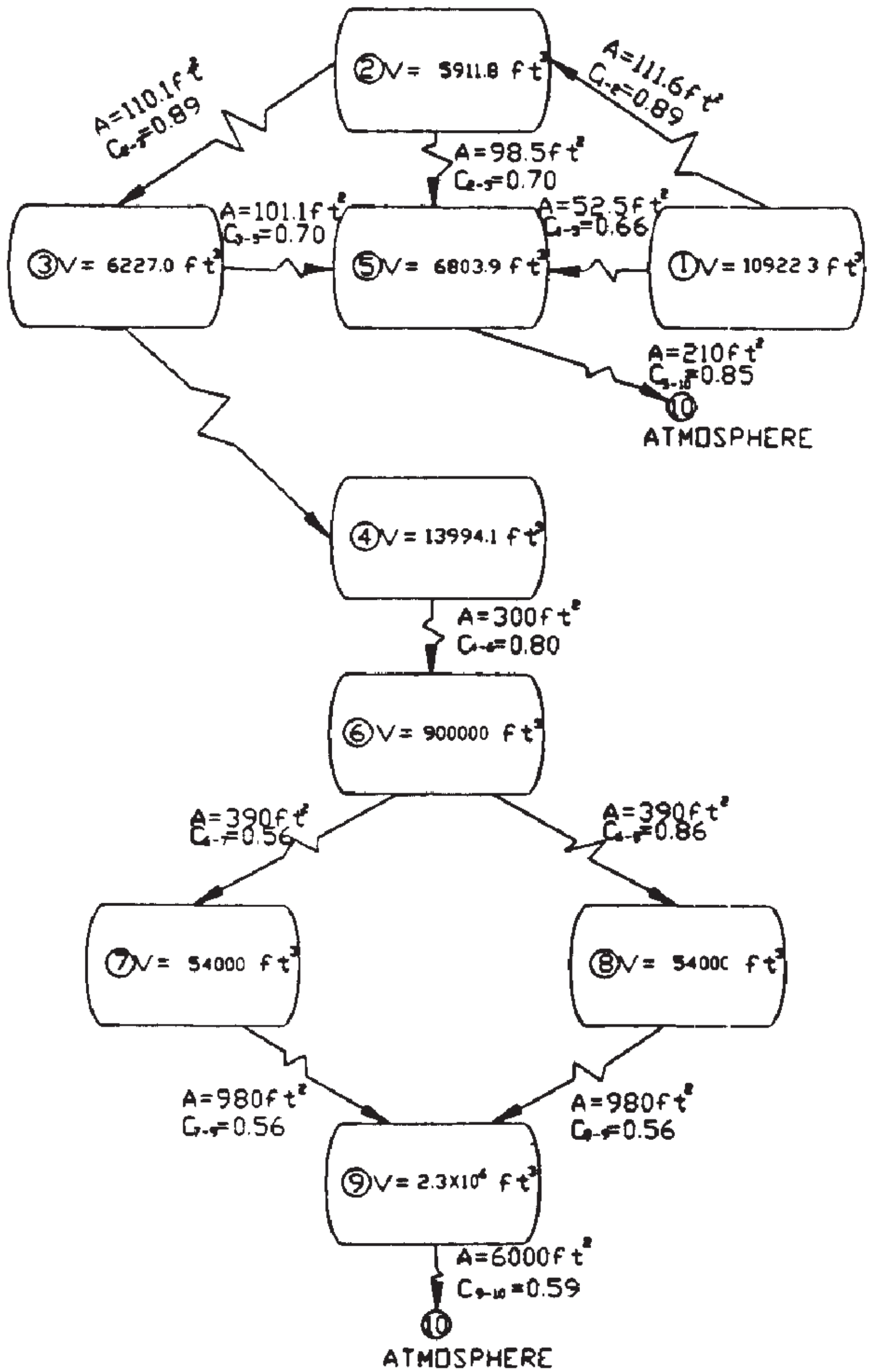
SUSQUEHANNA STEAM ELECTRIC STATION UNITS 1 & 2 FINAL SAFETY ANALYSIS REPORT
CASE B MSLB IN TURBINE BUILDING
FIGURE 3.6A-5



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SUSQUEHANNA STEAM ELECTRIC STATION
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FINAL SAFETY ANALYSIS REPORT

CASE B VOLUME FLOWS

FIGURE 3.6A-6, Rev. 47

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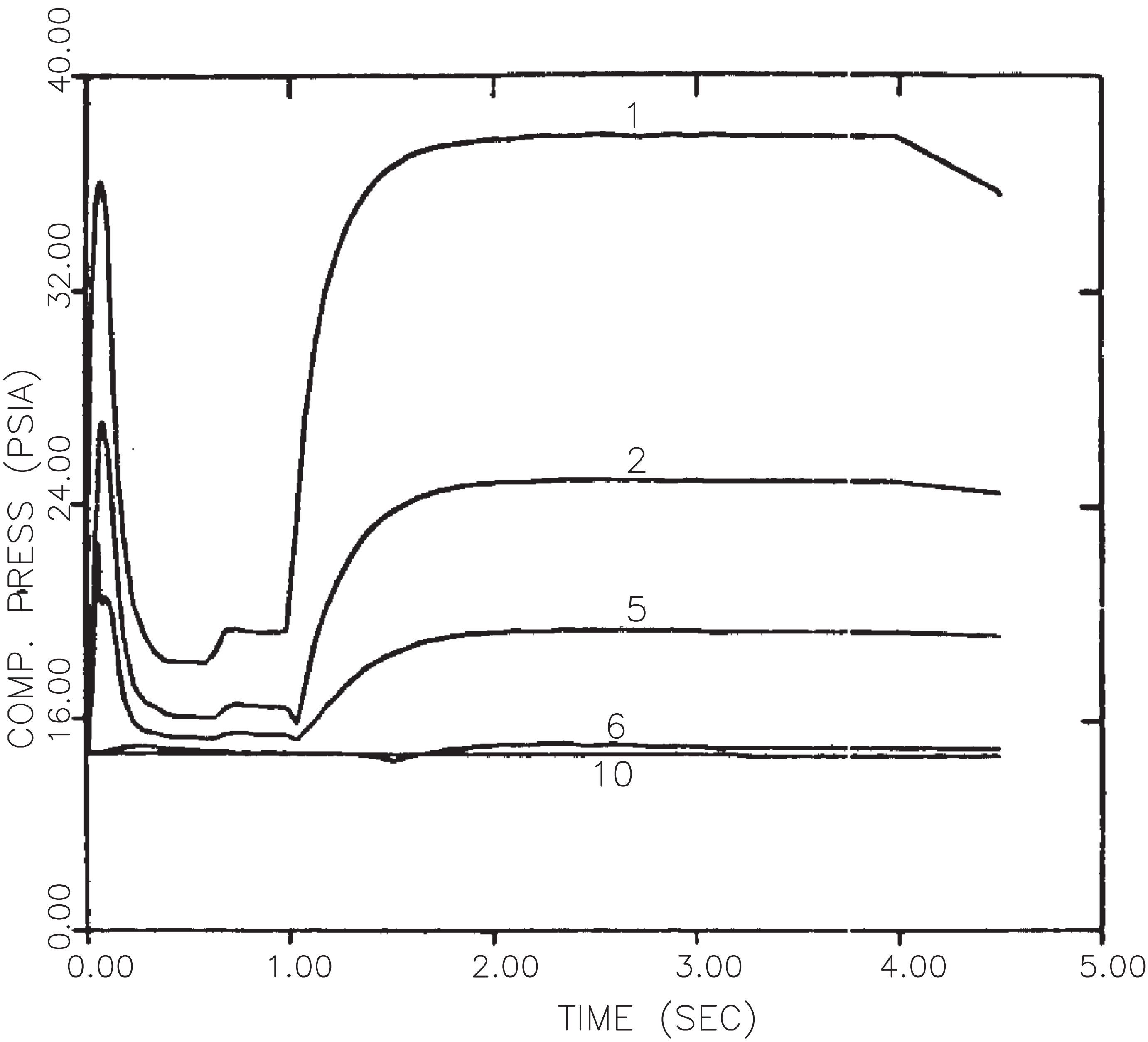

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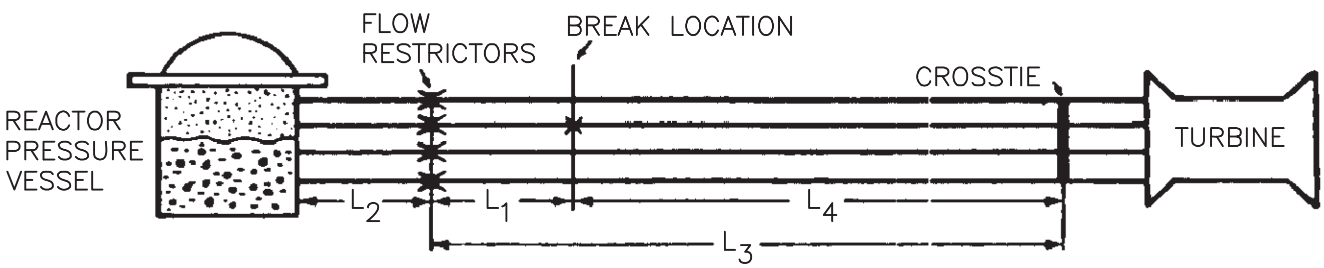
SUSQUEHANNA STEAM ELECTRIC STATION
UNITS 1 & 2
FINAL SAFETY ANALYSIS REPORT

CASE B PRESSURE TRANSIENT

FIGURE 3.6A-7, Rev. 47

Auto-Cad Figure Fsar 3_6A_7.dwg



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MODEL FOR DOUBLE-ENDED
GUILLOTINE

FIGURE 3.6A-8, Rev. 47

Auto-Cad Figure Fsar 3_6A_8.dwg