EVALUATION OF PRESSURIZER
SAFETY AND RELIEF VALVE SYSTEM

for

POINT BEACH NUCLEAR PLANT

Prepared for

Wisconsin Electric Power Company

by

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December 1982

EDS Report No. 09-0870-001
Revision 0

EDS NUCLEAR INC.

REPORT APPROVAL COVER SHEET

Client: Wisconsin Electric Power Company

Project: SRV Evaluation Job Number: 0870-005,006

Report Title: Evaluation of Pressurizer Safety and Relief Valve System for Point Beach Nuclear Plant

Report Number: 09-0870-001 Rev. Ø

The work described in this Report was performed in accordance with the EDS Nuclear Quality Assurance Program. The signatures below verify the accuracy of this Report and its compliance with applicable quality assurance requirements.

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REVISION RECORD

Rev. No.	Prepared	Reviewed	Approved	Approval Date	Revision

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 General

EDS Nuclear has completed an evaluation of the Point Beach Nuclear Plant (PBNP) pressurizer safety and relief valve system. This evaluation was performed for Wisconsin Electric Power Company in accordance with the recommendations of NUREG-0578, Section 2.1.2, clarified by NUREG-0737, Item II.D.1, and by the NRC's letter of September 29, 1981.

This report summarizes the evaluation.

1.2 Work Performed

The EDS scope of work included an evaluation of the operability of the safety valves and the functionality and integrity of the system piping. The operability of the power-operated relief valves (PORV's) and the block valves was not evaluated within this scope of work. PORV and block valve operability has been addressed in Wisconsin Electric Power Company letters to the NRC dated June 30, 1982 and August 9, 1982.

The operability of the safety valves was evaluated principally by correlation with the industry-sponsored Electric Power Research Institute (EPRI) Test Program.[1] The applicability of this program to PBNP is addressed in Section 3.2.1. The results of the evaluation are given in Section 3.2.2.

For the pressurizer safety and relief valve discharge piping system, thermal-hydraulic analyses were performed to calculate the bounding dynamic loading induced on the piping by rapid valve actuation. The computer program RELAP5/MØD1[2] was used, together with the post-processor REFØRC.[3] These analyses are described in Section 3.3.

Piping analyses were performed for these thermal-hydraulic loads, using the computer program SUPERPIPE.[4] Analyses were also performed for gravity, thermal, pressure, and seismic loads. These analyses are described in Section 3.4.

1.3 Modification of Loop Seal

As an ongoing part of the evaluation, potential modifications to the loop seal and the safety valves were considered as a means of either improving system performance or reducing discharge piping loads.

Based on the adequacy of the existing system, no modifications to the valves are planned. Furthermore, the loop seals will be retained. However, Wisconsin Electric has elected to raise the temperature of the loop seal water by adding insulation upstream of the safety valves.

The evaluation of safety valve operability (Section 3.2) is based on the cold, uninsulated loop seal. Raising the loop seal water temperature will further assure the valves' operability.

As the decision to insulate the loop seal was made before the thermal-hydraulic analyses were started, these analyses (Section 3.3) have been based on the modified loop seal temperature profile. Thus, they can be used as the basis for any future modification to the discharge piping system.

The discharge piping stresses reported in Section 4.0 are therefore also based on the modified temperature profile. Stresses for the existing, cold loop seal would be expected to be somewhat higher. However, this is not considered to impact the conclusions that have been drawn as to the adequacy of the existing system.

1.4 Conclusions

Based on the EPRI Test Program results and the plant-specific evaluation described in Section 3.2, it is concluded that the operability of the PBNP safety valves is confirmed. For the postulated, severe system operating transients under which they may be activated, the safety valves should relieve pressure and prevent overpressurization. Furthermore, their operating characteristics are such that the conclusions drawn with regard to the safety aspects of PBNP in Section 14 of the FFDSAR[5] should not be impacted.

Due to the high out-of-balance loads induced by the sudden discharge of the water loop seal, the stresses calculated on certain portions of the discharge piping system exceed the specified allowable stresses. Due to the conservatism of the transient definition and the thermal-hydraulic and piping analyses, the stresses may be significantly overpredicted. However, some yielding of the PBNP discharge piping system would probably occur following safety valve actuation. Also, the loads computed on certain supports exceed those to which these supports were evaluated in the recent IE Bulletin 79-14 effort (although it is probable that the ultimate capacity of these supports is significantly greater than the 79-14 loads).

Further evaluations are in progress to provide modifications to the discharge piping supports and increase the system's ability to withstand the calculated transient loads. As is discussed in Section 4.5, based on the transient nature of the loading, the function of the piping, and the low probability of safety valve actuation, there is no significant safety impact to the present piping and support configuration pending installation of these modifications.

2.0 SYSTEM DESCRIPTION

2.1 General

PBNP is a two unit power plant. Each unit is a Westinghouse pressurized water reactor with two primary coolant loops. Each unit is rated at 1518 MW_t. In general, Unit 2 is a mirror image of Unit 1.

The safety and relief valve system for each unit consists of:

- Two spring-loaded, Crosby Valve and Gage Co. HB-BP-86 series safety valves
- Two Copes-Vulcan Inc. power-operated relief valves
- Two Velan gate-type block valves with Limitorque operators
- Three pressurizer outlet piping lines: one line, including a loop seal, for each of the two safety valves, and one (branching) line for the block and power-operated relief valves
- A common discharge piping line, routed into the pressurizer relief tank (PRT)

Details of the safety and power-operated relief valves are given in Tables 2-1 and 2-2, respectively.

The inlet and outlet piping is described in Section 2-2.

The layout of the Unit 1 system is shown in Figure 2-1. The Unit 2 layout is essentially a mirror image of Unit 1, with some difference in the piping near the PRT.

If an abnormal transient causes a substained pressure increase in the pressurizer at a rate exceeding the control capacity of its spray system, a high-pressure trip signal is activated. This signal opens the PORV's. If the pressure continues to rise and reaches the set pressure of the safety valves, one or more of these valves will open to relieve the overpressure.

2.2 Piping System

Each safety valve is connected to a pressurizer outlet nozzle by 4-inch diameter piping in a loop seal configuration. The loop seal is currently uninsulated and contains cold water. Each safety valve also has a 6-inch discharge (or tail) pipe which runs into a common 8-inch header pipe.

The two PORV's share one pressurizer outlet nozzle. A 4-inch pipe from this nozzle branches into two 3-inch pipes, one for each PORV. For Unit 1, one PORV is a 3-inch, the other a 2-inch valve. For Unit 2, both are 2-inch valves. The 2-inch PORV's are attached to the 3-inch pipes through 3 by 2-inch reducers. Each PORV has a 3-inch discharge (or tail) pipe. These run into a common 4-inch header which runs into the 8-inch header common to the safety valve discharge piping.

The block valves are in series with (and upstream of) the PORV's.

The 8-inch header pipe discharges into the PRT. The PRT has a volume of 5984 gal and is equipped with an L-quencher and a 100 psig rupture disc.

2.3 Operating Conditions

The most severe reactor coolant system overpressure condition requiring operation of the PORV's or of the PORV's and the safety valves would occur following the postulated instantaneous seizure of a reactor coolant pump rotor - a "locked rotor" accident.[5,6]

The transient analysis for a locked rotor accident conservatively assumes that the PORV's do not operate and that pressure relief is through the safety valves only. The peak pressurizer pressure computed for this case is 2763 psig with a maximum pressure ramp rate of 297 psi/sec.

Upon clearing of the loop seal water, the fluid condition is saturated steam only. No postulated PBNP transient results in the passage of solid water through the safety valves after discharge of the loop seal water. Cold overpressurization may result in passage of solid water through the PORV's only; however, given the slow opening time of the PORV's relative to the safety valves, the locked rotor transient would induce a much more severe loading of the system piping.

3.0 POINT BEACH NUCLEAR PLANT EVALUATION

3.1 Introduction

The evaluation was performed in three parts.

First, the operability of the PBNP safety valves was evaluated by correlating the EPRI Test Program data to the PBNP-specific design.

Secondly, thermal-hydraulics analyses were performed to determine the bounding forces imposed on the piping by valve actuation. Actuation of a valve allows the discharge of loop seal water and high-pressure steam from the pressurizer into the discharge piping, inducing pressure and momentum transients. Until steady-state is achieved, these transients create significant unbalanced forces on each straight run of the piping.

Thirdly, dynamic piping analyses were performed to determine the response of the piping to these (and other relevant) loads. From these analyses, upper-bound stresses on the piping and upper-bound loads on the supports were calculated.

These analyses are described below.

3.2 Safety Valve Evaluation

At the request of the PWR utility industry, EPRI directed a full-scale test program to evaluate the performance of pressurizer safety and relief valve piping system. A number of valves, representative of those currently installed, were tested under conditions that encompassed typical, postulated pressure relief transients. Actual testing was completed in December 1981. Reports on the results of these tests have been issued to the participating utilities and the NRC.[7,8,9]

3.2.1 Applicability of EPRI Test Results

The EPRI Test Program included tests on a number of Crosby and Dresser spring-loaded safety valves. These valves were tested with various inlet piping configurations and for various fluid and flow conditions. Those tests which are relevant to PBNP and their applicability are discussed in this section. Valve type and installation, inlet and outlet piping configuration, and operating conditions are addressed.

Valve Type

Crosby 3K6 and 6M6 safety valves were tested. These valves are structurally and functionally similar to the PBNP Crosby 4K26 valves. A comparison was performed by Crosby Valve and Gage Company and is included in the EPRI Valve Selection/Justification Report.[10] This report considered the effect on valve operability of differences in valve operational characteristics, materials, design details, and size. The conclusion states that the selected test valves (3K6 and 6M6) do represent (and thus the EPRI test results are fully applicable to) the Crosby valves presently installed in PWR plants (including the 4K26).

Inlet Piping Configuration

The Crosby valves were tested with both short and long (loop seal) inlet piping configurations. Both PBNP units have long inlet, loop seal configurations.

The geometry of the long inlet configurations used for both the 6M6 and the 3K6 tests was essentially the same as that installed at PBNP - however, specific pipe dimensions and lengths differed. For example:

- The 6M6 and 3K6 inlet piping was of 6 and 3-inch diameter, respectively: The PBNP piping is 4-inch diameter.

- The distance from the pressure source nozzle to the valve inlet was approximately 142 and 114 inches for the 6M6 and 3K6 valves, respectively: For the PBNP units, it is less than 100 inches.

- The volume of the loop seal water was approximately 1760 and 470 cubic inches for the 6M6 and 3K6 valves, respectively: For the PBNP units, it is less than 370 cubic inches.

- Similarly, the lengths of the loop seal water slug were 94 and 61 inches for the test valves, but less than 48 inches for the PBNP units.

In summary, while the 6M6 and 3K6 tests are clearly applicable, it is noted that the PBNP water loop seal slugs are much smaller that those used in the Test Program. Also, the inlet piping length is shorter - this will lead to the plant-specific inlet pressure drop being generally less than the tested inlet pressure drop.

Outlet Piping Configuration

The test configuration is essentially similar to that for PBNP. However, the distance from the valve outlet to the first elbow was considerably more than that for PBNP (approximately 59 inches versus 22 inches). Similarly the second straight run was longer (approximately 280 inches versus 60 to 110 inches). The effect on valve operability is covered under the discussion of backpressure. However, the shorter runs at PBNP will result in generally lower transient out-of-balance forces on the outlet piping than were recorded in the tests.

Fluid Conditions

The valve inlet fluid conditions used in the loop seal tests included cold loop seal water followed by saturated steam, saturated water, or subcooled water. Transitions from steam to water, and heated loop seal water cases were also run.

For the current PBNP configuration, the tests with a cold loop seal followed by saturated steam only are applicable - for the planned, modified configuration (see Section 1.3), the tests with a heated loop seal water followed by saturated steam are also applicable. These tests are listed on Table 3-1.

Inlet Pressure

For the PBNP safety valves, the analysis of the critical, locked rotor transient is based upon the safety valve opening at 2485 psig. The calculated pressure ramp rate at this pressure is 297 psi/sec., and the peak pressurizer pressure is 2763 psig. These are the maximum ramp rate and peak pressures for any transient analyzed.

All the tests listed on Crosby safety valves were on valves set at 2485 psig. The pressure ramp rates range up to 375 psi/sec. Clearly, these inlet pressure test conditions envelope those under which the PBNP safety valves may be required to operate.

Backpressure

The steady-state backpressures for the EPRI tests listed in Table 3-1 ranged from 227 to 700 psia. The thermal-hydraulic analyses described later in this report determined backpressures for the PBNP valves of approximately 550 psig.

Applicable Tests

Table 3-2 includes a comparison of pressure ramp rates and backpressures for the relevant tests listed in Table 3-1. Based on these, tests which are directly relevant to the PBNP configuration (specifically, those with high pressure ramp rates and backpressures) are indicated. While the remaining tests in this table do provide applicable data on the operability of the PBNP valves, they are of less direct relevance.

3.2.2 PBNP Safety Valve Operability

The Crosby 6M6 and 3K6 safety valves operated successfully in all tests applicable to the PBNP loop seal configuration - a water loop seal followed by saturated steam. In all cases they relieved pressure and prevented excessive overpressurization.

The applicability of these tests to PBNP has been addressed in the previous section. Thus, on the basis of the EPRI Test Program, it is concluded that the operability of the PBNP safety valves is confirmed.

As has been noted in the EPRI Test Program reports, valve flutter occurred during some tests with loop seals; however, subsequent valve performance was not affected substantially. Also, delayed lift (until the loop seal had cleared) and instances of valves opening and closing slightly outside the system specifications were observed on some tests. The impact of these test valve response characteristics on PBNP is discussed below.

Valve Flutter

On certain of the EPRI tests, the valve stem did not immediately open to its rated, full-lift position. Rather, oscillation (flutter) occurred, particularly during clearance of the solid water in the loop seal. In more severe instances, the valve reclosed during these oscillations (chatter). In other tests, this flutter (or chatter) occurred during the closing cycle.

The flutter and chatter was confined to long inlet configurations. It was most pronounced on tests in which solid water conditions occurred. With the exception of the loop seal water clearance, these solid water conditions are not applicable to PBNP. Note also that chatter only occurred on three of the tests listed in Table 3-2. These were all low backpressure tests - PBNP has high backpressure.

The phenomenon is apparently related to upstream water hammer. Upon initial valve lift, a pressure wave (pressure drop) is propagated upstream through the long inlet piping. This wave is reflected at the pressurizer interface and travels back to the valve. The resultant pressure drop at the valve may cause the valve to momentarily start closing until the pressure rebuilds. Under certain resonance conditions between the valve stem and this pressure wave, flutter may occur.

The tendency for flutter to occur will thus be dependent on the valve characteristics, the fluid conditions, and the length of the inlet piping - that is, the distance to the pressurizer.

In interpreting the significance of the EPRI Test Program results with respect to flutter and chatter, it is assumed that the valve characteristics of the PBNP-specific 4K26 valves and the 6M6 and 3K6 valves are essentially the same.

For the test on the 3K6 valve listed in Table 3-2 as directly applicable to PBNP, the valve response was stable. For the three corresponding tests on the 6M6 valve, some flutter occurred in each case. This was confined to the period during loop seal clearance.

As noted in the previous section however, the extent and volume of the loop seal and the length of the inlet piping at PBNP is considerably less than for either the 6M6 or 3K6 tests. Based on this, it is concluded that any flutter that may occur at PBNP will be of lesser extent and severity than that observed in these EPRI tests. This is because less loop seal water must be discharged and subsequent water hammer will be of higher frequency and thus unlikely to resonate with the valve.

Furthermore, should flutter (or even chatter) occur, it will not affect the operability of the valves. They will continue to open to relieve pressure and to close as-required. Damage to the valve seat may occur, but any post-activation leakage (the maximum observed in the tests listed in Table 3-1 was 1.5 gpm) will not be significant.

Delayed Lift

In most tests on the loop seal configuration, the valve opened partially to discharge the loop seal water before opening fully on the subsequent saturated steam. The time between initial opening and full lift was of the order of one second or less.

Similar behavior would be expected of the PBNP valves. However, given the lesser volume of the PBNP loop seals (370 cubic inches versus 470 and 1760 cubic inches for the 3K6 and 6M6, respectively), the time between initial opening and full lift will be correspondingly less.

This slight delay in full lift is not considered to be of consequence in evaluating the pressure relief system's ability to relieve the postulated operating transients for PBNP.

Valve Opening Pressure

Valve specifications require that the safety valves open within ±3 percent of their set pressure. The opening pressures of the 3K6 and 6M6 safety valves in the tests relevant to PBNP (Table 3.1) ranged to +8.9% of the set pressure.

Given the conservatism of the limiting, locked rotor transient definition for PBNP - which, among other conservatisms, does not consider the relieving capacity of the PORV's - the variation is not considered significant.

Valve Lift and Flow

The 3K6 generally achieved rated lift and at least 90 percent of the required rated flow. The 6M6 generally exceeded the required rated flow. Based on this, it is deduced that the PBNP 4K26 valves will provide sufficient relieving capacity.

Valve Blowdown

The blowdown specified for the PBNP valves is 5 percent. The actual blowdown in the EPRI tests ranged from 5 to 10 percent for the 6M6 valve, and from 17 to 20 percent for the 3K6.

Based on this, the blowdown for the PBNP safety valves may exceed 5 percent. This is not considered significant. Since PBNP is designed to accommodate losses of reactor coolant resulting from postulated openings in the reactor coolant system, it is clear that increased blowdown is not a safety concern.

Ring Settings

For the Crosby 6M6 tests listed in Table 3-1, a limited variation of the ring settings was carried out. The effect of these ring setting variations on Crosby valve performance during the tests was not significant.

3.3 Thermal-Hydraulic Analysis

This section describes the development of force time histories induced on the piping system by safety valve actuation. This includes:

- Development of a thermal-hydraulic computer model of the system
- Performance of analysis to determine transient state histories at discrete locations
- Integration of these transient state histories to develop force time histories on the piping

3.3.1 Thermal-Hydraulic Models

The thermal-hydraulic analysis was performed using the computer program RELAP5/MØD1, which is described in Appendix A.

RELAP5/MØD1 thermal-hydraulic models were developed for each unit. Each consists of a number of fluid control volumes connected by flow paths or junctions. These volumes extend through the piping system from the pressurizer to the PRT, and through the rupture disc to the containment.

The Unit 1 model contains 196 control volumes and 196 interconnecting junctions. The Unit 2 model used 210 control volumes and 210 interconnecting junctions.

The size of the volumes used was decreased in regions where the hydrodynamic behavior is expected to change more rapidly. In particular, the control volume size in the areas where loads could be underestimated due to numerical smearing was maintained less than or equal to the loop seal water volume. Since the probability of numerical smearing decreases as the water slug travels downstream, the control volume size was increased gradually toward the PRT.

Control junctions were included at all changes in flow area - such as the safety valves, reducers, tees, and the pressurizer and PRT nozzles. Other junction locations were chosen to maintain dynamic stability and to provide sufficient force detail.

Individual control volumes and junctions were defined in terms of fluid state and phase parameters, geometry, and flow characteristics. The boundaries were placed to ensure adequate representation of the fluid transient.

To model each valve, a valve area, opening time, and loss coefficient were input. The critical flow correlations built into the code determine the valve flow rate based on these input parameters and the inlet pressure.

The alternate choking model in RELAP5/MØD1 was not used in the discharge piping for the transient calculations. It was, however, used upstream of and at the valves since choked flow would occur in these areas.

3.3.2 Parameters and Assumptions for Thermal-Hydraulic Analysis

This section defines (and describes the basis for) key assumptions and parameters for the thermal-hydraulic analysis.

Safety Valve Parameters

Each unit has two safety valves mounted on the pressurizer. Pertinent safety valve data is given in Table 2-1.

Flow Rate - The rated capacity of each Point Beach safety valve is 288,000 lbs/hr of saturated steam. This value was used in the analyses. In the EPRI tests, the larger 6M6 valve achieved flows in excess of its rated capacity, while the smaller 3K6 achieved flows slightly lower than its rated capacity. Thus, the use of rated capacity is considered appropriate.

Set Pressure - Both safety valves were assumed to open simultaneously with the PORV's at the safety valve setpoint of 2485 psig.

Valve Opening Time - Valve opening (pop) time was based on the valve achieving full lift in 20 milliseconds. This is conservative. The poptimes recorded for the 6M6 and 3K6 valves in the EPRI test ranged from 20 to 80 milliseconds.

PORV Parameters

Each unit has two PORV's. These are attached to the pressurizer through a common nozzle. Pertinent PORV data is given in Table 2-2.

Flow Rate - The maximum rated capacity of each PORV is 210,000 lb/hr. This value was used in the analyses.

Set Pressure - The set pressure for the PORV's is 2335 psig; however, the analysis assumes that both valves open at 2485 psig. The degree of conservatism introduced by this assumption has been investigated using a sequential valve actuation model - the effects were found to be negligible.

Valve Opening Time - The thermal-hydraulic analysis assumes a 0.80 second opening time for the PORV's.

Initial Conditions

The initial conditions for components upstream of the safety and power-operated relief valves were assumed to be those of the pressurizer. The pressurizer was assumed to contain saturated steam. The initial conditions for downstream components were assumed to be those of the PRT, the normal operating pressure of which is less than 5 psig. Initially, it was assumed to contain water and nitrogen at 14.7 psia.

Loop Seal Temperature Profile - The safety valve loop seals were assumed to be heated by means of enclosed insulating boxes as shown in Figure 3-1 (see discussion in Section 1.3). The temperature profile used in the RELAP5/MØD1 analysis is shown on Figure 3-2.

Heat Structure Model

Condensation effects were conservatively ignored because

- considerable uncertainties are involved in the definition of a heat transfer coefficient, and
- a leaky valve would cause high pipe wall temperatures, thereby reducing the beneficial effect of wall heat transfer.

PRT Level

Under normal operating conditions, the PRT is 72 percent full. This level was used in the analysis. As the level only determines quench capacity, the short-duration transient considered in this analysis would not be sensitive to differences in the tank level.

3.3.3 Development of Force Time Histories

After the transient state histories were determined using RELAP5/MØD1, force time histories on the piping system at changes in flow direction and flow area were generated using REFØRC. REFØRC is described in Appendix A.

These forcing functions include wave forces (control volume forces) and blowdown forces (control surface forces). Gravity forces were determined separately within the piping analyses.

3.3.4 Thermal-Hydraulic Results and Discussion

From the RELAP5/MØD1 analyses, transient pressures in the piping system, backpressures on the safety valves, and steady-state temperature profiles were determined. From the REFØRC analyses, forces on the piping system were calculated.

The analyses were reviewed for reasonableness. In particular, the adequacy of the simulation of the valves was verified.

Key results for both units are summarized below. As expected, results for the two units are very similar - only in the region of the PRT, where the geometries differ significantly, do the results show marked differences.

Backpressures - A typical plot of safety valve backpressure is shown on Figure 3-3. Maximum backpressures for each valve are summarized on Table 3-3.

Temperature Profiles - Similarly, maximum discharge line temperatures were those in the steady-state phase at the end of the transient. Maximum temperatures at each valve and at the PRT nozzle are given on Table 3-4.

Discharge Piping Forces - The force time-histories on the elbow immediately downstream of safety valve PCV-435, on the second elbow downstream of PORV PCV-431, and on the fourth elbow from the PRT nozzle are shown in Figures 3-4 through 3-7.

3.4 Piping Evaluation

3.4.1 Jurisdictional Limits

The piping evaluated includes the upstream piping from the pressurizer outlet nozzles to the safety and power-operated relief valves, and the downstream (or discharge) piping from each of these valves to the PRT nozzle.

The 4-inch branch lines from relief valves 1-314 and 2-314 (Units 1 and 2, respectively), which join the 8-inch discharge header in the region of the PRT, were modeled beyond these valves so as to account correctly for their influence on the discharge piping response.

Loads on valves, nozzles, and flanges were determined, but no evaluation of the adequacy of these components was performed.

3.4.2 Mathematical Models

The piping system for each unit was idealized as SUPERPIPE mathematical models. These consist of concentrated masses connected by massless elastic members. The concentrated masses were located so as to adequately represent the dynamic properties of the system. The Unit 1 and Unit 2 mathematical models are provided in Appendix B.

EDS Nuclear's computer program SUPERPIPE was used for all analyses. SUPERPIPE performs static, dynamic response spectra, and transient dynamic analyses. It also performs the required load combinations, code verification, and support load summaries. A description of SUPERPIPE is included in Appendix A.

The piping system supports were modeled by specifying the support type and applicable direction. Actual support stiffnesses were calculated and included.

3.4.3 Description of Analyses

Deadweight Analysis

The weight of the piping, components, and contained water (as appropriate) was applied. The design preloads of the spring hangers were modeled as vertical forces on the pipe. Snubber supports were assumed inactive for this analysis.

Thermal Expansion Analysis

For the calculation of secondary stresses due to thermal expansion, the following design temperatures were used:

- Piping upstream of safety valves and PORV's - 680°F
- Balance of piping - 477°F

The pressurizer was also assumed to be at 680°F. The stress-free temperature for the analysis was taken as 70°F. Neither spring hangers nor snubber supports were included in the thermal analysis.

Seismic Analysis

The seismic analysis input was based on Reference 11.

Two co-directional earthquakes were modeled (X + Y, and Z + Y). Each was treated as an independent event, and the envelope of the resulting response was used. Consistent with the design basis for PBNP, differential seismic building movements were not considered.

The pressurizer was included in the mathematical model for the seismic analysis in order to accurately represent its seismic input to the piping system.

The spectral curve used in the analysis is shown on Figure 3-8. The spectral accelerations given by this curve are conservative in that they envelope the spectral curves for the different support levels in the piping system. The corresponding accelerations for the Maximum Potential Earthquake were obtained by doubling these Design Basis Earthquake values.

Damping was taken to be one-half of one percent of critical for all seismic analyses.

Valve Discharge Time History Analysis

Thermal-hydraulic force time histories at changes in flow direction and flow area, calculated for each unit by REFØRC, were applied.

The direct integration solution method was used. SUPERPIPE allows the system dynamic characteristics to be written as a set of differential equations of the form:

$$M\ddot{u} + C\dot{u} + Ku = P$$

where M, C, and K represent the mass, damping, and stiffness of the system, u is the time-dependent displacement, and P is the applied load.

This set of equations is solved in coupled format by generating the response of the system as a function of the response at the previous time step. By assuming that the damping matrix is a linear combination of the mass and stiffness matrices, two unique frequency damping ratio pairs can be selected. These values were taken as one percent of critical damping at both the fundamental structural frequency and at the highest significant mode considered in the analysis, (125 cycles/sec.). The frequencies of interest - that is, those between these limits - are conservatively underdamped.

The integration time step for the time history analysis was selected to provide accurate response in the higher frequencies of the system. A value of one millisecond was used.

The event durations were taken as 0.70 and 0.75 seconds for Units 1 and 2, respectively. Stresses were determined using the maximum of each moment component.

During certain of the EPRI tests, very high frequency pressure spikes were recorded in the upstream, loop seal piping. These water hammer stresses occurred principally during valve opening and were associated with valve flutter. For a discussion of the phenomenon, see Section 3.2.3.

These high frequency pressure spikes were not included in the time history analysis. The B31.1 code allowable stresses are based on quasi-statically applied pressure throughout the pipe, not on localized pulses. Furthermore, should these pressure spikes actually occur at PBNP, they would be of even higher frequency than those observed in the EPRI tests (due to the small volume of the loop seal and the short length of the inlet piping - see Section 3.2.3). It is not considered feasible that any significant permanent strain would occur in the PBNP piping. Thus, the potential for these pressure spikes is not of significance with regard to the piping integrity.

3.4.5 Load Combinations

Load combinations are given in Tables 3-5 and 3-6.

The grouping method (modes with frequencies within 10 percent being regarded as closely-spaced) was used to combine modal components in the seismic analyses. Seismic responses from multi-directional input were combined using the SRSS method. Seismic and valve actuation responses were also combined by the SRSS method.

For all pipe support combinations, the loads were maximized (maximum positive and maximum negative) by considering the line both hot (thermal loads included) and cold (thermal loads not included).

3.4.6 Code Evaluation

The Code of Record for PBNP is USAS B31.1 (1967).[12] As part of the piping evaluation, the pipe stresses resulting from the above load combinations were compared to the appropriate allowables.

In this evaluation, the (more convervative) stress intensification factors (SIF's) defined in ANSI B31.1 (1973)[13] were used for piping design with the following excpeption: For butt-welded reducers, the Code of Record SIF was adopted.[14]

Allowable Stresses

The piping between the pressurizer outlet nozzles and the safety and power-operated relief valves is seismic class piping. The discharge piping between these valves and the PRT is non-seismic class piping.

The allowable stresses for the seismic and non-seismic class piping are given on Tables 3-7 and 3-8, respectively.

For the seismic class, pressure-retaining piping, the allowable stresses for load combinations 1, 2, 4, 6, and 6a are as per the FFDSAR[5] and the Code of Record.[12] The allowables for the valve actuation load combinations (numbers 3 and 5), which are not addressed in the FFDSAR, are consistent with the 1980 ASME Boiler and Pressure Vessel Code.[15] In particular, the stress criterion for load combination 3 is the Level C (Emergency) service limit and that for load combination 5 is the Level D (Faulted) service limit.

The non-seismic class, non-pressure retaining discharge piping's function for the dynamic load cases (seismic and valve actuation) is to 'support' the valves and seismic class piping. Thus, less restrictive allowables are appropriate.

To ensure that discharge piping integrity is maintained under these conditions, the faulted allowable per the 1980 ASME Code[15] (2.4 S_h) was used.

Note that higher stress or nonlinear strain allowables may be appropriate for this non-seismic piping, with justification being provided that integrity is maintained such that the response of the seismic class piping and valves is not affected adversely.

4.0 RESULTS

4.1 Piping Stresses

For full computer summaries, see Appendix C.

Maximum stresses for each valve actuation load combination are given in Tables 4-1 and 4-2.

The stresses are given for two regions of piping - the PORV section and the safety valve (SV) section.

The PORV section includes the inlet piping to the PORV's and their discharge piping to the tee-junction in the vertical run of the 8-inch header. The SV section consists of the remaining piping - including the inlet piping to the safety valves and their discharge piping to the PRT nozzle.

Both are further divided to distinguish the seismic class piping upstream of the valves and the non-seismic class discharge piping.

Load combinations 1, 2, and 4 were considered as part of the IE Bulletin 79-14 reanalysis. These combinations do not include valve actuation and are thus not reported here. However, the stresses computed for thermal and gravity load cases at the upstream reducers on both Unit 2 PORV's were higher than those computed in the 79-14 reanalysis. The maximum factored thermal and gravity stresses at this location were calculated to be 34,325 and 9,530, psi, respectively.

4.2 Nozzle and Valve Flange Loads

Detailed nozzle and valve flange loads are included in the computer summaries (see Appendix C). Table 4-3 gives the maximum components of load on each.

4.3 Valve Accelerations

Approximate maximum safety valve accelerations in the horizontal and vertical directions are given on Table 4-4. These accelerations are due to valve actuation only.

4.4 Support Loads

For detailed support load summaries, see Appendix C.

Maximum support loads from the load combinations given in Table 3-6 are shown on Table 4-5. Original design loads for the supports are not available. However, the supports' adequacy for seismic loading has been verified in accordance with IE Bulletin 79-14. The loads given in Table 4-5 generally exceed these 79-14 loads. However, it is probable that the supports' ultimate capacity is significantly greater than the 79-14 loads.

4.5 Discussion of Piping Results

Piping Stresses

SV Section - Seismic Class Piping - The stresses at the elbow immediately adjacent to the nozzles exceed the specified code allowables for load combinations 3 and 5. This exceedance occurs at the butt weld at the elbow, the SIF for which is 1.8. It is directly due to the relatively high valve actuation loading. Some local yielding may occur, but piping integrity should be maintained. However, given the conservatism of the load definition and the extremely low probability of safety valve actuation, this is not considered a significant safety concern.

SV Section - Non-Seismic Class Piping - The stresses in portions of this section of piping exceed the allowables given in Table 3-8. This exceedance is due to the large valve actuation forces imposed by the discharge of the loop seal water slug. The maximum exceedances occur remote from the seismic portion of the line and the safety valves. Yielding in this area would have a lesser effect on the response of the pressure-retaining, seismic class piping.

PORV Section - The stresses for load combinations 3 and 5 in this portion of the piping exceed the allowables. The most severe exceedance is at the reducers at each end of the 2-inch PORV's. However, the allowable stresses are also exceeded at several other locations.

The PORV section of the line is not directly subjected to significant valve actuation loads - the out-of-balance piping forces determined for this section are an order lower than those for the SV section. This is because of the slow action of the PORV's and the absence of PORV loop seals.

Thus, the response of the PORV section is primarily due to the large vertical displacements and accelerations imposed by the movement of the SV section at their common tee-junction. As the PORV section is lightly supported, this motion at its extremity induced large resonance in the SUPERPIPE model. This resonance led, in turn, to the large stresses recorded.

In actuality, this resonance is considered to be significantly overpredicted. Minor yielding would alter the dynamic characteristics of the PORV section - this would greatly reduce its tendency to resonate. Also, the analysis was performed for very low damping - effectively, significantly less than one percent of critical. The actual damping in the PORV section at these levels of stress would be much higher, and the calculated response would reduce accordingly.

Also, as discussed in Section 4.1, increased thermal and gravity stresses (compared to the 79-14 reanalysis stresses) were calculated at the reducers on both Unit 2 PORV's. The factored thermal stress was 34,325 psi. The allowable stress is 27,440 psi (Table 3-7). Thus, the calculated overstress is approximately 25 percent. This is conservative because:

- Design rather than operating temperatures were assumed.
- The analysis assumes that there is no gap between active thermal supports and the piping - in fact, finite gaps exist and this will decrease these thermal stresses.

The maximum calculated gravity stress of 9,530 psi exceeded that reported for the 79-14 reanalysis effort. This would reduce the margins for load combinations including gravity. However, this gravity stress is, again, conservative. It is primarlily induced by the presence of a stiff support nearby. The gap at this support was not considered - this gap will reduce the stresses. Also, this particular gravity stress is secondary in the sense that, were the support in question to deflect or not be present (or the pipe to slightly yield), the stress at this point would be relaxed.

Thus, these slight overstresses are not considered to be a safety concern. The adequacy of the line for thermal and gravity stresses will be addressed in the ongoing program to modify the pipe support system for valve actuation loading.

Support Loads

In several instances, the valve actuation-induced support loads exceed the loads to which the supports were assessed under the 79-14 effort. However, it is probable that the actual support capacity is significantly greater than the 79-14 loads.

REFERENCES

1. "EPRI PWR Safety and Relief Valve Test Program Safety and Relief Valve Test Report" (Interim Report), Electric Power Research Institute, dated April 1982.

2. RELAP5/MØD1 Code Manual, NUREG/CR-1826.

3. REFØRC V.2A: A Computer Program for Calculating Fluid Forces Based on RELAP5 Results, User's Manual, Revision 1, dated June 1982.

4. SUPERPIPE Users Manual, EDS Nuclear Inc, Version 15C, dated June 25, 1982.

5. "Final Facility Description and Safety Analysis Report - Point Beach Nuclear Plant Unit No. 1 and 2," Chapter 14, Wisconsin Electric Power Company and Wisconsin Michigan Power Company.

6. "Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Westinghouse-Designed Plants" (Interim Report), Westinghouse Electric Corporation, dated February 1982.

7. "EPRI/CE Safety Valve Test Data for the Crosby 3K6 Safety Valve (Long Inlet Pipe Configuration)," Electric Power Research Institute, November 10, 1981.

8. "EPRI/CE Safety Valve Test Data for the Crosby 6M6 Safety Valve (Long Inlet Pipe Configuration)," Electric Power Research Institute, January 12, 1982.

9. "EPRI/CE Safety Valve Test Data for the Crosby 6M6 Safety Valve (Long Inlet Pipe Configuration)," Electric Power Research Institute, February 18, 1982.

10. "EPRI PWR Safety and Relief Valve Test Program Valve Selection/Justification Report" (Interim Report), Electric Power Research Institute, dated December 1981.

11. "Seismic Analysis - Point Beach Nuclear Plant Units One and Two Reactor Building Job No. 6118", Bechtel Corporation, dated March 1970.

12. USA Standard B31.1.0-1974, "Power Piping," American Society of Mechanical Engineers.

13. American National Standard ANSI B31.1-1973, "Power Piping," American Society of Mechanical Engineers.

14. Letter from Wisconsin Electric Power Company to EDS Nuclear, "Point Beach Nuclear Plant Stress Intensification Factors," dated November 22, 1982.

15. "1980 ASME Boiler and Pressure Vessel Code," an American National Standard, American Society of Mechanical Engineers.

Table 2-1: Safety Valve Parameters

Number of Valves (per unit)	2	
Manufacturer	Crosby Valve and Gage Co.	
Type	Spring-loaded nozzle type relief valve	
Designation: Size	4 K2 6	
Style	HB-BP-86	
Type	E	
Weight	520 lbs.	
Steam Flow Capacity (rated and maximum)	288,000 lbs/hr (sat. steam)	
	Inlet	Outlet
Design Pressure and Temperature	2485 psig 650°F	500 psig 470°F
Set Pressure	2485 psig	

Table 2-2: Power-Operated Relief and Block Valve Parameters

Number of Valves (per unit)	PORV's: 2 Block: 2
Manufacturer	PORV's: Copes-Vulcan Inc. Block: Velan
Type	PORV's: Globe Valves Block: Gate Valves
Steam Flow (PORV's)	210,000 lbs/hr (max) 179,000 lbs/hr (normal)
Design Pressure and Temperature (PORV's and Block Valves)	2485 psig/650°F
Set Pressure (PORV's)	2335 psig

Table 3-1: Applicable EPRI Tests for PBNP Safety Valves

3K6 Valve Tests	6M6 Valve Tests
525	906
526	908
529	910
536	913
	917*
	920*
	923
	929
	1406
	1415*
	1419*

* heated loop seal

Notes:

1. Above tests are for a filled loop seal
2. Test fluid is saturated steam

Table 3-2: Comparison of Results for Applicable EPRI Tests

EPRI Test Number	Pressure Ramp Rate (psi/sec)	Steady State Backpressure (psia)	Directly[1] Applicable to PBNP
(3K6 Valve)			
525	3	445	
526	200	520	*
529	18	385	
536	8	432	
(6M6 Valve)			
906	3	253	
908	297	613	*
910	375	227	
913	375	233	
917	291	238	
920	297	240	
923	283	650	*
929	319	700	*
1406	325	245	
1415	360	245	
1419	360	240	

Note:

1. That is, both high backpressure and high pressure ramp rate.

Table 3-3: Maximum Calculated Backpressures

	Backpressure (psia)
Unit 1	
Safety Valve PCV-434	635
Safety Valve PCV-435	546
Unit 2	
Safety Valve PCV-434	586
Safety Valve PCV-435	555

Table 3-4: Maximum Calculated Temperatures

	Temperature (^{O}F)
Unit 1	
Safety Valve PCV-434	682
Safety Valve PCV-435	682
PRT Nozzle	364
Unit 2	
Safety Valve PCV-434	682
Safety Valve PCV-435	682
PRT Nozzle	364

Table 3-5: Load Combinations for Piping Analysis

Load Combination Number	Load Combination
1 (Sustained)	Pr + Gr
2 (Occasional)	Pr + Gr + OBE
3 (Occasional)	Pr + Gr + SOT
4 (Faulted)	Pr + Gr + SSE
5 (Faulted)	Pr + Gr + SSE + SOT
6 (Thermal Expansion)	Th
6a (Thermal Expansion and Sustained)	Th + Pr + Gr

Table 3-6: Pipe Support Load Combinations

Combination Number	Loading Condition	Support Design Load
1	Sustained	Gr + Th
2	Occasional	Gr + Th + OBE
3	Occasional	Gr + Th + OBE + SOT
4	Faulted	Gr + Th + SSE
5	Faulted	Gr + Th + SSE + SOT

<u>where</u>

Pr = Pressure
Gr = Gravity
OBE = Design Basis Earthquake
SOT = System Operating Transient (Valve Actuation)
Th = Thermal

Table 3-7: Allowable Stresses for Seismic Class Piping

Load Combination Number	Allowable Stress
1 (Sustained)	1.0 S_h
2 (Occasional)	1.2 S_h
3 (Occasional)	1.8 S_h
4 (Faulted)	1.8 S_h
5 (Faulted)	2.4 S_h
6 (Thermal Expansion)	S_A
6a (Thermal Expansion and Sustained)	$S_A + S_h$

Table 3-8: Allowable Stresses for Non-Seismic Class Piping

Load Combination Number	Allowable Stress
1 (Sustained)	1.0 S_h
5 (Faulted)	2.4 S_h
6 (Thermal Expansion)	S_A
6a (Thermal Expansion)	$S_A + S_h$

where

$S_A = (1.25\ S_c + 0.25\ S_h)$

Note:

The allowable stress for load combinations number 2, 3, and 4 is 2.4 S_h - these cases are thus enveloped by load combination 5.

Table 4-1: Unit 1 Pipe Stresses

	Load Combination Number	Joint Name/Type[1]	Maximum Stress, psi	Allowable[2] Stress, psi
PORV Section/Seismic				
	3	56/Reducer	177,100	28,800
	5	56/Reducer	177,214	38,400
PORV Section/Non-Seismic				
	5	34/Tee	114,677	35,140
SV Section/Seismic				
	3	C21A/Elbow	59,143	28,800
	5	C21A/Elbow	59,151	38,400
SV Section/Non-Seismic				
	5	C20B/Elbow	138,454	35,140

Notes:

1. For joint name/location, see Appendix B
2. Per Tables 3-7 and 3-8

Table 4-2: Unit 2 Pipe Stresses

	Load Combination Number	Joint Name/Type[1]	Maximum Stress, psi	Allowable[2] Stress, psi
PORV Section/Seismic				
	3	26/Reducer	198,340	28,800
	5	26/Reducer	201,075	38,[illegible]00
PORV Section/Non-Seismic				
	5	40/Tee	124,705	35,140
SV Section/Seismic				
	3	C26B/Elbow	54,880	28,800
	5	C26B/Elbow	54,920	38,400
SV Section/Non-Seismic				
	5	102/Tee	476,805	35,140

Notes:

1. For joint name/location, see Appendix B
2. Per Tables 3-7 and 3-8

Table 4-3: Nozzle/Flange Loads

Nozzle/ Flange	Load Case	Axial Load (lbs)	Resultant Shear Load (lbs)	Torsional Moment (ft-lbs)	Bending Moment My(ft-lbs)	Bending Moment Mz(ft-lbs)
Unit 1						
PORV	Gravity	17	35	229	301	633
Nozzle	Thermal	170	1437	932	3554	180
at inter-	Seismic OBE (X+Y)	147	120	109	202	580
face of	Seismic OBE (Z+Y)	252	222	176	395	1084
press.	Seismic SSE (X+Y)	294	240	218	404	1160
nozzle &	Seismic SSE (Z+Y)	504	444	352	790	2168
PORV	SOT	5581	5374	10550	6843	6778
inlet						
piping						
SV						
Piping	Gravity	461	495	273	221	89
Nozzle	Thermal	112	1292	735	1348	2937
at inter-	Seismic OBE (X+Y)	79	88	47	55	208
face of	Seismic OBE (Z+Y)	79	89	39	51	155
press.	Seismic SSE (X+Y)	158	176	94	110	416
nozzle &	Seismic SSE (Z+Y)	158	178	78	102	310
PCV-435	SOT	5217	5475	8750	6466	9205
inlet						
piping						
SV	Gravity	34	72	395	457	454
Piping	Thermal	793	723	362	54	140
Nozzle	Seismic OBE (X+Y)	76	102	63	46	98
at inter-	Seismic OBE (Z+Y)	72	94	71	57	104
face of	Seismic SSE (X+Y)	152	204	126	92	196
press.	Seismic SSE (Z+Y)	144	188	142	114	208
nozzle &	SOT	4496	7768	9545	6541	11499
PCV-434						
inlet						
piping						
PRT	Gravity	963	209	329	1358	517
at	Thermal	904	269	1073	1580	4043
nozzle	Seismic OBE (X+Y)	721	805	1069	1134	341
	Seismic OBE (Z+Y)	354	573	697	2595	705
	Seismic SSE (X+Y)	1442	1610	2138	2268	682
	Seismic SSE (Z+Y)	708	1146	1394	5190	1410
	SOT	29115	73570	86357	24234	84610
Flange	Gravity	16	382	20	38	196
down-	Thermal	385	881	332	370	118
stream	Seismic OBE (X+Y)	120	173	212	47	206
of PORV	Seismic OBE (Z+Y)	209	283	369	82	375
1-PCV-	Seismic SSE (X+Y)	240	246	424	94	412
431C	Seismic SSE (Z+Y)	418	566	738	164	750
	SOT	9726	17372	4599	4040	6130

Table 4-3 (con't)

Nozzle/ Flange	Load Cases	Axial Load (lbs)	Resultant Shear Load (lbs)	Torsional Moment (ft-lbs)	Bending Moment My(ft-lbs)	Bending Moment Mz(ft-lbs)
Flange	Gravity	0	134	169	10	100
down-	Thermal	380	323	142	806	386
stream	Seismic OBE (X+Y)	97	112	116	98	257
of PORV	Seismic OBE (Z+Y)	69	173	206	191	445
1-PCV-430	Seismic SSE (X+Y)	194	224	232	196	314
	Seismic SSE (Z+Y)	138	346	412	382	890
	SOT	17216	16760	3456	2570	5597
PCV-435	Gravity	414	50	61	347	787
at valve	Thermal	738	1066	648	491	520
inlet	Seismic OBE (X+Y)	78	38	53	52	56
	Seismic OBE (Z+Y)	76	47	58	51	54
	Seismic SSE (X+Y)	156	76	106	104	112
	Seismic SSE (Z+Y)	152	94	116	102	108
	SOT	5842	8530	3998	5265	4181
PCV-435	Gravity	39	195	304	97	596
at valve	Thermal	231	1276	318	1505	950
outlet	Seismic OBE (X+Y)	93	74	60	57	66
	Seismic OBE (Z+Y)	88	132	64	120	58
	Seismic SSE (X+Y)	186	148	120	114	132
	Seismic SSE (Z+Y)	176	264	128	240	116
	SOT	28612	13068	8264	10850	5073
PCV-434	Gravity	261	80	1612	173	360
at valve	Thermal	986	422	117	1005	111
inlet	Seismic OBE (X+Y)	78	37	28	45	64
	Seismic OBE (Z+Y)	69	41	29	39	54
	Seismic SSE (X+Y)	156	74	56	90	128
	Seismic SSE (Z+Y)	138	82	58	78	108
	SOT	4221	7429	4677	3819	6372
PCV-434	Gravity	79	868	1392	141	420
at valve	Thermal	401	995	851	6	181
outlet	Seismic OBE (X+Y)	98	97	70	62	34
	Seismic OBE (Z+Y)	52	97	73	71	32
	Seismic SSE (X+Y)	196	194	140	124	68
	Seismic SSE (Z+Y)	104	194	146	142	64
	SOT	35059	10804	8344	7858	6820

Table 4-3 (con't)

Nozzle/ Flange	Load Cases	Axial Load (lbs)	Resultant Shear Load (lbs)	Torsional Moment (ft-lbs)	Bending Moment My(ft-lbs)	Bending Moment Mz(ft-lbs)
Flange	Gravity	114	305	3095	283	265
on branch	Thermal	24	62	86	73	176
line up-	Seismic OBE (X+Y)	429	788	2843	2439	2149
stream	Seismic OBE (Z+Y)	680	489	1461	963	2114
of PRT	Seismic SSE (X+Y)	858	1576	5686	4878	4298
	Seismic SSE (Z+Y)	1360	978	2922	1926	4228
	SOT	3940	5606	4273	11038	7813
Unit 2						
PORV	Gravity	209	352	922	273	611
Nozzle	Thermal	191	995	4192	192	227
at inter-	Seismic OBE (X+Y)	772	1154	1337	917	1488
face of	Seismic OBE (Z+Y)	238	469	499	686	468
press.	Seismic SSE (X+Y)	1544	2308	2674	1834	2976
nozzle &	Seismic SSE (Z+Y)	476	938	998	1372	936
PORV	SOT	4451	6720	9313	9652	9412
inlet						
piping						
SV	Gravity	295	428	176	92	188
Piping	Thermal	573	983	1852	2229	736
Nozzle	Seismic OBE (X+Y)	188	216	278	276	238
at inter-	Seismic OBE (Z+Y)	105	111	91	90	163
face of	Seismic SSE (X+Y)	376	432	556	552	476
press.	Seismic SSE (Z+Y)	210	221	182	180	326
nozzle &	SOT	6786	10563	9794	11454	8113
PCV-435						
inlet						
piping						
SV	Gravity	341	267	672	733	671
Piping	Thermal	3827	3432	1996	2232	2342
Nozzle	Seismic OBE (X+Y)	86	202	288	303	114
at inter-	Seismic OBE (Z+Y)	77	112	108	124	89
face of	Seismic SSE (X+Y)	172	404	576	606	228
press.	Seismic SSE (Z+Y)	154	224	216	248	178
nozzle &	SOT	5655	10193	5583	6057	15876
PCV-434						
inlet						
piping						

Table 4-3 (con't)

Nozzle/ Flange	Load Cases	Axial Load (lbs)	Resultant Shear Load (lbs)	Torsional Moment (ft-lbs)	Bending Moment My(ft-lbs)	Bending Moment Mz(ft-lbs)
PRT at nozzle	Gravity	803	100	57	369	1132
	Thermal	2927	5726	2684	396	11775
	Seismic OBE (X+Y)	187	235	434	754	465
	Seismic OBE (Z+Y)	186	293	574	989	556
	Seismic SSE (X+Y)	374	470	868	1508	930
	Seismic SSE (Z+Y)	372	586	1148	1978	1112
	SOT	59328	48140	37798	21499	116105
Flange downstream of PORV 2-PCV-431C	Gravity	42	380	157	46	57
	Thermal	313	377	1590	601	651
	Seismic OBE (X+Y)	219	423	1837	123	866
	Seismic OBE (Z+Y)	243	238	529	181	464
	Seismic SSE (X+Y)	438	846	3674	246	1732
	Seismic SSE (Z+Y)	486	476	1058	362	828
	SOT	12410	17528	2511	7883	7272
Flange downstream of PORV 2-PCV-430	Gravity	29	1240	34	19	13
	Thermal	180	6893	1193	523	2487
	Seismic OBE (X+Y)	233	2695	307	230	1322
	Seismic OBE (Z+Y)	84	873	288	134	590
	Seismic SSE (X+Y)	466	5390	614	460	2644
	Seismic SSE (Z+Y)	168	1746	576	268	1180
	SOT	7980	24984	5659	3962	3613
PCV-435 at valve inlet	Gravity	251	97	165	241	668
	Thermal	971	593	6	1419	2052
	Seismic OBE (X+Y)	167	217	104	80	45
	Seismic OBE (Z+Y)	103	74	58	58	45
	Seismic SSE (X+Y)	334	634	208	160	90
	Seismic SSE (Z+Y)	206	148	116	116	90
	SOT	6794	9011	3855	3940	6182
PCV-435 at valve outlet	Gravity	74	362	194	216	510
	Thermal	413	1059	1096	349	2546
	Seismic OBE (X+Y)	242	166	86	100	109
	Seismic OBE (Z+Y)	118	118	71	77	91
	Seismic SSE (X+Y)	484	332	172	200	218
	Seismic SSE (Z+Y)	236	236	142	154	182
	SOT	24218	14332	13340	8909	6563

Table 4-3 (con't)

Nozzle/ Flange	Load Cases	Axial Load (lbs)	Resultant Shear Load (lbs)	Torsional Moment (ft-lbs)	Bending Moment My(ft-lbs)	Bending Moment Mz(ft-lbs)
PCV-434	Gravity	6	343	330	57	398
at valve	Thermal	5103	615	245	3842	827
inlet	Seismic OBE (X+Y)	80	189	47	57	70
	Seismic OBE (Z+Y)	75	75	26	43	66
	Seismic SSE (X+Y)	160	378	94	114	140
	Seismic SSE (Z+Y)	150	150	52	86	132
	SOT	5366	11117	5516	4497	7206
PCV-434	Gravity	326	611	135	417	269
at valve	Thermal	616	5103	3916	334	4616
outlet	Seismic OBE (X+Y)	212	100	86	56	144
	Seismic OBE (Y+Z)	89	106	49	63	60
	Seismic SSE (X+Y)	224	200	172	112	288
	Seismic SSE (Z+Y)	178	212	98	126	120
	SOT	27509	19587	10311	12512	6783
Flange	Gravity	50	278	49	317	634
on branch	Thermal	117	472	89	477	1964
line up-	Seismic OBE (X+Y)	85	181	367	608	270
stream	Seismic OBE (Z+Y)	100	246	522	903	338
of PRT	Seismic SSE (X+Y)	170	362	734	1216	540
	Seismic SSE (Z+Y)	200	492	1044	1806	676
	SOT	43371	44113	10603	14860	74871

Table 4-4: Safety Valve Accelerations [1,2]

Safety Valve	Horizontal Acceleration	Vertical Acceleration
Unit 1		
PCV-434	37.6	14.4
PCV-435	30.8	10.9
Unit 2		
PCV-434	35.1	21.9
PCV-435	29.5	15.3

Notes:

1. The accelerations shown above are a result of valve actuation
2. All accelerations are in units of gravity (g's), and are given at the valve's center of gravity

Table 4-5: Piping Support Loads

Support Mark No. (Data Point No.)	Support Type	Load (lbs)	Load Combination No. 1	3	5
Unit 1					
HS-14 (15)	Snubber	Fx	-	11555	12002
S-247 (37)	Rigid	Fx	1597	12506	12705
		Fz	840	8745	9231
HS-14 (43)	Snubber	Fx	-	8588	8741
RS-200 (71)	Rigid	Fz	35	28446	28699
HS-17 (73)	Snubber	Fx	-	18348	18520
HS-18 (80)	Snubber	Fx	-	23041	23173
HS-200 (84)	Snubber	Fy	-	44089	44376
S-248 (86)	Rigid	Fx	59	14569	14671
S-248 (86)	Rigid	Fz	1222	8887	9122
H-200 (93)	Hanger	Fy	2498	15922	16472
H-200 (93)	Hanger	Fz	584	17507	17967

Table 4-5 (cont'd)

Support Mark No. (Data Point No.)	Support Type	Load (lbs)	Load Combination No. 1	3	5
Unit 2					
2S-266 (58)	Hanger	Fy	8480	36770	39560
		Fz	1267	14888	15452
HS-28 (15)	Snubber	Fx	-	7386	8771
2S-265 (37)	Rigid	Fx	5205	19616	21402
		Fz	971	7520	7988
HS-28 (43)	Snubber	Fx	-	11210	11653
H-201 (C14A)	Rigid	Fz	1118	30375	30772
HS-30 (72)	Snubber	Fx	-	18628	18933
HS-29 (80)	Snubber	Fx	-	22949	23236
HS-1 (82)	Snubber	Fy	-	53901	56536
2S-265 (85)	Rigid	Fx	6132	22691	23912
		Fz	744	14850	15288
H-200 (99)	Rigid	Fx	5699	108358	108778
		Fz	436	39993	40445

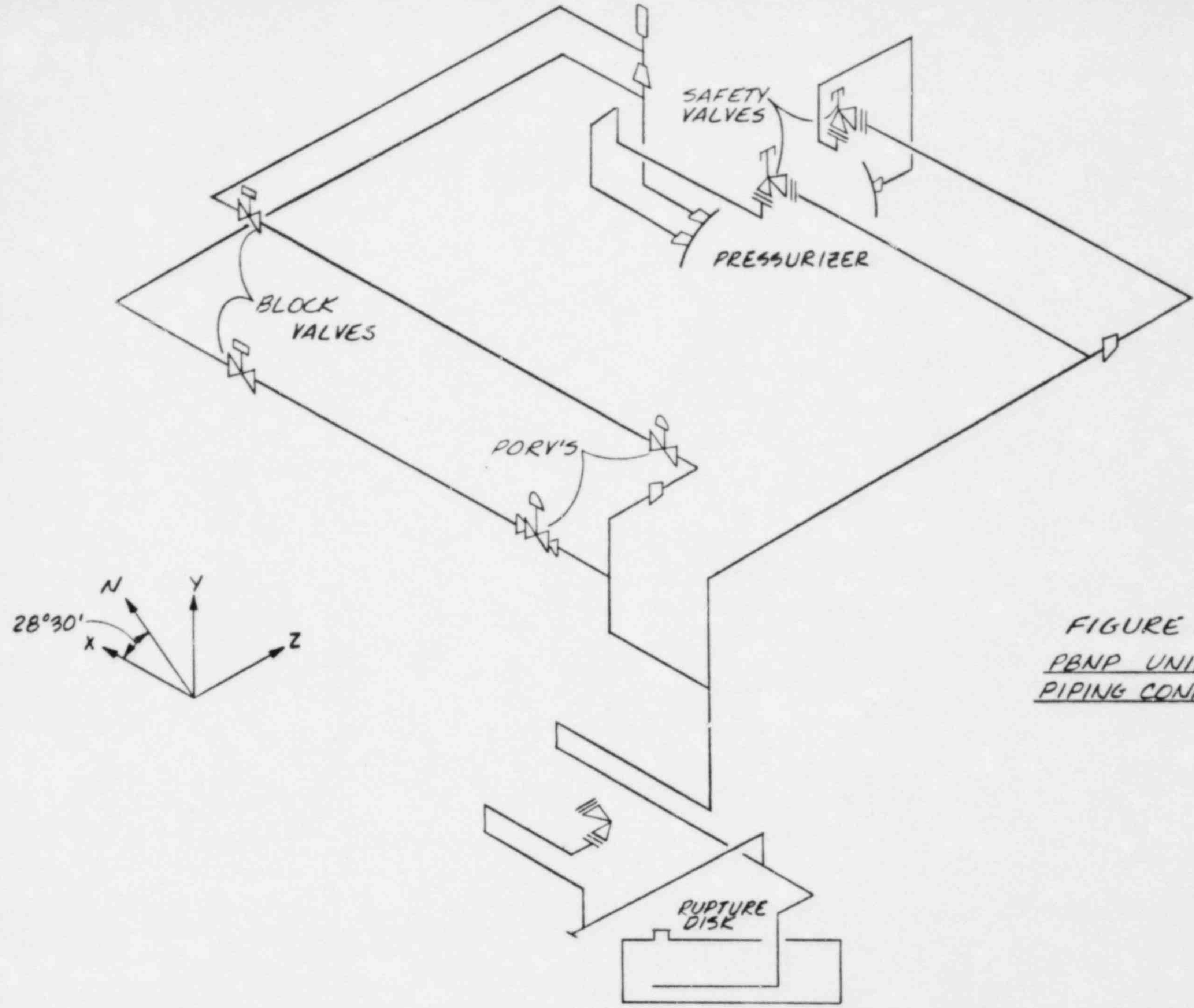


FIGURE 2-1:

PBNP UNIT 1
PIPING CONFIGURATION

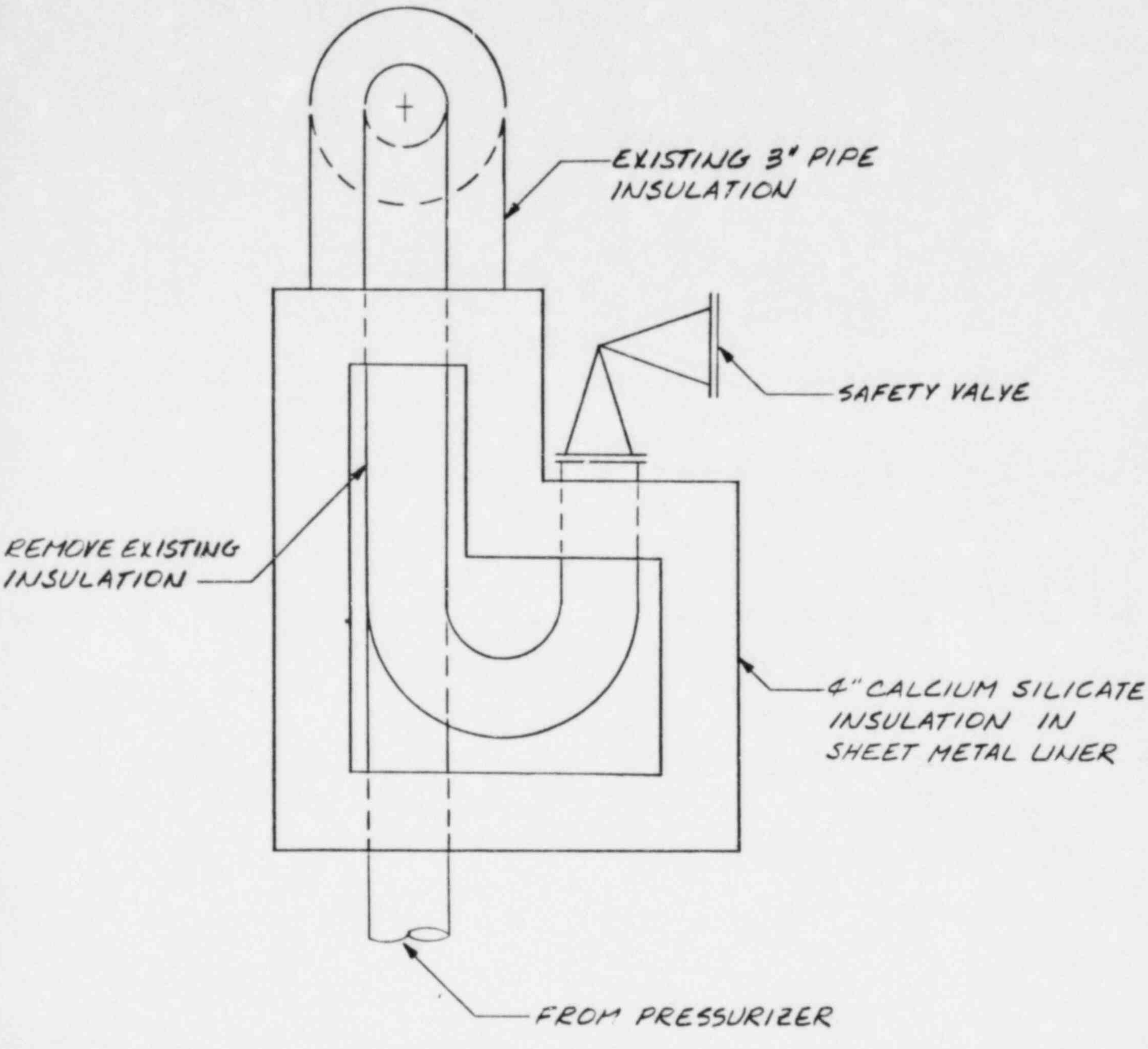
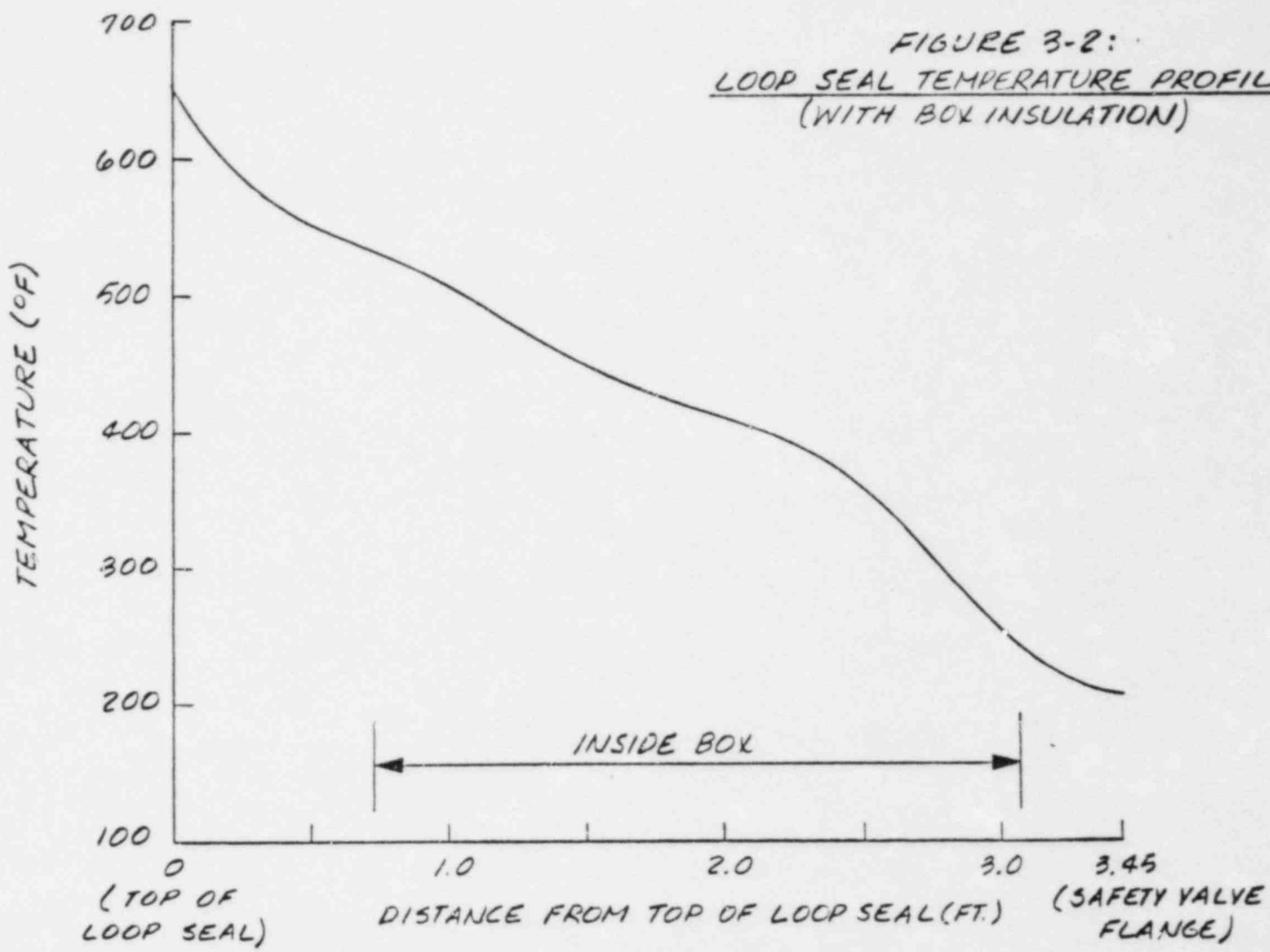


FIGURE 3-1:

LOOP SEAL BOX INSULATION (TYPICAL)

FIGURE 3-2:
LOOP SEAL TEMPERATURE PROFILE
(WITH BOX INSULATION)



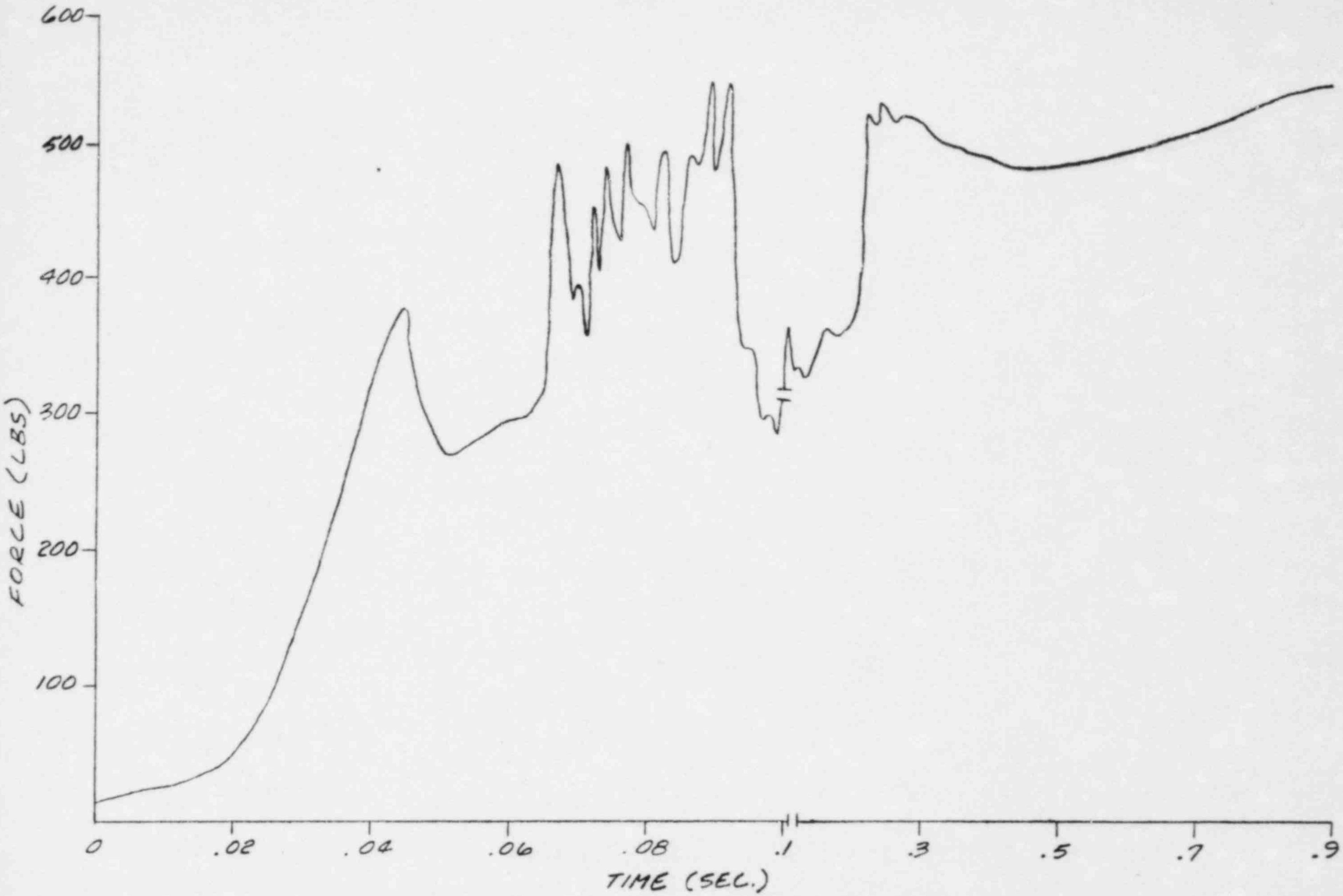


FIGURE 3-3:
TYPICAL PLOT OF SAFETY VALVE BACKPRESSURE

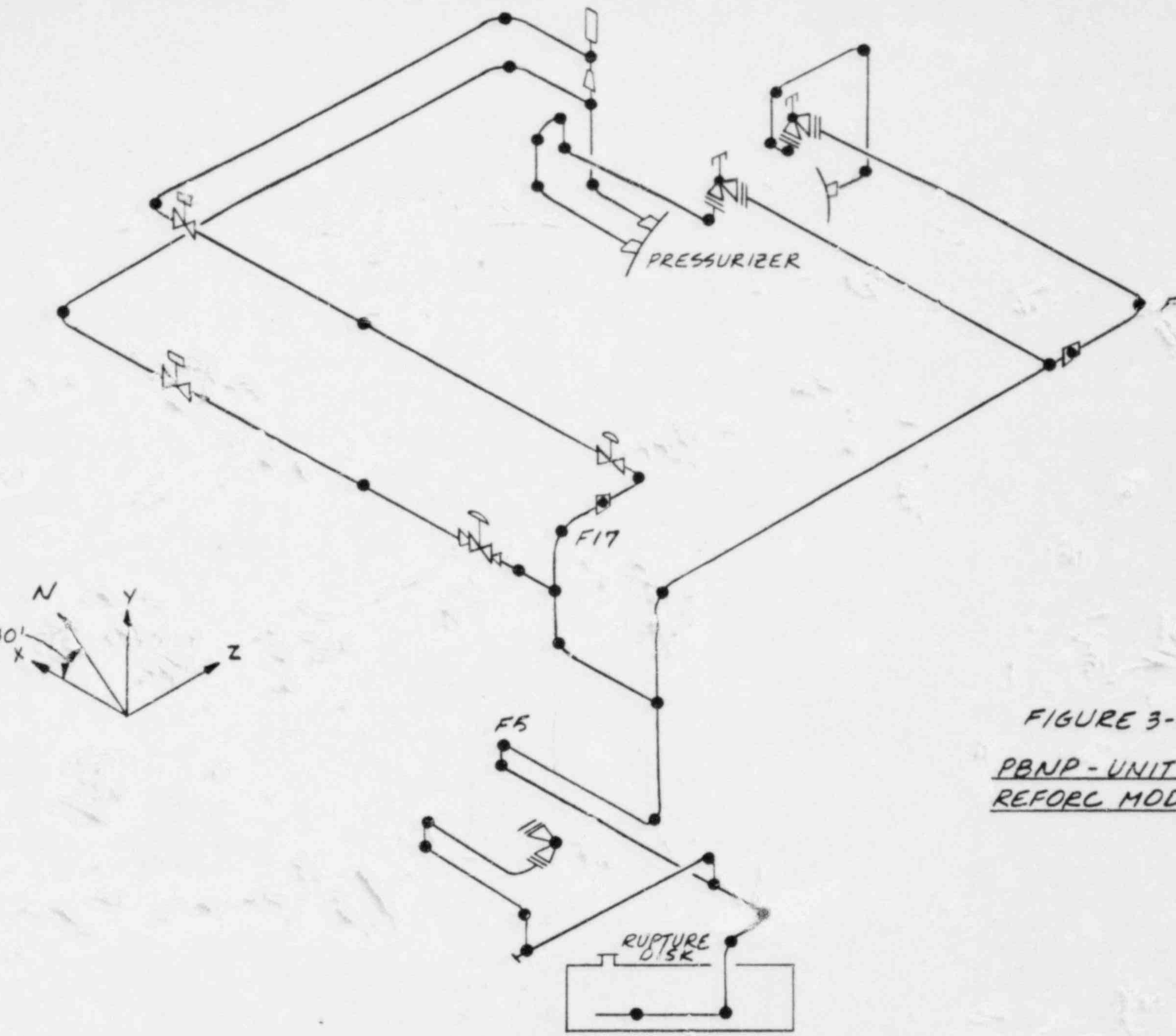


FIGURE 3-4:

PBNP - UNIT 1
REFORC MODEL

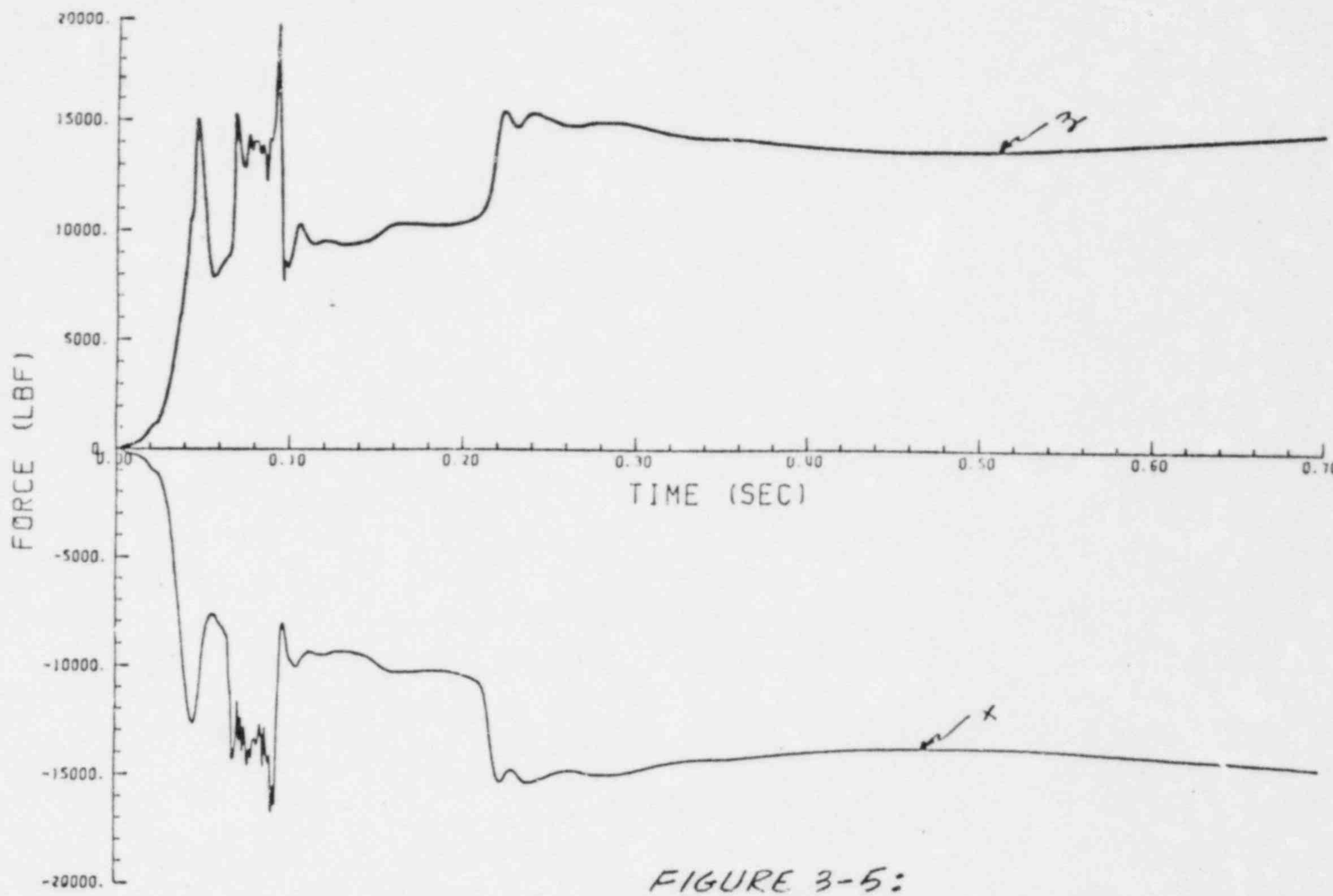


FIGURE 3-5:

UNIT 1- FORCE TIME HISTORY
FOR DATA POINT - F-1

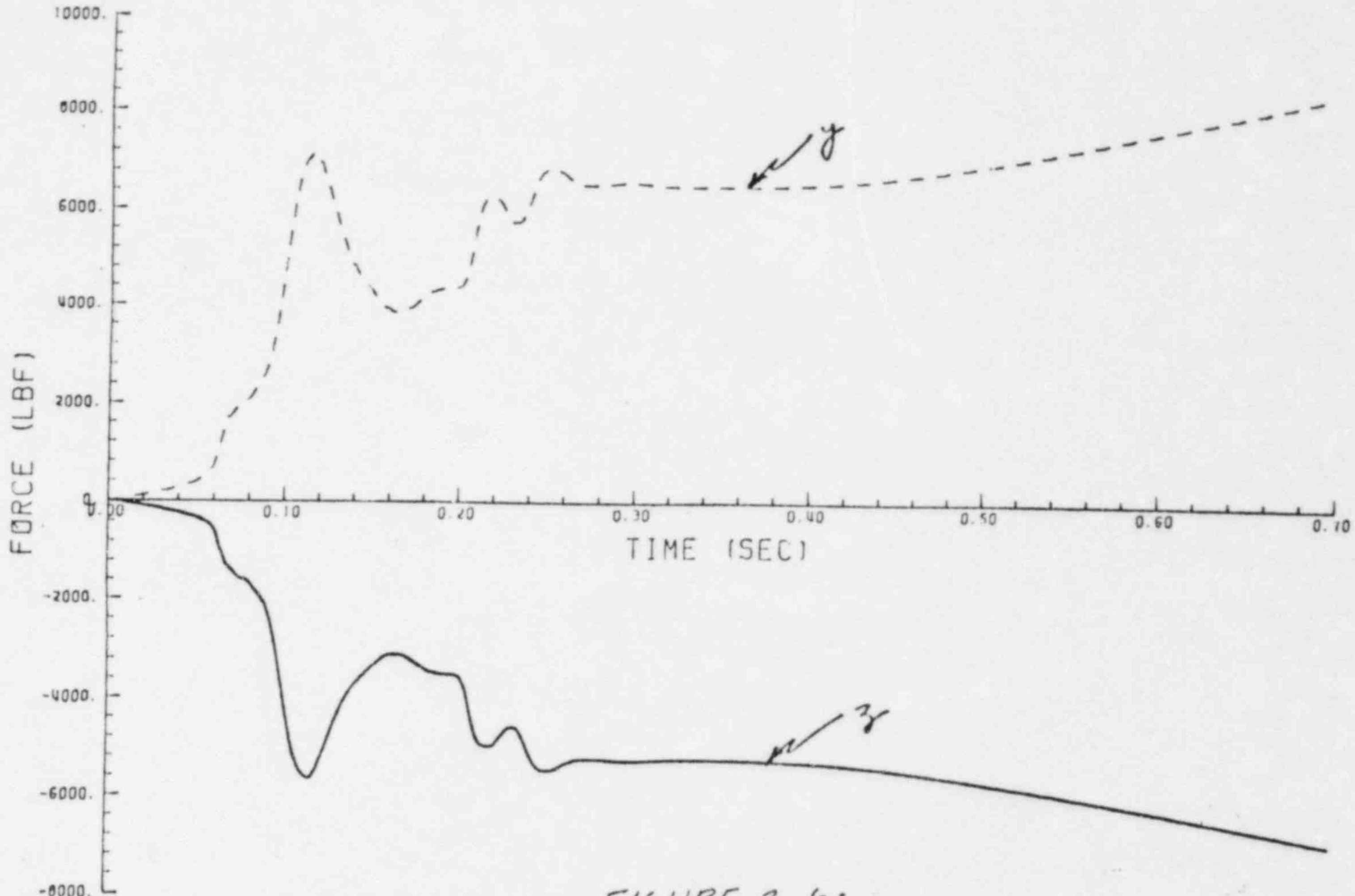


FIGURE 3-6:

UNIT-1 FORCE TIME HISTORY
FOR DATA POINT F-17

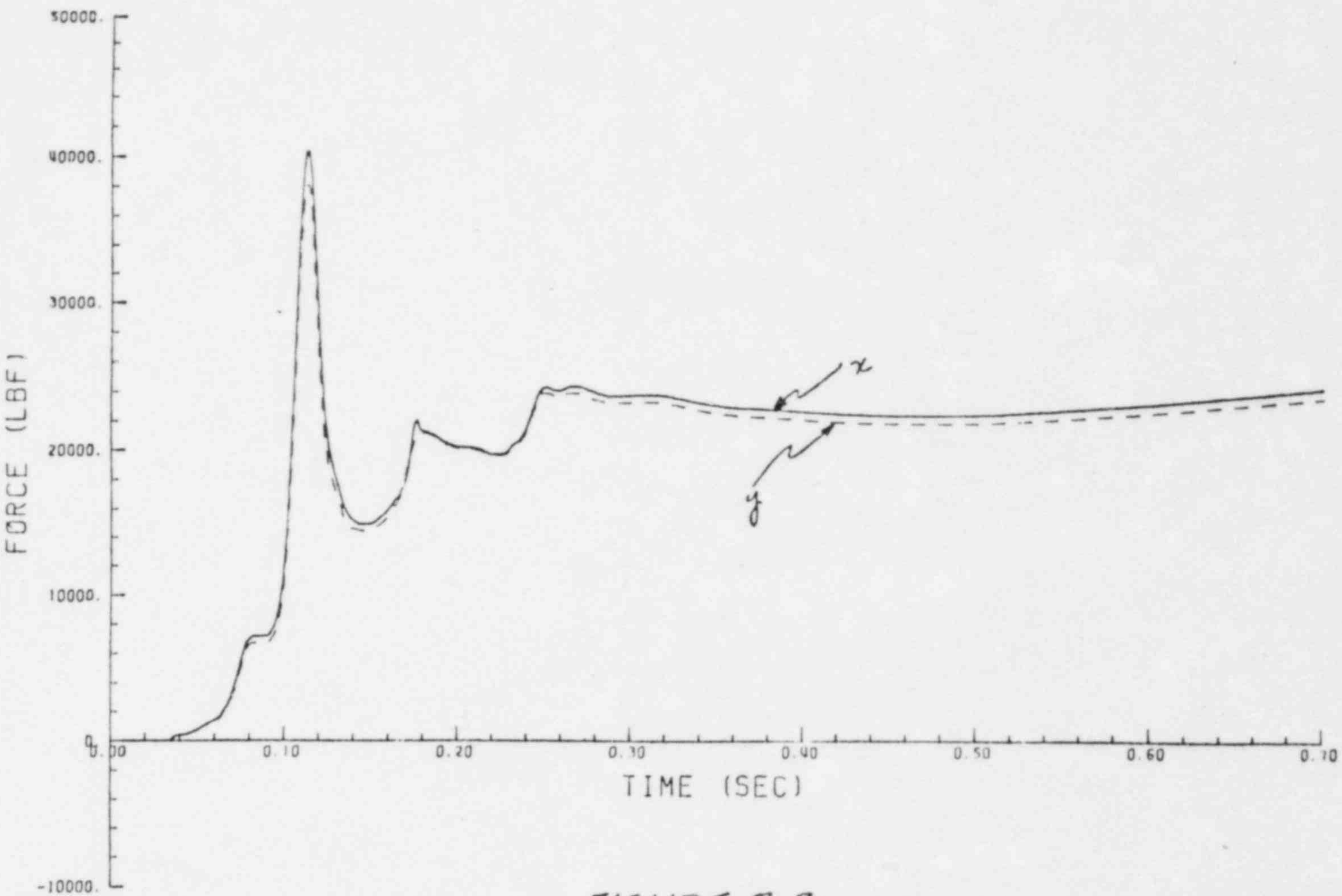


FIGURE 3-7:

UNIT 1 - FORCE TIME HISTORY
FOR DATA POINT F-5

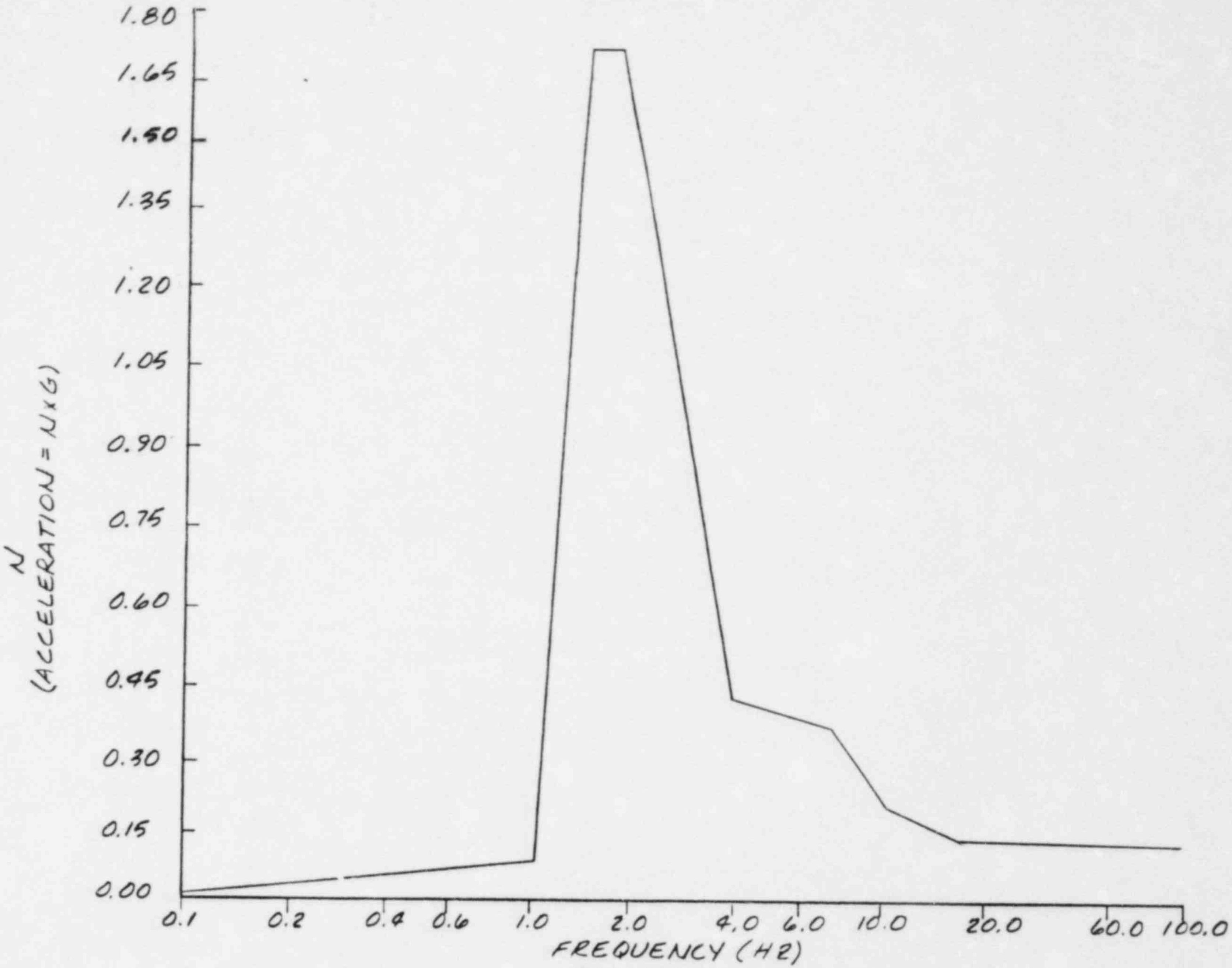


FIGURE 3-8:

<u>SEISMIC RESPONSE SPECTRUM</u>
(DAMPING = 0.005)

APPENDIX A: DESCRIPTION OF COMPUTER PROGRAMS

SUPERPIPE

SUPERPIPE is a comprehensive computer program developed by EDS for the structural analysis and design checking of piping systems. Analysis may be carried out in accordance with the requirements of any one of several standard piping codes.

SUPERPIPE executes in distinct phases; namely, specification of system geometry, static analysis, determination of dynamic characteristics, response spectrum or time history analysis, and design checking against code requirements. Appropriate combinations of these phases may be executed during any specific computer run.

SUPERPIPE can generate its own finite element mesh, lumped masses being automatically positioned along the pipe.

Supports may be specified as active or inactive depending on the type of loading. Support participation can be changed from one analysis to the next within the same computer run.

Output from SUPERPIPE includes a detailed summary of stresses and displacements. Results of analyses can be saved permanently on problem data files and recalled for use in subsequent computer runs. A code compliance summary based on any of several standard piping codes built into the program is output. Nozzle and penetration summaries are also available. SUPERPIPE features a number of post processors and plotting routines.

The SUPERPIPE program has been extensively benchmarked against several other piping analysis programs and has been found to be both accurate and cost effective.

RELAP5/MØD1

RELAP5/MØD1 was originally developed to calculate PWR thermal-hydraulic loads induced by a loss-of-coolant accident . Recently, it has been benchmarked against the EPRI Safety and Relief Valve Test Program.

The basic parameters used in modeling the hydraulic network are control volumes and connecting junctions. RELAP5/MØD1 solves the conservation of momentum, energy, and mass equations for the resulting network of control volumes and junctions.

The program calculates thermal-hydraulic transients with a complete two-fluid, two-velocity, two-temperature description. A set of five equations (two mass, two momentum, one energy) describes the two fluids. The need for a second energy equation has been eliminated by assuming that the least-massive phase is at saturated conditions. Two-velocity phenomena such as entrainment and slip are calculated by simultaneous solution of separate phasic mass and momentum equations. Interphase friction correlations are flow regime dependent, and there is no reliance on direct empirical correlations for slip velocity, flooding rate, or entrainment fraction.

Thermal nonequilibrium of either phase is accounted for in RELAP5/MØD1. Calculations of evaporation/condensation determine the rate at which the two fluids reach equilibrium. One phase in each control volume is assumed to be at its saturated condition, thus, both subcooled water and superheated steam can be treated simultaneously in an overall model, but not within an individual control volume.

For liquid discharge, the critical flow rate is calculated in RELAP5/MØD1 by application of a modified Bernoulli equation between the upstream fluid volume and the choking plane. Nonequilibrium is accounted for by allowing the pressure at the choking plane to undershoot the local saturation pressure based on the Alamgir-Leinhard-Jones correlation. For two-phase discharges, the critical flow rate is calculated from a characteristic analysis of the conservation equations. For vapor discharge, the critical flow rate is calculated based on the local fluid-sonic velocity.

REFØRC

REFØRC was developed as part of the EPRI Safety/Relief Valve Test Program. It calculates the fluid forces acting on a piping network by application of Newton's Second Law of Motion.

The method of force-history generation is to develop the total transient force (F_t) in the axial direction at opposing components (such as bends or tees) according to the following equation:

$$F_t = F_w + F_{cs}$$

F_w is the wave force due to the fluid acceleration and F_{cs} is the blowdown force due to the pressure and momentum at the control surface normal to the direction of F. Total transient forces are calculated in this fashion at variations in flow areas and/or changes in flow direction.

APPENDIX B: SUPERPIPE MODELS

Models for Units 1 and 2 are attached.

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APPENDIX C: DETAILED PIPE STRESS AND SUPPORT LOAD SUMMARIES

Detailed computer summaries are held under separate cover.