PSNH

Public Service of New Hampshire

New Hampshire Yankee Division

SEABROOK STATION
Engineering Office

February 7, 1985

SBN- 761
T.F. B7.1.2

United States Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. George W. Knighton, Chief
Licensing Branch No. 3
Division of Licensing

References: (a) Construction Permits CPPR-135 and CPPR-136, Docket Nos. 50-443 and 50-444

Subject: Elimination of Arbitrary Intermediate Pipe Breaks

Dear Sir:

The New Hampshire Yankee Division of Public Service Company of New Hampshire has noted that the Nuclear Regulatory Commission (NRC) has approved industry proposals to modify certain aspects of current pipe break criteria. These approvals include the elimination from design consideration the postulation of those pipe breaks commonly referred to as Arbitrary Intermediate Breaks (AIBs).

Currently, AIBs are postulated to provide the minimum of two pipe breaks at the two highest stress locations between piping terminal ends, even though analyses have shown stresses and/or cumulative usage factors do not exceed current Staff criteria. Consequently, AIBs are frequently postulated at locations where calculated stresses and/or cumulative usage factors are significantly below allowables. AIB postulation necessitates the design, fabrication, installation, and maintenance of complicated mitigating devices to afford protection from dynamic effects, such as pipe whip and/or jet impingement. In cases where these selected break locations have stress levels slightly greater than the remainder of the system, the installation of mitigating devices not only lends little to overall plant safety, but also provides the potential for inadvertent thermal bind-up.

By way of this letter, we request that the Staff approve the elimination of arbitrary intermediate breaks in all high energy piping systems (excluding the Feedwater System, which will be the subject of a separate request) at Seabrook Station, Units 1 and 2. The AIBs we are seeking to eliminate are delineated in Enclosure E. This request includes the exclusion of all dynamic effects associated with AIBs, (i.e., pipe whip, jet impingement, and compartment pressurization loads).

P.O. Box 300 • Seabrook, NH 03874 • Telephone (603) 474-9521

B001
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We currently utilize break selection criteria derived from NRC Branch Technical Position MEB 3-1 as delineated in Section 3.6(B) of the Seabrook Station Final Safety Analysis Report (FSAR). Our proposed break criteria revision is incorporated in an annotated version of the Seabrook Station FSAR Section 3.6(B) which is provided as Enclosure F to this letter.

In support of the Staff's review of our proposed elimination of AIBs from the Seabrook Station design bases, we have included six enclosures to this letter which address the evaluations required by the Staff prior to the granting of break criteria revisions:

Enclosure	Subject
A	Benefit Summary
B	Technical Justification
C	Transient Forces and Vibrational Effects
D	Potential for Stress Cracking in PWR Piping
E	Breaks to be Eliminated
F	Proposed FSAR Revision

In summary, it is apparent that the elimination of AIBs on the noted high energy piping systems will not in any way compromise overall plant safety or structural design. Staff acceptance of our request would result in substantial benefits in terms of reduced occupational radiation exposure and cost savings over the forty-year plant life. Due to the advanced stage of design and construction of Unit 1, the realization of these potential benefits will be severely tempered if our request is not granted in a timely manner. We therefore request a decision on this proposal by March 15, 1985.

If I can be of further assistance, or if a meeting with the Staff is deemed beneficial, do not hesitate to contact me.

Very truly yours,

J. DeVincentis, Director
Engineering and Licensing

Attachments

cc: Atomic Safety and Licensing Board Service List

William S. Jordan, III
Diane Curran
Harmon, Weiss & Jordan
20001 S Street N.W.
Suite 430
Washington, D.C. 20009

Robert G. Perlis
Office of the Executive Legal Director
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Robert A. Backus, Esquire
116 Lowell Street
P.O. Box 516
Mancehster, NH 03105

Philip Ahrens, Esquire
Assistant Attorney General
Department of the Attorney General
Augusta, ME 04333

Mr. John B. Tanzer
Designated Representative of
the Town of Hampton
5 Morningside Drive
Hampton, NH 03842

Roberta C. Pevear
Designated Representative of
the Town of Hampton Falls
Drinkwater Road
Hampton Falls, NH 03844

Mrs. Sandra Gavutis
Designated Representative of
the Town of Kensington
RFD 1
East Kingston, NH 03827

Jo Ann Shotwell, Esquire
Assistant Attorney General
Environmental Protection Bureau
Department of the Attorney General
One Ashburton Place, 19th Floor
Boston, MA 02108

Senator Gordon J. Humphrey
U.S. Senate
Washington, DC 20510
(Attn: Tom Burack)

Diana P. Randall
70 Collins Street
SEabrook, NH 03874

Donald E. Chick
Town Manager
Town of Exeter
10 Front Street
Exeter, NH 03833

Brentwood Board of Selectmen
RED Dalton Road
Brentwood, New Hampshire 03833

Edward F. Meany
Designated Representative of
the Town of Rye
155 Washington Road
Rye, NH 03870

Calvin A. Canney
City Manager
City Hall
126 Daniel Street
Portsmouth, NH 03801

Dana Bisbee, Esquire
Assistant Attorney General
Office of the Attorney General
208 State House Annex
Concord, NH 03301

Anne Verge, Chairperson
Board of Selectmen
Town Hall
South Hampton, NH 03842

Patrick J. McKeon
Selectmen's Office
10 Central Road
Rye, NH 03870

Carole F. Kagan, Esq.
Atomic Safety and Licensing Board Panel
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Angie Machiros
Chairman of the Board of Selectmen
Town of Newbury
Newbury, MA 01950

Town Manager's Office
Town Hall - Friend Street
Amesbury, Ma. 01913

Senator Gordon J. Humphrey
1 Pillsbury Street
Concord, NH 03301
(Attn: Herb Boynton)

Richard E. Sullivan, Mayor
City Hall
Newburyport, MA 01950

ENCLOSURE A

SEABROOK STATION

BENEFIT SUMMARY

ELIMINATION OF ARBITRARY INTERMEDIATE PIPE BREAKS

1. Improved access for inspection, maintenance and operation.	Improve quality of inservice inspection. Reduce radiation exposure during ISI. Reduce plant down-time during ISI outages. A savings of 80-100 man-rem/unit is estimated over the 40 year plant life.
2. Engineering, fabrication and installation of 22 pipe rupture restraints and jet shields.	Estimate $1.2 million/unit (1984 dollars).
3. Reduction of heat loss and elimination of expensive Min-K insulation of pipe restraint locations.	Relatively minor, but real savings. Delicate Min-K insulation may be replaced by durable sections, designed to be removable for ISI.
4. Improvement in overall plant safety (NUREG-CR-2136).	Eliminate potential for unintentional restricted piping movement.

ENCLOSURE B

SEABROOK STATION
JUSTIFICATION FOR THE ELIMINATION OF ARBITRARY INTERMEDIATE PIPE BREAKS

We feel that sufficient technical justification exists for the elimination of the arbitrary intermediate pipe breaks required to be postulated in High Energy, ASME Code Section III Piping to comply with Standard Review Plan 3.6.2. Our justification is as follows:

1) Operating Experience Does Not Support the Need for the Criteria

The combined operating history of commercial nuclear plants, both domestic and foreign, has not shown the need to provide protection from the dynamic effects of arbitrary intermediate breaks.

2) System Piping Stresses Are Well Below ASME Code Allowables

Branch Technical Position MEB 3-1 requires the postulation of intermediate breaks in Class 2 and 3 piping where the stresses exceed 0.8 (1.2 $S_h + S_A$). This is only 80% of the ASME Code allowable stresses.

Intermediate breaks for Seabrook Station were postulated in Class 2 and 3 piping where stresses exceeded 0.8 ($S_h + S_A$), which provides additional conservatism.

Welded attachments are generally not located near (approx. 5 pipe diameters) arbitrary intermediate breaks. Any arbitrary intermediate break located near welded attachments, such as shear lugs, will not be deleted. Therefore, local bending stresses from these attachments will not affect the stress levels at the arbitrary break locations being deleted.

Deletion of pipe rupture restraints associated with the arbitrary intermediate breaks will reduce possible unanticipated thermal restraint of piping.

3) Arbitrary Intermediate Breaks Complicate the Design Process

Since the design of piping systems is generally an iterative process, the location of the highest stress points usually change several times as the design evolves. The alternate criteria of SRP 3.6.2 (NUREG 0800) provides little relief from moving arbitrary break locations as the revised break locations must still be evaluated as to their effects on essential equipment and structures.

4) Substantial Cost Savings

The elimination of pipe whip restraints and jet shields is the primary cost benefit realized by the elimination of the arbitrary intermediate breaks. Plant operation costs will also be reduced, as reduced manhours for inservice inspection and maintenance will result. The cost benefit for Seabrook Station is provided in Attachment A.

5) Improved Inservice Inspection

Pipe whip restraints are normally located adjacent to or surrounding the welds at changes in pipe direction. The dismantling and reinstallation of portions of the restraint structures associated with arbitrary breaks to gain proper access for the performance of inservice inspection would be eliminated. Also, the absence of structural framing will allow for better inspection technique and quality.

6) Reduction in Radiation Exposure

The elimination of pipe whip restraints and jet shields associated with arbitrary breaks, and the large structures necessary to support them, will result in more efficient maintenance, inspection and decontamination operations. Improved access for firefighting will also be gained. A reduction in the time required to perform all of these activities will result in a significant reduction in personnel exposure to radiation over the 40 year plant life. Attachment A provides an estimate of the man-rem benefit to be realized if the arbitrary breaks are eliminated.

7) Improved Operational Efficiency

The elimination of pipe whip restraints associated with arbitrary breaks will preclude the requirement for cut back insulation or special insulating assemblies near the close fitting restraints and will reduce the heat load in plant buildings, especially inside containment.

8) Proper System Design and Operating Procedures

The Mechanical Engineering Branch, in Branch Technical Position MEB 3-1, recognizes that "...pipe rupture is a rare event which may occur only under unanticipated conditions such as those which might be caused by possible design, construction, or operation errors; unanticipated loads or unanticipated corrosive environments." For Seabrook Station, there are many ways in which those unanticipated conditions may be detected. The system transient (water-hammer) and vibrational stress testing portions of the preoperational and startup test programs, as discussed in Attachment C, minimize unanticipated conditions arising from design, construction or operation errors and also from unanticipated loads, while control of water chemistry and materials used during fabrication, installation, startup testing and operation minimize exposure to potentially corrosive environments, as discussed in Attachment D. Once Seabrook station begins operation, an extensive In-Service Inspection (ISI) Program will continue to provide that assurance and will detect any system degradation before unsafe conditions develop.

9) Adequacy of Equipment Qualification

The elimination of arbitrary intermediate breaks will not downgrade the environmental qualification levels of Class 1E equipment. The break postulation for environmental effects is performed independently of break postulation for pipe whip and jet impingement.

ENCLOSURE C

SEABROOK STATION
TRANSIENT FORCES AND VIBRATIONAL EFFECTS
ASSOCIATED WITH ARBITRARY INTERMEDIATE BREAKS

Seabrook Station piping systems were designed in accordance with good engineering practice. The steam systems were sloped and will be provided with adequate drainage where necessary to prevent unacceptable condensate build-up. Water systems were routed to minimize void formation. In addition, the possibility of large transient (water-hammer) forces due to normal and abnormal plant conditions in piping systems with postulated arbitrary intermediate breaks has been thoroughly analyzed for Seabrook. A limited set of transients was originally addressed for Seabrook Station design, however, the INPO design audit of 1983 highlighted the need to increase the scope of the evaluation and to have the basis and results fully documented.

A systematic review was performed for all systems designed under the ASME Section III Code and a Transient Analysis Program instituted to determine the thermal and hydraulic transients forces generated in response to an extensive matrix of initiating events. The forces thus generated will be included in the piping stress analysis and considered in the design of the pipe support systems. This program is still in progress and is scheduled to be completed so as to permit incorporation into the stress reconciliation program.

Systems within the Westinghouse scope of supply are not, in general, susceptible to water hammer. The Reactor Coolant, Chemical and Volume Control, and Residual Heat Removal Systems have been designed to preclude water hammer. Preoperational testing and operating experience have verified that the Westinghouse design is not susceptible and furthermore, have indicated that significant water hammer events have usually been initiated within the Balance of Plant (BOP) scope of supply. As previously discussed, hydraulic transients postulated for BOP systems are incorporated in the design loads and system design features to preclude water hammer effects. Concurrently, Westinghouse has conducted a number of investigations into the causes and consequences of water hammer. The results of these investigations have been reflected in the BOP design interface requirements to assure that water hammer events that may be initiated in the BOP secondary systems do not compromise the performance of the Westinghouse supplied safety-related systems and components.

The lines for which arbitrary intermediate break elimination is being requested and that have any potential for water hammer/steam hammer effects are being designed to minimize or preclude such effects. Water hammer mitigation efforts for each system involved in the elimination of arbitrary breaks are discussed below. Also, each system description is supplemented with the list of significant transients that have been postulated.

1. Reactor Coolant System (RC)

   a. Unanticipated Transients

      There is a low potential for water hammer in the Reactor Coolant System because it is designed to preclude steam void formation.

However, excessive cooling of the Reactor Coolant System, which initiates safety injection, could potentially result in water hammer. If any problems are experienced during preoperational testing, they will be eliminated by modifying operating procedures.

b. Postulated Transients for RC System - (Non-NSSS Portion)

- Opening of Pressurizer PORV(s)
- Opening of Pressurizer Safety Valves(s)
- Opening of RHR Suction Line Relief Valves
- Closure of Containment Isolation Valves

2. Safety Injection System (SI)

a. Unanticipated Transients

The safety injection lines are all water solid and at ambient temperature. Therefore, there is a low probability of water hammer problems in this system.

b. Postulated Transients for SI System

- SI Pump Trip
- Spurious Closure of SI Pump Suction Valves
- Spurious Closure of SI Pump Discharge Valves
- Opening of System Relief Valves

3. Chemical and Volume Control System (CVCS)

a. Unanticipated Transients

Normally, the CVCS System is water solid. In the low temperature lines water hammer would not be expected because of the small probability of steam void formation. In the high temperature lines, the piping has been designed to maintain water solid conditions during normal operation, thus minimizing the possibility of water hammer effects.

b. Postulated Transients for the CS System - (Letdown/Charging Portion)

- Charging Pump Trip (Positive Displacement or Centrifugal)
- Closure of Containment Isolation Valves
- Opening of System Relief Valves
- Spurious Operation of Letdown Flow Control Valves

4. Main Steam (MS)

a. Unanticipated Transients

As a result of the four-inch warm-up lines being designed to be normally filled with steam and the steam drain lines being designed for water flow with no water accumulation, water hammer due to improper condensate drainage is not expected.

b. Postulated Transients for MS System

- Turbine Trip
- Moisture Separator/Reheater Trip
- Safety Valve Actuation
- Load Change > 10%
- Main Steam Isolation Valve Closure (Including Spurious)
- Reactor Trip

5. Steam Generator Blowdown System

a. Unanticipated Transients

Blowdown flow from the steam generators is normally two-phase and of 0-10 percent quality. The normal flow regime between the steam generator and the blowdown control valve is slug flow. This section of pipe is run in horizontal and descending vertical legs to the piping low point drain. The normal flow regime downstream of the containment isolation and blowdown control valves to the flash tank lies in the dispersed flow regime. Operating procedures calling for gradually increasing flow into the normal operating range minimize the potential for water hammer downstream of the blowdown control valve while establishing flow during startup and during re-initiation after containment isolation.

b. Postulated Transients for SB System

- Change in Blowdown Rate
- Containment Isolation Valve Closure (Including Spurious)

Note, many of the above transients will be investigated during the preoperational test and initial startup programs as discussed in FSAR Subsection 3.9(B).2.1.c.

The preoperational vibration testing program at Seabrook will help minimize the potential for vibration fatigue. During the testing, both transient and steady-state vibration of high energy critical piping will be monitored and evaluated.

A listing of the systems which will be monitored for vibration during preoperational and startup testing is contained in FSAR Table 3.9(B)-1 and is included herein.

For the vibration tests, selected lines will be visually inspected and sections to be investigated will be identified, with special attention paid to piping between supports, instrument connections, vent and drain connections, and valve operators. Displacement, frequency, and acceleration will be measured as applicable.

If measured parameters exceed acceptable tolerances, the effect of the vibration on the system design will be evaluated by analysis. The analysis will consider piping stresses based on vibration amplitude and combined stresses due to other applicable loads including vibration. The evaluation will determine fatigue life based upon stress level, frequency, and endurance limit. In addition, the evaluation will take into account the operability of any in-line components based on the measured accelerations compared to the component qualification and also the operability and accuracy of instruments connected to the piping.

Acceptance criteria for steady-state vibration will limit peak vibratory stress to a conservative limit based upon material type; that limit is selected well below the material fatigue endurance limits defined in the ASME Code.

In conclusion, we expect that Seabrook Station will not experience problems due to transient forces or vibrational fatigue in the piping systems containing arbitrary breaks.

TABLE 3.9(B)-1
(Sheet 1 of 3)

SYSTEMS REQUIRING MONITORING OF THERMAL EXPANSION,
VIBRATION AND DYNAMIC EFFECTS DURING START-UP FUNCTIONAL TESTING

System	Line No.	Parameter Measured	Location/Comments
Reactor Coolant	1 thru 12	See Comments	See 3.9(N).2.1
	74-2	Vibration, thermal displ.	Immediately downstream of pressurizer
	75-2		
	76-2		
	80-5		
Residual Heat Removal	155-2	Vibration	Immediately downstream of the connecting RHR HX Bypass and Discharge Lines
	158-2		Immediately downstream of the connecting RHR HX Bypass and Discharge Lines
Safety Injection	250-15	Vibration	Immediately downstream of the SI pumps
	251-19		Immediately downstream of the SI pumps
Chemical and Volume Control	355-1	Vibration	At suction and discharge of charging pump.
	357-1		At suction and discharge of charging pump.
	362-1		Immediately downstream of charging pumps.
	364-1		Immediately downstream of charging pumps.
	437-3		Chiller inlet and outlet lines downstream of PCV-131.
	439-1		Chiller inlet and outlet lines downstream of PCV-131.
	441-3		Downstream of connection between letdown chiller HX bypass and outlet lines.
Primary Component Cooling	752-1	Vibration	Downstream of the connection between CCHX bypass and outlet lines.
	798-1		Downstream of the connection between CCHX bypass and outlet lines.
	816-1		Downstream of TV-130

TABLE 3.9(B)-1
(Sheet 2 of 3)

System	Line No.	Parameter Measured	Location/Comments
Spent Fuel Pool Cooling	1704-2	Vibration	Downstream of the connection with line 1704-7.
Service Water		Vibration	Immediately downstream of valves SW-V15, V16, V18, V19, V20, V26, V55.
Waste Gas	562-1 567-1	Vibration	Immediately downstream of compressor. Immediately downstream of compressor.
Steam Generator Blowdown	1301-2 1304-2 1307-2 1309-2	Vibration, ther. expansion	Downsteam of valves SB-V189, V191, V193 and V195. Downstream of valves SB-V21, V22, V23 and V24 in lines to the flash tank.
Condensate	4046-1, 4047-1, 4048-1 4053-4 4068-3, 4068-5 4600-1, 4001-1	Vibration, ther. expansion	Condensate pump discharge. Stm. packing exhauster condensate outlet. Stm. generator feedpump suction. Stm. generator pump discharge.
Feedwater	4606-1, 4607-1, 4608-1, 4609-1 4606-2, 4607-2, 4608-2, 4609-2 4606-3, 4607-3, 4608-3, 4609-3	Vibration, ther. expansion Thermal expansion Vibration Thermal expansion Vibration, ther. expansion	Feedwater regulator inlet. Feedwater regulator outlet. Feedwater upstream of flow nozzle. 18" check valve Downstream of 18" check valve. Downstream of 18" shut-off valve. Start-Up feedpump discharge.
Emergency Feedwater	4081-1, 4082-1 4610-1, 4612-1 4614-1, 4615-1, 4616-1, 4617-1	Vibration	Emergency feedpump suction. Emergency feedpump discharge. Downstream of flow control valve.

<u>TABLE 3.9(B)-1</u>
(Sheet 3 of 3)

System	Line No.	Parameter Measured	Location/Comments
Main Steam	4000-2, 4001-2, 4002-2, 4003-2	Vibration	Containment penetration
	4000-3, 4001-3, 4002-3, 4003-3	Thermal expansion	Restraint upstream of MSIV
	4000-11,4001-11,4002-9, 4003-9	Vibration	Upstream of power operated relief valve
	4000-11,4001-11,4002-9, 4003-9	Dynamnic (transients)	Power operated relief valve.
	4000-12,4001-12,4002-10,4003-10	Vibration	Downstream of power operated relief valve
	4000-3, 4001-3, 4002-3, 4003-13	Thermal expansion	Restraint downstream of main steam isolation valve
	4000-9	Vibration, ther. expansion	Emergency feedpump turbine supply.
Diesel Generator	4366-1, 4367-1, 4368-1, 4369-1	Vibration	Starting air
	4379-1, 4380-1		Fuel oil supply from day tank
	4405-3, 4408-1	Vibration, ther. expansion	Jacket cooling water to and from cooler

ENCLOSURE D

SEABROOK STATION

POTENTIAL FOR STRESS CORROSION CRACKING IN PWR PIPING SYSTEMS

The following review, encompassing a literature survey, service experience, and fabrication/installation and operational requirements, provides convincing proof that stress corrosion cracking of stainless steel and carbon steel in primary and secondary pressure boundary piping systems is an unlikely event for the Seabrook Station. This review focused primarily on austentic stainless steel (types 304 and 316.

Carbon steel piping materials are considered immune to stress corrosion cracking basically because their overall corrosion rate in aqueous environments typical of PWR system service is high compared to the stainless steels and copper base alloys. A metal or alloy will be subject to the highly localized form of attack known as stress corrosion cracking only if the overall corrosion rate in the subject environment is low.

In order for stress corrosion cracking to occur, three conditions involving stress, temperature and corrosive environment must occur simultaneously. Of these three, the corrosive environment is considered to be the key parameter since it is the most difficult to control. Stress and temperature are relatively fixed parameters although residual stresses from welding or operation may produce undesirable stress levels. Thus, to prevent stress corrosion cracking of stainless steel such as chlorides, fluorides, various froms of sulphur, caustics, and oxygen; and (2) rigid control of water chemistry.

Numerous measures are taken to prevent the introduction of contaminants into the system such as (1) assuring that materials coming in contact with stainless during fabrication or operation do not contain harmful levels of impurities such as in crayons, insulation, gaskets, and lubricants, (2) cleaning prior to heat treatment and welding, (3) final cleaning and capping prior to shipment to site, (4) use of high quality water (low chloride, fluorides, and controlled pH) for preoperational flushing and testing, and (5) final cleaning of O.D. surfaces followed by chloride and fluoride checks prior to preoperational testing.

In addition to the above, other requirements are imposed on material suppliers and component manufacturers to assure the use of optimum practices to control carbide precipitation (sensitization) and cold work which are known to promote stress corrosion cracking. Precise heat treatment practices are required to be used to promote optimum metallurginal structures for resisting stress corrosion cracking. Procedures are reviewed to assure the use of effective but safe cleaning solutions. Cold working (bending) after solution annealing is prohibited except for small diameter pipe. Heavy sensitization is avoided by prohibiting stress relieving after welding and control of heat input during welding. During plant operation, primary and secondary water chemistry is carefully monitored to assure compliance with specification requirements shown in Table 1. Note in particular that oxygen levels are maintained for the primary side by a combination of hydrogen and hydrazine and for the secondary side by hydrazine additions.

Except for incidents involving inadvertent chloride intrusions, no known stress corrosion failures have been reported in PWR operating plants.

References:

1. Pacific Northwest Laboratories Report - Stress Corrosion in Nuclear Systems - March, 1973

2. WPPSS - WNP-1/4 Intergranular Stress Corrosion Task Force Report - June 1980

3. Pacific Northwest Laboratories - Stress Corrosion in Nuclear Systems September 1975

4. NUREG - 0791 - Investigating and Evaluating Cracking Incidents in Pressurized Water Reactor - September 1980

5. Private telephone conversations with W personnel.

6. Corrosion Engineering - Fontana & Green, 1967.

7. NACE Corrosion Data Survey, 1974.

SEABROOK STATION

WATER CHEMISTRY SPECIFICATIONS FOR LINES CONTAINING ARBITRARY BREAKS

SYSTEM	NO. OF ARBITRARY BREAKS	ASME CLASS	PIPE MAT'L	OPERATING TEMP. (°f)	HYDROGEN CONCEN. (cc/kg H_2O)	MAX. OXYGEN (ppm)	MAX. CHLORIDES & FLUORIDES (ppm)	pH (@ 25°C)	pH CONTROL AGENT	O_2 CONTROL AGENT
REACTOR COOLANT	8	1	SS	557	25-50	0.005	0.15	4.2-10	Lith. Hydrox.	H_2 + Hydr.
SAFETY INJECTION	9	1	SS	557	25-50	0.005	0.15	4.2-10	Lith. Hydrox.	H_2 + Hydr.
CHEM. & VOLUME CONTROL	8	1&2	SS	557	25-50	0.10	0.10	6.0-8.0	Lith. Hydrox.	H_2 + Hydr.
CHEM. & VOLUME CONTROL	8	2	SS	490	-	0.10	0.10	6.0-8.0	Lith. Hydrox.	H_2 + Hydr.
CHEM. & VOLUME CONTROL	38	2	SS	120	25-50	0.10	0.10	6.0-8.0	Lith. Hydrox.	H_2 + Hydr.
STEAM GENERATOR BLOWDOWN	35	2	CS	557	-	-	-	8.5-9.2	Morpholine	Hydrazine
MAIN STEAM (PRIMARY LINES)	8	2	CS	557	-	0.005	-	8.8-9.2	Morpholine	Hydrazine
MAIN STEAM TO AUX. EQUIP.	2	2	CS	557	-	0.005	-	8.8-9.2	Morpholine	Hydrazine

ENCLOSURE E

SEABROOK STATION
INTERMEDIATE BREAKS TO BE ELIMINATED

SYSTEM	LOCATION*	PIPE SIZE	NUMBER OF BREAKS ELIMINATED	EST. NO. OF DEVICES ELIMINATED: WHIP RESTRAINTS	EST. NO. OF DEVICES ELIMINATED: JET SHIELDS
REACTOR COOLANT	IC (Ctmt. Interior)	2"	4	0	0
		3"	2	0	0
		4"	2	0	0
SAFETY INJECTION	IC (Ctmt. Interior)	1-1/2"	7	0	0
		6"	2	0	0
CHEM. & VOLUME CONTROL	IC (Ctmt. Interior)	2"	8	0	0
		3"	4	0	0
	IC (Ctmt. Annulus)	2"	9	0	0
		3"	3	0	0
		4"	2	0	0
	OC (Prim. Aux. Bldg.)	2"	11	0	0
		3"	14	C	0
		4"	3	0	0
MAIN STEAM	OC (MS&FW Pipe Chase)	6"	8	1	0
	IC (Ctmt. Interior)	32"	4	4	0
	IC (Ctmt. Annulus)	30"	4	10	4
STEAM GENERATOR BLOWDOWN	OC (MS&FW Pipe Chase)	2"	2	0	0
		3"	5	0	0
	IC (Ctmt. Interior)	2"	8	0	0
		3"	11	0	1
	IC (Ctmt. Annulus)	3"	9	2	0
TOTALS			122	17	5

* IC - Inside Containment
OC - Outside Containment

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

a. Introduction

General Design Criterion 4 of Appendix A to 10CFR50 requires that structures, systems and components important to safety be protected against the dynamic effects of piping failures. This section discusses the design bases and design measures employed to ensure that all essential structures, systems and components located inside and outside the reactor containment, including the components of the reactor coolant pressure boundary, have been adequately protected against the effects of possible blowdown jet and reactive forces and pipe whips resulting from postulated rupture of piping located both inside and outside of containment.

The required information is furnished in two sections:

1. Sections 3.6(B).1 and 3.6(B).2 and respective subsections address all piping systems inside and outside containment, exclusive of the reactor coolant loop piping.

2. Section 3.6(N).2 and subsections, which have been furnished by the NSSS supplier, address only the reactor coolant loop piping inside the reactor containment and the loops' support system.

The criteria used in postulating pipe rupture and leakage locations in high and moderate energy piping systems located outside containment correspond with the guidance set forth in the NRC's Branch Technical Position APCSB 3-1.

The criteria employed for identifying high energy fluid piping, and for postulating pipe break locations, break orientations and break flow areas inside containment are consistent with the criteria established in Regulatory Guide 1.46, "Protection Against Pipe Whip Inside Containment". The Westinghouse Topical Report, WCAP-8082, "Pipe Break for the LOCA Analysis of the Westinghouse Primary Coolant Loop", is referenced as the basis concluding that the reactor coolant piping system will provide an equivalent level of protection, as recommended in Regulatory Guide 1.46. The Seabrook Station coolant system piping is consistent with the design considered in WCAP-8082, which has been approved by the NRC Staff.

b. Definitions

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

- Maximum operating temperature exceeds 200°F,

- Maximum operating pressure exceeds 275 psig.

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

- Maximum operating temperature is 200°F or less, and

- Maximum operating pressure is 275 psig or less.

Normal Plant Conditions - Plant operating conditions during reactor start-up, operation at power, hot standby or reactor cooldown to cold shutdown conditions.

Upset Plant Conditions - Plant operating conditions during system transient conditions that may occur with moderate frequency during plant service life and are anticipated operational occurrences, but not during system testing.

Essential Systems and Components - Systems and components required to shutdown the reactor and mitigate the consequences of a postulated piping failure without offsite power.

Postulated Piping Failure - Longitudinal and circumferential breaks in high-energy fluid system piping and through-wall leakage cracks in moderate energy fluid system piping posultated according to the provisions of Subsection 3.6(B).2 below.

S_A - Allowable stress range for thermal expansion as defined in subarticle NC3600 of the ASME Code, Section III, 1971 Edition, with Addenda up to and including Winter, 1972.

S_h - Allowable stress at maximum temperature.

S_m - Design stress intensity defined in subarticle NB-3600 of the ASME Code.

Single Active Component Failure - Malfunction or loss of function of a component of an electrical or fluid system. A failure of an active component of a fluid system is not considered to include loss of component structural integrity. The direct consequences of a single active component failure are considered to be part of the single failure.

Terminal Ends - Extremities of piping runs that connect to structures, components (vessels, pumps, valves) or pipe anchors that act as rigid constraints to thermal expansion. A branch connection to a main piping run is a terminal end of the branch run.

Intersections of runs of comparable size and fixity need not be considered terminal ends when so justified by the analysis. Terminal ends, for the purpose of postulating breaks, should be selected at points located immediately outside or beyond the required pipe whip restraints located inside and outside containment at penetration areas. In piping runs that are maintained pressurized during normal plant conditions for only a portion of the run (up to the first normally closed valve), a terminal end of such runs is the piping connection to this first valve.

<u>Five Degree Restraint</u> - A device which restrains the pipe in such a way that only axial loads can be transmitted past the restraint.

3.6(B).1 <u>Postulated Piping Failures in Fluid Systems Outside of Containment</u>

3.6(B).1.1 <u>Design Bases</u>

a. <u>Equipment Potentially Susceptible to Effects of Piping Failure</u>

Systems and components important to plant safety or shutdown (herein referred to as essential systems and components), located proximate to high or moderate energy piping systems, and which are potentially susceptible to the consequences of piping systems breaks and cracks, are listed in Table 3.6(B)-1. The identification of this equipment is related to predetermined piping failure locations, determined in accordance with the methodology discussed in Section 3.6(B).2.

Figures 3.6(B)-1, 3.6(B)-2 and 3.6(B)-5 through 3.6(B)-38b show the locations of the postulated pipe ruptures, locations of pipe whip restraints, and relative locations of potentially affected essential components.

The limiting acceptable conditions for, and the measures taken to protect the essential systems and components, are listed in the pipe rupture analysis summary sheets in Appendix 3A. 47

b. <u>Design Criteria for Protection Against Piping Failures</u>

The following criteria were utilized as guidelines during the station design to assure the protection of essential equipment from potential failure of nearby piping systems:

1. <u>Piping Systems Containing High Energy Fluids</u>

   a. Piping systems are to be isolated by adequate physical separation, and remotely located from essential systems and components required to shut down the reactor safely and maintain the station in a cold shutdown condition.

b. Where isolation by remote location is considered impractical, piping systems, or portions of the systems, are enclosed within structures suitably designed to protect adjoining essential systems and components from postulated piping failures within the enclosure.

c. Where both isolation by remote location and enclosure in protective structures are considered impractical, the piping systems or portions of the systems are provided with restraints and protective measures such that the operability and integrity of the structures, safety systems and components would not be impaired.

d. Protective enclosures for the piping systems are designed as seismic Category I structures capable of withstanding the combined effects of a postulated pipe break, the dynamic effects of pipe whipping, the jet impingement forces and the compartment pressurization resulting from discharging fluids in combination with the specified seismic event of the Safe Shutdown Earthquake and normal operating load.

e. Piping systems containing high-energy fluids are designed so that the effects of a single postulated pipe break will not initiate unacceptable failures of other pipes or components. In addition, any systems, or portions of systems, that are designed to mitigate the consequences of a postulated pipe failure and place the reactor in the cold shutdown condition, are provided with design features that will ensure the performance of their safety function, assuming a single active component failure.

f. For a postulated pipe failure, an escape of steam, water and heat from structures enclosing the piping shall not preclude: 1) the accessibility to surrounding areas important to the safe control of reactor operations, 2) the habitability of the control room, 3) the ability of instrumentation, electric power supplies, and components and controls to initiate, actuate and complete a safety action. In this regard, a loss of redundancy is considered permissible, but not the loss of function.

g. The design measures employed for the protection of structures, systems, and components important to safety will not prevent inservice examinations of ASME Class 2 and 3 pressure-retaining components, as required by the rules of ASME B&PV Code, Section XI, "Inservice Inspection of Nuclear Power Plant Components".

2. Piping Systems Containing Moderate-Energy Fluids

   a. Piping systems containing moderate-energy fluids are designed to comply with the criteria applied to high-energy fluid piping systems, as stated above, except that the piping is postulated to develop a limited-size through-wall leakage crack instead of a pipe break.

   b. For each postulated leakage condition, design measures are provided that will provide protection from the effects of the resulting water spray and flooding.

3. Exceptions

   Measures for protection against pipe whipping or jet impingement resulting from the breaks postulated in Subsection 3.6(B).2 are not provided for piping where any of the following applies:

   a. Piping is physically separated or isolated from any essential system or component necessary for plant safety or shutdown by means of barriers, or is restrained from whipping by plant design features such as encasement.

   b. The broken pipe cannot cause unacceptable damage to any essential system or component.

   c. The energy associated with the whipping pipe can be demonstrated to be insufficient to impair to an unacceptable level the safety function of an essential system or component. For example, a whipping pipe is considered unable to rupture an impacted pipe of equal or larger nominal pipe size and equal or heavier wall thickness.

3.6(B).1.2 Description

High energy lines are listed in Table 3.6(B)-2; moderate energy lines include all other lines not listed in this table. For a complete listing of all high and moderate energy lines, see the Seabrook line designation tabulation, Appendix 3B.

Relative to possible dynamic effects of pipe failure in the Seabrook plant layout, essential systems and components are protected from the dynamic effects of rupture of high energy piping primarily by separation and redundancy. Routing of high energy lines has been arranged to provide the maximum amount of protection by utilizing plant structural elements, such as walls or columns, and routing the high energy lines as far as practicable from essential components. In cases where separation is not possible, pipe whip restraints are used to prevent uncontrolled whipping of the high energy piping. Compartments of primary interest are the containment structure, the main steam and feedwater pipe tunnels, and the containment enclosure building and its attached compartments. 44

In the case of the control room, there are no high energy lines in the area which could affect habitability as a result of pipe whip. The main steam and feedwater lines on the pipe bridge are separated from the control room by the seismic Category I control building wall, which has been reinforced to protect the control room environment from postulated breaks in, or whip loads from, the main steam and feedwater lines. Control room habitability systems are discussed in Section 6.4.

The high energy lines outside containment whose breaks or cracks could have the greatest effect on environment within the structures housing components essential for safe plant shutdown are listed below:

1. Primary Auxiliary Building
    a. Steam generator blowdown lines
    b. Auxiliary steam and condensate lines
    c. Chemical and volume control system letdown line
    d. Hot water heating lines
2. Fuel Storage Building
    a. Hot water heating lines
3. Containment Enclosure and Connected Buildings
    a. Hot water heating lines
4. Main Steam and Feedwater Pipe Chase
    a. Main steam lines
    b. Feedwater lines
5. Diesel Generator Building
    a. Hot water heating line
6. Control Building
    a. Hot water heating line
7. Emergency Feedwater Pumphouse
    a. Hot water heating line
8. Service Water Pumphouse
    a. Hot water heating lines

Table 3.6(B)-1 lists the essential components located outside containment which are potentially susceptible to the effects of high and moderate energy piping ruptures. 44

Table 3.9(B)-23 tabulates all active valves, including those in zones outside containment, whose function must be unimpaired in the event of a pipe rupture accident.

3.6(B).1.3 Safety Evaluation

Appendix 3I summarizes the environments in each of the structures housing essential components which result from postulated rupture of the high energy lines.

An analysis of the potential effects of missiles is discussed in Section 3.5.

Pressure rise analyses of structures and compartments due to piping breaks are discussed in Sections 3.7 and 6.2.

A summary of the results of failure or leakage from high energy or moderate energy lines on nearby safety systems (failure modes and effects analysis), presented in Appendix 3A, verifies that the consequences of failures of high and moderate energy lines will not affect the ability of the plant to be shutdown safely. The analyses considered the effects of single active component failures occurring in required systems concurrent with the postulated event. 44

3.6(B).2 Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping

This section describes the design bases for locating postulated breaks and cracks in piping situated both inside and outside of containment, the procedures used to define the jet thrust reaction at the break or crack location, and the jet impingement loading on adjacent safety-related structures, equipment, systems and components.

3.6(B).2.1 Criteria Used to Define Break and Crack Location and Configuration

The criteria employed for defining break and crack locations and configurations in primary loop piping inside containment is discussed in Subsection 3.6(N).2.1. This section discusses all other piping.

The criteria are provided for those high and moderate energy piping systems for which separation or enclosure cannot be achieved.

a. High Energy Piping

1. ASME Section III Code Class I Piping

Breaks were postulated to occur at the following locations in each piping run or branch run:

(a) Terminal ends.

(b) At all intermediate locations where the maximum stress range as calculated by Eq(10) and either (12) or 13) exceeded 2.4 Sm; based upon Subsection NB-3600 of Section III of the ASME B&PV Code, 1977 Edition, up to and including the Summer, 1979 Addenda. The loadings considered were all Level A and B loads including an operating basis earthquake.

(c) At all intermediate locations where the cumulative usage factor derived from the piping fatigue analysis under the loads described above exceeded 0.1.

2. ASME Section III Code Class 2 and 3 Piping

Breaks were postulated to occur at the following locations for each piping run or branch run which does not penetrate the containment:

(a) Terminal ends.

(b) Any intermediate locations between terminal ends where either circumferential or longitudinal stresses derived by elastic methods under the loadings associated with operational plant conditions and an operating basis earthquake exceed 0.8 $(S_H + S_A)$.

See below for piping penetrating the containment.

3. Non-Nuclear Piping

Breaks in non-nuclear piping were postulated at the following locations in each piping run or branch run:

(a) Terminal ends.

(b) Each structural discontinuity (elbows, tees, reducers, valves).

4. Piping Penetrating Containment

All piping penetrating the containment is ASME Section III, Code Class 2. All high energy, high temperature lines penetrating containment make use of integrally forged flued heads. A detailed discussion of the design of these flued heads is given in Reference 1.

For main steam and feedwater piping penetrating containment, no breaks were postulated between the first whip restraint inside the containment and the five-degree restraint outside containment, since the following conditions are met:

(a) The maximum stresses, as calculated by the sum of equations (9) and (10) in paragraph NC-3652 of Section III* of the Code, considering normal and upset conditions and an OBE event, do not exceed 0.8 $(1.2\ S_h + S_A)$.

(b) The maximum stress, as calculated by equation 9 of paragraph NC-3652 under the loadings resulting from a postulated piping failure of fluid system piping beyond these portions of the piping, does not exceed 1.8 S_h.

(c) The number of circumferential and longitudinal weld points in piping have been minimized. 49

(d) The length of those portions of piping have been reduced to the minimum practical.

(e) The design of pipe restraints and anchors have not generally required welding directly to the outer surface of the pipe. Where anchors or restraints were needed, forgings were used to avoid welding to the surface of the pipe. Where lugs were used for riser clamps, a detailed analysis was made to assure compliance with stress limits stated above.

Lug attachments welded to Class 2 and 3 pipes are qualified by a procedure whose methodology is equivalent to, but more conservative than, that presented in Code Case N-318.

Local stress levels in the pipe resulting from applied lug loads are obtained by multiplying the nominal stress in the lug at the lug/pipe interface by the appropriate B or C index (as defined in Code Case N-318) for each individual loading condition. The local stresses are superimposed upon the general pipe stress as determined from program ADLPIPE to establish the total stress level in the pipe for that loading condition.

Loading conditions required to be considered for Plant Normal, Plant Upset, Plant Emergency, and Plant Faulted Operating Condition are defined (per appropriate FSAR section), and total stress in the pipe is obtained from summing the stresses for each individual loading condition that must be considered.

Local stress levels determined using B indices are added to the general stress levels from ADLPIPE and this sum is 49

* For piping design, the applicable Code edition is the 1971 Code, with addenda up to and including Winter 1972.

compared against allowable limits to demonstrate structural integrity. For the pipe wall, local stress levels determined using C indices are added to the general stress levels from ADLPIPE, and this sum is compared against the allowable range of stress (S_h+S_a).

Finally, weld stress is evaluated considering the absolute sum from all loads, independent of the operating condition, and compared against allowable stress from Table NF329.1-1, Subsection NF, ASME III. 47

The terminal ends of these portions of piping are considered to originate at a point adjacent to the restraints located inside and outside containment which are:

(a) Located reasonably close to the isolation valve.

(b) Capable of withstanding the loadings resulting from a postulated pipe rupture beyond this portion of the piping, such that neither valve operability nor the leaktight integrity of the containment is impaired.

Details of typical containment piping penetrations showing location of process pipe welds, anchorage and points of discontinuity are shown in Figures 3.6(B)-3 and 3.6(B)-4.

Inservice inspection of Code Class 2 components, including penetrations, is discussed in Section 6.6.

b. Moderate Energy Piping

Through-wall leakage cracks are postulated to occur in seismic Category I and non-nuclear fluid system piping located within or outside and adjacent to protective structures, with the following exceptions:

1. Fluid system piping between isolation valves, provided they meet the requirements of ASME Section III, subarticle NE-1120, and are designed such that the maximum stress range does not exceed 0.4 $(1.2\ S_h + S_A)$ for ASME Class 2 piping.

2. Fluid system piping located in an area in which a break in a high energy system is postulated, provided a break in a moderate energy fluid system does not result in a more limiting condition than the break in the high-energy system.

3. Seismic Category I fluid systems in which the maximum stress range in Class 2 or Class 3 or non-nuclear piping is less than 0.4 $(1.2\ S_h + S_A)$.

The cracks were postulated to occur in those locations that result in the maximum effects from flood spraying or flooding.

Through-wall leakage cracks were postulated instead of breaks in the piping of those systems that qualify as high energy fluid systems for only short operational periods, but qualify as moderate energy fluid systems for the major operational period. These systems include containment spray, safety injection and residual heat removal.

An operational period is considered short if the fraction of time that the system operates within the pressure-temperature limits specified for a high-energy system is 2 percent or less of the time that it operates as a moderate energy fluid system.

c. Type of Breaks

The following types of breaks and cracks were postulated to occur in high-energy and moderate energy piping as described below:

1. High Energy Piping

(a) Circumferential breaks were postulated to occur in high-energy piping larger than one inch nominal pipe size. Circumferential breaks are presumed to occur at right angles to the axis of the pipe, to completely sever the pipe within one millisecond and to separate the ends of the pipe to permit a flow area equal to the flow area of the pipe. See Subsection 3.6(N).2.1 for exception for RCS piping.

(b) Longitudinal splits were postulated to occur in high-energy piping four inches or larger nominal pipe size. The area of the longitudinal split was assumed to be equal to the flow area of the pipe, and the split was assumed to be parallel to the axis of the pipe. Crack orientation was selected on the basis of the most serious effects.

(c) Certain longitudinal break orientations were excluded on the basis of the state of stress at the location considered. Specifically, where the maximum stress range in the axial direction is at least one and a half times that in the circumferential direction considering upset plant conditions, then only a circumferential break was postulated.

(d) Longitudinal breaks were not postulated to occur in piping at terminal ends where the piping contains no longitudinal welds or at intermediate locations where the criteria for a minimum number of break locations were satisfied.

2. Moderate Energy Piping

Through-wall leakage cracks were postulated to occur in moderate energy piping larger than one inch nominal pipe diameter, and to have openings up to one-half pipe diameter by up to one-half the pipe wall thickness.

d. Jet Impingement Force Criteria

The criteria used to evaluate jet impingement forces are described in Appendix 3C, Procedure for Evaluation of Jet Impingement Loads from High Energy Piping Failures. After jet forces imposed on structures or equipment have been determined, the capacity of the structures or equipment to support these loads without damage is investigated using conservative methods. Jet impingement loads are considered to be faulted condition loads and are so evaluated.

3.6(B).2.2 Analytical Methods to Define Forcing Functions and Response Models

This section presents a description of the methods used to define forcing functions and response models for pipe whip analysis. For RC Loop piping, see Subsection 3.6(N).2.2.

a. Forcing Functions

1. Time Dependence

The normal steady-state operating conditions of the plant were assumed prior to postulating a pipe rupture.

When circumferential ruptures were postulated, the through-wall crack was assumed to develop across the circumference of the pipe instantaneously, and the ruptured pipe was assumed to separate to the full flow area (e.g., double ended rupture) in one millisecond.

When longitudinal ruptures were postulated, the time for a longitudinal rupture to open to its maximum length was assumed to be one millisecond.

2. System Friction Loss Dependence

In calculating forces acting on the piping system, full credit may be taken for any restrictions or line losses between the break and the pressure reservoir(s). For Seabrook, however, the simplified conservative analyses did not consider friction losses.

3. Closed-Ended Lines

For the closed end of a line (dead end or normally-closed valves) when it was obvious that the fluid dynamic forces could not be sustained, pipe whip response was not considered.

4. Discharge Coefficient

For flashing or nonflashing flow through circumferential and longitudinal breaks, a discharge coefficient, C_d, of 1.0 was used to determine the flow rate through the break,

$$Q = C_d AV$$

where: Q = flow rate through break
A = break flow area
V = velocity
C_d = discharge coefficient

5. Options

The jet thrust reaction, forcing function at the break locations may be generated from a dynamic fluid system model. However, a simplified approach was used, applying a maximum thrust value defined for discharge of non-flashing liquid or for discharge of saturated or superheated vapor as:

$$T = K_1 \ (K_2 \, P_o - P_a) \ A$$

Where: T represents the thrust force
P_o represents vessel pressure (psig)
A represents break flow area
K_1, K_2 represents thrust coefficients
P_a pressure of ambient outside system (psig)

Representative values of K reported by Moody (2) are:

(a) Saturated and superheated vapor, $K_1 = 1$, $K_2 = 1.26$

(b) Subcooled liquid - non flashing, $K_1 = 2$, $K_2 = 1$

Other values may be used when substantiated; however, the Moody coefficients have been used for pipe rupture analysis on this project.

For circumferential breaks, direction of thrust was assumed to be along the centerline of the pipe in a direction opposite the jet flow.

For longitudinal breaks, thrust was assumed in a direction opposite jet flow.

For all breaks, maximum thrust was assumed to occur within 1 millisecond and to be a steady state condition thereafter.

3.6(B).2.3 Dynamic Analysis Methods to Verify Integrity and Operability

a. Dynamic Analysis Methods

The analysis of a piping system and its restraints under pipe rupture conditions requires consideration of the interaction effects of both piping and restraints. The magnitude and distribution of loadings depends upon such parameters as the restraint load-deflection gaps between piping and restraint, piping flexibility, break location, etc.

1. Energy-Balance Analysis

In this method, kinetic energy generated during the first quarter cycle movement of the ruptured pipe is imparted to the piping/restraint system through impact and is converted into equivalent strain energy. Deformations of the pipe and the restraint are compatible with the level of absorbed energy. For applications where pipe rebound may occur upon impact of the restraint, an additional amplification factor 1.5 was used to establish the magnitude of the forcing function in order to determine the maximum reactor force of the restraint after the first quarter cycle of response. Amplification factors other than 1.5 may be used if justified by more detailed dynamic analysis. Appendix 3D presents the procedure used for calculating piping/restraint system loads by the energy balance method.

2. Quasi-Static Analysis

In order to satisfy the system capability requirements, a dynamic analysis is the preferred method. In the event a dynamic analysis is not possible or feasible for a piping and restraint system, a quasi-static analysis may be possible if it is shown to give more conservative results.

Two design considerations are required as in the dynamic analysis. The system must be capable of supporting both the dynamic and the steady-state blowdown loads.

If a constant, conservative blowdown force is assumed, the system is independent of the dynamic event occurrence time. Since the dynamic inertia effects are therefore unknown, the load-sharing relationship between the pipe and the restraints, etc., cannot be determined.

The jet force can be represented by a conservatively amplified static loading, and the ruptured system is analyzed statically. The amplification factor that is used to establish the magnitude of the forcing function is a conservative value obtained by comparison with the factors derived from detailed dynamic analysis performed on comparable systems. Appendix 3E presents the procedure used for calculating piping/restraint system loads by the equivalent static analysis method.

b. Design Considerations

Pipe rupture locations and orientation were determined as stated in Subsections 3.6(B).2 and 3.6(N).2. Effects of each rupture were evaluated and, if necessary, whip restraints were located to protect the essential systems or components.

Pipe whip restraints for the reactor coolant system piping were designed to limit the motion of the ruptured piping and to restrict the flow area of the breaks in order to limit jet thrust forces.

For other Code Class 1, 2 or 3 piping, the whip restraints were designed to prevent unrestrained whipping of the piping, but at the same time permit unrestrained thermal movement of the piping.

In some cases, such as on the main steam and feedwater lines in the penetrations and piping tunnel areas, it was appropriate to use pipe whip restraint steel as intervening elements or as supplementary steel for the attachment of seismic restraints. Wherever this was done, the boundary between PWR steel and ASME Class 2 seismic restraints was defined by showing the PWR steel and the seismic restraints on separate fabrication and installation drawings. All Code Class supports and restraints are identified on the drawings as N-Stamp Items. 45

After the whip restraints were located, the following information was developed:

(a) Jet thrust force
(b) Pipe seismic displacement
(c) Pipe thermal displacement
(d) Maximum allowable pipe travel
(e) Insulation thickness

Minimum gap between pipe and restraint is determined from consideration of (b), (c) and (e) above. Restraint stiffness is determined from (a) and (d). Where the whip restraint is also a seismic restraint, the following values for stiffness were used:

(a) For piping larger than 8" nominal diameter: 10^6 or 10^7 lb/inch.

(b) For piping from 2½" to 6" nominal diameter: 10^5, 10^6 or 10^7 lb/inch.

(c) For piping up to 2" nominal diameter: 10^4, 10^5 or 10^6 lb/inch.

Analyses of representative piping configurations show that a change in stiffness of one order of magnitude in either direction will not change pipe stresses significantly, so that the designers generally used the lowest values for stiffness in the ranges given, unless pipe deflection is the critical parameter.

In the design of the whip restraints, the energy absorption capacity of the pipe was not considered. For structural steel whip restraint members, when elasto-plastic design methods were used, the stress limit for design is 90% of the yield stress value shown in the AISC Steel Construction Manual. When elastic design methods were used, the stress limit for design is 63% of yield. 45

In general, for pipe whip restraints, elastic design criteria were used. In cases where elasto-plastic design criteria were used, and the pipe whip restraint was also used as an intervening element for attachment of pipe supports or restraints, it was first designed as a whip restraint using elasto-plastic criteria, and was then checked to verify its ability to support the pipe support/restraint loads using elasto-plastic criteria. 45

In order to determine the adequacy of a system, including pipes and restraints, following postulated pipe rupture accident, two design considerations must be evaluated:

1. <u>Dynamic Response</u>

Upon the occurrence of the postulated pipe rupture, the system of pipe restraints structure, etc., will respond dynamically to the suddenly applied blowdown thrust, F_B (t). This thrust will move the pipe so that it impacts against the restraint with an impulse equal to the pipe mass times the impact velocity. The product of blowdown thrust, F_B, and the time after this impact until motion ceases, t, will be an additional impulse on the system.

2. Static Equilibrium

Following the occurrences of the dynamic event (when motion ceases), the system must be able to support the active applied forces (the blowdown thrust). Therefore, the system must satisfy the requirements of a static analysis.

For a conservative static analysis, each component (i.e., pipe, restraint) is capable of supporting the total load (or it is shown which component(s) support the load). When this is done and the components will have the load capacity to support the steady-state blowdown, the system design is considered to be conservative.

c. Design Loading Combinations

Pipes which have been identified in accordance with Subsection 3.6(B).1 as those which could cause adverse effects due to pipe movement were provided with means of controlling their motion, if barriers, separation, or some other acceptable method was not used for protection.

1. Piping

The pipe will be subjected to dynamic forces following a postulated pipe break event. An evaluation was made to insure that the load carrying capability of the pipe is not exceeded.

(a) Adequacy Requirements

In order for the motion of pipes to be controlled, it is necessary that the load on the pipe during the dynamic event be less than the load capacity of the pipe. The dynamic load capacity of the pipe can be determined by test or by a suitable analytical model.

Without testing, the load capacity for analysis is limited to the bending associated with a maximum fiber strain of 50 percent of the ultimate strain of the pipe material. Ultimate strain is defined as the value of strain which corresponds to the maximum stress on the engineering stress-strain diagram. For a given material where there is a range of values due to statistical variation, the guaranteed minimum value of ultimate strain is used.

The second requirement, to insure that the motion of pipes is controlled, is for the moment-carrying capacity of the pipe to be greater than the applied moment after the occurrence of the dynamic event. An ultimate moment, M_u, is defined as the maximum moment that the pipe cross section can support. If the applied moment, M_a, defined as a force times lever arm is numerically smaller than M_u, uncontrolled rotation of the pipe will not occur.

(b) Material Properties

Careful consideration was given to the piping material properties used. The rapid loading conditions due to pipe rupture may require the consideration of high strain-rate effects on material behavior, in addition to strain-hardening considerations. Section III of the ASME Code provides tabulations of material properties which may be used for some evaluations. The values of yield strength at temperature, for example, are minimum values for static loadings. In calculating the allowable span distance between restraints, use of minimum values is conservative. In calculating the maximum moment which could be exerted on an anchor point, the use of minimum values would be unconservative. The applied moments, M_a, during the steady state blowdown will be no greater than 90 percent of the moment capacity of the pipe based on minimum pipe material properties determined from test, applicable specifications, or codes.

2. Restraints

For BOP piping, pipe whip restraints are provided to maintain the motion of the ruptured pipe within controlled limits. The limit of pipe motion is the area within which no essential component would be affected by impact or jet impingement. 49

The primary function of a restraint is to control pipe motion upon the occurrence of a pipe rupture. As used in this context, a restraint is considered to be different from a support. In certain instances, a restraint may also function as a support, and is designed according to the faulted conditions rules of Subsection NF of ASME Code, Section III.

Typical whip restraints consist of heavy structural members extending from the building structure to the pipe, and a structural box or a series of U-bolts which surround the pipe to restrain lateral motion. Unless the restraint acts also as a thermal or seismic restraint, contact between the pipe and the whip restraint is prevented by means of a suitable air gap. Where it is necessary to reduce pipe impact loads on critical structures, energy-absorbing devices are used between the pipe and the structure.

(a) Design Limits

Pipe restraints are designed for one-time usage, and as such may be allowed to have greater distortion, plastic deformation, etc., than normally permitted for support design.

For elasto-plastic system analysis, wherein the effects of strain-rate, strain-hardening, etc., are included, the 49
permanent strain in metallic ductile materials is limited to 50 percent of the uniform strain. When a crushable energy-absorbing material is used, the deformation is limited to that corresponding to 50 percent of the total energy absorption capacity of the crushable material.

(b) Material Properties

Materials selected for restraints designed to significant strain levels must have well-known dynamic mechanical properties. Assurance was provided by material inspection.

3.6(B).2.4 Guard Pipe Assembly Design Criteria

Guard pipes are employed in the following locations: a) on the main steam and feedwater lines to prevent pressurization of the annulus in the event of a pipe rupture; b) on the main steam lines just north of the main steam and feedwater pipe chase to protect the main steam isolation valves from missile damage due to jet impingement of the pipe chase north wall; and c) on the main steam line in the pipe bridge area to protect the control building wall from jet impingement. The guard pipes in the containment enclosure were designed as a part of the flued head penetrations for the main steam and feedwater lines. 49

A discussion of the design criteria and analysis of the high energy containment penetrations is given in Reference 1. The purpose of the penetration assemblies is to permit penetration of the containment by process pipes without jeopardizing containment integrity. Where they are used as guard pipes, they also serve to prevent overpressurization of the containment enclosure and annulus. No other lines in this area require guard pipes.

In general, all process pipes penetrating containment are seamless. Penetration assemblies for large high temperature lines are integrally forged flued head design. Penetration assemblies for cold lines or small lines (under 1" nominal diameter) are seamless pipe welded to flat plate heads which are in turn welded to sleeves anchored in the containment structure. All penetration sleeves are seal welded to the steel containment liner, and leak test channels are provided for periodic testing of containment leak-tightness.

There are no process pipe welds located within the protective assemblies, with the exception of the 2" diameter steam generator blowdown lines. The process pipe welds for these lines do not require inservice inspection (Ref. IWC-1220d of ASME XI).

Moment-limiting restraints have been provided for all penetrations carrying high energy piping in order to maintain process pipe stress levels below the limits defined in Equation 8 of NC3652 for maximum stress range considering all upset design transients in combination with OBE.

3.6(B).2.5 Material to be Submitted for the Operating License Review

The results of the analyses performed on high and moderate energy piping systems and their supports to determine the loadings from postulated pipe breaks and cracks, as well as the procedures used, are presented in the following appendices:

Appendix 3A	Pipe Break Analysis Summary Sheets
Appendix 3B	Line Designation Tabulation (Seabrook Line List)
Appendix 3C	Procedure for Evaluating Jet Impingement Loads from High Energy Piping Failures
Appendix 3D	Procedure for Calculating Elasto-Plastically Designed Pipe Whip Restraint Loads by the Energy Balance Method
Appendix 3E	Procedure for Calculating Elastically-Designed Pipe Whip Restraint Loads by Equivalent Static Analysis Method

3.6(B).3 References

1. "Stress Report for High Energy Piping Penetrations for PSNH-Seabrook Station Units 1 and 2", Stress Report No. 9763-325-1, dated September, 1976, United Engineers & Constructors Inc.

2. Moody, F.J., "Prediction of Blowdown Thrust and Jet Forces", Paper No. 69-HT-31, presented at the ASME-AICHE Heat Transfer Conference, Minneapolis, Minnesota, August 3-6, 1969