EVALUATION OF PALISADES SAFETY AND RELIEF VALVE DISCHARGE PIPING

Volume 1

Prepared for

Consumers Power Company

by

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1.0 INTRODUCTION

1.1 General

EDS Nuclear has completed an evaluation of the Palisades Nuclear Station safety and relief valve as-built discharge piping. This evaluation was performed for Consumers 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 principal objective of the evaluation was to determine the piping's response to the shock loading induced by rapid opening of the power-operated relief and/or safety valves. However, other types of loading which could act concurrently with this shock loading were also considered.

Two thermal-hydraulic analyses were performed to calculate the bounding dynamic loading induced on the piping by postulated combinations of rapid valve actuation. The computer program RELAP5/MØD1[1] was used, together with the post-processor REFØRC.[2] These analyses are described in Section 3.2.

Piping analyses were performed for these thermal-hydraulic load cases. Analyses were also performed for gravity, thermal, and pressure loads. The computer program SUPERPIPE[3] was used. These analyses are described in Section 3.3.

1.3 Conclusions

The calculated pipe stresses have been compared to the conservative, Code of Record allowable stresses.

Upstream of the pressure retaining valves, these code-allowable stresses are met. At the safety valve outlet flanges and at certain points of the non-pressure retaining, non-seismic class discharge piping, code-allowable stresses for valve actuation loading are exceeded. However, for the bounding system transient with the plant in its current configuration, at no point do the combined, factored valve actuation and sustained pipe stresses exceed the faulted allowables. (The faulted allowable is $2.4S_h$).

Computed support loads have been compared to the loads for which each support was evaluated in the recent 79-14 reevaluation effort. The valve actuation induced support loads generally exceed these loads. However, the actual capacity of each support may, of course, considerably exceed these 79-14 loads.

2.0 SYSTEM DESCRIPTION

2.1 General

Palisades is a single-unit plant. The nuclear steam supply system is a Combustion Engineering PWR, rated at 798 Mw net capacity.

The pressurizer relief piping system is a closed system designed for overpressure protection and transient pressure control of the pressurizer. The system includes:

- three spring-loaded safety valves
- two gate-type block valves
- two power-operated relief valves (PORV'S)
- associated inlet and outlet piping

Figure 2-1 is a sketch of the system layout. The inlet piping to the PORV's has been omitted for clarity. Also, only supports active under dynamic loading are shown.

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

The outlet piping culminates in a common header which discharges into the quench tank. The inlet and outlet piping is described in Section 2.2.

Currently, the plant is operated with the block valves closed. This renders the PORV's inactive. For completeness, both this condition and the condition in which the block valves are open during operation (and thus the PORV's are active) were considered.

In the event of an abnormal transient which causes a pressure rise exceeding the control capacity of the pressurizer spray system, the valves may be actuated. If the PORV's are active, they will open first. Then, if the pressure continues to rise, the lowest-set safety valve will open. Further rise in pressure would open one or both of the remaining safety valves. The most severe transient analyzed indicates that, even with the PORV's inactive, only the lowest-set safety valve may open.

2.2 Piping System

Each safety valve is directly connected to its own pressurizer outlet nozzle by a short, straight stub of 3-inch diameter piping. Each also has its own, 6-inch discharge (or tail) pipe. These tail pipes run, in turn, into a common 10-inch header pipe.

The two PORV's share one pressurizer outlet nozzle, A 4-inch pipe from this outlet branches into two 2-1/2 inch pipes, one for each PORV. The block valves are in series with (and upstream of) the PORV's. Each PORV has a 4-inch discharge (or tail) pipe. These run into the common 10-inch header pipe.

The header pipe discharges into the quench tank through a short, 10-inch branch pipe at its midpoint.

2.3 Operating Conditions

The most severe reactor coolant system overpressure condition would occur following a loss-of-load event.[4,5]

Transient analysis has been performed for this loss-of-load event for the two operating modes considered in this evaluation:

a. PORV's not active (block valves closed - current Palisades configuration)
b. PORV's active

For case a, the transient analysis shows one safety valve may lift to provide reactor coolant system overpressure protection. The peak pressurizer pressure for this case is 2,520 psia, with a pressure ramp rate of 45 psi/sec.

When the PORV's are active (case b), the peak pressurizer pressure is 2,450 psia with a pressure ramp rate of 20 psi/sec. For this case, the PORV's may open but no safety valves will lift.

The fluid condition for each case is saturated steam. Solid water discharge due to extended high pressure injection is not postulated since the HPSI pump shutoff head is below the safety valve and PORV set pressures.

3.0 PALISADES EVALUATION

3.1 Introduction

The evaluation was performed in two parts.

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

Secondly, 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 Thermal-Hydraulic Analysis

3.2.1 Description of Load Cases

To determine the transient loads on the discharge piping, two separate load cases were analyzed:

1. The two lower-set safety valves (RV-1040 and RV-1041) lift, each at its own set-point.

2. The two PORV's lift, followed by the upper-set safety valve (RV-1039). Again, each valve lifts at its own set-point.

These load cases were selected to evaluate the piping for the following operating modes:

a. the current operating mode, in which the PORV's are isolated and inactive

b. the mode in which the PORV's may open

The selection of these load cases was based on the following considerations.

- Both conservatively provide more relieving capacity than is required to mitigate the loss-of-load event.
- The principal load on each safety valve "tail-pipe" (the discharge piping for each valve, from valve to header) is due to that safety valve lifting.
- Similarly, the principal load on the PORV's tail-pipe is due to their lifting.
- Therefore, at a minimum, each tail-pipe should be evaluated for its associated valve(s) lifting.
- The header should be evaluated for bounding combinations of valves lifting.
- The maximum load on the common header is due to the combined effect of the valves lifting.
- The header load is dominated by the faster-acting safety valves.

Given the limiting transient and considering the above, these load cases are clearly bounding.

In both cases, the pressure ramp-rate was artificially increased until the last valve in the sequence lifts. This has no significant impact on the system's response.

3.2.2 Thermal-Hydraulic Model

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

The RELAP5/MØD1 thermal-hydraulic model 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 quench tank, and through the rupture disc to the containment.

The model contains 232 control volumes and 242 interconnecting junctions (Load Case 2 used a slightly expanded model). The pressurizer is modeled as a time-dependent volume so that the pressure of the saturated steam can be varied as a function of time.

In accordance with Reference 6, the piping nodalization was selected to provide an accurate calculation of hydrodynamic forces. The short pipe segments (less than 5 feet) immediately downstream of the valves include eight to ten control volumes to avoid underestimation of the hydrodynamic loads. Farther down the line, where the hydrodynamic loads are smaller, the nodalization is coarser to minimize the computer model size. An abbreviated form of the overall nodalization scheme is shown on Figure 3-1. Table 3-1 summarizes the model properties.

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 quench tank. The normal operating pressure of the quench tank is 17.7 psia. Initially, it contains water and nitrogen at this pressure.

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. Thus, to achieve the required flow through the valves, the area which will allow the desired flow rate was calculated and used.

3.2.3 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

The Palisades plant has three safety valves mounted on the pressurizer. Pertinent safety valve data are given in Table 2-1.

Flow Rate - the rated capacity of each Palisades safety valve is 230,000 lb/hr.[5] Experience has shown that the actual capacity is greater than this rated value. Specific flow rates for relevant EPRI tests and calculated flow rates were considered together to determine an appropriate flow rate for this analysis.

The flow rate for this valve (at full lift) was calculated to be 347,480 lbm/hr, based on the Napier correlation with the discharge coefficient and pressure correction factor applied as recommended in Reference 8. However, for the Palisades valves, the lift is limited to 0.35 inches (or 78 percent of the rated lift). Assuming the critical flow area is linear with lift, the flow rate can be reduced by the ratio of .35/.45. This results in a maximum Palisades safety valve flow rate of 270,200 lbm/hr. This is based upon a valve inlet pressure of 2,520 psia, which is the peak pressure following a loss-of-load event.[4]

A review of the CE test matrix for this valve shows test 1104a most closely resembles the Palisades configuration.

Test 1104a conditions were:[7]

- 2550 psia pressure at valve opening
- 316 psi/sec pressure ramp rate
- 600 psia peak backpressure
- 0.013 sec. valve opening (pop) time
- 77 percent lift, 107 percent rated steam flow (318,690 lbm/hr) at 3 percent accumulation (based on tank pressure)

The measured flow at 77 percent lift is higher than the calculated flow using the Napier equation.

Based on comparison of the EPRI test data to the calculated flow rate, the higher flow rate from test 1104a (318,690 lbm/hr or 88.5 lbm/sec) was used in the analysis to estimate the safety valve flow area.

Valve Opening Time - valve opening (pop) time was based on this model valve achieving full lift in 12 msec. This is the minimum time measured during the steam tests (12 msec. was measured for tests 316 and 326).[7] Since the lift for the Palisades valve is only 0.35 inches (as opposed to 0.45 inches for the tested valve), the opening time was reduced by the ratio .35/.45. The opening time used in the analysis was thus 9.33 msec.

PORV Parameters

The two PORV's are attached to the pressurizer through a common nozzle. Pertinent PORV data are given in Table 2-2.

Flow Rate - The rated capacity for each Palisades PORV is 153,000 lbm/hr.[5] A calculated flow rate for this valve is 160,210 lbm/hr, based on the Napier correlation.[8]

Flow rates were measured in the Dresser PORV tests. However, the bore for the tested valves was 1.312 inches.[7] The bore for Palisades is 1.375 inches. Therefore, no direct correlation between the calculated flow and the test can be made.

The Marshall steam tests measured a flow of 155,000 lbm/hr under conditions similar to Palisades (that is, high back pressure and 2435 psia at the valve inlet).[7] This value of 155,000 lbm/hr was increased by the ratio of the valve areas (1.48/1.35) to determine the final value used, 170,000 lbm/hr.

This "area-corrected" measured flow rate is greater than the flow rate calculated with the Napier correlation.

Therefore, a flow rate of 170,000 lbm/hr (or 47.2 lbm/sec) was used to estimate the PORV flow area.

Opening Time - measured opening times from the EPRI test program are given in Table 3-2. An opening time of 0.17 seconds was used. This is an average value of the measured valve opening times.

3.2.4 Analysis Results and Discussion

Valve Flow Rates

Table 3-3 lists the analyzed steady-state flow rates, backpressures, and pressure conditions for the valves. A typical plot of backpressure is shown in Figure 3-2.

Note that the safety valve and PORV flow rates calculated by RELAP5/MØD1 are slightly lower than the target values. This lower flow rate does not significantly affect the magnitude of the transient force loadings. Moreover, the flow rates from the EPRI tests were based upon higher pressure conditions than are postulated at Palisades following a loss-of-load event.

Load Case 1

Safety valves RV-1040 and RV-1041 are postulated to lift for this case; RV-1039 and the two PORV's remain closed. RV-1041 has the lower setpoint and opens first.

The transient loads on the "dead" legs from the pressurizer to the inlet of the PORV's are very small since no flow occurs in these lines. Therefore, the acceleration or wave force term and the portion of the blowdown force term which is flow-dependent is very small. The peak forces are only pressure and pipe area dependent.

The maximum force (14.5 kips) on the active piping sections (the RV-1040 and 1041 tailpipes) occurs at the first elbow. The forces decrease at each elbow down the pipe to about 10 kips at the last elbow before the pipe enters the common header. Loads for the two tailpipes are similar.

Forces also occur on the tailpipes of the inactive valves. These forces are a result of steam backflow from the common header. Their magnitude is much less than for the corresponding locations on the active tailpipes.

Load Case 2

Both PORV's and safety valve RV-1039 are postulated to open. RV-1040 and 1041 remain closed. The PORV's begin opening first - however, due to their slower opening time compared to the safety valves (170 msec versus 9.33 msec), RV-1039 reaches its full open position first.

The force loadings on the RV-1039 tailpipe are similar to those for RV-1040 and 1041 for Load Case 1.

The absolute magnitude of the forces on the PORV inlet piping for Load Case 2 are comparable to those for Load Case 1. However, the opening of the PORV's creates a pressure transient which results in higher unbalanced forces on each piping segment. Therefore, Load Case 2 is the bounding case for the piping attached to the PORV's.

All forcing functions were calculated over the entire transient duration using a time step of 1.0×10^{-3} sec. Typical force time-histories are included in Appendix B.

3.3 Piping Evaluation

3.3.1 Jurisdictional Limits

The piping evaluated extends from the welds on the flanges upstream of the three safety valves and the weld at the PORV pressurizer nozzle, to the weld at the quench tank nozzle. Loads on valves, nozzles, and flanges were determined, but no evaluation of the adequacy of these components was performed.

3.3.2 Mathematical Model

The piping system was idealized as SUPERPIPE mathematical models. These consist of concentrated masses connected by massless elastic members. The concentrated masses were so located as to adequately represent the dynamic and elastic properties of the piping system. The stiffness of elbows and bends was reduced in accordance with the requirements of the Code of Record.

Two models were developed. The first includes the two PORV's and the two block valves. The second includes the three safety valves, their tailpipes, the 10-inch header, and the connection to the quench tank. The two models are structurally divided by in-line anchors H877.1 and H877.1A.

The piping layout, valve locations, and other relevant data related to the system were taken from the references listed in Appendix C. Support stiffnesses were included in the models.

3.3.3 Description of Analyses

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

Deadweight Analysis

The weight of the piping, components, and contained water (as appropriate) was applied. Since the spring hangers and constant load vertical supports are in-place, their actual design loads were applied as upward loads to the pipe.

Thermal Expansion Analysis

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

- Piping upstream of safety valves and PORV's - 650°F
- Balance of piping - 479°F

The pressurizer was also assumed to be at 650°F. The stress-free temperature for the analysis was taken as 70°F. Neither spring hangers nor constant load supports were included in the thermal analysis.

Valve Discharge Time History Analysis

Thermal-hydraulic force time histories of load at changes in flow direction and flow area calculated for each load case 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 (150 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 of the higher frequencies of the system. Based on sensitivity studies, a value of .001 seconds was used.

The event durations were taken as 0.75 and 0.50 seconds for Load Cases 1 and 2, respectively. Stresses were determined using the maximum of each moment component.

Load Combinations

Load combinations (Tables 3-4 and 3-5) were based on Reference 5.

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).

3.3.4 Code Evaluation

A code evaluation was performed for the pipe stresses. The Code of Record is USAS B31.1 (1967). For purposes of calculating stresses, the primary stress incorporates a .75i factor, as introduced into ANSI B31.1 (1973) and ASME Code Section III, Subsection NC (1974). In addition, the qualification criteria includes an allowable of $2.4S_u$ or $1.1S_y$ (whichever is greater), for the primary stresses caused by normal loads and the Safe Shutdown Earthquake (SSE).

The design, operating and peak pressures were taken as:

- Piping upstream of safety valves and PORV's - 2485 psig
- Balance of piping - 582 psig

4.0 RESULTS

4.1 Piping Stresses

For full computer summaries, see Appendix E.

Maximum stresses for each load combination are given in Tables 4-1 and 4-2. Table 4-1 includes the PORV section piping. Table 4-2 includes the remaining piping.

4.2 Nozzle and Valve Flange Loads

Summaries of nozzle loads are included in the Appendix E summaries. Table 4-3 gives the maximum components of load on each nozzle.

4.3 Valve Accelerations

Approximate maximum horizontal and vertical safety valve accelerations for each valve actuation load case are given in Table 4-4.

4.4 Support Loads

For full support load summaries, see Appendix E.

The supports' adequacy for seismic loading has been verified in accordance with IE Bulletin 79-14. Maximum support loads from load combination 3 of Table 3-5 are compared with these 79-14 loads in Table 4-5. It should be noted that the supports' capacity may be considerably greater than the 79-14 loads.

4.5 Discussion of Results

Piping Stresses

The response of the piping upstream of the anchors in the PORV section meets the allowables specified in the Code of Record.

The remaining piping - specifically the safety valve tailpipes and their connection to the common header, and the connection between the header and the quench tank - shows stresses in excess of the allowables specified in the Code of Record.

This exceedance of the Code of Record allowable stresses is due to the thermal-hydraulic, valve actuation loads.

Support Loads

Many support loads exceed the loads to which these supports were evaluated in the 79-14 program. This is due to the thermal-hydraulic, valve actuation loads. However, the actual capacity of these supports may be considerably greater than these 79-14 loads.

REFERENCES

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

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

3. SUPERPIPE Users Manual, EDS Nuclear, Version 15C, June 25, 1982.

4. EPRI Report No. NP-2318-LD, "Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Combustion Engineering -Designed Plants," Interim Report, April, 1982.

5. Palisades Final Safety Analysis Report.

6. "Application of RELAP5/MØD1 for Calculation of Safety and Relief Valve Discharge Piping Hydrodynamic loads," Intermountain Technologies Inc.

7. EPRI Report, Safety and Relief Valve Test Report (Interim), dated April, 1982

8. Critical Flow Predictions Through Safety and Relief Valves, prepared by S. Levy, Inc. for EPRI, dated June, 1982.

Table 2-1: Safety Valve Parameters

• Number of Valves	3
• Manufacturer	Dresser, Model No. 31739A
• Type	Spring-loaded nozzle type relief valve
• Steam Flow Capacity	318,690 lbm/hr.
• Design Pressure and Temperature	2500 psig 700 °F
• Set Pressure	RV-1039: 2565 psig RV-1040: 2525 psig RV-1041: 2485 psig

Table 2-2: Power-Operated Relief Valve Parameters

• Number of Valves	2
• Manufacturer	Dresser, Model No. 31533VX
• Type	Globe valves
• Steam Flow Capacity	170,000 lbm/hr.
• Design Pressure and Temperature	2500 psia 700 ^{o}F
• Set Pressure (Note 1)	PRV-1042B: 2400 psig PRV-1043B: 2400 psig

Note 1: Palisades is currently operated with the power-operated relief valves inactive.

Table 3-1: RELAP5/MØD1
Model Properties

Item	Modeled As	Component Numbers	No.of Junct.	No.of Control Volumes
Pressurizer	Time-dependent volume, and branch volume	1,2,3	5	2
Nozzle leading to RV 1039	Pipe	10,11	1	1
Nozzle leading to RV 1040	Pipe	20,22	3	3
Nozzle leading to RV 1041	Pipe	30,33	3	3
Nozzle leading to PORVs	Pipe	40	0	1
RV1039 line to the header	Pipe, single branch volume, and valve	100,101,-136	26	25
RV1040 line to the header	Pipe, single branch volume, and valve	200,201,-230	50	49
RV1041 line to the header	Pipe, single branch volume, and valve	300,301,-340	54	53
Line from the nozzle to first tee before the PORVs	Pipe, single and branch volume	400,401,-420	15	12
Line from PORV1042 to header	Pipe, single volume, branch volume, and valve	500,501,-548	37	36
Line from PORV1043 to header	Pipe, single volume, branch volume, and valve	600,601,-658	36	35
Main header, with the line going to the Quench Tank	Pipe, single volume, branch volume	700,701-712	10	9
The Quench Tank, and through the rupture disc to containment	Single volume, time-dependent volume, and valve (for rupture disc)	800,801,803 804	2	3

Table 3-2: Dresser Power-Operated Relief Valve Test Data

Steam Test No.	Opening Time (sec)
Marshall 1	.19
Marshall 2	.17
Marshall 3	.19
Marshall 4	.19
Marshall 5	.19
Marshall 6	.18
Marshall 7	.23
Marshall 8	.17
Marshall 9	.18
Marshall 10	.17
Marshall 11	.19
Wyle Phase II DR-1-S	.15
Wyle Phase II 10-DR-1S	.11
Wyle Phase III 20-DR-1S	.17
Wyle Phase III 23-DR-1S	.13

Table 3-3: Pressures and Flow Rates for each Load Case

Valve	Load Case 1 Press. Pressure[1]	Load Case 1 Valve Inlet Press.	Load Case 1 Valve Outlet Press.[2]	Load Case 1 Flow Rate (lbm/sec)	Load Case 2 Press. Pressure	Load Case 2 Valve Inlet Press.	Load Case 2 Valve Outlet Press.[2]	Load Case 2 Flow Rate (lbm/sec)
RV-1039	----	----	----	----	2589.0	2514.1	355.0	87.1
RV-1040	2560.0	2487.0	344.0	87.4	----	----	----	----
RV-1041	2560.0	2487.0	355.3	87.4	----	----	----	----
PRV-1042B	----	----	----	----	2589.0	2245.1	438.8	44.1
PRV-1043B	----	----	----	----	2589.0	2278.0	451.9	44.8

Notes:

1. All pressures in psia
2. Steady-state backpressure

Table 3-4: Piping Load Combinations

Load Combination Number	Load Combination	Allowable Stresses (Note 1)
1 (Sustained)	P + DW	$1.0S_h$
2 (Occasional-Note 2)	P + DW + OBE	$1.2S_h$
3 (Occasional)	P + DW + F	$1.2S_h$ (Note 3)
4 (Faulted-Note 2)	P + DW + SSE	$2.4S_h$ (Note 4)
5a (Thermal)	TE	S_A
5b (Thermal + Sustained)	TE + P + DW	$S_A + S_h$

Table 3-5: Pipe Support Load Combinations

Load Combination Number	Load Combination
1 (Sustained)	DW + TE
2 (Occasional-Note 2)	DW + TE + OBE
3 (Occasional)	DW + TE + F
4 (Faulted-Note 2)	DW + TE + SSE

Definitions:

P = Pressure
DW = Gravity
TE = Thermal Expansion
OBE = Design Earthquake
F = System Operating Transient (Valve Actuation)
SSE = Hypothetical Earthquake

Notes:

1. As per B31.1 (1967) - Code of Record
2. Not included in this evaluation
3. Per ASME Code, corresponds to upset allowable - emergency allowable is $1.8S_h$
4. But not less than $1.1S_y$ (Reference 5)

Table 4-1: Pipe Stresses - PORV Section

Load Combination Number	Joint Name/Type	Maximum Stress, psi	Allowable[1] Stress, psi	Ratio
1 (Sustained)	480C/Elbow	7444	12789	0.58
3 (Occasional-F)	529/Fillet Weld	11795	12780	0.92
5a (Thermal)	508/Fillet Weld	15498	26332	0.59

Table 4-2: Pipe Stresses - Balance of Piping (SV Section)

Load Combination Number	Joint Name/Type[2]	Maximum Stress, psi	Allowable[1] Stress, psi	Ratio
1 (Sustained)	115/Tee	9242	11579	0.80
3 (Occasional-F)	135/Tee	29811	13894	2.15
5a (Thermal)	150/Tee	20549	26332	0.78

Notes:

1. Per B31.1 (1967) - Code of Record - and Reference 5

2. For joint name location, see Figure 2-1.

Table 4-3: Nozzle Loads

Nozzle	Load Case	Axial Load lbs	Resultant Shear lbs	Torsional Moment ft-lbs	Resultant Bending Mome[r]nt ft-lbs
RV-1039 press. and valve inlet -at face of flange	Gravity	693	15	95	1279
	Thermal	11	76	129	744
	Load Case 1	984	3300	1647	4750
	Load Case 2	4534	8519	5350	13608
RV-1039 valve outlet -at face of flange	Gravity	14	172	164	1071
	Thermal	37	66	705	390
	Load Case 1	3945	699	387	2179
	Load Case 2	10245	3240	961	10286
RV 1040 press. and valve inlet -at face of flange	Gravity	717	91	605	1013
	Thermal	1	186	35	1202
	Load Case 1	4612	8380	3059	16343
	Load Case 2	1803	3280	2461	4230
RV-1040 valve outlet -at face of flange	Gravity	14	215	36	950
	Thermal	186	5	226	1330
	Load Case 1	10397	4047	522	11624
	Load Case 2	3679	761	268	2494
RV 1041 press. and valve inlet -at face of flange	Gravity	690	83	380	718
	Thermal	16	94	138	842
	Load Case 1	3717	8092	6670	14535
	Load Case 2	1833	3001	2764	3944
RV-1041 valve outlet -at face of flange	Gravity	78	171	311	643
	Thermal	6	95	916	69
	Load Case 1	10520	3672	2171	11598
	Load Case 2	3554	798	663	3292
Quench Tank at face of nozzle	Gravity	537	159	772	1335
	Thermal	198	5884	109	6344
	Load Case 1	12770	3599	2636	4735
	Load Case 2	11659	3756	3429	5008
PORV Nozzle at interface of press. nozzle and PORV inlet piping	Gravity	155	1	11	73
	Thermal	208	103	320	616
	Load Case 1 (Note 1)				
	Load Case 2	1680	357	491	1497

Note 1: Bounded by Load Case 2

Table 4-4: Safety Valve Accelerations

	Load Case 1		Load Case 2	
Safety Valve	Horiz.Accel.	Vert.Accel.	Horiz.Accel.	Vert.Accel.
RV-1039	0.52	0.03	2.22	0.28
RV-1040	2.53	2.20	0.59	0.36
RV-1041	1.80	1.38	0.54	0.42

Note 1:

All accelerations are in units of gravity (g's), and are given at the valve's center of gravity.

Table 4-5: Support Loads

Support Mark No.[1] (Joint No.)	Support Type	Load	79-14 Loads Comb.2	79-14 Loads Comb.4	Calculated Load, Comb.
PORV Section					
R1 (480)	Anchor	Fx	404	547	1413
		Fy	372	448	4050
		Fz	975	1187	2151
		Mx	1081	1214	1197
		My	560	673	1107
		Mz	740	1031	935
R2 (695)	Anchor	Fx	240	321	1285
		Fy	326	387	3802
		Fz	352	436	1510
		Mx	546	634	485
		My	498	658	1457
		Mz	450	646	266
R864.2 (530)	Rigid	Fy	320	414	815
H875.1 (485)	Rigid	Fz	736	1200	4630
R876.1 (462)	Rigid	Fx	556	463	543
		Fz	-	-	1937
R866.1 (675)	Rigid	Fx	248	280	406
		Fz	713	726	1236
H877.1 (435)	Anchor	Fx	265	323	894
		Fy	478	556	10,096
		Fz	759	854	460
		Mx	4136	5267	2172
		My	1442	1828	1326
		Mz	589	966	4363
H877.1A (640)	Anchor	Fx	99	141	790
		Fy	513	569	9614
		Fz	585	764	249
		Mx	3514	5226	1276
		My	1533	2103	971
		Mz	1149	1452	4333

Table 4-5: Support Loads (continued)

Support Mark No.[1] (Joint No.)	Support Type	Load	79-14 Loads Comb.2	79-14 Loads Comb.4	Calculated Load, Comb.3
Balance of Piping (SRV Section)					
H878.1 (417)	Rigid	Fz	238	466	172
H869.1 (615)	Rigid	Fz	238	466	233
H858.1 (35)	Snubber	-	399	798	2257
H858.2 (35)	Snubber	-	156	311	2753
R860.1 (65)	Rigid	Fx	127	212	1621
		Fy	302	343	2091
H862 (85)	Rigid	Fy	263	414	499
R854.1 (240)	Rigid	Fx	197	329	1800
		Fz	540	979	1615
S850.1 (355)	Snubber	-	271	541	3754
S850.2 (350)	Snubber	-	364	727	5896
R857.1 (130)	Rigid	Fx	3681	4131	6876
R880.1 (170)	Rigid	Fx	3506	3795	2980

Notes:

1: For support location, see Figure 2-1.
2: Comb. 2 is TE + DW + OBE - Load used in 79-14 Qualification
3: Comb. 4 is TE + DW + SSE - Load used in 79-14 Qualification
4: Comb. 3 is TE + DW + F

Definitions:

TE = Thermal Expansion
DW = Gravity
OBE = Design Earthquake
SSE = Hypothetical Earthquake
F = System Operating Transient (Valve Actuation)

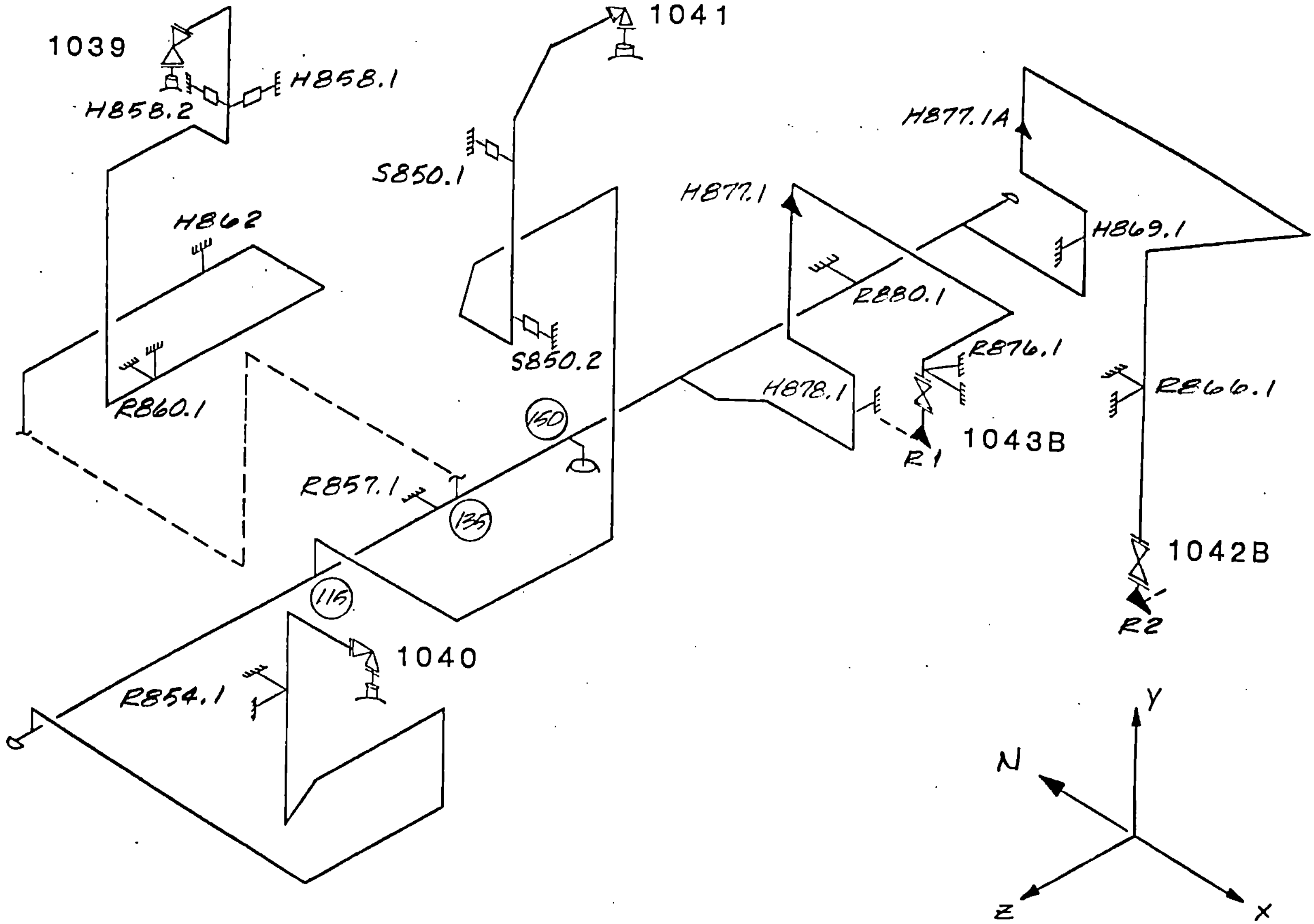

FIGURE 2-1
System Layout

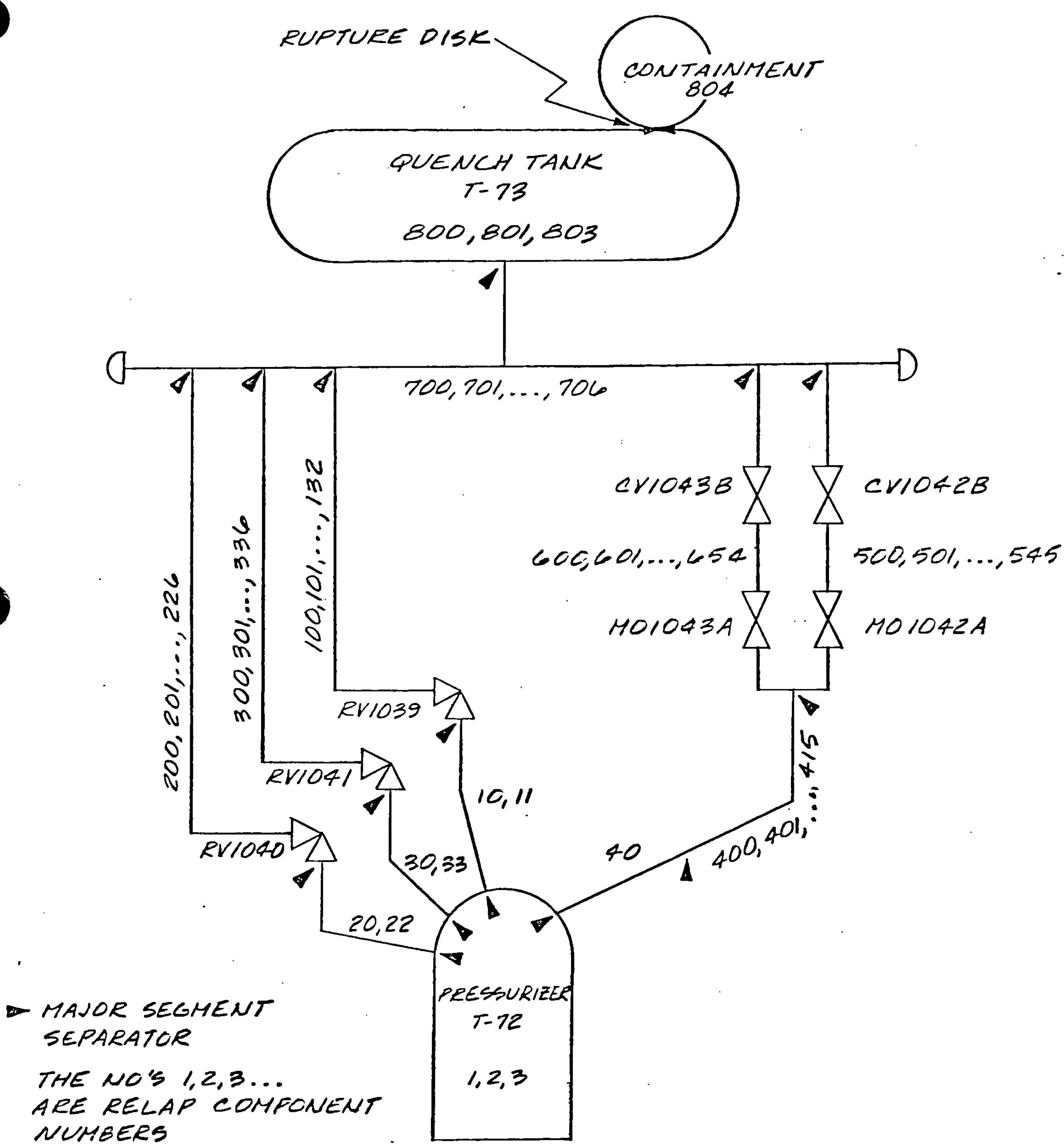

FIGURE 3-1

Palisades RELAP5/MØD1 Model

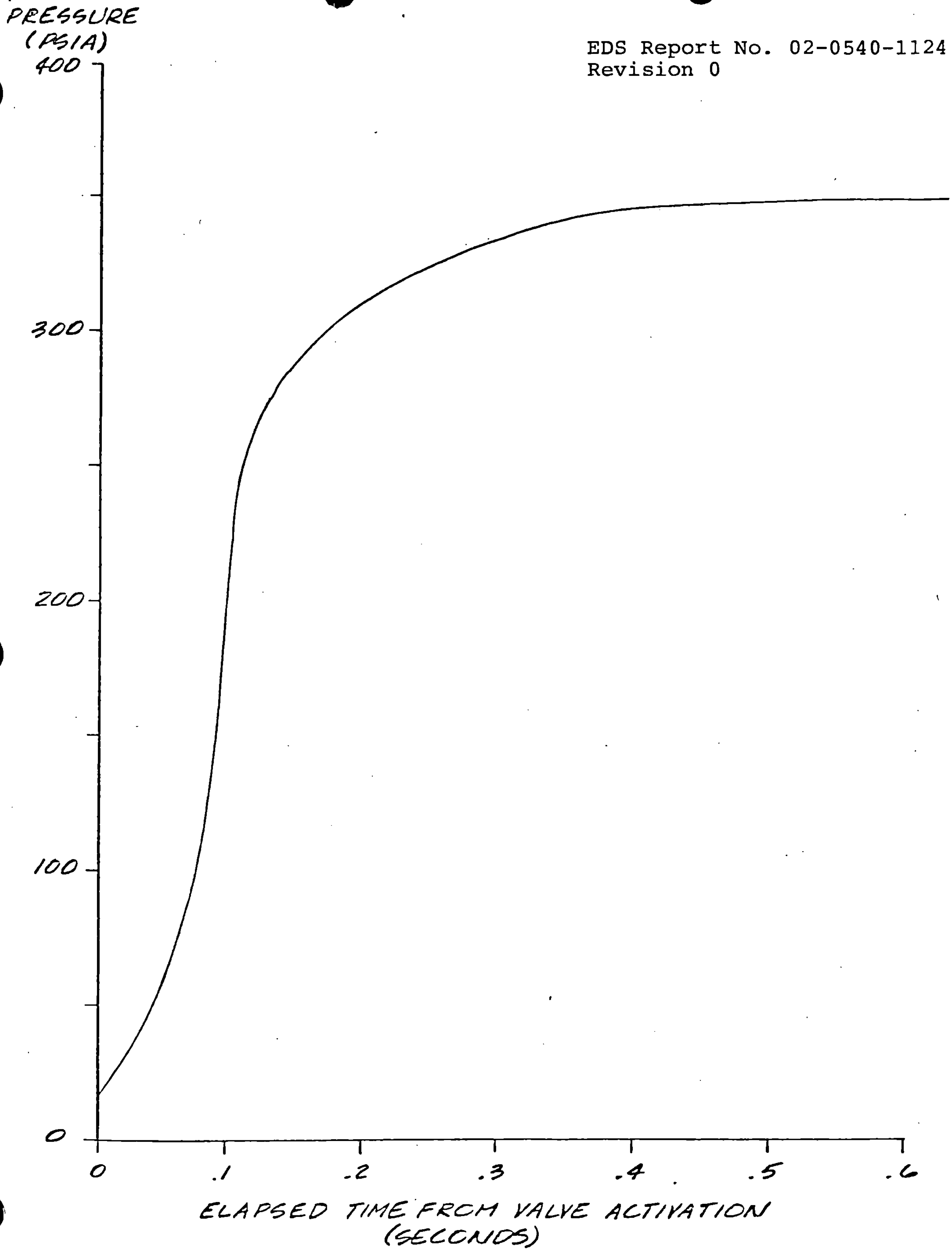

FIGURE 3-2

Typical Safety Valve Backpressure

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 to be 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 on Motion.

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

$$F = F_W + F_{CS}$$

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 forces are calculated in this fashion at variations in flow areas and/or changes in flow direction.

APPENDIX B: REFØRC FORCE TIME-HISTORIES

Representative force time-histories are shown on Figures B-2 to B-120. All forces are in global co-ordinates. A key to identify force locations is shown on Figure B-1.

For these figures, see Volume 2 of this report.

APPENDIX C: REFERENCES FOR PIPING SYSTEM DATA

The following references were used to determine piping system data.

- o Bechtel Palisades Plant Drawings
  Consumers Power Company GWO 6786
  Pressurizer Safety and Relief Valve Discharge

  - Drawing No. 03375 Stress Isometric Sheet 1 of 6 (Q) Rev. 0
    Sheet 2 of 6 (Q) Rev. 2
    Sheet 3 of 6 (Q) Rev. 0
    Sheet 4 of 6 (Q) Rev. 0
    Sheet 5 of 6 (Q) Rev. 0
    Sheet 6 of 6 (Q) Rev. 0

  - Equipment Location - Reactor Building Plan at El. 607' 6"
    Dwg. No. M-3 Rev. 10

  - Equipment Location - Reactor Building Plan at El. 602' 0"
    Dwg. No. M-9 Rev. 6

- o Combustion Engineering Inc. Drawings
  Chattanooga Division

  - Pressurizer Outline for Consumers Power Pressurizer
    Dwg. No. 231-980-5

  - Top Head Forming and Welding for Consumers Power Pressurizer
    Dwg. No. 231-983-6

  - Nozzle Details for Consumers Power Pressurizer
    Dwg. No. 231-986-5

- o Dresser Industrial Valve & Instrument Division Drawings
  Alexandria, Louisianna

  - ASME Section III Maxiflow Safety Valve
    Flanged Inlet 2500 psig Class, Through Bushing
    Dwg. No. 2 1/2-31739A-1 X6-XFA1-XOS122 Rev. 0

  - ASME Section III 2-1/2-31533VX
    Consolidated Electromatic Relief Valve
    2500 lh Class (Non-Bellows)
    Dwg. No. 3CP-1687 Rev. 5

- o **Alpha Tank and Metals Mfg. Co. Drawings**
  St. Louis, Mo.

  - 114 Inch O.D. Pressurizer Quench Tank
    Combustion Engineering Inc.
    Consumers Power Company
    Dwg. No. D-7284

- o **Southwest Fabrication and Weld Co. Drawings**
  Houston, Texas

  - Spool Piece Drawings
    Drawings No. S.O. 7453 Sheet No. 660
    7453 Sheet No. 661
    7453 Sheet No. 662
    7453 Sheet No. 664
    7453 Sheet No. 665
    7453 Sheet No. 666
    7453 Sheet No. 667
    7453 Sheet No. 668F
    7453 Sheet No. 669
    7453 Sheet No. 670
    7453 Sheet No. 671
    7453 Sheet No. 672F
    7453 Sheet No. 673
    7453 Sheet No. 674
    7453 Sheet No. 675
    7453 Sheet No. 676F
    7453 Sheet No. 677
    7453 Sheet No. 678
    7453 Sheet No. 679
    7453 Sheet No. 681
    7453 Sheet No. 683

  - Fabrication Isometrics
    Drawing Nos. S.O. 12447-033 Iso No. 132 Rev. 5
    133 Rev. 4
    134 Rev. 4
    135 Rev. 4
    136 Rev. 4
    137 Rev. 4

- o <u>Bechtel Support Designs and Calculations</u>
    - Bechtel Stress Package No. 03375
      File No. 03375-1 through 03375-43
- o EDS Calculation Index
  <u>Palisades Nuclear Station</u>
    - SRV Discharge Piping Reevaluation
      EDS Job No. 0540-006-641
- o Consumers Power Palisades Nuclear Station
  <u>Final Safety Analysis Report</u>

APPENDIX D: SUPERPIPE MODELS

EDS Drawing No. 0540-006-01 Rev. 0 (two sheets) shows the mathematical models used for analysis of this system. This drawing is held under separate cover.

APPENDIX E: DETAILED STRESS AND SUPPORT LOAD SUMMARIES

Detailed computer listings of the pipe stress and support load summaries are held under separate cover.