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APPENDIX I

POSTULATED PIPE FAILURE ANALYSIS OUTSIDE OF CONTAINMENT

In AEC-DOL's letter to NSP of December 12, 1972 (Mr. Giambusso to Mr. Dienhart) it was stated that the Regulatory Staff's continuing review of reactor power plant safety indicates that the consequences of postulated pipe failures outside of the containment structure, including the rupture of a main steam or feedwater line, need to be adequately documented and analyzed by licensees and applicants, and evaluated by the staff as soon as possible.

The information presented in this Appendix is in response to the above request for information.

I.1 DESCRIPTION OF HIGH ENERGY SYSTEMS

I.1.1 DEFINITION

High energy piping systems are defined as those which have a service temperature above 200°F and a design pressure above 275 psig. The plant operational conditions, under which this definition applies, includes normal reactor operation and upset conditions (for example, anticipated operational occurrences).

I.1.2 IDENTIFICATION OF SYSTEMS

The systems of the Prairie Island Nuclear Generating Station which fall under the definition listed above are:

a) Main Steam System
b) Feedwater System
c) Steam Generator Blowdown System
d) Chemical and Volume Control System
e) Steam Supply to Auxiliary Feedwater Pump Turbine

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I.2 CRITERIA FOR PROTECTION AGAINST PIPE RUPTURE

I.2.1 DEFINITION OF A PIPING SYSTEM

A piping system is defined as having pressure-retaining components consisting of straight or curved pipe and pipe fittings such as elbows, tees and reducers. The boundaries of a system are described in terms of a piping run. A piping run interconnects components such as pressure vessels, pumps and rigidly-fixed valves or structural anchors that may act to restrain pipe movement beyond that required for design thermal displacement. A branch run differs from a main piping run only in that it originates at a piping intersection as a branch of the main pipe run.

Design Basis Breaks

Design Basis breaks in high-energy piping systems are defined in this section. The criteria for considering the effects of pipe whip, jet impingement and differential pressure are considered in subsequent sections.

Break Location Based on High Stress Points

There is no ASME Section III Code Class I piping outside containment for the Prairie Island Nuclear Generating Station.

The criteria used to determine the design basis piping break locations are as follows:

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

1) The terminal ends
2) At intermediate locations where:
   a) 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 or

b) a high-stress point has been calculated (minimum of 2 points)

Size and Orientation

Once a design basis break location has been established, as defined above, the break orientation and size depend upon the following additional conditions.

Longitudinal breaks in piping runs or branch runs will be examined for pipes of 4" nominal diameter and larger. A longitudinal break is parallel to the pipe axis and oriented at any point around the pipe circumference. The break area is equal to the effective cross-sectional flow area upstream of the break location with the length of the break equivalent to twice the inside pipe diameter. Dynamic forces resulting from such breaks are assumed to cause lateral pipe movements in the direction normal to the pipe axis.

Circumferential breaks must be considered in piping runs and branch runs exceeding a nominal 1-inch diameter. A circumferential break is perpenpicular to the pipe axis, and the break area is equivalent to the cross-sectional area of the ruptured pipe. Dynamic forces resulting from such breaks are assumed to separate the piping axially and cause whipping in any direction normal to the pipe axis.

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*S_h is the stress calculated by the rules of NC-3600 and ND-3600 for Class 2 and 3 components, respectively, of the ASME Code Section III Winter 1972 Addenda.

S_A is the allowable stress range for expansion stress calculated by the rules of NC-3600 of the ASME Code, Section III, or the USA Standard Code for Pressure Piping, ANSI B31.1.0-1967.

Design Basis Crack

A design basis crack is defined as a single open crack of a size of one-half the pipe diameter in length and one-half the pipe wall thickness in width. The location of this break can be anywhere along the length of the pipe.

Location

Where high-energy pipes are routed in the vicinity of structures and systems necessary for safe shutdown of the nuclear plant, a postulated crack in the pipe system will be postulated. The criteria for evaluating the effects of jet impingement and resulting steam-air environment will be considered and are discussed in subsequent paragraphs.

Size and Orientation

The orientation of the postulated crack can be in any direction in terms of affected required equipment. The most adverse locations with respect to the affected equipment will be selected.

I.2.2 CRITERIA FOR PIPE RUPTURE INDUCED LOADS

Pipe Whip

The reaction load resulting from pipe rupture will have the duration and initial conditions to adequately represent the jet stream dynamics and the system pressure characteristics.

The location of breaks for pipe-whip considerations are those defined in Section I.2.1. The loads induced from pipe rupture will include the effects of any line restrictions, for example, flow limiters, between the pressure source and the break location.

The effect of break-opening geometry on the magnitude of reaction loads will be incorporated in the analysis by the application of an appropriate, but conservative, discharge coefficient. For all circumferential breaks the discharge coefficient will have a value of 1.0. For longitudinal breaks the discharge coefficient will be determined by the postulated break-opening geometry for each case and may have a value less than but not greater than 0.85.

If a whipping pipe impacts adjacent pipes of equal or greater nominal pipe size and equal or heavier wall thickness, the adjacent pipe will be considered to be free from rupture. Protection from pipe-whip will not be provided if pipe rupture occurs in such a manner that the unrestrained pipe movement of either end of the ruptured pipe, in any possible direction about a plastic hinge formed at the nearest pipe-whip restraint, cannot impact any structure, system or component required for that incident.

Piping that is physically separated or isolated from structures, systems or components important to safety will be excluded from the analysis. The physical separation or isolation may take the form of protective barriers or pipe restraints designed specifically for pipe whip, such as concrete encasement.

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Compartment Pressure

Compartment differential pressure loadings from design basis events will be considered. The mass and energy flow rate, from either a single-ended or double-ended break, will be computed on the basis of the flow characteristics of the pipe immediately adjacent to the break. The mass and energy flow characteristics will be chosen such that a conservative calculation of compartment pressures can be made. The steam quality will be based upon the steam generator blowdown characteristics.

Jet Impingement

Jet impingement loads of safety-related equipment, components and structures will be considered for the design basis cases defined in Section I.2.1 in a high-energy system. The magnitude and area of influence of the jet will be determined for each break according to the break location, size and orientation criteria given in Section I.2.1 and the procedures described in Section I.5. The jet forces or loads at the point of rupture will be consistent with those used in the pipe whip analysis.

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I.2.3 DESIGN CRITERIA TO MITIGATE CONSEQUENCES OF PIPE RUPTURE

Pipe Restraints

The piping restraints will be designed to accommodate the loading induced by the reaction or whipping forces from design basis breaks. For a specific break location the pipe restraint will accommodate a longitudinal break extending one pipe diameter on each side of the high-stress point and a circumferential break at the high-stress point.

Structural Components

Existing seismic Class I structures will be reviewed for their adequacy. If required, these structures will be modified to the extent necessary to guarantee their integrity. Any new seismic Class I structures will be designed to withstand the effects of a postulated high energy system pipe failure. The analysis will consider the effects of pressure and temperature transients, static, thermal and dynamic reactions of the pipe in conjunction with the applicable loads as listed in Appendix B of the FSAR.

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

Failure of any structure, including seismic Class II or Class III structures, caused by the postulated accident will be reviewed to assure that it will not cause failure of any other structure, system, or component in a manner to preclude the mitigation of the consequences of the accident and the capability to bring the plant to a cold shutdown condition.

Criteria to analyze the structural adequacy of the existing or modified seismic Class I structure and the design of new seismic Class I structures where required will be in accordance with Appendix B.6. The method of evaluating stresses will be in accordance with the working-stress method.

Local Protection of Equipment

Barriers will be provided to protect needed equipment from adverse jet-force loadings from all design bases events. The barriers provided will be shown to withstand the impingement loads as well as the normal working loads.

I.2.4 CRITERIA FOR PLANT OPERABILITY FOLLOWING PIPE RUPTURE

Control Room Habitability

The control room will be maintained habitable and its equipment functional for all design bases events. Thus, the capability to bring the reactor to a cold shutdown condition from the control room will be maintained.

Operation of Needed Equipment

Electrical equipment required to function following the accident will be capable of withstanding the steam-air environment resulting from the postulated pipe rupture. Environmental qualifications of the equipment will be provided in the form of vendor test data or the equipment performance for these accident conditions under which the equipment must function will be conservatively evaluated.

Redundancy

The capability to mitigate the consequences of an accident and bring the reactor to a cold shutdown condition will be assured. Loss of redundancy of equipment required for a particular accident will not be permitted in the protection system (as defined in IEEE-279) and Class II electric system (as defined in IEEE-308), or for engineered safety features equipment, cable penetrations and their interconnecting cables.

Environmentally induced failures caused by a leak or rupture which would not in itself result in protective action but may disable protective

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function will also be considered. In this regard, a loss of redundancy will be permitted but a loss of function will not be permitted. For such situations the capability for bringing the plant to cold shutdown will be assured.

Separation Criteria

Separation criteria for cable systems will be identical to that described in Section 8.3.11.

Emergency Procedures

General emergency procedures will allow for evaluation of the specific incident and determination of appropriate actions to be taken to achieve a safe shutdown condition. Prompt achievement of hot shutdown will be assured automatically by adherence to the aforementioned criteria and maintenance of hot shutdown will be accomplished by adherence to general emergency procedures. These procedures will also allow for placing the reactor in a cold shutdown condition.

I.3 MAIN STEAM LINE ROUTING AND RUPTURE EVALUATION

I.3.1 ROUTING DESCRIPTION

The Main Steam piping from Steam Generator No. 11 exits from the southwest quadrant of containment on the Mezzanine Floor whereupon it enters the stopcheck and check (isolation) valves and anchor block assembly. The pipe then rises to the Operating Floor where it turns northward and runs horizontally through the Auxiliary Building and into the Turbine Building. The Main Steam pipe from Steam Generator No. 12, exits from the northwest quadrant of containment on the Mezzanine Floor and rises vertically to the Operating Floor where the stop-check and check (isolation) valves and anchor block are located. Steam Line No. 12 then rises to elevation 747' where it turns northward and runs horizontally parallel to pipe No. 11, through the Auxiliary Building and into the Turbine Building.

The above routing is shown isometrically on Fig. I.3-1. This isometric also shows all branch connections to the 30" Main Steam headers as well as the entire run of the 20" equalizing line near the turbine.

I.3.2 DESIGN BASES BREAKS

Description of Break Locations

Potential design basis pipe break locations are as shown on the Main Steam Isometric, Fig. I.3-1, and as described below. The stresses for the main steam piping system, were calculated with the aid of a computer program using general flexibility and response spectra model analysis techniques. The combined stress values due to thermal expansion, pressure, weight, and seismic loading conditions have been computed. 250

Description of Break Locations (Continued)

Postulated design basis break locations outside containment have been determined on the basis of calculated stress values and the criteria given in Section I.2.1 for Code Class 2 and 3 piping breaks. These consist of:

A. The terminal points of the main steam lines at the turbine stop valves in the turbine building and the anchor elbow inside containment.

B. Branch point connections in the main steam line for the atmospheric steam dump lines, the moisture separator and condenser steam dump lines, the auxiliary feedwater steam turbine lines, the equalizing line, and risers to safety valve and relief valve headers.

C. Two additional points having the highest calculated stress values in each main steam line, and the 20" equalizing line.

At no points do the calculated stress values exceed $0.8S_A$ or $0.8 (S_h + S_A)$. The two intermediate large break locations have been selected on the basis of their having the highest calculated stress values.

Required Equipment

The equipment required for a design basis break in the main steam line is given in Table I.3-1. Operability of this equipment provides for reactor trip and the capability to maintain the reactor at hot shutdown after the break as well as ultimately achieving cold shutdown. Required equipment includes associated piping, cables and structures required for the equipment to perform its function.

Protection from Potential Pipe Whip Damage

Pipe Rupture restraints will be provided, if required, in order to protect required equipment listed in Table I.3-1.

Protection from Jet Impingement

Impingement barriers or guardpipes will be provied, where required, in order to protect the needed equipment listed in Table I.3-1.

Protection from Adverse Environmental Conditions

Ventilation penetrations will be sealed as necessary to prevent Steam Environment from affecting required equipment located within the Control Room Air Conditioning Room, Control Room, Relay Room, Class 1 Area, Control Rod Drive Mechanism (CRDM) Room and Diesel Generator Rooms.

Protection from Potential High Compartment Differential Pressure

The compartments in which mainsteam and feedwater isolation valves associated with steam generator 11 are located appends the southwest quadrant of the Reactor Building and are a part of the Category I Ventilation Zone. The compartments are housed in a seismic Class I structure. The compartment for the main steam isolation valves is between the mezzanine and operating floors while the feedwater isolation valves are in a compartment between the operating and fuel handling floors. Both compartments are contiguous with the reactor building.

The compartments in which the Main Steam and Feedwater isolation valves from Steam Generator 12 are located append the Northern quadrant of the Reactor Building and are a part of Category I Ventilation Zone. The compartments located within the Auxiliary Building structure are contiguous with the Reactor Building at all levels.

Openings to the outdoor atmosphere will be provided through the existing exterior walls to the extent necessary to reduce the resultant compartment pressure of a high energy line rupture to a tolerable limit. The existing modified structure will be analyzed to assure structural integrity for all applicable environmental load conditions.

All communicating avenues including wall and floor openings and doors will be reviewed and modified as necessary to maintain Category I integrity from a high energy line rupture outside the zone. 252

I.3.3 DESIGN BASIS CRACK

Description

The orientation and location of a design basis crack can be anywhere along the piping shown on the Main Steam Isometric, Fig. I.3-1.

Required Equipment

The equipment required to place the reactor in a cold-shutdown condition is shown in Table I.3-1. Required equipment includes associated piping, cabling and structures required for the equipment to perform its functions.

Protection from Potential Pipe Whip Damage

No additional pipe restraints are required.

Protection from Jet Impingement

Impingement barriers or guard pipes will be provided, where required, in order to protect the needed equipment listed in Table I.3-1.

Protection from Environmental Conditions

Required equipment exposed to environmental conditions are analyzed for their capacity to perform their function and will be qualified to perform in the anticipated environment.

I.4 FEEDWATER ROUTING AND RUPTURE EVALUATION

I.4.1 ROUTING DESCRIPTION

The 16" discharge of each main feedwater pump is routed through a check valve, motor operated valve and feedwater heater before joining in the Turbine Building into a single 22" line. Before entering the Auxiliary Building the Feedwater Line bifurcates into two 16" lines - one for each steam generator. The line to Steam Generator No. 11 enters the Auxiliary Building on the Operating Floor Running in a southerly direction parallel to main steam line 11, before entering containment in the southwest quadrant. The line to Steam Generator No. 12 enters the Auxiliary Building on the Operating floor running in a southerly direction parallel to main steam line 12, before entering containment in the northwest quadrant. Each line is provided with a flow nozzle, control valve, motor operated isolation valve and anchor block before entering containment.

I.4.2 DESIGN BASIS BREAKS

Description of Break Locations

Postulated design basis pipe break locations are as shown on the Feedwater Isometric, Fig. I.4-1. These locations have been determined on the basis of calculated stress values based on the as built system and the criteria given in Section I.2.1 for Code Class 2 and 3 piping breaks.

These consist of:

A. The terminal points which are located at the high pressure feedwater heaters, and the anchor elbow inside containment.

B. Branch point connections for the 4" feedwater control valve by-pass lines, and the feedwater heater by-pass lines.

C. Two additional points having the highest calculated stress values in the main feedwater lines to each steam generator.

At no point do the calculated stress values exceed $0.8 S_A$ or $0.8 (S_h + S_A)$, and that the two intermediate large break locations have been selected on the basis of their having the highest calculated stress values. Some of these points correspond with branch point connections.

Required Equipment

The equipment needed for a design basis in the feedwater line is given in Table I.4-1. Operability of this equipment provides for reactor trip and the capability to place and maintain reactor in a cold shutdown condition. Required equipment includes associated piping, cables and structures required for the equipment to perform its function.

Protection from Potential Pipe Whip Damage

Pipe Rupture restraints will be provided, where required, in order to protect required equipment listed in Table I.4-1.

Protection from Jet Impingement

Impingement barriers or guardpipes will be provided, where required, in order to protect the required equipment listed in Table I.4-1.

Protection from Adverse Environmental Conditions

Ventilation penetrations will be sealed or necessary to prevent the steam environmental from affecting required equipment located within the Control Room Air Conditioning Room, Control Room, Relay Room, Class I Area CRDM Room and Diesel Generator Rooms.

I.4.3 Design Basis Cracks

Description

The orientation and location of a design basis crack can be anywhere along the piping shown on the feedwater Isometric, Fig. I.4-1.

Required Equipment

The equipment required to place the reactor in a cold-shutdown condition is given in Table I.4-1. Required equipment includes associated piping, cabling and structures required for the equipment to perform it functions.

Protection from Potential Pipe Whip Damage

No additional pipe restraints are required.

Protection from Jet Impingement

Impingement barriers or guard pipes will be provided, where required, in order to protect the needed equipment listed in Table I.4-1.

Protection from Environmental Conditions

Required equipment exposed to environmental conditions resulting from small breaks will be analyzed for their capability to perform their function and will be qualified to perform in the anticipated environment.

I.5 CVCS LETDOWN LINE ROUTING AND RUPTURE EVALUATION

Ruptures of the CVCS letdown line (upstream of the letdown heat exchanger) are being analyzed in a manner similar to that described for the main steam and feedwater lines.

I.6 STEAM GENERATOR BLOWDOWN LINE ROUTING AND RUPTURE EVALUATION

Ruptures of the steam generator blowdown line are being analyzed in a manner similar to that described for the main steam and feedwater lines.

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I.7 STEAM SUPPLY TO AUXILIARY FEEDWATER PUMP TURBINE

Rupture of the Auxiliary Feedwater Pump Turbine Steam lines are being analyzed in a manner similar to that described for the main steam and feedwater lines.

I.8 EMERGENCY PROCEDURES

The emergency procedures listed below are general in nature since it is deemed appropriate to allow for assessment of the incident prior to ultimately bringing the reactor to cold shutdown.

I.8.1 MAIN STEAM LINE RUPTURE

Design Basis Breaks

In the unlikely event of a design basis break in a Main Steam Line, the reactor will be automatically tripped and the Safety Injection sequence initiated due to low steam generator pressure. The Safety Injection pumps will deliver highly concentrated boric acid (20,000 ppm Boron) from the boric acid storage tanks to the reactor coolant system in sufficient quantity to allow cold shutdown. In order to replace the volume of water in the reactor coolant system lost due to increased density because of temperature reduction (shrinkage), the Safety Injection pumps will also deliver water from the refueling water storage tank. After the pipe rupture, and the reactor coolant system has cooled to conditions below 750 psi and 400°F, the auxiliary feedwater system and main steam power-operated relief valves will provide the heat removal capability for reducing the reactor coolant system to the cold shutdown condition. As described in Section 14, the plant is designed to accept this failure with concurrent loss of off-site power (diesel power available only) and a single active failure in a required system. In addition, all required systems are operable from the control room or accessible for manual operation.

If a rupture should occur in the main steam line that would not directly cause a reactor trip, the operator has numerous devices (steam flow versus feedwater flow, steam generator pressure, steam generator level, etc.) to detect such an event. If deemed necessary by the operator, shutdown of the reactor could be manually initiated using manual safety injection controls which would then automatically initiate the following:

1. Reactor trip and subsequent hot shutdown
2. Start safety injection pumps
3. Start auxiliary feedwater pumps
4. Initiate containment isolation

In order to take the reactor from hot shutdown to cold shutdown, the pressurizer power-operated relief valves would be operated to temporarily reduce reactor coolant system pressure to allow the safety injection pumps to deliver enough boric acid to achieve cold shutdown conditions and replace the volume of water in the reactor coolant system lost due to "shrinkage". After closing the pressurizer power-operated relief valves, the auxiliary feedwater system and the main steam power-operated relief valves will provide the heat removal capability for reducing reactor coolant system to the cold shutdown condition. As described in Section 14, the plant is designed to accept this failure with concurrent loss of off-site power (diesel power available only) and a single active failure in a required system. In addition, all required systems are operable from the Control Room or accessible for manual operation.

However, the operator would have other alternate systems available to him following the incident to facilitate an orderly shutdown of the reactor. Hence the method and procedure to be used for shutdown will be determined by the operator based on the equipment available to him.

I.8.2 FEEDWATER LINE RUPTURE

Design Basis Breaks

In the unlikely event of a design basis break in a main feedwater line, the reactor will be automatically tripped and the safety injection sequence initiated due to low-low steam generator level or steam flow-feedwater flow mismatch with coincident low steam generator water level. As described in Section 6.6, the Auxiliary Feedwater System and the Steam Generator safety valves provide the ultimate heat sink for the reactor coolant system following this incident. In order to take the reactor from hot shutdown to cold shutdown, the pressurizer power operated relief valves would be operated to temporarily reduce reactor coolant system pressure to allow the safety injection pumps to add enough boric acid to achieve cold shutdown conditions and replace the volume of water in the reactor coolant system lost due to "shrinkage." After closing the pressurizer power-operated relief valves, the auxiliary feedwater system and the main steam power-operated relief valves will provide the ultimate heat sink for reducing reactor coolant system temperature and pressure. As described in Section 14, the plant is designed to accept this failure with concurrent loss of off-site power (diesel power available only) and a single active failure in a required system. In addition, all required systems are operable from the Control Room or accessible for manual operation.

If a rupture should occur in the feedwater line that would not directly cause a reactor trip, the operator has numerous devices (steam flow versus feedwater flow, steam generator pressure, steam generator level, etc.) to detect such an event. If deemed necessary by the operator, shutdown of the reactor could be manually initiated by a safety injection signal which would then automatically initiate the following:

1. Reactor trip and subsequent hot shutdown
2. Start safety injection pumps
3. Start auxiliary feedwater pumps
4. Initiate containment isolation

In order to take the reactor from hot shutdown to cold shutdown, the pressurizer power-operated relief valves would be operated to temporarily reduce reactor coolant system pressure to allow the safety injection pumps to deliver enough boric acid to achieve cold shutdown conditions and replace the volume of water in the reactor coolant system lost due to "shrinkage". After closing the pressurizer power operated relief valves, the auxiliary feedwater system and the main steam power operated relief valves will provide the heat removal capability for reducing reactor coolant system temperature and pressure. As described in Section 14, the plant is designed to accept this failure with concurrent loss of off-site power (diesel power available only) and a single active failure in a required system. In addition, all required systems are operable from the control room or accessible for manual operation.

However, the operator would have other alternate systems available to him following the incident to facilitate an orderly shutdown of the reactor. Hence the method and procedure to be used for shutdown will again be determined by the operator based on the equipment available to him.

I.9 DESCRIPTION OF PIPE WHIP DYNAMIC ANALYSIS

Restraints will be provided to prevent pipe whip where there is any possibility that whip following a pipe rupture would damage systems, components or structures that are needed to mitigate the consequences of that pipe rupture.

A nonlinear elastic-plastic analysis is performed to evaluate the adequacy of the pipe rupture restraint system to provide protection following postulated circumferential and longitudinal pipe breaks. The coupled nonlinear dynamic analysis of the restraint - piping system will account for the dynamic nature of the rupture force, the elastic-plastic deformation of the pipe restraint system, and the impact effects resulting from clearance between the restraint and pipe.

The results of the analysis includes identification of plastic hinges formed in the pipe, strain in hinges, and restraint status including gap closure, elastic or plastic deformation and reacting loads.

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I.10 DESCRIPTION OF COMPARTMENT PRESSURE DIFFERENTIAL ANALYSIS

The widely used CONTEMPT code is used to determine the local pressure on building walls and floor, and compartment temperatures. Modifications have been made to the code to analyze a group of connected compartments to determine the transient conditions. The blowdown is assumed to occur when the reactor coolant system is at hot standby with the steam generator pressure at 1000 psig. The blowdown rate and duration depend on the break location and size. Exposed steel and concrete are considered as heat sinks, and individual fan-coil units and normal ventilation are used for heat removal when available.

In the compartment where pipe rupture occurs, the mass and energy input rates are based on the blowdown for the specific break. The initial conditions of all compartments are identical. A sequence of calculations is performed to determine the mass and energy transferred between compartments for a short time interval. The time interval is carefully selected to assure that the solution for compartment pressure transients converges. The sequence begins in the compartment where the break occurs by evaluating the mass and energy input rates at the midpoint of a time interval and adding these increments to the current amounts in the compartment. An intermediate state is then obtained by applying energy- and mass-balance equations to the total contents of the compartment. No discharge or outflow is assumed to take place at this intermediate phase of the calculation.

The intermediate state in the break compartment, the adjacent compartment conditions at the beginning of the time interval, and the flow geometry, determine the amount of steam and air to be discharged to adjacent compartments. The final state of the break compartment, after a portion of steam and air has been discharged, is obtained again by an energy and mass balance. The same calculational procedures are repeated for each adjacent compartment.

I.11 DESCRIPTION OF JET IMPINGEMENT LOAD ANALYSIS

The jet impingement load is defined as the load on a component (piping, equipment or structure) of the undeflected jet from an instantaneous circumferential or longitudinal break ina high energy pipe.

At the point of rupture, the jet pressure is assumed equal to the critical flow rate exit pressure P_e, and the jet area is assumed to be the effective break area (A). For pipes initially containing steam, the jet flow away from the point of rupture is assumed to diverge at an included angle (Ø) of 20°. The angle of divergence (Ø) for a jet from pipes initially containing saturated or subcooled water is determined by the expansion ratio necessary to establish equilibrium at ambient pressure, and depends on the initial fluid conditions. Hence, the area of the jet at some distance from the point of a longitudinal break is:

$$A_i = [L_1/2 + (L_3/2) \text{ Tan } (\phi/2)] \; [L_2/2 + (L_3/2) \text{ Tan } (\phi/2)]\pi$$

where:

L_1 = width of break

L_2 = length of break

L_3 = distance to target

Ø = divergence angle

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The 2-phase maximum impingement pressure along the jet centerline is:

$$P = \frac{U_f^2}{2g_c V_f} (\alpha - 1) + (P_0 - P_{static})\alpha$$

where:

C_{ave} = averaging factor based on experimental velocity profiles

P_0 = jet fluid stagnation pressure

P_{static} = jet fluid static pressure

U_f = velocity of fluid phase in jet

V_f = specific volume of fluid

α = steam void fraction

The average jet pressure at some distant target is,

$$P_i = P\ C_{ave}$$

The effective load on a distant target is:

$$F_e = f\ P_i A_e$$

where:

A_e = projected area of the target object

f = shape factor of the target object

Once the effective jet impingement load is determined, each target is analyzed to determine the necessity for providing protection.

I.12 CONTAINMENT INTEGRITY

The present anchor block and restraint system design will preclude any damage to the Containment Vessel, Shield Building, containment penetrations and Shield Building Penetrations due to any of the postulated breaks previously described.

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TABLE I.3-1

REQUIRED EQUIPMENT LIST FOR MAIN STEAM LINE BREAK

A. MECHANICAL EQUIPMENT

*Safety Injection Pumps 1A, 1B, 2A & 2B
Auxiliary Feedwater Pumps 11, 12, 21 & 22
Diesel Cooling Water Pumps 12 & 22
Cooling Water Pump Strainers 11, 12, 21 & 22
Diesel Generators 11 & 12 With Auxiliaries
Control Room Ventilation System 121 & 122

B. VALVES

*32079 (32182) SIS Pump Suction From RWST
*32080 (32183) SIS Pump Suction From RWST
*32081 (32184) SIS Pump Suction From Boric Acid Tanks
*32082 (32185) SIS Pump Suction From Boric Acid Tanks
32025 (32030) AFWP 11 (22) Suction From Cooling Water
32027 (32026) AFWP 12 (21) Suction From Cooling Water
32264 (32265) AFWP 11 (22) Steam Supply
31059 (31060) AFWP 11 (22) Steam Supply Throttle Valve
32023 (32038) Steam Gen. 11 (21) Feedwater Isolation
32024 (32029) Steam Gen. 12 (22) Feedwater Isolation
31098 (31116) Main Stream Isolation Valve 11 (21)
31099 (31117) Main Steam Isolation Valve 12 (22)
*31084 (31102) Atmospheric Relief Valve 11 (21)
*31089 (31107) Atmospheric Relief Valve 12 (22)

C. ELECTRICAL COMPONENTS

The controls, power and protection for the mechanical equipment previously listed as well as:

Reactor Trip Breakers
Batteries 11, 12, 21 & 22
480 Volt Buses 110, 120, 210 & 220
4160 Volt Buses 15, 16, 25 & 26

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D. INSTRUMENTATION

Steam Generator 11 (21) Pressure PT-468, 469 & 482

Steam Generator 12 (22) Pressure PT-478, 479 & 483

Steam Generator 11 (21) Level LT-461, 462 & 463

Steam Generator 12 (22) Level LT-471, 742 & 473

*Boric Acid Tank 11 (12) Level LT-106, 172 & 190 **

*Boric Acid Tank 121 Level LT-102, 171 & 189 **

E. VENTILATION DAMPERS (CONTROL ROOM)

34177 (34176) Outside Air Inlet

34145 (34142) Outside Air Inlet to Air Conditioner

34144 (34143) Air Conditioner Outlet

34180 (34178) Outside Air Inlet to PAC Filter

34181 (34179) Recirculation inlet to PAC Filter

34183 (34182) PAC Filter Outlet

Notes:

* These items are not required to function immediately, due to a design basis crack, but will be used during subsequent operation to achieve a cold shutdown condition.

** A fourth level channel will be provided for each boric acid storage tank, however, only one channel will be required for indication to achieve cold shutdown.

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TABLE I.4-1

REQUIRED EQUIPMENT FOR FEEDWATER LINE BREAK

A. MECHANICAL EQUIPMENT

*Safety Injection Pumps 1A, 1B, 2A & 2B
Auxiliary Feedwater Pumps 11, 12, 21 & 22
Diesel Cooling Water Pumps 12 & 22
Cooling Water Pump Strainers 11, 12, 21 & 22
Diesel Genrators 11 & 12 With Auxiliaries
Control Room Ventilation System 121 & 122

B. VALVES

*32079 (32182) SIS Pump Suction From RWST
*32080 (32183) SIS Pump Suction From RWST
*32081 (32184) SIS Pump Suction From Boric Acid Tanks
*32082 (32185) SIS Pump Suction From Boric Acid Tanks
32025 (32030) AFWP 11 (22) Suction From Cooling Water
32027 (32026) AFWP 12 (21) Suction From Cooling Water
32264 (32265) AFWP 11 (22) Steam Supply
31059 (31060) AFWP 11 (22) Steam Supply Throttle Valve
32023 (32038) Steam Gen. 11 (21) Feedwater Isolation
32024 (32029) Steam Gen. 12 (22) Feedwater Isolation
31098 (31116) Main Stream Isolation Valve 11 (21)
31099 (31117) Main Steam Isolation Valve 12 (22)
*31084 (31102) Atmospheric Relief Valve 11 (21)
*31089 (31107) Atmospheric Relief Valve 12 (22)
*31231 (31233) Pressurizer Relief Valve
*31232 (31234) Pressurizer Relief Valve

C. ELECTRICAL COMPONENTS

The controls, power and protection for the mechanical equipment previously listed as well as:

Reactor Trip Breakers
Batteries 11, 12, 21 & 22
480 Volt Buses 110, 120, 210 & 220
4160 Volt Buses 15, 16, 25 & 26

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D. INSTRUMENTATION

Steam Generator 11 (21) Pressure PT-468, 469 & 482

Steam Generator 12 (22) Pressure PT-478, 479 & 483

Steam Generator 11 (21) Level LT-461, 462 & 463

Steam Generator 12 (22) Level LT-471, 742,& 473

*Boric Acid Tank 11 (12) Level LT-106, 172 & 190 **

*Boric Acid Tank 121 Level LT-102, 171 & 189 **

Steam Generator 11 (21) Steam Flow FT-464 & 465

Steam Generator 12 (22) Steam Flow FT-474 & 475

Steam Generator 11 (21) Feedwater Flow FT-466 & 467

Steam Generator 12 (22) Feedwater Flow FT-476 & 477

*Pressurizer Level LT-426, 427 & 428

*Pressurizer Pressure PT-429, 430 & 431

E. VENTILATION DAMPERS (CONTROL ROOM)

34177 (34176) Outside Air Inlet

34145 (34142) Outside Air Inlet to Air Conditioner

34144 (34143) Air Conditioner Outlet

34180 (34178) Outside Air Inlet to PAC Filter

34181 (34179) Recirculation inlet to PAC Filter

34183 (34182) PAC Filter outlet

Notes:

* These items are not required to function immediately, due to design basis events, but will be used during subsequent operation to achieve a cold shutdown condition.

** A fourth level channel will be provided for each boric acid storage tank, however, only one channel will be required for indication to achieve cold shutdown.

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