10A.1 MAIN STEAM

Each steam generator is connected with a single 34" pipe line to the steam header near the turbine. Each steam line will carry approximately 5.6 million pounds of steam per hour during rated power operation. These lines penetrate the Containment at Elevation 38'0" and pass through the Auxiliary Building to the Turbine Building. The MS System, shown in Figure 10A.1-1, will vary normally between 900 and 850 psia for no-load and full-load operation, respectively. A flow-limiting nozzle, located in the Containment, will protect the primary system against an excessive cooldown rate in the event of a main steam line break (MSLB). Pressure in the MS system is maintained primarily by the reactor coolant temperature. A turbine by-pass system, with a capacity of 40% of the rated steam flow, and an atmospheric dump system, with a capacity of 5% of the rated steam flow, provide additional control of the MS pressure during load changes. In addition, 16 relief valves protect the MS system from abnormal pressure above 1050 psia.

10A.1.1 PIPE WHIP

The MS system normally operates at a pressure above 275 psig and 200°F and, therefore, protection is provided for pipe whip following a longitudinal or circumferential break.

10A.1.2 CRITERIA FOR PIPE BREAK LOCATION

Pipe breaks are postulated to occur at the following locations:

a. Terminal ends;
b. Any intermediate locations between terminal ends where either the circumferential or longitudinal stresses derived on an elastically-calculated basis under the loadings associated with seismic events and operational plant conditions exceed 0.8 $(S_h + S_A)^*$ or the expansion stresses exceed 0.8 S_A; and,
c. Two additional intermediate locations are selected on the following reasonable bases:
    1. The points of highest stress, Figure 10A.1-2 identifies the location of the high stress points. Table 10A-1 lists the stress values for these points; and,
    2. No break in short-run pipes up to five pipe diameters.
d. A critical crack defined as one-half the pipe diameter in length and one-half the pipe wall thickness in width is postulated to occur at any location.

10A.1.3 CRITERIA FOR PIPE BREAK ORIENTATION

A longitudinal pipe break is considered for lines 4" and larger. The break is assumed to be parallel to the pipe axis and oriented at any point around the pipe circumference. A circumferential break is considered for lines exceeding a nominal pipe size of 1". The break is assumed to be oriented perpendicular to the pipe axis. A critical crack is assumed to be oriented at any point around the pipe circumference.

10A.1.4 SUMMARY OF PIPE WHIP DYNAMIC ANALYSIS

10A.1.4.1 Location of Number of Breaks

The locations and number of design basis breaks are chosen in accordance with the criteria in Section 10A.1.2. Two types of breaks, longitudinal break and circumferential break, are considered in accordance with the criteria in Section 10A.1.3.

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[*] Pressure greater than 275 psig and/or temperature greater than 200°F.

The critical crack is considered to occur anywhere on the line. Figure 10A.1-2 shows the postulated pipe break locations for the MS line.

10A.1.4.2 The Postulated Rupture Orientation

The longitudinal break is parallel to the pipe axis and oriented at any point around the pipe circumference. The longitudinal break area is equal to the effective cross-sectional flow area upstream of the break location. The circumferential break is perpendicular to the pipe axis, and the break area is equivalent to the internal cross-sectional area of the ruptured pipe. Dynamic forces resulting from a circumferential break are assumed to separate the piping axially, and cause whipping in any direction normal to the pipe axis.

The critical crack is oriented at any point around the pipe circumference.

10A.1.4.3 Description of Forcing Function

Design parameters to estimate steam-water blowdown thrust and jet impingement forces expressed in term of F_T/P_OA_B as a function of the friction parameter. Flow resistance coefficient (fL/D), and upstream area restriction parameter, A_B/A_R, are respectively presented in Figures 10A.1-9 and 10A.1-10. In addition, graphical solutions to predict the impingement force experienced by the target object as a function of fL/D are also plotted in Figures 10A.1-11 and 10A.1-12.

DISCUSSION AND APPLICATION

1. Blowdown Thrust Loads

Thrust and jet impingement forces are produced during a rapid blowdown of a high pressure vessel. Thrust reaction force is a summation of the momentum expulsion rate and the exit plant pressure force. Momentum flow rate is the product of velocity and mass flow rate. Furthermore, the blowdown mass flow rate, velocity, and exit plane pressure are determined by vessel pressure, fluid properties, and the escape geometry. It follows that, for a given pressure vessel blowdown, thrust reaction force is totally determined. The total steady thrust reaction force may be written as follows:

$$\frac{F_T}{A_B} = (P_2 - P_\infty) + \frac{(V_2)^2}{\psi_2 g_c} \qquad (1)$$

or

$$\frac{F_T}{A_B} = (P_2 - P_\infty) + \frac{(G_2)^2\ \psi_2}{g_c} \qquad (2)$$

For definition of terms, refer to the list of notations at the end of this section.

Figure 10A.1-8 shows a blowdown of steam or saturated water from a vessel through an arbitrary pipe. The impingement target is located sufficiently far away that full jet expansion to environ pressure, P_∞ has occurred. It follows from conservation of momentum equations that the steady thrust reaction force and total jet impingement force per unit break area A_B can be expressed by:

$$\frac{F_T}{A_B} = (P_2 - P_\infty) + \frac{(G_2)^2\ \psi_2}{g_c} \qquad (2)$$

$$\frac{F_j}{A_B} = \frac{A_B}{A}\frac{(G_2)^2\ \psi_2}{g_c} = \frac{A_\infty}{A_B}\frac{(G_2)^2\ \psi_\omega}{g_c} \qquad (3)$$

Furthermore, a simple force balance on the steady jet which impinges normally on the flat wall shows that the total jet force and the total thrust are equal but opposite in direction giving

$$\frac{F_T}{A_B} = \frac{F_j}{A_B} \tag{4}$$

If ideal gas is assumed as the fluid flowing and blowdown through an isentropic nozzle (zero friction), it follows that for $k=C_p/C_v = 1.3$ the thrust may reach the maximum value

$$\frac{F_T}{A_B} = \frac{F_j}{A_B} = 1.26P_o - P \tag{5}$$

However, pipe friction and upstream area restrictions significantly affect the steady thrust loads.

Pipe friction effects on steam or saturated water blowdown steady thrust can be incorporated in the steady thrust loads from Figure 10A.1-9. Figure 10A.1-9 can also be used to estimate the thrust load for pipe break of any water line that is directly connected to the pressure vessel provided that subcooling of the blowdown zone in the pressure vessel is not greater than 22 Btu/lb.

If the postulated rupture pipe has an upstream area restriction such as flow-limiting venturi or feedwater orifice, the steady thrust loads can be seriously affected. Figure 10A.1-10 should be used to determine steady thrust loads for various break-to-restriction-area ratios in circumferentially ruptured pipes that initially contained steam or water.

2. Jet Impingement Loads

Blowdown flow will form a jet which can produce impact forces on pipes or other mechanical target objects in its path.

Total steady-state jet impingement force per unit break area is given in Equation (3). It follows from Equations (4) and (5) that the maximum value of total steady-state jet load for saturated steam or steam/water mixture blowdown through an isentropic nozzle where entire jet intercepted by target is

$$\frac{F_j}{A_B} = 1.26P_o - P_\infty \tag{6}$$

If the blowdown pipe friction is significant, Figure 10A.1-9 would be used to determine F_j/A. If there is an area restriction in the line, use Figure 10A.1-10 with $F_j = F_T$.

Total force on target objects, which are submerged in a jet (i.e., target area A_T is less the fully expanded free jet area A_∞) and do not fully intercept the jet, can be estimated from the product of "jet pressure" F_j/A_∞ (Figure 10A.1-11) and projected target area, A_T. If A_T is greater than A_∞ (target intercepts the jet), the full jet load F_j, which is equal to total thrust in Figure 10A.1-9 should be used. If the target is very close to a break where jet originates, full expansion will not occur so that Figure 10A.1-11 is invalid. Data of Faletti (Reference 1) indicates that full jet expansion probably occurs about five pipe diameters of axial travel after leaving the break. Therefore, whenever $L_\infty/D \geq 5$, jet pressure of Figure 10A.1-11 is valid. However, if $L_\infty/D<5$, a jet pressure equal to F_T/A, and jet area A would be more appropriate.

Whether or not the target is fully submerged in a jet can be determined from the jet expanded area as follows:

A) $L_\infty/D \geq 5$.

Figure 10A.1-12 gives the expanded area, A_∞.

If $A_T < A_\infty$ target is fully submerged and impingement load = jet pressure x A_T.

If $A_T \geq A_\infty$ target intercepts entire jet and impingement load = F_j.

B) $L_\infty/D < 5$.

If $A_T < A$ target is fully submerged and impingement load = $F_j A_T / A$.

If $A_T > A$ target intercepts entire jet and impingement load = F_j.

Notations

A = Jet area, ft^2
A_B = Pipe flow area or break flow area, ft^2
A_R = Restriction flow area, ft^2
A_∞ = Fully expanded free jet area, ft^2
A_T = Projected target area, ft^2
D = Pipe hydraulic diameter, ft
F_T = Total thrust, lbf
F_j = Jet impingement force, lbf
f = Moody friction factor
L = Equivalent pipe length for pressure loss from vessel
L_∞ = Distance from pipe break to target, ft
P_o = Vessel pressure, lbf/ft^2
P_{sat} = Saturation pressure, lbf/ft^2
P_2 = Exit plane pressure, lbf/ft^2
P = Atmospheric pressure, lbf/ft^2
ρ = Fluid density, lbm/ft^3
ψ = Fluid specific volume, ft^3/lb
G = Mass flow rate per unit area
V = Velocity
C_P = Constant pressure specific heat
C_V = Constant volume specific heat
g_c = Newton's constant, 32.2 $lbm\text{-}ft/lbf\text{-}sec^2$

10A.1.4.4 Mathematical Model and Dynamic Analysis

A large pipe break is assumed to be a one-time event, requiring a plant shutdown and necessary repairs. Permanent deformation of the pipe and restraint are allowed.

An energy balance method was used for the pipe whip restraint design. This method is similar to the maximum deflection of a system subjected to a long duration loading relative to the natural period as presented on Page 222 of Reference 6. The mathematical model is shown in Figure 10A.1-5. When required to accommodate the thermal movement of the pipe, gaps were provided between the pipe and the restraint, and the effects of these gaps were considered in the dynamic analysis. Thus, the formula shown on Page 222 of "Introduction to Structural Dynamics" is modified as follows:

$$F\left(\frac{Y_g}{Y_{el}}+\mu\right)=R_m(\mu-1/2)$$

where:

F = Jet force acting upon the pipe
Y_g = Gap between the pipe and the restraint
m = Ductility ratio, i.e., Y_{max}/Y_{el}
R_m = Restraint resistance force
Y_{el} = Deflection of the pipe and the restraint at the yield stress

As suggested by the AEC, a comparison was made between a time-history analysis method and the energy balance method of the restraint design. The results of this comparison are shown in Table 10A-7. A comparison was made on four different restraints. As shown in this table, a stepped forcing function was used in the time-history analysis, compared to a straight line forcing function (Figure 10A.1-15) used in the energy balance method of analysis. Two different sets of analyses were performed in the comparison. In the first set of calculations, the elastic deflections given by the time-history method, were used in the energy-balance method. In the second set of calculations, properties of a given restraint were used in the energy-balance method.

The results of this comparison indicated that the resistance force on the restraint (yield capacity of the restraint) will be similar in both analyses.

10A.1.4.5 Unrestrained Motion of the Ruptured Line

The MS line is restrained at the postulated break locations and additional restraints are provided to preclude axial movement within the encapsulation sleeve. No damage, therefore, can occur to structures, systems and components important to the plant safety due to a MSLB.

10A.1.5 PROTECTION AGAINST PIPE WHIP, JET IMPINGEMENT, AND REACTIVE FORCE

10A.1.5.1 Pipe Whip Restraints and Encapsulation

10A.1.5.2

The MS line is encapsulated and restrained to prevent pipe whip, jet impingement, or reactive forces from damaging other plant components and structures required for safety following a longitudinal or circumferential break.

The MS line encapsulation sleeve is designed in accordance with the following criteria:

a. The encapsulation sleeve is designed and supported in a manner which will not introduce significant strain concentrations on the encapsulated section of piping.
b. The piping beyond the encapsulation sleeve is provided with pipe whip restraints (or anchors) which restrict its axial displacement and motion within the sleeve following a postulated circumferential pipe break.
c. The encapsulation sleeve is designed (a) to withstand the dynamic forces of internal pressurization resulting from the escape of high energy fluid at the postulated pipe break location assuming complete pipe severance and axial separation to the extent permitted by the pipe restraints, and (b) to

restrict the flow at the open ends of the sleeve to a level required to preclude compartment pressurization beyond the allowable structure design limits.

d. The stresses imposed on the encapsulation sleeve during dynamic pressurization are limited to the design limits associated with "emergency condition" as permitted by the rules of American Society of Mechanical Engineers (ASME) Section III - Nuclear Power Plant Components Code, for Class 2 components.

e. All material for use in the encapsulation sleeves was procured to the requirements of Article NC-2000 of ASME Code, Section III, 1971.

f. Fabrication of the encapsulation sleeves is in accordance with the requirements of Article NC-4000 of ASME Code, Section III, 1971.

g. Full-penetration shop welds were radiographed in accordance with ASME Code, Section III, Class 2, and Code Case 1554.

h. Full-penetration field welds of the encapsulation sleeve were magnetic particle or liquid penetrant examined in accordance with the procedures described in Appendix IX-3500 or IX-3600 of ASME Code, Section III, 1971, with the acceptance standards of paragraph NB-5320 of the Code. Examinations were performed at the one-third level, two-thirds level and of the final welded surface.

i. The design of the encapsulation sleeve permits either its removal by machinery or flame-cutting techniques, or the replacement of encapsulated pipe section in the event leaks develop which require repair or replacement of the pipe.

j. Pipe weld joints located within the encapsulation sleeve and not accessible for subsequent ISI were non-destructively examined prior to the assembly of the encapsulation sleeve. The results satisfy the acceptance standards of ASME Section XI, Inservice Inspection Code.

k. The encapsulation sleeve is provided with open vent and drain pipe nipples as a means of monitoring the encapsulated pipe section for any leaks which might develop in service. These nipples extend beyond the pipe insulation.

l. The piping welds not encapsulated within the piping runs traversing safety-related areas, or within compartments adjoining safety-related areas were subjected to periodic inservice examinations in accordance with ASME Section XI Code Class 2 component requirements except that 100% of such welds were examined during each inspection interval. Alternatively, a risk-informed process for piping outlined in Reference 8 may be used for the weld selections and the determination of additional examinations when defects are discovered. This applies to the MFW and MS systems within the Auxiliary Building.

Figure 10A.1-3 shows an encapsulation detail for the MS System. The fluid head at the containment penetration is designed for pressure build-up or movements due to a pipe break in the Auxiliary Building.

The jet forces from a critical crack of less than 10 kips are not significant enough to create a pipe whip affecting Category I structures, systems, and components. The jet forces will produce low bending stresses well within the elastic range of the pipe with an expected pipe movement of less than 1/4" in the worst case. The jet impingement force resulting from a single critical crack will be shielded as required to prevent damage to the safety-related components, systems, and equipment. For further discussion see Section 10A.1.13C.

For those locations where the postulated break area would exceed 28.9 in^2, (the area of the largest branch line) the pipe is encapsulated to limit the blowdown to less than 291 lbm/sec (analysis in Section 10A.1.20). This is accomplished by limiting the release area between the ends of the encapsulation and the pipe to a net area less than 28.9 in^2. The encapsulation will also dissipate the jet impingement forces.

Following a steam line break, the pressure will instantaneously build up inside the encapsulation because of the restriction of blowdown through the gap. Supports are located between the encapsulation and the pipe to prevent displacement of the pipe normal to its axis. Whipping restraints are located so that the encapsulations are rigidly held in place and the MS lines are prevented from pulling out of the encapsulations.

A vent stack has been provided to vent the MS line Penetration Room to a compartment pressure below the acceptable level, which would affect the integrity of the Category I structures, system or components important to plant safety (Section 10A.1.20).

10A.1.5.3 Separation Provisions
10A.1.5.4

The MS lines are run parallel to each other approximately 5'10" apart. Separation of redundant features of the MS lines is accomplished by a combination of encapsulation and properly placed restraints.

The safety relief valves are arranged such that jet forces from the safety relief valves on one line will not affect the valves on the adjacent line.

The existing exhaust stack support steel (12" structural members) between each relief valve inlet will provide protection and separation of adjacent MS relief valves from the jet impingement force resulting from a circumferential or slot break at the 6" MS nozzle to the relief valves.

Additional steel was provided in the area of the relief valves where required to ensure complete protection against jet impingement from a 6" MSLB.

A jet impingement barrier, which consists of a steel plate, is provided between the MS line and L_b wall to protect the wall from the jet force resulting from a 6" MSLB.

10A.1.5.5 Description of a Typical Pipe Whip Restraint

The pipe whipping restraints are provided at the postulated break locations. Additional restraints are provided near elbows and other critical locations to control the pipe whip impact and axial movement due to a full break at the postulated break locations. Figure 10A.1-2 shows the location of restraints for the MS line.

The design and detail of a pipe whip restraint depends upon many variables, such as physical location, amount of force to be sustained and thermal movement of the pipe. A typical pipe whip restraint is a rigid structure of heavy structural steel members and/or steel plates. It is supported from the existing structural components, such as floors, walls and columns. When the restraint loads cannot be sustained by the existing structure of structural components, these loads are transferred to the foundation level using additional supports. Figure 10A.1-4 shows details of a pipe whip restraint for the MS line.

10A.1.6 EVALUATION OF SEISMIC CATEGORY I STRUCTURES

10A.1.6.1 Method of Evaluating Stresses

Category I existing and added structures were evaluated for structural adequacy following a postulated rupture using the design bases shown in Appendix 5A. Ultimate strength design method for concrete was used as given in the above reference.

10A.1.6.2 Allowable Design Stress

Design stresses are proportioned such that the combined stresses are within the limits established in Appendix 5A.

10A.1.6.3 Load Factors and Load Combinations

Load factors and load combinations are discussed in Section 10A.1.7. A further discussion of load factors and load combination is provided in Section 5.

10A.1.6.4 Stresses in Category I Structure

Main steam line is encapsulated at the postulated break locations. The jet impingement forces resulting from a postulated pipe break are retained in the encapsulation pipe and are not taken by the structure or structural components. Any jet forces escaping from the encapsulation pipe are distributed such that they will not affect the structure.

The magnitude of a jet impingement force, due to a critical crack in the MS line, will be less than 10 kips. A simplified approach to impingement forces assumes the jet to disperse uniformly at the half angle of incidence between jet axis and the target surface. The half angle, ϕ, is taken as 10°. Thus, the pressure at distance X is:

$$P_j = F_j/A_j$$

where,

P_j = Effective jet pressure on the target

F_j = Jet impingement forces in kips

A_j = The cross-sectional area, in square inches, normal to the jet

Table 10A-2 shows the concrete and steel stresses due to jet impingement forces resulting from a critical crack plus 1 psi compartment pressurization on various structural components in the vicinity of the MS line.

Table 10A-3 shows the concrete and reinforcing steel stresses due to the pressurization of 2.6 psi resulting from a postulated pipe rupture.

The calculated stresses shown in the above tables are combined stresses, including the effects of pipe rupture, plus the effects of live load, dead load, equipment load, and Safe Shutdown Earthquake (SSE) loads. Allowable stress for the concrete is taken at 85% of the ultimate strength. Concrete, having an ultimate strength of 4,000 psi, is used. The allowable stress for the reinforcing steel is taken at 90% of the yield strength. Reinforcing steel, having a minimum yield of 40,000 psi, is used. The structures are also evaluated for the effects of pipe breaks which are transmitted through the restraints.

10A.1.6.5 Erosion of Concrete from Jet Impingement Forces

Since encapsulation pipes are used to prevent full area pipe rupture jet forces from effecting the structure, the only jet impingement force that must be considered is from the critical crack. The most severe jet force condition occurs where the steam line is 1' away from the concrete. The exit velocity is expected to be approximately 1500 fps with a total force of 10,000 lbs distributed over an area of 84 in^2.

Most of the work done relating to blast erosion of concrete has been with reference to blast from jet engines of aircraft. Some of the effects of jet blast have been discussed in Reference 7. The work has been done at 1250°F and velocities at 3500 fps. The results of these tests and actual service showed that concrete pavement suffered light damage. Since our velocities and temperatures are considerable less than those obtained from the jet engine, excessive erosion of our structure concrete will not be a problem. The jet impingement forces which are expected will be on a local area for a relatively short duration and should not damage the structure adequacy.

However, if the effects of these jet forces are determined to significantly erode the concrete, steel shielding plates will be provided as required.

10A.1.7 STRUCTURAL DESIGN LOADS

The following design loads are used to evaluate the adequacy of Category I structures following a postulated rupture:

Dead Load - Actual weight of structural elements supported.

Live Load - Maximum expected live load in the area under consideration.

Equipment Load - Actual static load of equipment.

Pipe Load - Maximum calculated forces expected under normal operating and upset conditions. The forces include dead load, seismic forces, and thermal forces.

Pressurization - The maximum expected compartment pressure build up that would result from a postulated rupture.

Jet Impingement - Jet impingement forces resulting from full pipe area breaks are retained in the encapsulation pipe and are not taken by the structure. The forces resulting from critical cracks were considered.

Temperature - The effects of temperature increase from a pipe rupture are considered to be short term increases and will not affect the structure adequacy.

Seismic Forces - Seismic forces as shown in Appendix 5A.

These loads are combined using the following load combination equations to evaluate the structural integrity of a Category I structure following a postulated high energy pipe line rupture.

$$Y = 1/\phi\ (1.25D + 1.00R + 1.25E)$$
$$Y = 1/\phi\ (1.25D + 1.25H + 1.25E)$$
$$Y = 1/\phi\ (1.00D + 1.00R + 1.00E')$$
$$Y = 1/\phi\ (1.00D + 1.00H + 1.00E')$$

Y = required yield strength of the structure

D = dead load of structure, actual static weight of equipment, expected live load in the area under consideration. In addition, any other permanent loads contributing stress, such as soil or hydrostatic loads.

R = reactions from the pipe whip restraints, the maximum expected compartment pressure build-up that would result from a postulated rupture and jet impingement forces resulting from the critical crack (jet impingement forces resulting from a postulated pipe break are retained in the encapsulation pipe and are not taken by the structure).

H = maximum calculated forces expected under normal operating and upset conditions. The forces include dead loads, seismic loads and thermal expansion of restrained pipes under normal operating conditions.

E = Operating Basis Earthquake (OBE) load.

E' = SSE load.

ϕ = yield capacity reduction factor as defined in Appendix 5A.

10A.1.8 REVERSAL OF LOADS ON THE STRUCTURE

The forces which could cause reversal of loadings due to the postulated accident, on the Seismic Category I structures or structural components are:

a. Jet Impingement Force
b. Compartment Pressurization
c. Reaction from Pipe Whip Restraint

Since the MS line is encapsulated at the postulated full break locations, the existing Category I structures or structural components will not be affected by the jet impingement forces.

A vent stack is provided to vent the MS line compartment at Elevation 27'0" (Figure 10A.1-7). The pressure in the MS line compartment, due to a postulated full break, will be limited to an acceptable level by providing the vent stack and the encapsulation pipe (Section 10A.1.20). The maximum pressure, in the MS line compartment, will not affect the integrity of the Category I structures or structural components.

Pipe whip restraints are supported by the existing structural components. When the restraint loads cannot be sustained by the existing structure of structural components, these loads are transferred to the foundation level using additional supports.

The effects of jet impingement forces and the pressurization due to the postulated single critical crack were insignificant except in the existing pipe tunnel. The roof of this pipe tunnel was adequately strengthened in order to make the tunnel safe against the reversal of loads due to the postulated single critical crack.

10A.1.9 STRUCTURAL EFFECTS OF OPENINGS

The openings are designed and located such that no adverse structural effects are incurred. Venting from the MS compartment was accomplished by the use of the existing pipe tunnel and the addition of a vent to the roof. The vent to the roof was made through existing tendon access openings, which required no additional reinforcing.

10A.1.10 EFFECT OF STRUCTURAL FAILURE

There will not be a failure of any structure, including Category II (non-seismic Category I) structures, due to the accident, that could cause failure of any other structure in a manner to adversely affect:

a. Mitigation of the consequences of the accident; and
b. Capability to bring the unit(s) to a cold shutdown condition.

10A.1.11 VERIFICATION THAT PIPE RUPTURE WILL NOT AFFECT SAFETY

In the event of a MSLB in the Auxiliary Building the only region affected is the MS Penetration Room (Figure 10A.1-2).

The structures are designed to contain the escaping high energy fluid and to vent and/or drain this fluid safely.

The only passages through which steam can pass are the vents to the outside atmosphere and the tunnel to the Turbine Building (Section 10A.1.20.4). All doors, piping penetrations, and electrical penetrations are leak tight and capable of withstanding the pressure in the Penetration Room. The plant ventilation system does not communicate with this Penetration Room. A separate duct to the atmosphere is provided for normal ventilation in this room. Both the vent stack (Figure 10A.1-7) and the normal ventilation duct are designed to withstand a Penetration Room pressure of 5.0 psig so that steam cannot break through to any other region in the Auxiliary Building. As this paragraph illustrates, steam is prevented from propagating into the other areas of the Auxiliary Building.

Any steam escaping to the Turbine Building will not reach any vital equipment, instruments, electrical supplies, or cables, and will not flow back into the Auxiliary Building.

The only safety-related equipment located in the MS Penetration Room are:

a. Main steam isolation valves (MSIVs)
b. Main feedwater isolation valves (MFIVs)
c. Control valves (CVs) on the MS line to the AFWP turbines
d. Cable trays

Section 10A.1.13 describes the qualification of items a, b, and c above to properly function in the steam environment. Section 10A.1.20 describes the methods used to determine the standards to be met for environmental qualification and lists the resulting values. Section 10A.1.5 describes the protection provided against pipe whip, jet impingement, and reactive forces. The cable trays are enclosed in metal shielding to prevent damage from jet forces or a steam environment.

The steel conduits will withstand a pressure of 5 psig and 300°F of steam environment. The junction boxes are designed to withstand the above conditions (5 psig and 300°F).

In the event of a MS line rupture in the Turbine Building, the only regions affected are in the Turbine Building. The pressure levels that would result are insufficient to cause damage to the adjoining Auxiliary Building structures or security doors (Section 10A.1.20). The steam will not propagate into the Auxiliary Building.

Safety-related portions of main steam drains 5 and 6 penetrate the K-line wall and are located adjacent to it on the 12' and 27' Elevations of the Turbine Building. While some of this piping downstream of the included level switches exceeds 1", it is supplied by 1" piping. Therefore, no pipe breaks are required to postulated. Even if a break were postulated, there are no other safety-related components around this piping on the Unit 1 side and only the 36" saltwater ram's head on the Unit 2 side. Clearly, this small piping poses no threat to the ram's head's integrity. However, the main steam headers pass over these drains on the 27' Elevations of both Units 1 and 2. A postulated break in these main steam headers could potentially rupture either or both of these drains. This condition was evaluated, and the results showed that this event would not impair the ability to achieve shut down and would not increase the consequences beyond that of the ruptured team line alone. Therefore, no barriers or restrains are required to protect these drains from a break in the main steam headers.

The location of the instrumentation associated with the Reactor Protection System and the ESF Systems in relation to the high energy piping is such that the instruments will not be affected by pipe whip or jet impingement. The instruments have been qualified for a high temperature and pressure environment.

The safety relief valve operation will not be affected by the steam environment in the MS valve room after a pipe rupture. The turbine bypass line and the turbine bypass valve are located in the Turbine Building and their operation will not be affected by the steam environment.

The atmospheric steam dump valves are discussed in Section 10.1.2.1. These valves are located in the Auxiliary Building immediately above the MS Penetration Room and are in an enclosure that communicates with the MS Penetration Room (Section 10A.1.20.5). The atmospheric dump valves are not safety-related and are not required to operate during this accident. Should one of these valves inadvertently open, the operator has sufficient time to feed the unaffected steam generator with the AFW System.

10A.1.12 EFFECT ON CONTROL ROOM

The results of the analysis presented in Section 10A.1.20 show that the Control Room will not be affected by a break in the MS line.

10A.1.13 ENVIRONMENTAL QUALIFICATION OF AFFECTED REQUIRED EQUIPMENT

A. Identification

The following electrical equipment and valves must be qualified to meet the requirements of Section 10A.1.20:

1. Both MSIVs and both gas/hydraulic actuators
2. Main Steam to AFWPs CVs, 1/2-CV-4070/4071 and 1/2-CV-4070A/4071A
3. Both MFIVs, Motor-Operated Valves (MOVs)-4516 and 4517

B. Testing

The Limitorque valve operators on the MFIVs are similar to Limitorque valve operators which have been tested in simulated reactor containment post-accident steam environment conditions. These tests were performed by Franklin Institute Research Laboratories and are summarized in their report Number F-C3441. The valve operators were exposed to a steam environment for 30 days, including two temperature cycles going to 340°F during the first day. The resulting pressure/temperature profile closely followed that recommended by a cognizant IEEE committee. (Reference 3)

The AFWP steam isolation valves are Fisher Controls Valves [1/2-CV-4070/4071] and Rockwell bypass valves adapted to accept Valtek actuators [1/2-CV-4070A/4071A]. These valves and associated appurtenances have been analyzed to be qualified for the anticipated environments.

The worst-case environment in the MS piping Penetration Room following a MS line critical crack will be a wet steam and air mixture at 2.23 psig and 331°F. The MSIV actuator has been tested and demonstrated its ability to perform its design function under the above environmental conditions.

C. Criteria for Protecting Category I Systems, Components, or Equipment

The MS line is encapsulated at the postulated break locations. The jet impingement forces due to a postulated break are retained in the encapsulation pipe and the Category I systems, components, or equipment will not be affected by the jet impingement forces.

The magnitude of a jet impingement force resulting from a critical crack in the MS line will be less than 10 kips. A simplified approach to impingement forces assumes the jet to disperse uniformly at the half angle of incidence between the jet axis and the target surface. The half angle, ϕ, is taken as 10°. Thus, the jet pressure at distance X is:

$$P_j = F_j/A_j$$

where,

F_j = Jet impingement force

A_j = Cross-sectional area normal to the jet (expanded jet area)

When the target (Category I equipment or systems such as cable, cable trays, instruments) is fully submerged in a jet, jet impingement force = $P_j \times A_T$

where,

P_j = Jet pressure

A_T = Target area

When the target intercepts the jet, that is, target area is larger than the expanded jet area.

Jet impingement force = F_j

When necessary, barriers are provided to protect Category I systems, components, and equipment against the jet impingement forces. A detail of a typical barrier for protecting cable trays is shown in Figure 10A.1-13. The design criteria for barrier design are similar to the Category I structure design criteria and are discussed in Section 10A.1.7.

To prevent steam from escaping into areas affecting vital equipment and instrumentation, pressure seals designed to withstand the necessary pressure and temperature have been provided where required. The doors in the compartment walls are also designed as pressure retaining doors and are sealed accordingly.

All conduits at the junction boxes in the MS valve room are sealed against the steam environment such that no steam can pass through conduits to any other areas.

D. Control Room

A break at any of the postulated locations has no effect on the Control Room environment.

E. Onsite Power

The steam is prevented by walls from propagating into the Switchgear and the Emergency Diesel Generator (EDG) Rooms and, therefore, the onsite power sources and distribution systems will remain operable.

10A.1.14 DESIGN DIAGRAMS AND DRAWINGS

Figure 10A.1-1 is the MS System diagram. The routing of the MS line through the Auxiliary Building is shown on Figure 10A.1-2. This drawing shows the location of safety-related equipment located near the MS lines. It also shows the pressure retaining walls that will prevent the propagation of steam, and the vents that limit the pressure rise in the MS Penetration Room.

Figure 10A.1-3 shows a pipe encapsulation detail and Figure 10A.1-4 shows a whipping restraint detail. Figure 10A.1-5 shows a mathematical model for pipe whip restraint.

Figure 10A.1-14 shows the AFWP Room and Service Water (SRW) Pump Room ventilation system.

10A.1.15 FLOODING

The postulated break of the MS line in the Auxiliary and Turbine Buildings will release high quality steam, most of which is vented so as not to damage vital equipment or structures. Any moisture separated from the escaping steam or formed by condensation on cold surfaces can be adequately handled by two 6"-diameter drain lines penetrating the tunnel wall at floor level and gravity draining to the turbine room floor drain system at floor Elevation 12'0". Watertight doors are provided in the Auxiliary Building to prevent flooding the Penetration Room to other parts of the building. There are administrative controls (including Technical Specifications) on the open/closed status of the doors.

10A.1.16 QUALITY CONTROL

The quality control and quality assurance for the safety-related piping is in accordance with Appendix 1B. The level of quality control coverage for the remainder of the piping runs was selected on the basis of importance to plant operating reliability and it is intended that the same degree of quality controls will be maintained.

10A.1.17 LEAK DETECTION

Temperature switches are located within the MS line Penetration Room, which will alarm and will alert the operator to the abnormally high temperatures that could result from a small crack. No credit is taken for these switches. In the event there is a large rupture, the instrumentation associated with the steam generators will alert the operator to an MSLB (Section 10A.1.18).

10A.1.18 EMERGENCY PROCEDURES

Following a steam line rupture in the Auxiliary Building or the Turbine Building, the applicable emergency operating procedure would be implemented.

Depending on the size of the leak, indications may or may not be received. If indications are not received after a small leak has occurred, the operator would note the leak on his rounds in the Auxiliary Building and Turbine Building (four hours maximum). The operator would then evaluate the need to shut down the plant.

10A.1.19 SEISMIC AND QUALITY CLASSIFICATION

The MS lines are designed and constructed to meet American National Standards Institute (ANSI) B31.1 requirements with 100% radiograph of butt-welds in piping greater than 2" NPS, except for the portion that penetrates the Containment out through the MSIV. This portion is designed and constructed to meet the requirements of ASME Section III, Class 2. The non-destructive examination requirements of butt-welds in those portions of the MS piping built to ANSI B31.1 and outside of the ISI boundary have been revised to the following requirements:

NPS > 8"	100% Radiographic Examination
NPS ≤ 8"	The weld root pass is to be fabricated by GTAW method. A surface examination will be performed on the weld root and the final weld. Examination method is to be magnetic particle when practical, otherwise the liquid penetrant method shall be used. Also, a radiographic examination may be performed as an alternative to the above requirements. For 2" NPS and under piping, weld inspection shall be per code requirements.

The MS line from the steam generator outlet to the Turbine Building wall is designed as a Category I (seismic) system. The design data for the MS line are given in Table 10-1. The seismic requirements for Category I (seismic) systems are described in Appendix 5A.

10A.1.20 DESCRIPTION OF ASSUMPTIONS, METHODS AND RESULTS OF ANALYSIS FOR PRESSURE AND TEMPERATURE TRANSIENTS IN COMPARTMENTS

The opening at the end of the tunnel between the MS Penetration Room and the Turbine Building serves as a vent to relieve the pressure buildup. A wall obstructs the end of the tunnel; however, this wall is of lighter construction than any other structural component of the tunnel. With the wall in place, the pressure will build up until the wall collapses (at less than 1.0 psig). The pressure will immediately decay in the tunnel. The results of this analysis indicate, therefore, that the maximum pressure in that area will not exceed 1.0 psig.

The wall will be designed to fail at 0.5 psi or a hydrostatic pressure of 3' of water. The construction will consist of gypsum wallboard with 24 gauge metal frame work. The retainer clips used in the construction of the wall will be designed to fail on the application on either of the above design loads.

No credit is taken in the following analyses for the tunnel or the blow-out wall.

10A.1.20.1 Circumferential Break of 34" Line - 1608 in^2

In accordance with the break location criteria, presented in Section 10A.1.2, circumferential breaks are postulated in the MS line Penetration Room in the Auxiliary Building and in the Turbine Building (Figure 10A.1-2).

The effect of a full, double-ended break and its associated blowdown was not considered in the Auxiliary Building due to the encapsulation design which limits the steam release rates (Section 10A.1.20.3).

The postulated break in the Turbine Building, however, is not encapsulated and the effects of a full, double-ended break were studied. The break is located at the turbine nozzle (terminal end). The mass and energy release data was computed by the Nuclear Steam Supply System supplier for the accident postulated in Section 14.14. The assumptions used to generate system blowdown data for this accident are applicable to a break located in the Turbine Building. This blowdown data, which is given in Table 10A-4, was used to evaluate the pressure transient in the Turbine Building.

The Bechtel computer code Compartment Pressure Analysis (COPRA) was used to analyze the pressure transient for this problem. Compartment Pressure Analysis is a computer code for predicting the pressure differential across the walls of two adjoining compartments following rapid steam and water blowdown within one of the compartments. The code is intended as a design tool. It is written in FORTRAN IV for the Honeywell 635 computer.

The equations and corresponding solutions are divided into two phases: an initialization or steady-state phase, and a calculational or transient phase. The initialization phase sets up quantities such as pressure, masses and temperatures in the compartment atmospheres for the steady state just prior to the blowdown accident. The transient phase described the transient behavior of these quantities during and after blowdown.

The following assumptions are incorporated in the analysis:

A. The steam, water, and air throughout each compartment are in thermal equilibrium at all times.

B. Water, steam, and air entering a compartment are mixed homogeneously and instantaneously; no accumulation of water occurs on the walls or in the sump.

C. There is no heat transfer to the compartment walls or floor.

D. The blowdown expands into Compartment 1 by the following thermodynamic process: first the mass expands isenthalpically to the total compartment pressure. The water present at that time could form more steam only by relatively slow evaporation. The water is assumed to undergo no further change of phase, maintaining thermal equilibrium with steam and air. The steam then completes its isenthalpic expansion to the partial pressure of the steam already in the compartment.

E. If equilibrium calculations result in a superheated atmosphere, then a sufficient quantity of the water suspended in the atmosphere is flashed into steam such that the atmosphere is just saturated. The energy to flash to water is taken from the atmosphere. If all the suspended water were ever used up, the containment atmosphere would remain superheated.

F. For masses passing between compartments, the thermodynamics differ slightly. The steam-air-water mixture entering from the other compartment will be brought to thermodynamic equilibrium without the intermediate step of flashing at the total pressure.

G. The mass flowing between the compartments is a homogeneous, two-phase, water-steam-air mixture. The flow equations, in addition, assume a frictionless, compressible, adiabatic, no-slip model.

H. Two completely separate flow equations are used: one for sharp-edged orifices, and one for all other apertures.

I. The first law of thermodynamics for an open system with no heat transfer, as applied to each compartment, is:

$$\frac{\partial E}{\partial t} = \Sigma_1 \frac{dM_i}{dt} h_i$$

where:

E = Total system energy
dM_i = Mass transfer into compartments
hi = Enthalpy of mass being transferred
t = Time

The break was postulated at the turbine nozzles which are below the operating deck. The pressure buildup in this region is relieved by venting through the floor grating areas to the upper and lower elevations. These openings were treated as sharp-edged orifice type passages.

The following assumptions are made for the Turbine Building:

Room Volume below operating deck	=	869,000 ft^3
Room Volume above operating deck	=	$9.0x10^6$ ft^3
Vent Area	=	1492 ft^2
Vent Flow coefficient	=	Orifice type coefficient (supplied by COPRA)

Additional vent areas will occur when the Turbine Building siding breaks off. The siding is released when the differential pressure across the siding exceeds 0.45 psi. The value of 0.45 psi is based on the failure of the retaining clips which hold the siding in place. The failure load of the retaining clips was determined by the siding manufacturer's laboratory test of the ultimate strength of the clips. On this basis there is no reason to expect any pressure greater than 0.45 psig in the region above the operating deck.

The COPRA analysis indicated that the differential pressure across the operating deck reached a maximum value of 0.39 psi and was decreasing before the pressure above the operating deck reached 0.45 psig. This decrease in differential pressure is caused by more mass flowing through the grating area than is coming out of the break; hence, the entire Turbine Building is tending toward an equilibrium pressure. The differential pressure is below 0.30 psi across the operating deck when 0.45 psig is reached above the operating deck. Since the pressure will not exceed 0.45 psig above the operating deck after the siding is released, the pressure below the operating deck will not exceed 0.75 psig after this occurrence. An examination of the COPRA analysis also shows that the pressure below the operating deck never exceeds 0.71 psig prior to the release of the siding.

The conclusion of this analysis is that the pressure will not exceed 0.45 psig above the operating deck, and will not exceed 0.75 psig below the operating deck, following a double-ended MSLB in the Turbine Building.

The wall separating the Auxiliary Building and the Turbine Building is a 3'-thick reinforced concrete wall capable of withstanding an external pressure of 15 psi.

All ventilation openings between the Turbine Building and the Auxiliary Building are protected with quick closing dampers which are actuated by a gauge pressure of 0.125" water column in the Turbine Building. These dampers are designed and tested to withstand a 1.0 psi differential pressure.

The roll-up doors which are located below the operating deck are reinforced by adding removable vertical columns at the third points. This strengthens the doors to withstand pressures in excess of 1 psi.

The remaining doors to the Auxiliary Building are personnel doors which swing open into the Turbine Building. Personnel doors located above the operating deck have been tested to withstand 90 psf (0.65 psi) differential pressure. Personnel doors located below the operating deck will be designed to withstand 1.0 psi differential pressure (Table 10A-8).

10A.1.20.2 Circumferential Break (Single Ended) of 6" Line - 28.9 in^2

The MS branch lines to the relief valves (6" lines), to the AFWP turbines (6" lines) and to the atmospheric dump valves (4" lines) join the 34" MS line in the MS Penetration Room (Figures 10A.1-2 and 10A.2-2). These connections are considered terminal ends which are circumferential break locations as defined in Section 10A.1.2.

The maximum mass and energy release rates for a 6" circumferential break were calculated using the two-phase, single component, annular flow model developed by Moody (References 4 and 5). To account for the stored energy in the MS lines, an "infinite" reservoir was conservatively assumed just up-stream of the break. To account for the break entrance and exit effects, one velocity head loss was assumed. Normal maximum system pressure of 900 psia and temperature of 532°F were assumed. With this approach, the maximum blowdown is 1450 lb/sec-ft^2. The maximum exit conditions at the break were found to be as follows:

Mass discharge rate, lb/sec	-	291
Enthalpy (average), Btu/lbm	-	1150 (November 1981 analysis used 1200)

The Bechtel computer code COPATTA was used in November 1981, to analyze the pressure transient in this compartment following the postulated break. The COPATTA program is discussed in Section 14.20. The discharge mass rate and enthalpy were assumed constant at the maximum values given above.

The following assumptions are made for the Penetration Room:

Room Volume	=	24,000 ft^3
Vent Area	=	44.1 ft^2
Vent flow coefficient	=	0.71
Initial Room Temperature	=	160°F
Relative Humidity	=	70%
Total Heat Sink Area (Concrete Walls, Floor, Ceiling)	=	6765 ft^2

The following additional assumptions were used in the analysis.

a. No credit is taken for equipment such as heat sinks.

b. Room volume does not include the adjacent pipe tunnel nor is credit taken for steam flow into that area.

c. No credit is taken for heating, ventilation and air conditioning operation and the capability to remove heat.

d. Process heat loads are 130,285 Btu/hr until isolation and 65,142 Btu/hr for 3-1/2 hours thereafter. Heat load becomes zero 3-1/2 hours after isolation.

Results of the analysis are presented in Table 10A-1A. This table indicates that the maximum sustained temperature continues until the blowdown is isolated (also Figures 10A.1-15 and 10A.1-16).

10A.1.20.3 Circumferential Break Inside Encapsulation - 53.8 in^2 Clearance

The MS line encapsulations are located inside the MS valve compartment of the Auxiliary Building as shown in Figure 10A.1-2. The construction tolerances imposed on the design limit the gap between the MS line and the closure plates on the ends of the encapsulation and between the MS branch lines and the encapsulation. The total escape area of all openings in any encapsulation section will not exceed 53.8 in^2 for a guillotine break inside the encapsulation. This area does not include the 1" drain and 3/4" vent or take credit for the restraint bolt obstructions; however, these are insignificant in the pressure calculations. This will correspond to a break flow of approximately 545 lbm/sec using the same mass flux employed in the preceding section.

The November 1981, COPATTA analysis of this break assumed the same room characteristics as listed above. The flow rate of 545 lbm/sec and the enthalpy of 1200 Btu/lbm are assumed constant.

Results of this analysis are presented in Table 10A-1A. This table indicates that the maximum sustained temperature continues until the blowdown is isolated (also Figures 10A.1-17 and 10A.1-18.)

10A.1.20.4 Critical Crack in 34" Line - 8.5 in^2

A major MS line rupture in the tunnel between the MS valve compartment in the Auxiliary Building and the Turbine Building is not a credible event because it does not meet the criteria presented in Section 10A.1.2. Specifically, the steam lines in the tunnel are long, straight sections that have no high stress points or terminal ends. A critical crack, however, is postulated anywhere in the MS line.

The maximum mass and energy released from a critical crack were calculated in the same manner as discussed in Section 10A.1.20.2. The maximum exit conditions were found to be as follows:

Mass discharge rate, lbm/sec - 86
Enthalpy (average), Btu/lbm - 1150 (November 1981 analysis used 1200)

The Bechtel computer code COPATTA was used in the November 1981 analysis of this problem. The discharge mass rate and enthalpy were assumed constant at the maximum values given above. Assumptions are listed in 10A.1.20.2.

Results of this analysis are presented in Table 10A-1A. This table indicates that the maximum sustained temperature continues until the blowdown is isolated (also Figures 10A.1-19 and 10A.1-20.)

10A.1.20.5 Critical Crack in 4" Atmospheric Dump Line-0.32 in^2

The 4" lines between the MS header in the MS Penetration Room and the atmospheric dump valves are high energy lines. The atmospheric dump valves are normally closed; hence, the lines downstream of these valves are not in the high energy class.

All of the postulated break locations in the high energy portion of this line are in the MS Penetration Room. These breaks in the 4" lines are smaller than the encapsulated guillotine break discussed in Section 10A.1.20.3, and result in smaller peak compartment pressure.

To protect against critical cracks in those portions of the high energy atmospheric dump valve lines in the compartment above the MS Penetration Room, the lines are completely enclosed from the floor penetrations to a point beyond the valves.

These enclosures are sealed around the lines downstream of the valves and attached to the floor to prevent propagation of steam into the compartment. Steam leakage will be vented from the enclosure into the MS Penetration Room through the floor penetrations.

Therefore, the postulated break discussed in Section 10A.1.20.4 is controlling for the design of the enclosure. That break resulted in a maximum pressure in the MS Penetration Room of 2.2 psig. The enclosure is designed to contain an internal pressure of 5 psig. This affords protection against a critical crack in the atmospheric dump line and also against the postulated line breaks in the MS Penetration Room.

10A.1.21 INTEGRITY OF THE CONTAINMENT STRUCTURE AND A PIPE RUPTURE OUTSIDE THE CONTAINMENT

The Containment Structure is designed using load combinations as discussed in Appendix 5A. The method used in the analysis of the Containment Structure is discussed in Chapter 5.

Since the MS line is encapsulated from the containment boundary to the first high stress point, there will be no jet impingement forces due to a full postulated break to impair the structural integrity of the prestressed concrete Containment Structure.

10A.1.22 EFFECT OF THE BABCOCK & WILCOX, CANADA REPLACEMENT STEAM GENERATORS

The replacement of the original steam generators with Babcock & Wilcox, Canada replacement steam generators does not involve changes to the design of the main steam line piping or its supports and restraints located outside Containment. Babcock & Wilcox, Canada has evaluated the effect of the replacement steam generators on those hydraulic parameters that are significant in determining the magnitude of the forces caused by a pipe break. It is concluded that the loads from secondary side pipe breaks are either unchanged or are reduced with the replacement steam generators in place.

10A.1.23 REFERENCES

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2. General Electric Company Document No. 26A2625, "Systems Criteria and Application for Protection Against the Dynamic Effects of Pipe Break," February 1972
3. Proposed Guide for Type Test of Class I Electrical Valve Operators for Nuclear Power Generating Stations, Draft 13, IEEE Project Number 382, JCNPS/SC2.3, June 1972
4. Maximum Flow Rate of a Single Component, Two Phase Mixture," by F.J. Moody; ASME Transactions, Series C, Volume 87, 1965
5. Maximum Two Phase Vessel Blowdown from Pipes," by F.J. Moody, APED-4827; General Electric Company, April 20, 1965
6. Introduction to Structural Dynamics by Professor John M. Biggs, 1964 Edition, published by McGraw-Hill Book Company
7. Perry H. Peterson "Resistance to Fire and Radiation," American Society for Testing and Materials (ASTM) Special Technical Publication No. 169, page 201, dated 1956
8. EPRI Topical Report No. TR-1006937, Extension of the EPRI Risk-Informed ISI Methodology to Break Exclusion Region Programs, Rev. 0-A, August 2002

TABLE 10A-1A

MAIN STEAM PENETRATION ROOM ANALYSIS RESULTS

INITIAL ROOM TEMP. = 160°F	6"	34" (Encapsulation)	CRITICAL CRACK
Maximum Sustained Temperature[(d)]	316°F for 13.5 min[(a)]	316°F for 7.7 min[(b)]	308-320°F for 4 hrs[(c)]
Peak Temperature	327°F < 20 sec	318°F < 20 sec	331°F < 20 sec
Peak Pressure	0.52 psig at 0.35 sec	1.49 psig at 0.50 sec	2.23 psig at 101.5 sec
Time to Return to 160°F	16.9 hrs	9.7 hrs	40.4 hrs

[(a)] Based on time to isolate feedwater plus time to empty one steam generator.

[(b)] Based on time to empty one steam generator

[(c)] Based on leak being located and isolated during required four-hour tours.

[(d)] Times listed are those taken to isolate blowdown; i.e., maximum temperature persists until blowdown isolation in each analyzed case.

TABLE 10A-1

MAIN STEAM STRESS VALUES

Following is a stress summary of the intermediate points considered between the terminal ends. The postulated full break locations are shown on Figure 10A.1-2. All values are in psi.

		PRIMARY STRESS					
POINT NUMBER	SECONDARY STRESS[a] ($0.8S_A$)	LONGITUDINAL PRESSURE	LONGITUDINAL WEIGHT	SEISMIC OBE	OTHER[c]	TOTAL S_{PR}[b,d] ($<0.8\ S_h$)	TOTAL STRESS[e] [$<0.8\ (S_A + S_h)$]
2	14,513	4,910	415	50	569	5,944	20,457
3	18,121	4,910	1,968	210	323	7,411	25,532
4	22,131	4,910	4,154	343	304	9,711	31,842
6	10,943	4,910	315	22	539	5,786	16,729
7	18,845	4,910	1,726	88	375	7,099	25,944
8	20,069	4,910	2,908	326	107	8,148	28,217

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[a] S_A = The larger of $f\ [1.25\ S_c + 0.25\ S_h + (S_h - S_{PR})]$ or

$f(1.25\ S_c = 0.25\ S_h)$ as per paragraph 102.3.2(c) and (d) of the USAS Code for Pressure Piping, USAS B31.1.0-1967, and as per NC-3600 of Section III (Nuclear Power Plant Components), ASME Boiler and Pressure Vessel (B&PV) Code. 0.85 S_A taken as 21,000 psi.

[b] S_c and S_h are the allowable stresses at cold and hot conditions, respectively, for Class 2 and Class 3 components as per ASME B&PV Code, Section III (Nuclear Power Plant Components).

[c] Other stresses are: 1) Due to steam or water hammer
2) Due to relief valve discharge.

[d] S_{PR} is the total of columns 3 through 6.

[e] $0.8\ (S_A + S_h)$ taken as 35,000 psi.

TABLE 10A-2

STRESSES ON STRUCTURAL COMPONENTS DUE TO JET IMPINGEMENT FORCES RESULTING FROM A CRITICAL CRACK OF THE MAIN STEAM LINE

					CALCULATED STRESSES[a] DUE TO JET FORCE PLUS 1 psi		CALCULATED STRESSES VS. ALLOWABLE STRESSES	
STRUCTURAL COMPONENT	THICKNESS	DIST FROM RUPTURE	JET FORCE 1.26 PA	CROSS SECTION TARGET AREA ft^2	COMPRESSIVE CONC (psi)	TENSILE REINF (psi)	CONCRETE	REINFORCING
North Tunnel Wall	1'0"	2'0"	9,640	1.40	710	26,000	0.209	0.722
South Tunnel Wall	2'0"	3'0"	9,640	2.40	539	18,400	0.158	0.511
Tunnel Floor	1'3"	1'0"	9,640	0.60	1,012	20,950	0.297	0.582
Tunnel Ceiling EL 33'6"	1'4"	2'6"	9,640	2.00	650	14,039	0.191	0.390
New Wall @ Col. Line 6.1	1'3"	4'0"	9,640	3.90	1,065	25,885	0.313	0.719
Wall L_b	1'9"	3'6"	9,640	3.15	518	16,791	0.152	0.466
Wall 17	2'0"	3'0"	9,640	2.50	539	18,400	0.158	0.511
New Wall @ Col. Mc	1'3"	10'0"	9,640	17.30	376	9,129	0.110	0.253
Floor EL 27'0"	2'6"	1'0"	9,640	0.60	655	20,600	0.193	0.572
Ceiling EL 45'0"	1'3"	11'5"	9,640	21.80	480	11,640	0.141	0.323
Ceiling EL 45'0"	2'6"	3'0"	9,640	2.50	50	1,580	0.01	0.044

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[a] Stresses shown are maximum stresses and include live load, dead load, equipment load & SSE seismic stresses.

TABLE 10A-3

STRESSES ON STRUCTURAL COMPONENTS IN THE MAIN STEAM COMPARTMENT DUE TO POSTULATED MAIN STEAM PIPE RUPTURE

		CALCULATED STRESSES[(a)] DUE TO PRESSURIZATION OF 2.6 psi[(b)]		CALCULATED STRESSES VS. ALLOWABLE STRESSES	
STRUCTURAL COMPONENT	THICKNESS	COMPRESSIVE IN CONCRETE (psi)	TENSILE IN REINFORCING (psi)	CONCRETE	REINFORCING
North Tunnel Wall	1'0"	230	8,420	0.068	0.234
South Tunnel Wall	2'0"	492	16,312	0.145	0.453
Tunnel Floor	1'3"	555	11,480	0.163	0.319
Tunnel Ceiling EL 33'6"	1'4"	245	5,292	0.072	0.147
New Wall @ Col. Line 6.1	1'3"	592	14,388	0.174	0.40
Wall L_b	1'9"	438	13,454	0.129	0.374
Wall 17	2'0"	492	16,312	0.145	0.453
New Wall @ Col. Mc	1'3"	592	14,388	0.174	0.40
Floor EL 27'0"	2'6"	615	19,330	0.181	0.537
Ceiling EL 45'0"	1'3"	525	12,710	0.154	0.353
Ceiling EL 45'0"	2'6"	38	1,184	0.01	0.033

(a) Stresses shown are maximum stresses which include live load, dead load, equipment load, and SSE seismic forces.

(b) This pressure is based on original design analyses, later reviews have shown this value to be conservative - Section 10A.1.

TABLE 10A-4

STEAM LINE RUPTURE INCIDENT NO LOAD, 1-LOOP OPERATION BREAK INSIDE TURBINE BUILDING

TIME (sec)	TOTAL BLOWDOWN (lb/sec)	TOTAL MASS (lbs)
0.00	6655.01	0.00
1.00	6215.92	6.409×10^3
2.00	5836.57	1.241×10^4
3.00	5509.71	1.806×10^4
4.00	5219.13	2.338×10^4
5.00	4959.82	2.838×10^4
6.00	4731.27	3.315×10^4
7.00	4523.20	3.767×10^4
8.00	4339.18	4.201×10^4
9.00	4177.27	4.619×10^4
10.00	4033.25	5.022×10^4
20.00	1860.79	8.048×10^4
30.00	1725.64	9.850×10^4
40.00	1485.61	1.146×10^5
50.00	1300.55	1.283×10^5
60.00	1175.84	1.407×10^5
70.00	1067.60	1.518×10^5
80.00	980.12	1.620×10^5
90.00	908.10	1.714×10^5
100.00	848.02	1.802×10^5
150.00	658.80	2.171×10^5
180.00	585.99	2.358×10^5
200.00	546.93	2.470×10^5

TABLE 10A-7

COMPARISON OF TIME-HISTORY PIPE WHIP DESIGN METHOD WITH ENERGY BALANCE DESIGN METHOD

TIME-HISTORY DESIGN METHOD					CALVERT CLIFFS ENERGY BALANCE					
					USING GIVEN RESTRAINT DEFLECTION			USING PROPERTIES OF GIVEN RESTRAINT		
LOAD. COND.	FORCING FUNCTION	TIME SECONDS	MAX. LOAD ON RESTRAINT (kips)	RESTRAINT CAPACITY AT YIELD (kips)	FORCING FUNCTION (kips)	RESTRAINT CAPACITY AT YIELD (kips)	DUCTILITY RATIO	FORCING FUNCTION (kips)	RESTRAINT CAPACITY AT YIELD	DUCTILITY RATIO
1	258	0.0027	615	930	324	1080	5	324	994	5
	180	0.11								
	103	0.30								
2	258	0.0018	646	1050	324	1080	5	324	994	5
	180	0.0625								
	281	0.30								
3	310	0.0063	793	930	324	1080	5	324	994	5
	216	0.031								
	303	0.09								
	257	0.30								
4	310	0.0063	850	1050	324	1080	5	324	994	5
	216	0.031								
	303	0.09								
	257	0.30								

TABLE 10A-8

LOCATION OF DOORS BETWEEN TURBINE BUILDING AND AUXILIARY BUILDING

UFSAR FIGURE NO.	ELEVATION	LOCATION[a]	CAPABILITY
1-6	5'0"	Between columns 105 & 106	10 psig
1-6	5'0"	Between columns 107 & 108	10 psig
1-10	5'0"	Between columns 206 & 207	10 psig
1-10	5'0"	Between columns 208 & 209	10 psig
1-7	27'0"	Between columns 105 & 106	1 psig
1-7	27'0"	Between columns 107 & 108 (roll-up door)	1 psig
1-7	27'0"	Between columns 110 & 111	1 psig
1-7	27'0"	Between columns 112 & 113	1 psig
1-11	27'0"	Between columns 203 & 204	1 psig
1-11	27'0"	Between columns 206 & 207	1 psig
1-11	27'0"	Between columns 208 & 209	1 psig
1-8	45'0"	Between columns 105 & 106	0.65 psig
1-8	45'0"	Between columns 107 & 108 (roll-up door)	1 psig
1-8	45'0"	Between columns 110 & 111	0.65 psig
1-8	45'0"	Between columns 112 & 113 (double door)	0.65 psig
1-12	45'0"	Between columns 201 & 202 (double door)	0.65 psig
1-12	45'0"	Between columns 203 & 204	0.65 psig
1-12	45'0"	Between columns 206 & 207 (roll-up door)	1 psig
1-12	45'0"	Between columns 208 & 209	0.65 psig

(a) All doors are through the Turbine Building/Auxiliary Building wall.