GE Nuclear Energy

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Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: **Submittal Supporting Accelerated ABWR Review Schedule - SSAR Section 3.6**

Dear Chet:

Enclosed is a draft of the new Appendix 3L, "Procedure for Evaluation of Postulated Ruptures in High Energy Pipes" and SSAR markups for Subsections 3.6-1 and 3.6-2.

The balance of the SSAR markup will be transmitted by March 2, 1993.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Paul Chen (ETEC)
Norman Fletcher (DOE)
Maryann Herzog (GE)
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JF93-40

Response to:
SER Open Item 3.6.2-1

APPENDIX 3X L

PROCEDURE FOR EVALUATION OF POSTULATED RUPTURES IN HIGH ENERGY PIPES.

3X.1 BACKGROUND AND SCOPE

An evaluation of the dynamic effects of fluid dynamic forces resulting from postulated ruptures in high energy piping systems is required by SRP 3.6.1 and 3.6.2. The criteria for performing this evaluation is defined in Sections 3.6.1 and 3.6.2 of this SSAR and in the Standard Review Plans and ANS 58.2 which are referenced in the SSAR.

This Appendix defines an acceptable procedure for performing these evaluations. The procedure is based on use of analytical methodology, computer programs and pipe whip restraints used by GE, but it is intended to be applicable to other computer programs and to pipe whip restraints of alternate design. Applicability of alternate programs will be justifed by the COL.

The evaluation is performed in four major steps:

(1) Identify the location of the postulated rupture and whether the rupture is postulated as circumferential or longitudinal.

(2) Select the type and location of the pipe whip restraints.

(3) Perform a complete system dynamic analysis or a simplified dynamic analysis of the ruptured pipe and its pipe whip restraints to determine the total movement of the ruptured pipe, the loads on the pipe, strains in the pipe whip restraint, and the stresses in the penetration pipe.

(4) Evaluate safety related equipment that may be impacted by the ruptured pipe or the target of the pipe rupture jet impingement.

The criteria for locations where pipe ruptures must be postulated and the criteria for defining the configuration of the pipe rupture are defined in Subsection 3.6.2 of this SSAR. Also defined in SSAR Subsection 3.6.2 are: (1) the fluid forces acting at the rupture location and in the various segments of the ruptured pipe, (2) the jet impingement effects including jet shape and direction and jet impingement load.

The high energy fluid systems are defined in Subsection 3.6.2.1.1 and identified in Tables 3.6-3 and 3.6-4. Essential systems, components and equipments, or portions thereof, specified in Tables 3.6-1 and 3.6-2 are to be protected from pipe break effects which would impair their ability to facilitate safe shutdown of the plant.

The information contained in Subsections 3.6.1 and 3.6.2 and in the SRP's and ANS 58.2 is not repeated in this Appendix.

3X.2 IDENTIFICATION OF RUPTURE LOCATIONS AND RUPTURE GEOMETRY

3X.2.1 Ruptures in Containment Penetration Area.

Postulation of pipe ruptures in the portion of piping in the containment penetration area is not allowed. This includes the piping between the inner and outer isolation valves. Therefore, examine the final stress analysis of the piping system and confirm that, for all piping in containment penetration areas, the design stress and fatigue limits specified in Subsection 3.6.2.1.4.2 are not exceeded.

3X.2.2 Ruptures in Areas other than Containment Penetration.

(1) Postulate breaks in Class 1 piping in accordance with Subsection 3.6.2.1.4.3.

(2) Postulate breaks in Classes 2 and 3 piping in accordance with Subsection 3.6.2.1.4.4.

(3) Postulate breaks in seismically analyzed non-ASME Class piping in accordance with the above requirements for Classes 2 and 3 piping.

3X.2.3 Determine the Type of Pipe Break

Determine whether the high energy line break is longitudinal or circumferential in accordance with Subsection 3.6.2.1.6.1.

3X.3 DESIGN AND SELECTION OF PIPE WHIP RESTRAINTS

3X.3.1 Make Preliminary Selection of Pipe Whip Restraint

The load carrying capability of the GE U-Bar pipe whip restraint is determined by the number, size, bend radius and the straight length of the U-bars. The pipe whip restraint must resist the thrust force at the pipe rupture location and the impact force of the pipe. The magnitude of these forces is a function of the pipe size, fluid, and operating pressure.

A preliminary selection of one of the standard GE pipe whip restraints is made by matching the thrust force at the rupture location with a pipe whip restraint capable of resisting this thrust force. This is done by access to the large data base contained in the GE REDEP computer file. This file correlates the pipe size and the resulting thrust force at the pipe rupture with the U-bar pipe whip restraints designed to carry the thrust force. REDEP then supplies the force/deflection data for each pipe whip restraint.

3X.3.2 Prepare Simplified Computer Model of Piping-Pipe Whip Restraint System.

Prepare a simplified computer model of piping system as described in 3X.4.2.1 and as shown in Figures 5-2, 5-3 and 5-4. Critical variables are length of pipe, type of end condition, distance of pipe from structure and location of the pipe whip restraint. Locate the pipe whip restraint as near as practical to the ruptured end of the pipe but establish location to minimize interference to Inservice Inspection.

3X.3.3 Run "Pipe Dynamic Analysis" (PDA)

Run the PDA computer program using the following input:

1. The information from the simplified piping model, including pipe length, diameter, wall thickness and pipe whip restraint location.

2. Piping information such as pipe material type, stress/strain curve and pipe material mechanical properties.

3. Pipe whip restraint properties such as force-deflection data and elastic plastic displacements.

4. Force time-history of the thrust at the pipe rupture location.

3X.3.4 Select Pipe Whip Restraint for Pipe Whip Restraint Analysis.

PDA provides displacements of pipe and pipe whip restraint, pipe whip U-bar strains, pipe forces and moments at fixed end, time at peak load and lapsed time to achieve steady state using thrust load and pipe characteristics.

Check displacements at pipe broken end and at pipe whip restraint and compare loads on the piping and strains of pipe whip restraint U-bars with allowable loads and strains. If not satisfied with output results rerun PDA with different pipe whip restraint parameters.

3X.4 PIPE RUPTURE EVALUATION

3X.4.1 GENERAL APPROACH

There are several analytical approaches that may be used in analyzing the pipe/pipe whip restraint system for the effects of pipe rupture. This procedures defines two acceptable approaches.

(1) Dynamic Time-History Analysis With Simplified Model: A dynamic time history analysis of a portion of a piping system may be performed in lieu of a complete system analysis when it can be shown to be conservative by test data or by comparison with a more complete system analysis. For example, in those cases where pipe stresses in the containment penetration region need not be calculated, it is acceptable to model only a portion of the piping system as a simple cantilever with fixed or pinned end or as a beam with fixed ends.

When a circumferential break is postulated, the pipe system is modeled as a simple cantilever, the thrust load is applied opposite the fixed (or pinned) end and the pipe whip restraint acts between the fixed end and thrust load. It is then assumed that all deflection of the pipe is in one plane. As the pipe moves a resisting bending moment in the pipe is created and later a restraining force at the pipe whip restraint. Pipe movement stops when the resisting moments about the fixed (or pinned) end exceed the applied thrust moment.

When a longitudinal break is postulated, the pipe system has both ends supported. To analyze this case, two simplifications are made to allow the use of the cantilever model described above. First, an equivalent point mass is assumed to exist at D (See Fig 5-4) instead of pipe length DE. The inertia characteristics of this mass, as it rotates about point B, are calculated to be identical to those of pipe length DE, as it rotates about point E. Second, an equivalent resisting force is calculated (from the bending moment-angular deflection relationships for end DE) for any deflection for the case of a built-in end. This equivalent force is subtracted from the applied thrust force when calculating the net energy.

See Figures 5-2, 5-3 and 5-4 for the models described above.

(2) Dynamic Time-History Analysis with Detailed Piping Model. In many cases it is necessary to calculate stresses in the ruptured pipe at locations remote from the pipe whip restraint location. For example, the pipe in the containment penetration area must meet the limits of SRP 3.6.2. In these cases it is required the ruptured piping, the pipe supports, and the pipe whip restraints be modeled in sufficient detail to reflect its dynamic characteristics. A time-history analysis using the fluid forcing functions at the point of rupture and the fluid forcing functions of each pipe segment is performed to determine deflections, strains, loads to structure and equipment and pipe stresses.

3X.4.2 PROCEDURE FOR DYNAMIC TIME-HISTORY ANALYSIS WITH SIMPLIFIED MODEL.

3X.4.2.1 Modeling of Piping System:

For many piping systems, all required information on their response to a postulated pipe rupture can be determined by modeling a portion of the piping system as a cantilever with either a fixed or pinned end, as shown in Figures 5-2, 5-3 and 5-4, based on the piping configuration. The pipe whip restraint is modeled as two components acting in series; the restraint itself and the structure to which the restraint is attached. The restraint and piping behave as determined by an experimentally or analytically determined force-deflection relationship. The structure deflects as a simple linear spring of representative spring constant.

The model must account for the maximum clearance between the restraint and the piping. The clearance is equal to the maximum distance from the pipe during normal operation to the position of the pipe when the pipe whip restraint starts picking up the rupture load. This simplified model is not used if the piping has snubbers or restraints strong enough to affect the pipe movement following a postulated rupture.

3X.4.2.2 Dynamic Analysis of Simplified Piping Model.

When the thrust force (as defined in ~~Paragraph~~ Subsection 3.6.2.2.1) is applied at the end of the pipe, rotational acceleration will occur about the fixed (or pinned) end. As the pipe moves, the net rotational acceleration will be reduced by the resisting bending moment at the fixed end and by the application of the restraining force at the pipe whip restraint. The kinetic energy will be absorbed by the deflection of the restraint and the bending of the pipe. Movement will continue until equilibrium is reached. The primary acceptance criteria is the pipe whip restraint deflection or strain must not exceed the design strain limit of 50% of the restraint material ultimate uniform strain capacity.

The analysis may be performed by a general purpose computer program with capability for nonlinear time-history analysis such as ANSYS, or by a special purpose computer program especially written for pipe rupture analysis such as the GE computer program, "Pipe Dynamic Analysis" (PDA).

3X.4.3 PROCEDURE FOR DYNAMIC TIME-HISTORY ANALYSIS USING DETAILED PIPING MODEL.

3X.4.3.1 Modeling of Piping System:

In general, the rules for modeling the ruptured piping system are the same as the modeling rules followed when performing seismic/dynamic analysis of Seismic Category 1 piping. These rules are outlined in Subsection 3.7.3.3 of the SSAR. The piping, pipe supports and pipe whip restraints are modeled in sufficient detail to reflect their dynamic characteristics. Inertia and stiffness effects of the system and gaps between piping and the restraints must be included.

If the snubbers or other seismic restraints are included in the piping model they should be modeled with the same stiffness used in the seismic analysis of the pipe. However, credit for seismic restraints cannot be taken if the applied load exceeds the Level D rating.

The pipe whip restraints are modeled the same as for the simplified model described in 3X.4.2.1. For piping designed with the GE U-Bar pipe whip restraints, the selected size and dimensions, and the resulting force-deflection and elastic/plastic stiffness is first determined according to the procedure previously defined in Paragraph 3X.3.

3X.4.3.2 Dynamic Analysis using Detail Piping Model.

The pipe break nonlinear time-history analysis can be performed by the ANSYS, or other NRC approved non-linear computer programs. The force time histories acting at the break location and in each of the segments of the ruptured pipe are determined according to the criteria defined in ANS 58.2. The time step used in the analysis must be sufficiently short to obtain convergence of the solution. (GE has shown that for a rupture of the main steam pipe a time step of .001 seconds is adequate for convergence.) The analysis must not stop until the peak of the dynamic load and the pipe response are over.

The primary acceptance criteria are: (1) The piping stresses between the primary containment isolation valves are within the allowable limits specified in SRP 3.6.2, and MEB 3-1, Rev. 2. (2) the pipe whip restraint loads and displacements due to the postulated break are within the design limits, and (3) specified allowable loads on safety related valves or equipment to which the ruptured piping is attached are not exceeded.

3X.5 JET IMPINGEMENT ON ESSENTIAL PIPING

Postulated pipe ruptures result in a jet of fluid emanating from the rupture point. Safety related systems and components require protection if they are not designed to withstand the results of the impingement of this jet. Subsection 3.6.2.3.1 of this SSAR provide the criteria and procedure for: (1) defining the jet shape and direction, (2) defining the jet impingement load, temperature and impingement location and (3) analysis to determine effects of jet impingement on safety related equipment.

The paragraphs below provide some additional criteria and procedure for the analysis required to determine the effects of jet impingement on piping.

(1) Jet impingement is a faulted load and the primary stresses it produces in the piping must be combined with stresses caused by SSE to meet the faulted stress limits for the designated ASME Class of piping.

(2) If a pipe is subjected to more than one jet impingement load, each jet impingement load is applied independently to the piping system and the load which supplies the largest bending moment at each node is used for evaluation.

(3) A jet impingement load may be characterized as a two part load applied to the piping system - a dynamic portion when the applied force varies with time and a static portion which is considered steady state.

For the dynamic load portion, when static analysis methods are used, apply a dynamic load factor of 2. Snubbers are assumed to be activated. Stresses produced by the dynamic load portion are combined by SRSS with primary stresses produced by SSE.

For the static load portion, snubbers are not activated and stresses are combined with SSE stresses by absolute sum.

SIMPLIFIED PIPING MODELS

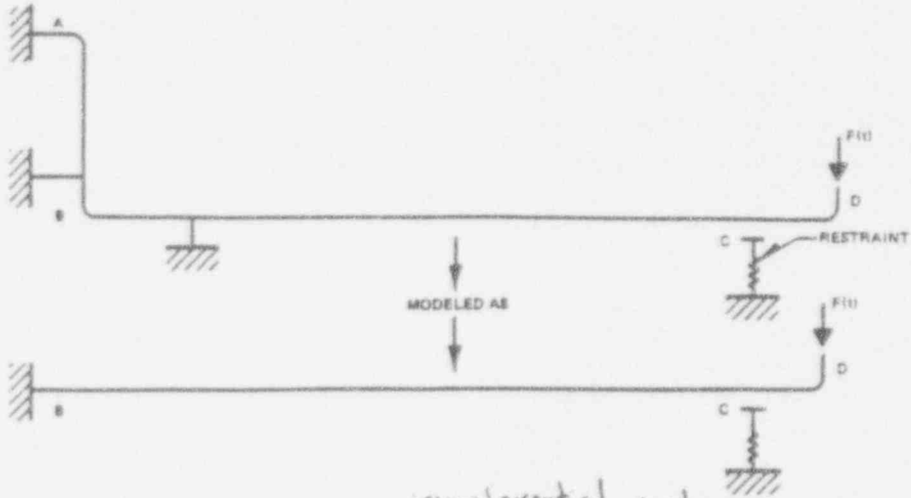

Figure 5-2. Representation of circumferential rupture using Built-In Pipe

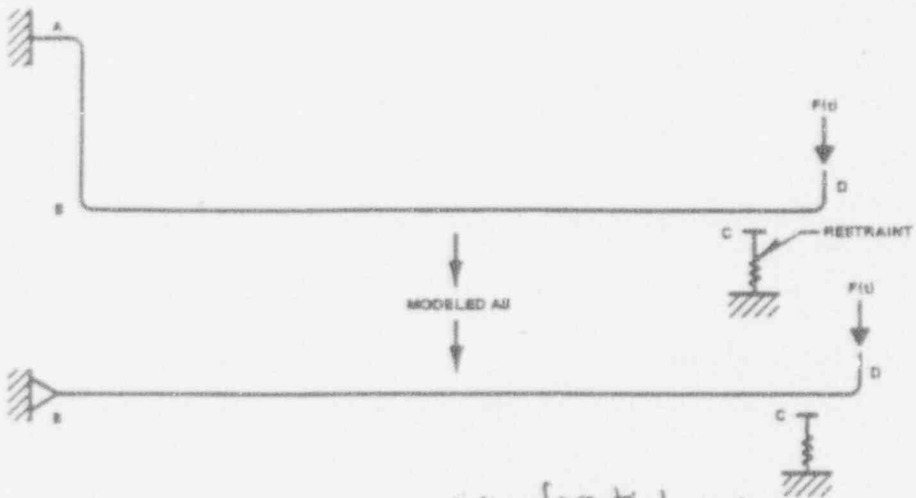

Figure 5-3. Representation of circumferential rupture using Pinned-End Pipe

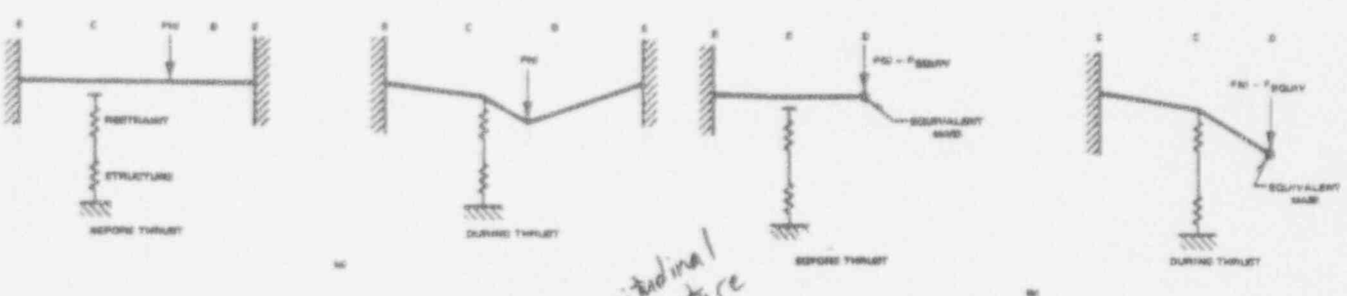

Figure 5-4. Representation of longitudinal rupture Pipe With Both Ends Built In

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

This Section deals with the structures, systems, components and equipment in the ABWR Standard Plant.

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

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

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

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

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

The dynamic effects that may result from a postulated rupture of high-energy piping include missile generation; pipe whipping; pipe break reaction forces; jet impingement forces; compartment, subcompartment and cavity pressurizations; decompression waves within the ruptured pipes and loads identified with loss of coolant accident (LOCA) on Table 3.9.2.

Subsection 3.6.3 and Appendix 3E describe the implementation of the leak-before-break (LBB) evaluation procedures as permitted by the broad scope amendment to General Design Criterion 4 (GDC-4) published in Reference 1. It is anticipated, as mentioned in Subsection 3.6.4.2, that a COL applicant will apply to the NRC for approval of LBB qualification of selected piping by submitting a technical justification report. The approved piping, referred to in this SSAR as the LBB piping, will be excluded from pipe breaks, which are required to be postulated by Subsection 3.6.1 and 3.6.2, for design against their potential dynamic effects. However, such piping are included in postulation of pipe cracks for their effects as described in Subsections 3.6.1.3.1, 3.6.2.2.1.5 and 3.6.2.1.6.2. It is emphasized that an LBB qualification submittal is not a mandatory requirement; a COL applicant has an option to select from none to all technically feasible piping systems for the benefits of the LBB approach. The decision may be made based upon a cost-benefit evaluation (Reference 6).

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

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

3.6.1.1 Design Bases

3.6.1.1.1 Criteria

Pipe break event protection conforms to 10CFR50 Appendix A, General Design Criteria 4, Environmental and Missile Design Bases. The design bases for this protection is in compliance with NRC Branch Technical Positions (BTP) ASB 3-1 and MEB 3-1 included in Subsection 3.6.1 and 3.6.2 respectively, of NUREG-800 (Standard Review Plan) except for the following:

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

(b) MEB 3-1, B.1.b.(1).(d) should read, "The maximum stress as calculated by the sum of Eqs. (9) and (10) in Paragraph NC-3652, ASME Code, Section III, considering those loads and conditions thereof for which Level A and Level B stress limits have been specified in the system's Design Specification (i.e., sustained loads, occasional loads, and thermal expansion) excluding earthquake loads should not exceed $0.8(1.8\ S_h + S_A)$."

(c) ~~The definitions contained in Subsection 3.6.2.1.4.2.~~

← MEB 3-1, B.1.C.(1).(b) should read, "At intermediate locations where the maximum stress range[2] as calculated by Eq.(10) exceeds 2.4 Sm, and the stress range calculated by either Eq.(12) or Eq.(13) in Paragraph NB-3653 exceeds 2.4 Sm."

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

The design of the containment structure, component arrangement, pipe runs, pipe whip restraints and compartmentalization are done in surge which in turn trips the main breaker), then a loss of offsite power occurs in a mechanistic time sequence with a SACF. Otherwise, offsite power is assumed available with a SACF.

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

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

(within RCIC capability)

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

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

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

3.6.1.1.4 Approach

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

3.6.1.2 Description

High energy lines are defined in

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

Table 3.6-5 for inside containment and in

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

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

3.6.1.3 Safety Evaluation

3.6.1.3.1 General

The control room is protected from high-energy line breaks.

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

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

3.6.1.3.2 Protection Methods

3.6.1.3.2.1 General

(in accordance with SRP 3.6.2)

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

(1) Protection against the dynamic effects of pipe failures is provided in the form of pipe whip restraints, equipment shields, and physical separation of piping, equipment, and instrumentation.

(2) The precise method chosen depends largely upon limitations placed on the designer such as accessibility, maintenance, and proximity to other pipes.

3.6.1.3.2.2 Separation

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

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

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

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

(2) Essential systems, components, and equipment at a distance greater than thirty feet from any high energy piping are considered as meeting spatial separation requirements. No damage is assumed to occur due to jet impingement since the impingement force becomes negligible beyond 30 feet. Likewise, a 30-ft evaluation zone is established for pipe breaks to assure protection against potential damage from a whipping pipe. Assurance that 30 feet represents the maximum free length is made in the piping layout.

(3) Essential systems, components, and equipment at a distance less than 30 feet from any high-energy piping are evaluated to see if damage could occur to more than one essential division, preventing safe shutdown of the plant. If damage occurred to only one division of a redundant system, the

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

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

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

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

(b) Habitability of the control room.

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

3.6.1.4 Break Location and Pipe Whip Restraint

The procedure of determining a break location and sizing a pipe whip restraint is as follows:

(1) Use break criteria in SRP 3.6.2 to find the break location.

(2) Use ANS 58.2 Appendix B and break type (logitudinal or circumferential; full or limited separation) to get the thrust load of the broken pipe.

(3) Use GE pipe whip restraint (PWR) data (REDEP file) to select applicable rod size, quality, bend, straight length, force and deflection, clearance, elastic and plastic displacements. Use other PWR design and characteristics as required for the calculation.

(4) Use pipe stress/strain curve, pipe mechanical properties and pipe dimensions for piping model.

(5) Use PDA computation program and a joystick model to confirm the adequate selection of PWR in capacity, displacement, time at peak load and lapsed time toward static state.

(6) Perform one dimensional wave propagation calculation to find the time history thrust load of each pipe segment (limited to 5 segments in one model) beyond the first one.

(7) Model a piping, apply thrust and retrain the pipe movement by using PWR as selected in step 3.

(8) Use ANSYS or equivalent program with input preparation (step 7).

(9) Check displacements at broken end and PWR; stresses in holy pipe against ASME Code, Section III, Equation 9 (NB3650) with 2.25 S_m limitation.

(10) Check operability of MSIV using limitation of bonnet flange bolt load and limits of acceleration.

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

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

3.6.2.1 Criteria Used to Define Break and Crack Location and Configuration

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

3.6.2.1.1 Definition of High-Energy Fluid Systems

High-energy fluid systems are defined to be those systems or portions of systems that, during normal plant conditions (as defined in

Subsection 3.6.1.1.3(1)),are either in operation or are maintained pressurized under conditions where either or both of the following are met:

(1) maximum operating temperature exceeds 200 F, or

(2) maximum operating pressure exceeds 275 psig.

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

3.6.2.1.2 Definition of Moderate-Energy Fluid Systems.

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

(1) maximum operating temperature is 200 °F or less, and

(2) maximum operating pressure is 275 psig or less.

Piping systems are classified as moderate-energy systems when they operate as high-energy piping for only short operational periods in performing their system function but, for the major operational period, qualify as moderate-energy fluid systems. An operational period is considered short if the total fraction of time that the system operates within the pressure-temperature conditions specified for high-energy fluid systems is less than two percent of the total time that the system operates as a moderate-energy fluid system.

New Para:
Table 3.6-5 lists the moderate energy lines inside containment, and Table 3.6-6 lists the moderate energy lines outside containment.

3.6.2.1.3 Postulated Pipe Breaks and Cracks

A postulated pipe break is defined as a sudden gross failure of the pressure boundary either in the form of a complete circumferential severance (guillotine break) or a sudden longitudinal split without pipe severance, and is postulated for high-energy fluid systems only. For moderate-energy fluid system, pipe failures are limited to postulation of cracks in piping and branch runs. These cracks affect the surrounding environmental conditions only and do

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

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

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

3.6.2.1.4.3 A.;ME Code Section Class 1 Piping In Areas Other Than Containment Penetration

With the exception of those portions of piping identified in Subsection 3.6.2.1.4.2, breaks in ASME Code, Section III, Class 1 piping are postulated at the ~~following~~ locations identified in (a), (b) and (c) in each piping and branch run. Earthquake loads are excluded from (b) and (c).

(a) At terminal ends*

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

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

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

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* *Extremities of piping runs that connect to structures, components (e.g., vessels, pumps, valves), or pipe anchors that act as rigid constraints to piping motion and thermal expansion. A branch connection to a main piping run is a terminal end of the branch run, except where the branch run is classified as part of a main run in the stress analysis and is shown to have a significant effect on the main run behavior. In piping runs which are maintained pressurized during normal plant conditions for only a portion of the run (i.e., up to the first normally closed valve) a terminal end of such runs is the piping connection to this closed valve.*

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

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

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

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

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

(a) At terminal ends (see Subsection 3.6.2.1.4.3, Paragraph (a))

(b) At intermediate locations selected by one of the ~~following~~ criteria below. Earthquake loads are excluded from criteria (ii).

(i) At each pipe fitting (e.g., elbow, tee, cross, flange and nonstandard fitting), welded attachment, and valve. Where the piping contains no fittings, welded attachments, or valves, at one location at each extreme of the piping run adjacent to the protective structure.

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

As a result of piping re-analysis due to differences between the design configuration and the as-built configuration, the highest stress

New section 3.6.2.2

3.6.2.2 Analytical Methods to Define Blowdown Forcing Functions and Response Models.

3.6.2.2.1 Analytical Methods to define Blowdown Forcing Functions.

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

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

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

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

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

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

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

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

3.6.2.2.2 Pipe Whip Dynamic Response Analyses

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

The alternative analytical approaches described in Paragraphs 6.3.1 through 6.3.5 of ANS 58.2 are acceptable approaches for piping response calculation. Criteria for an acceptable design are: (1) The piping stresses between the isolation valves ~~are within the allowable limits specified in SRP 3.6.2~~ [allowable limits specified in SRP 3.6.2 and BTP MEB 3-1 paragraph B.1.b], (2) the pipe whip restraint loads and displacements due to the postulated break are within the ~~design limits~~ and (3) ~~specified~~ calculated loads ~~on~~ or stresses for safety related valves or equipment to which the ruptured piping is attached do not exceed ~~Code requirements for faulted conditions and limits to ensure required~~ the operability, limits specified in Subsection 3.9.3.

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

Table 3.6-6 5

MODERATE-ENERGY PIPING OUTSIDE IN CONTAINMENT

Residual Heat Removal System
(Piping beyond outermost isolation valve)

High Pressure Core Flooder System
(Piping beyond outermost isolation valve)

Reactor Core Isolation Cooling System
(Suction line from condensate storage pool beyond second shutoff valve, vacuum pump discharge line from vacuum pump to containment isolation valve)

Control Rod Drive System
(Piping up to pump suction)

Standby Liquid Control System
(Piping beyond injection valves)

Suppression Pool Cleanup System
(Beyond containment isolation valve)

Fuel Pool Cooling and Cleanup System

Radioactive Waste System
(Beyond isolation valve)

Instrument/Service Air System
(Beyond isolation valve)

HVAC Cooling Water System

Makeup Water System (Condensate)

Reactor Building Cooling Water System

Turbine Building Cooling Water System

Atmospheric Control System
(Beyond shutoff valve)

410.21

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