ENCLOSURE 2

CEN-248(B)

Revision 2

BALTIMORE GAS AND ELECTRIC COMPANY

CALVERT CLIFFS NUCLEAR POWER PLANT
UNITS 1 AND 2
PRESSURIZER SAFETY VALVE
OPERABILITY REPORT

Nuclear Power Systems Division

January, 1984

C-E POWER SYSTEMS
COMBUSTION ENGINEERING, INC.

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Calvert Cliffs Nuclear Power Plant
Units 1 and 2
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PART A. INTRODUCTION

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PART A - INTRODUCTION

1.0 OBJECTIVE

The objective of this report is to provide a detailed evaluation demonstrating the operability of the as-installed pressurizer safety valves in Calvert Cliffs Nuclear Power Plant, Units 1 and 2. The evaluation is based on applying results from the EPRI Safety and Relief Valve Test Program. The test program is described in Part B of this report, and the plant-specific safety valve operability evaluation is discussed in Part C.

2.0 BACKGROUND

In the aftermath of the Three Mile Island (TMI) accident, the Nuclear Regulatory Commission issued requirements that utilities operating and constructing pressurized water reactor (PWR) power plants demonstrate the operability of pressurizer safety and relief valves and the structural adequacy of the discharge piping and supports. These requirements were promulgated in NUREG-0578 (Reference 6.7) and NUREG-0660 (Reference 6.8), and further clarified in NUREG-0737 (Reference 6.9). At the request of utilities with PWRs, EPRI developed and implemented a generic test program for pressurizer power operated relief valves and safety valves (Reference 6.10) which was accomplished during 1980-81. The testing of safety valves, as one phase of the test program, was implemented at a test facility at the Windsor, Connecticut, site of Combustion Engineering, Inc. The facility was specifically erected for the safety valve tests. The portion of the EPRI Valve Test Program performed at the C-E site is herein designated as the EPRI Safety Valve Test Program.

3.0 APPROACH

3.1 INTRODUCTION

The approach applied in the evaluation consisted of selecting tests most closely matching the Calvert Cliffs Units 1 and 2 conditions and then applying the test results to the plant-specific evaluation. The approach, although generally the same as was used in Reference 6.12, was modified slightly because of Calvert Cliffs specific requirements and conditions.

A Dresser 31739A safety valve, the same valve model as used in Calvert Cliffs Units 1 and 2, was tested in the EPRI program. The test condition variables included valve inlet piping configurations, inlet fluid conditions, valve adjusting ring settings, discharge (back) pressure buildup, and inlet pressure ramp rates. The overall approach was as follows:

3.2 SELECTION OF APPLICABLE TESTS AND ANALYSIS

Since the Calvert Cliffs Units 1 and 2 safety valves are specified for operation on steam conditions, only steam tests were considered to be applicable.[(1)]

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(1) In steam-to-water transition tests, the first cycle of opening occurred on steam and was considered to be applicable for purposes of evaluating opening stability.

Out of the applicable tests, only tests exhibiting stable valve performance were further considered.

Acoustic wave amplitudes [1] at valve opening were determined for each test.

Valve characteristics were developed and analyzed based on test data.

3.3 PLANT-SPECIFIC EVALUATION

The following approach was applied to show that the Calvert Cliffs Units 1 and 2 pressurizer safety valves were enveloped by a number of tests which resulted in acceptable valve operation.

The plant safety valve inlet piping configurations and the most limiting pressurization transients with the highest peak pressurizer pressure and pressure ramp rate were identified.

Calculations were performed to determine the acoustic wave amplitudes at valve opening based on the in-plant installations.

Tests that were directly applicable to the plant were identified based on the following:

- The valve stem reached a full flow position at opening. [2]
- The test valve inlet piping configuration is more limiting than that of the plant, based on comparison of corresponding values of acoustic wave amplitudes.

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(1) See Subsection 3.5, Part B, for discussion

(2) See Subsection 2.2, Part B, for definition

Directly applicable tests which resulted in reasonable blowdowns were then identified as tests which qualify the safety valve adjusting ring settings as being suitable for proper operation. Acceptable blowdown was determined by analysis of RCS pressure transients considering the response of pressurizer level and the effect of depressurization on loop subcooling. The study justifying extended safety valve blowdown [1] was conducted for Calvert Cliffs Units 1 and 2, as well as for other C-E designed plants, and presented in Reference 6.13.

4.0 SUMMARY

In this report results from the EPRI Safety Valve Test Program are applied to the Calvert Cliffs Units 1 and 2 safety valves. Safety valve operability is demonstrated on a plant-specific basis using the following criteria:

1. The safety valve model tested in the EPRI program is representative of the valves installed in the plant.

2. Based on a combination of test data and analysis, the plant valve inlet piping configuration is shown to enhance the stability of valve operation relative to the EPRI test configuration.

3. The range of valve inlet fluid conditions used in the testing either envelopes or approximates the corresponding conditions estimated for the plant.

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(1) The version of the ASME Code to which the safety valves used in C-E NSSSs were originally purchased required that blowdown not exceed 5%. Therefore, "extended" means any blowdown greater than 5%.

4. The valve stem lift measured in the tests is greater than or equal to full flow lift.

5. The maximum calculated bending moment at the plant valve discharge flange is lower than the maximum measured value for the test valve.

6. The plant-specific range of back pressures is enveloped by a range of back pressures measured in the tests.

Provided the above criteria are met, and the test valve exhibited stable operation, the plant-specific safety valve installation and valve adjustments are considered satisfactory.

5.0 CONCLUSION

The EPRI Safety Valve Test Program results, in conjunction with the Part C evaluation, identify the valve adjusting ring setting which are qualified for use in the Calvert Cliffs Units 1 and 2. They are (-48, -40, +11) [1], (-48, -40, +3), (-48, -60, +5) and (-48, -80 +11).

It is concluded that the (-48, -40, +11) setting is recommended for use in Calvert Cliffs Units 1 and 2 since stable operation was demonstrated, test conditions bounded the conditions in the plant, adequate valve lift was achieved, the resultant blowdowns are acceptable, and bending moments imposed by the discharge piping did not impair valve operability.

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(1) Dresser ring settings are designated in the order of upper, middle and lower ring positions.

6.0 REFERENCES

The following are references used throughout this report.

6.1 EPRI/C-E Safety Valve Test Report, EPRI Research Project V102-2, Interim Report, July 1982.

6.2 Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in C-E Designed Plants, EPRI NP-2318-LD, Project V102-20, Interim Report, April 1982.

6.3 PWR Safety and Relief Valve Test Program, Valve Selection/Justification Report, EPRI NP-2292-LD, Project V102, Interim Report, March 1982.

6.4 Flow of Fluids through Valves, Fittings, and Pipe by Crane, Technical Paper No. 410.

6.5 ASME Code, Section III, Subsection NB-7700.

6.6 Terminology for Pressure Relief Devices - American National Standard ANSI B95.1 - 1972.

6.7 NUREG-0578, TMI-2 Lessons Learned Task Force Status Report and Short Term Recommendations, Nuclear Regulatory Commission, July 1979.

6.8 NUREG-0660, Nuclear Regulatory Commission Action Plan Developed as a Result of the TMI-2 Accident, May 1980.

6.9 NUREG-0737, Clarification of TMI Action Plan Requirements, Nuclear Regulatory Commission, November 1980.

6.10 Program Plan for the Performance Testing of PWR Safety and Relief Valves, Revision 1, July 1980, by Electric Power Research Institute, Nuclear Power Division.

6.11 Instructions for Installation and Maintenance, Consolidated Closed Bonnet Maxiflow Safety Valves, Type 31700, Dresser Industries, October 1978, Revision 1.

6.12 Summary Report on the Operability of Pressurizer Safety Valves in C-E Designed Plants, Prepared for the C-E Owners Group, Combustion Engineering CEN-227, December 1982.

6.13 Effect of Pressurizer Safety Valve Extended Blowdown upon Pressurizer Liquid Level and Primary Loop Subcooling for C-E Plants. Enclosure to C-E Letter CEOG-576, by J. H. Hutton to the C-E Owners Group December 23, 1982.

PART B - EPRI TEST PROGRAM DESCRIPTION AND TEST DATA EVALUATION

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PART B - EPRI TEST PROGRAM DESCRIPTION AND TEST DATA EVALUATION

1.0 EPRI SAFETY VALVE TEST PROGRAM

1.1 VALVE SELECTION JUSTIFICATION

NUREG-0737 required that testing be performed on full-scale pressurizer safety and relief valves representative of those in use or planned for use in PWRs. To obtain the valve operability data for the large variety of valves used in domestic PWR plants it was necessary for EPRI to select a limited, but fully representative set of valves for test purposes.

In order to select the test valves, a complete list of valve types, models, and sizes used or intended for use in PWR plants was compiled based on information provided by the NSSS vendors, valve manufacturers and PWR utilities. From these lists, valves were selected for test which were considered to adequately represent the total PWR valve population. Justification that the test valve results are applicable to all plant/vendor valves was developed based on evaluations performed by the valve manufacturers. These evaluations considered the effects of differences in valve operating characteristics, materials, design details, orifice sizes and manufacturing processes on valve operability.

Table B1-1[1] provides a list of the selected test safety valves, the valves represented, and the valve distribution in PWR plants. As it can be seen from the table, a Dresser 31739A safety valve, the

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(1) From Reference 6.3.

TABLE B1-1

EPRI TEST PROGRAM

SELECTED SAFETY VALVES, VALES REPRESENTED, VALVE DISTRIBUTION IN EPRI PROGRAM PARTICIPANTS

Valve Manuracturer	Selected Test Valves				Valves Represented				No. of Plants
	Model No.	Inlet	Size Orifice	Outlet	Model No.	Inlet	Size Orifice	Outlet	
Crosby Valve & Gage Company	HB-BP-86	3	K	6	HB-BP-86	3	K	6(smallest)	3
		6	M	6		3	K2	6	2
		6	N	8		4	K2	6	6
						6	K2	6	2
						4	M1	6	3
						6	M1	6	6
						4	M	6	1
						6	M	6	38
						6	N	8(largest)	6
Dresser Industries	31739A	2.5	No. 3	6	31709KA	2.5	K	6(smallest)	1
	31709NA	6	N	8	31739A	2.5	No. 3	6	11
					31749A	3	No. 4	6	3
					31759A	3	No. 5	6	5
					31709NA	6	N	8(largest)	17
Target Rock Corp.	69C	6	$3.513 in^2$	6	69C	6	$3.513 in^2$	6	1
								Total	105

Note: Inlet and outlet sizes are nominal pipe sized in inches same valve model as used in Calvert Cliffs Units 1 and 2, was tested in the Program. This makes the tested valve model directly applicable to the plant-specific evaluation.

Detailed documentation justifying the selection of valves for the tests is provided in Reference 6.3.

1.2 TEST CONDITIONS JUSTIFICATION

The basis for the selection of the test conditions for the EPRI Safety Valve Test Program is described in detail in Reference 6.2. FSAR/Reload analyses were reviewed to identify the valve inlet fluid conditions resulting from pressurization transients which actuate safety valves. The fluid conditions identified were peak pressurizer pressure, pressure ramp rate at actuation, temperature, and fluid state.

As presented in Reference 6.2, the safety valve inlet fluid state for Calvert Cliffs Units 1 and 2 (as well as for all other C-E plants) transients initiated at normal power conditions would be saturated steam. For this reason only steam tests and the steam portion of steam-to-water transition tests were considered in this report.

1.3 TEST FACILITY DESCRIPTION

1.3.1 Introduction

The test facility for the EPRI Safety Valve Test Program is located at C-E's Kreisinger Development Laboratory in Windsor, Connecticut. Reference 6.1 provides a detailed description of the facility. A summary description is provided below.

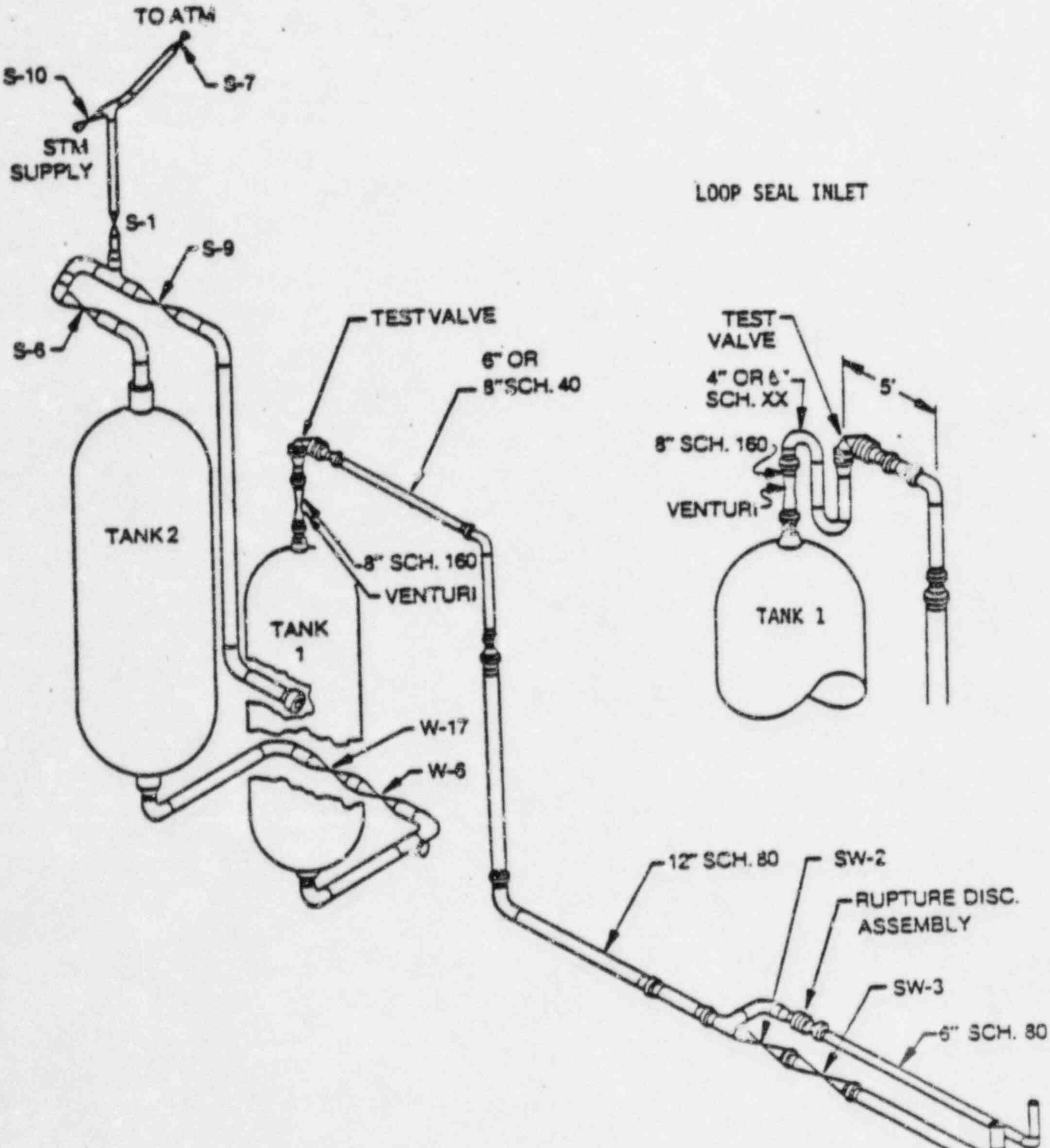
1.3.2 Test Loop Layout

The major components, piping and valves in the test system are shown in Figure B1-1. The system is capable of developing steam, water, and transition (steam-to-water) conditions at pressures up to 3000 psia. Design flow rates of the loop are 150,000 lb/hr steam continuously or 600,000 lb/hr for approximately 15 seconds and 5,500 gpm of water for approximately 15 seconds.

As shown in Figure B1-1, a test valve is mounted on top of Tank 1 with discharge to atmosphere through 6 inch or 8 inch (depending on the test valve) piping that is connected to 12 inch piping and valves. Tank 1 serves as a surge vessel in which the water and/or steam inventory simulates the thermal-hydraulic conditions in a PWR pressurizer. Tank 2 serves as a driver vessel through expansion or evaporation of its fluid contents. The tanks are interconnected by two 12 inch lines each containing a fast closing and tight shutoff valve. Steam is supplied to the facility through a 6 inch line from a boiler. A recirculation system is provided for each tank as well as a method for controlling loop pressure by venting steam to atmosphere. Means were provided to adjust back pressure buildup (up to 1000 psig). A line containing a rupture disk is provided to prevent overpressurization of the discharge piping should the leak check isolation valve, SW-2, be inadvertently left closed during a test. Considerable flexibility has been built into the test loop to allow testing of different valve sizes and inlet piping configurations.

In order to simulate the different inlet piping arrangements found in PWR plants, two generic inlet piping configurations were developed. These configurations consisted of a short vertical inlet configuration and a long inlet/loop seal configuration. In addition, one test series (1200 series with the Crosby Model HB-BP-86, 6N8 valve) was performed with an intermediate length vertical inlet configuration.

Figure B1-1. Test Loop Schematic Showing Major Components



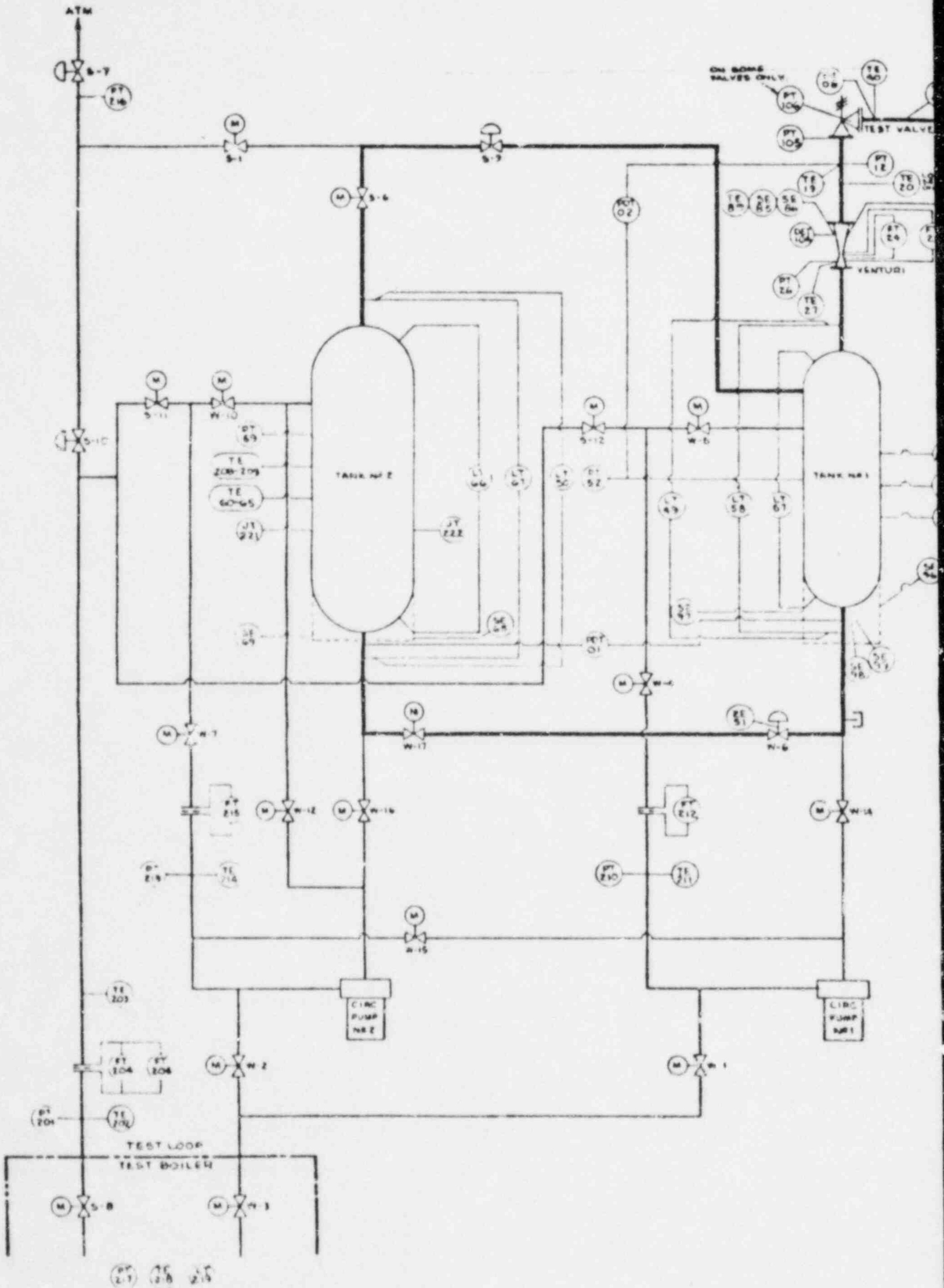
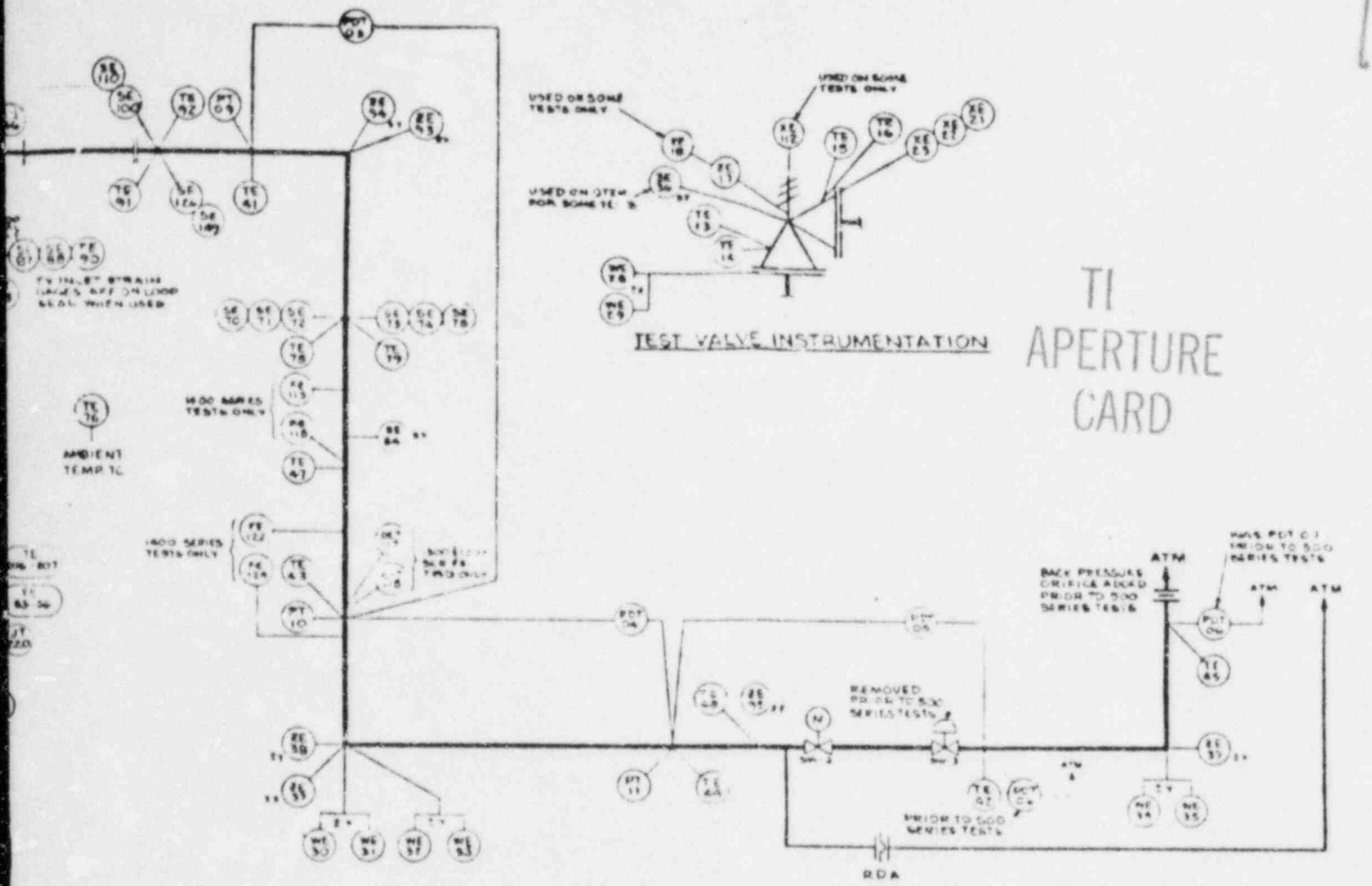


FIGURE B1-2. Piping and Instrumentation Drawing



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1.3.3 Instrumentation

A full range of test instrumentation is provided in the facility. The location of the instrumentation is shown in Figure B1-2[1]. In addition, process instruments were provided to assist the operator in controlling the test loop. A detailed description of the instrumentation is provided in Reference 6.1.

1.4 TESTING PROCEDURE

The general test procedure involved raising the pressure at a prescribed rate in order to actuate the test valve, starting from a valve inlet pressure below the valve opening setpoint.

The installed instrumentation recorded the valve behavior as it lifted, discharged, and closed. For each valve tested, runs were made with different valve adjusting ring settings, pressure ramp rates, back pressures, and inlet fluid conditions. The inlet fluid conditions tested were steam, water, and steam-to-water transition. The detailed procedure varied, depending upon the inlet fluid conditions being tested.

A valve leakage check was run prior and subsequent to each valve lift test. Safety valve opening set points were checked frequently throughout the test. The method of controlling the inlet conditions to the test valve is summarized below for each test type.

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(1) From Reference 6.1, Vol. 2.

In the case of a steam test with a high pressurization rate, Tanks 1 and 2 were filled with steam and isolated from each other. Tank 1 pressure was about 2300 psia while Tank 2 was at about 2950 psia. Valve lift was initiated by opening the isolation valve between the tanks.

For steam tests with low pressurization rate, Tank 1 was isolated from Tank 2, and filled with steam at about 2300 psia. Steam from the boiler was fed to Tank 1 to raise pressure at the desired low ramp rate to lift the valve.

For steam-to-water transition tests, Tanks 1 and 2 were partially filled with saturated water at 2300 psia. The isolation valve between the tanks was in the open position. Boiler steam was fed to Tank 2 to raise the pressure to lift the safety valve on steam. Safety valve lift resulted in the flow of water from Tank 2 to Tank 1. Eventually, Tank 1 filled with water and the safety valve inlet fluid changed from steam to water.

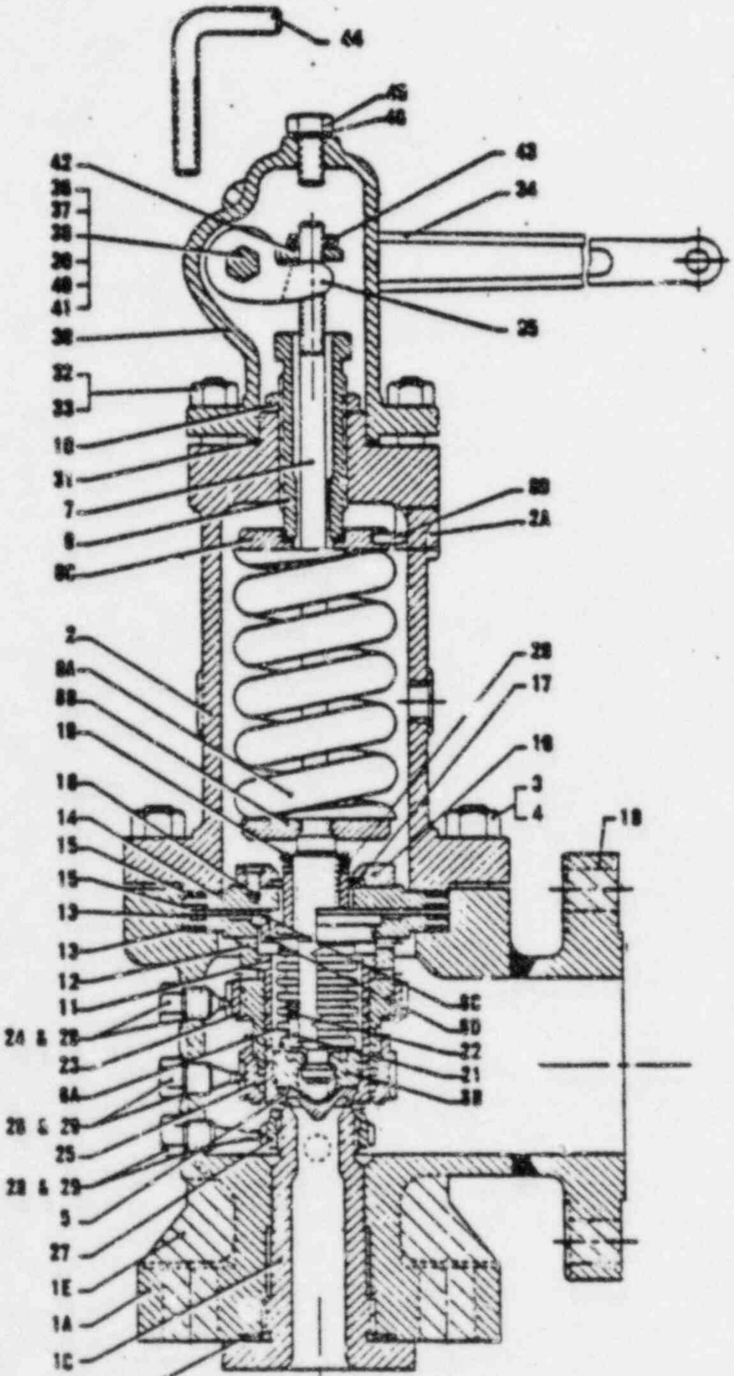
2.0 DRESSER SAFETY VALVES - GENERIC INFORMATION

2.1 DESCRIPTION

The Dresser closed bonnet maxiflow safety valve Type 31700 is a direct-acting spring loaded safety valve designed for use in PWR plants as a pressure relief device (Figure B2-1).

Dresser valves have two major adjustments for safety valve operation. The first is the set pressure adjustment. The valve set pressure is established by turning the compression screw clockwise to increase set pressure, or counterclockwise to decrease set pressure.

Figure B2-1. Dresser Safety Valve.Type 31700.



Ref. No.	Nomenclature	Ref. No.	Nomenclature
1	Base Assembly	17	Floating Washer
1A	Base	18	Reatiner Cap Screw
1B	Outlet Flange	19	Lift Stop
1C	Nozzle	20	Lift Stop Cotter Pin
1D	C Seal or gasket	21	Disc Collar
1E	Web	22	Disc Collar Cotter Pin
2	Bonnet	23	Upper Adjusting Ring
2A	Bonnet Plug	24	Upper Adjusting Ring Pin
3	Bonnet Stud	25	Middle Adjusting Ring
4	Bonnet Stud Nut	26	Middle Adjusting Ring Pin
5	Disc	27	Lower Adjusting Ring
6	Bellows Assembly	28	Lower Adjusting Ring Pin
6A	Bellows	29	Pin Gasket
6B	Disc Nut	30	Cap
6C	Flange	31	Cap Gasket
6D	Flange Adaptor	32	Cap Stud
7	Spindle	33	Cap Stud Nut
8	Spring & Washer Assembly	34	Lever
8A	Spring	35	Lifting Fork
8B	Bottom Spring Washer	36	Lever Nut
8C	Top Spring Washer	37	Lever Shaft
8D	Pin	38	Packing
9	Compression Screw	39	Packing Nut
10	Compression Screw Nut	40	Collar
11	Disc Holder	41	Retaining Ring
12	Guide	42	Release Nut
13	Guide Gasket	43	Release Nut Cotter Pin
14	Support Plate	44	Gag
15	Support Plate Gasket	45	Gag Plug
16	Washer Retainer	46	Gag Plug Gasket

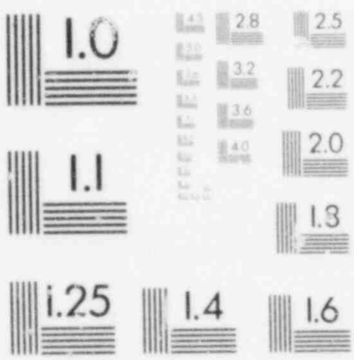
Figure B2-1 (continued)

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

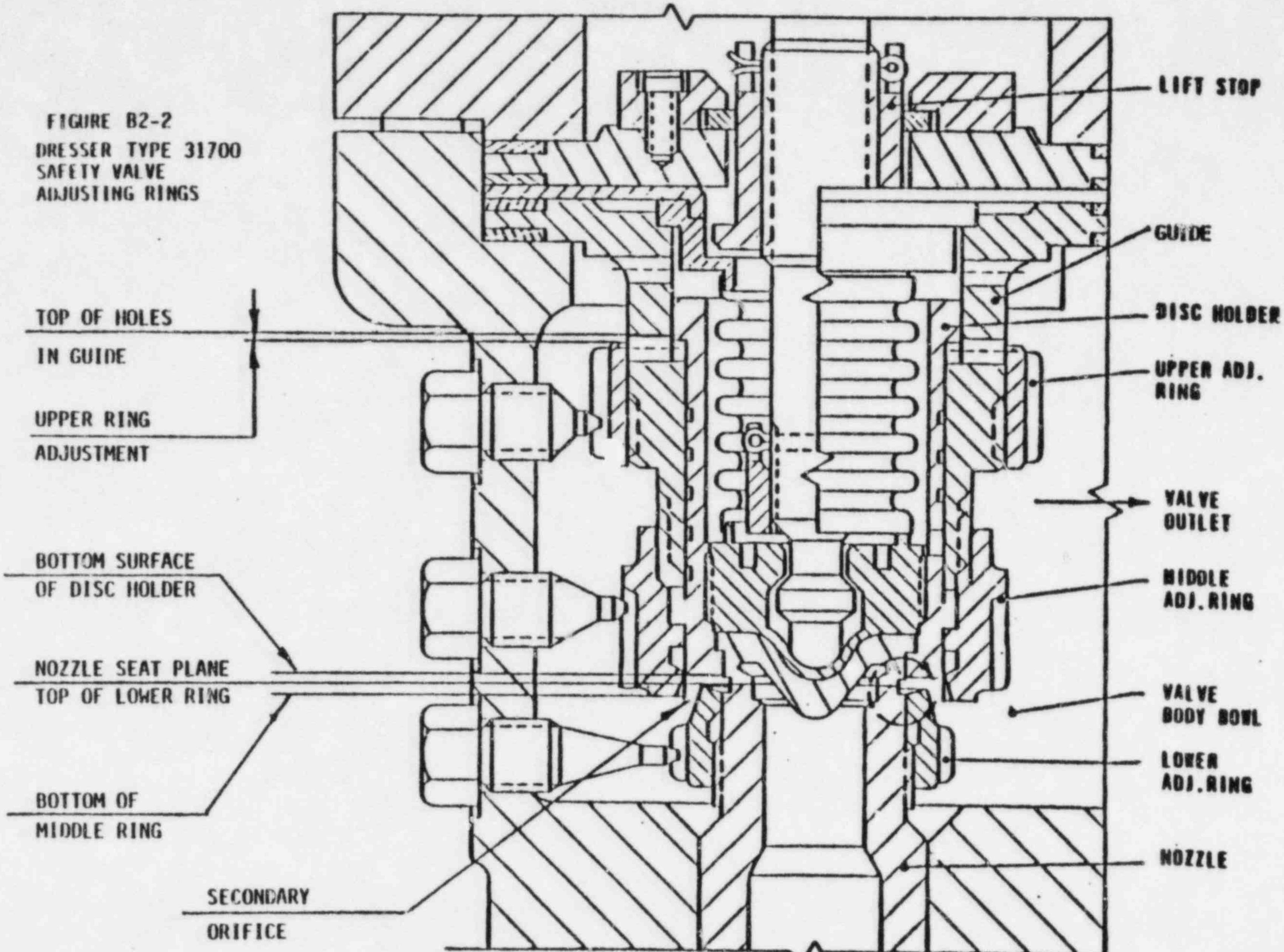
IMAGE EVALUATION TEST TARGET (MT-3)



150mm

6″

FIGURE B2-2
DRESSER TYPE 31700
SAFETY VALVE
ADJUSTING RINGS



The second major adjustment is accomplished through the valve adjusting rings (Figure B2-2). Three adjusting rings, termed upper, middle and lower, are mechanical devices incorporated in the valve to change the distribution of internal forces which control the valve lift and the valve closing pressure (i.e., blowdown).

Positions for the upper ring are given in notches relative to the position where the top of the upper ring is flush with the top of the compensator flow holes in the guide. Positions for the middle and lower rings, in the test data, are defined relative to the seat plane. Plant (field) settings may be given relative to the bottom of the disc holder instead of the seat plane. The Dresser Instruction Manual (Reference 6.11) relates the disc holder plane to seat plane positions in terms of notches for the lower and middle rings.

2.2 NOMENCLATURE

The following definitions of terms are based on Reference 6.6 except where noted otherwise.

2.2.1 Rated Lift - Design lift at which a valve attains its rated relieving capacity.

2.2.2 Discharge Area - Measured minimum net area which determines the flow through a valve.

2.2.3 Bore Area - Minimum cross-sectional area of a valve nozzle.

2.2.4 Curtain Area - Area of the cylindrical (of diameter D_c) or conical discharge opening created between the seating surfaces by the lift of the disc above the seat (see Figure B2-3).

2.2.5 (1)Full Flow Stem Position - Valve stem lift, at which curtain area becomes equal to bore area.

$$\text{Full flow stem position (full flow lift)} = \frac{\text{Bore Area}}{\pi \times D_c}$$

2.2.6 Valve Opening Pop Pressure - The value of increasing inlet static pressure at which the main disc moves in the opening direction at a faster rate as compared with corresponding movement at higher or lower pressures.

2.2.7 Reseating Pressure - The pressure at which the valve main disc reestablishes contact with the seat (reseats). The pressure is measured in Tank 1.

2.2.8 Chatter - Rapid reciprocating motion of the valve movable parts in which the disc contacts the seat.

2.2.9 Flutter - Rapid reciprocating motion of the valve movable parts in which the disc does not contact the seat.

2.2.10 (2)Stable Performance - The valve opens, remains open and closes without flutter and/or chatter.

2.2.11 Blowdown - The difference between actual popping pressure of a pressure relief valve and actual reseating pressure expressed as a percentage of set pressure or in pressure units (see Subsection 3.2 for additional clarification).

2.2.12 (2)Peak Back Pressure - The maximum sustained outlet pressure just downstream of the test valve which was observed during the test.

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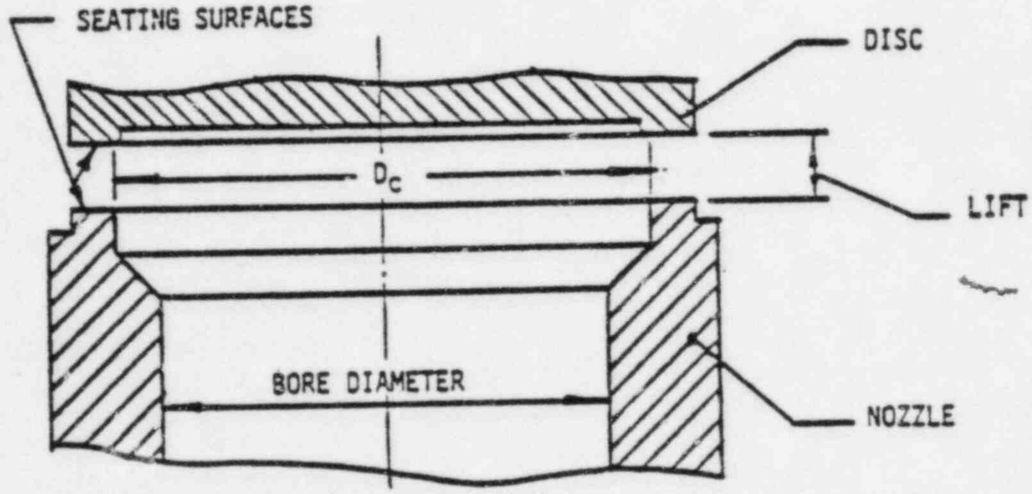
(1) Defined by Combustion Engineering Inc. for evaluation of the EPRI test result.

(2) Defined by EPRI during the test program.

Figure B2-3. Valve Nozzle
Cross Section (Typical)



2.2.13 (2)Opening Pop Time - The effective time for the valve stem to move from the closed position to the rated lift position. In cases where the pop starts from an intermediate lift and/or the valve does not reach rated lift, the slope of the stem position is extrapolated to give a pop time for the entire lift range. The pop time does not include the stem acceleration time which normally occurs at the beginning of the pop. This is included with the total simmer time (see Figure B2-4).

2.2.14 (2)Opening Simmer Time - The time elapsed between initial valve opening pressure and the valve pop pressure.

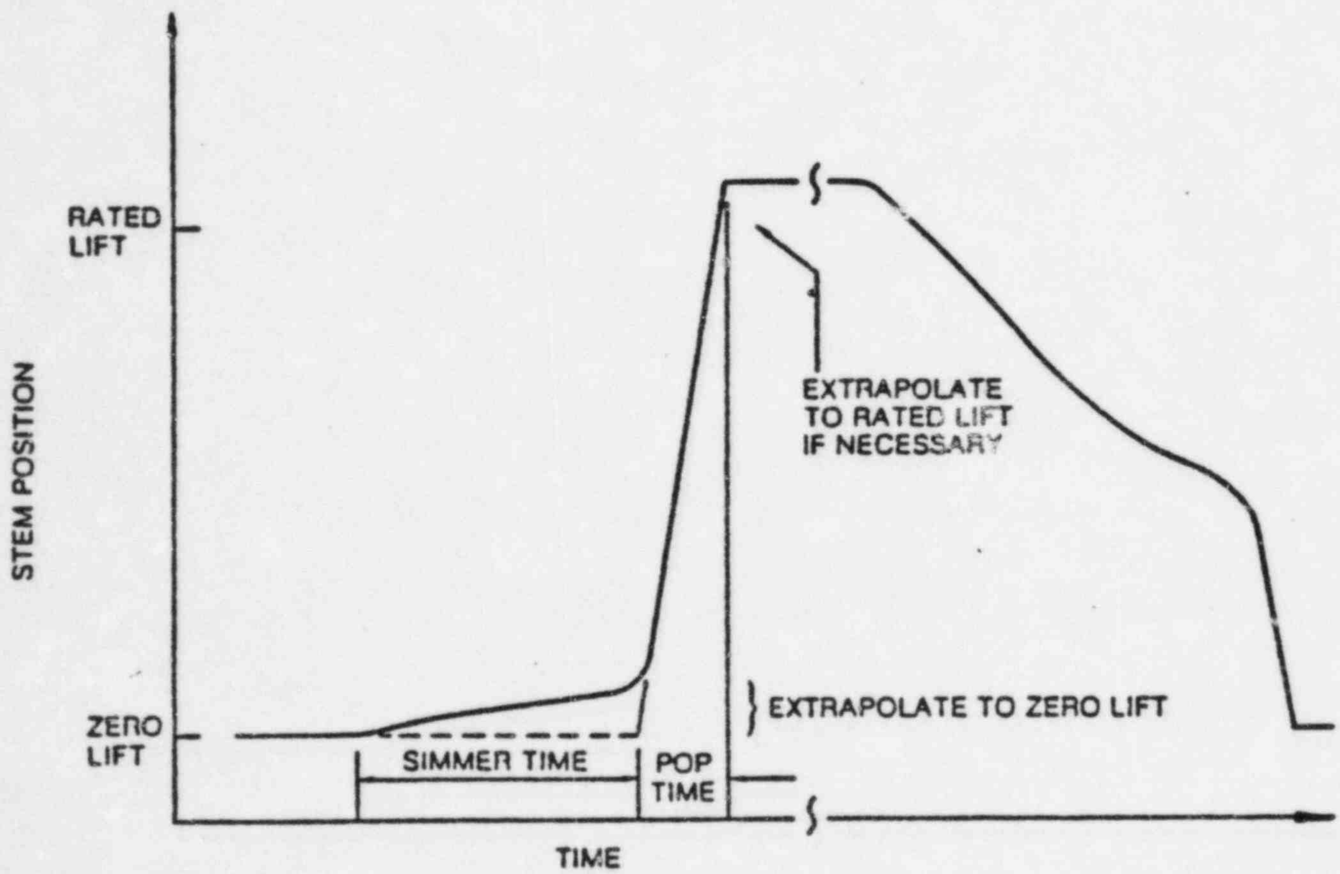
3.0 APPROACH USED IN EVALUATION OF TEST DATA

3.1 INTRODUCTION

Analysis of the EPRI test results revealed a number of factors affecting the performance of safety valves. The criteria for acceptable performance are: 1) stable valve operation, 2) full flow lift achieved, 3) reasonable blowdown results, and 4) valve operability is not affected by bending moments imposed by the discharge piping on the valve discharge flange. Factors that affected valve performance during the tests were valve adjusting ring settings, inlet piping configuration, peak back pressure and valve opening (pop) time.

Evaluation of the Dresser 31739A valve test results included establishing interrelationships between blowdown and peak back pressure, and, also, blowdown and adjusting ring settings; developing valve operating characteristics; and calculation of acoustic wave amplitudes. The approach used in evaluating each of these characteristics is described in this section.

Figure B2-4. Representation of Typical Safety Valve Stem Position as a Function of Time.



3.2 BLOWDOWN

Blowdown is the term used to describe the closing pressure of pressure relief valves. A standard definition of blowdown is provided in Subsection 2.2. It should be noted that the EPRI test program (Reference 6.1) used a different interpretation of blowdown than is used by the valve manufacturers (Reference 6.3). The method used by the valve manufacturers is employed in this report. The difference between the two methods is summarized below.

The EPRI version expresses blowdown in terms of design set pressure:

$$BD_{EPRI} = \frac{\text{Design Set Pressure - Actual Reseating Pressure}}{\text{Design Set Pressure}} \times 100\%$$

The manufacturers' version expresses blowdown in terms of actual opening pop pressure:

$$BD_{A} = \frac{\text{Actual Opening Pop Pressure - Actual Reseating Pressure}}{\text{Actual Opening Pop Pressure}} \times 100\%$$

The pressures are in psig. Both blowdowns will be shown in the following section of the report for each test for comparative purposes. However, evaluation of the test results and plant-specific evaluation use only the manufacturers' version.

Blowdown vs. Peak Back Pressure and Blowdown vs. Middle Ring Setting plots will be presented for the Dresser 31739A valve. These relationships demonstrate the sensitivity of blowdown. Each datum point on the plots represents a test for which the actual opening pop pressure was within ±1% of the design set pressure.

3.3 VALVE DISCHARGE FLANGE BENDING MOMENTS

The induced bending moments at the valve discharge flange during opening and closing were measured in the EPRI program. The maximum bending moment measured during the steam tests of the Dresser 31739A valve is presented in the following section. It is compared to the moments expected in the plant in order to demonstrate valve operability.

3.4 VALVE OPERATING CHARACTERISTICS

The Dresser 31739A safety valve operating characteristics were developed based on test data. Characteristic curves relate valve discharge area to valve inlet pressure for blowdowns of 10 and 15 percent. Since the tests resulted in blowdowns that were less than 20 percent, efforts were undertaken to estimate a characteristic curve for 20 percent blowdown, assumed as a bounding value.

The operating characteristics were based on the following data plots taken from Reference 6.1:

- Valve Stem Position vs. Time (ZE17) and,
- Tank 1 Pressure vs. Time (PT52).

It should be noted that, although the characteristics refer to the valve inlet pressure, Tank 1 pressure was used instead because of the higher accuracy of pressure measurements. Since there was no flow at valve opening and closing, Tank 1 pressure and valve inlet pressure in each test were practically the same. In the intermediate stage of valve operation, because of losses in inlet piping, the pressures were slightly different but the difference is considered negligible for the purposes of this evaluation.

The discharge area to bore area ratio characterizes the flow rate through a valve. Before the valve stem reaches a specific lift, termed full flow position, the area limiting the discharge is a curtain area which is smaller than the bore area (see Figure B2-3). When the valve stem is at full flow position, the bore and the curtain area become equal. After the stem lifts above the full flow position, the bore area becomes the factor limiting the discharge, since it is smaller than the curtain area. Since the bore area is a constant for each valve model, further valve lift, beyond the point when

$$\frac{\text{Discharge Area}}{\text{Bore Area}} = 1$$

does not affect the discharge area. Accordingly, stem lift beyond the full flow position does not increase the flow rate. This hypothesis assumes that the valve discharge coefficient does not change once the full flow position is reached.

3.5 ACOUSTIC WAVE AMPLITUDE

3.5.1 Introduction

The combination of inlet piping configuration and valve opening pop time causes an inlet transient pressure drop at valve opening (lasting less than 0.1 seconds) that may lead to valve instability. This pressure drop is due to the acoustic expansion wave developed by the rapid valve opening. The wave propagates upstream to Tank 1 and returns back to the valve inlet as a compression wave. Valve instability may result if the depressurization at the inlet is large enough and sustained long enough for the valve to react to the reduced force on the disc. Consequently, the acoustic wave amplitude is an important criterion in the application of the test results to plant-specific evaluations. The method of the pressure drop calculations for the tests is provided below.

3.5.2 Inlet Pressure Wave Propagation and Valve Opening Time

The acoustic wave travel time from the PT12 (or PT105) transducer location to Tank 1 and back is determined based on the water hammer theory as follows:

$$t_{aw} = \frac{2L}{C}\text{, where}$$

L = distance of travel in one direction, ft.

C = speed of sound in the stagnant steam upstream of the valve. For saturated steam at about 2500 psia pressure, C = 1400 ft/sec

Therefore, $t_{aw} = \frac{L}{700}$ sec

The time required for the valve stem to reach full flow position is calculated as follows:

$$t_{ff} = \frac{h_{ff}}{h_{rat}} \times t_{pop}\text{, where}$$

h_{ff}/h_{rat} is the ratio of full flow lift and rated lift and constant for each valve;

t_{pop} is valve opening pop time in a test.

If the ratio t_{aw}/t_{ff} is greater than or equal to 1, it means a relatively long inlet piping, i.e., the valve stem comes to full flow position before the wave returns back. Therefore, a full flow develops at $t = t_1$ (See the following subsection).

If the ratio is less than 1, it means a short inlet piping, i.e., the wave returns back (to the transducer location) before the valve stem attains full lift. Hence, there is no full flow achieved at $t = t_1$.

3.5.3 Measured Static Pressure Drop

The basis of the calculation is the valve inlet pressure data plot (Figure B3-1). In the EPRI tests, valve inlet static pressure was measured at the PT12 or PT105 pressure transducer locations. At the instant $t = t_0$, the valve opens and the acoustic expansion wave is initiated. P_0 is the inlet static pressure at the instant of opening, and also a stagnation pressure since there is no flow.

At the instant $t = t_1$, the static pressure measured at the valve inlet reaches a minimum (P_1). The corresponding $P_{stagn\ 1}$ is equal to a sum of P_1 and a velocity head ($P_{V.H.}$). The difference between P_0 and $P_{stagn\ 1}$ represents the pressure drop due to the acoustic expansion wave, i.e. acoustic wave amplitude ΔP_{aw}. It can be seen from Figure B3-1 that:

$$\Delta P_{measured} = \Delta P_{aw} + P_{V.H.}{}^{(1)}, \text{ and}$$

$$\Delta P_{aw} = \Delta P_{measured} - P_{V.H.}$$

Therefore, the magnitude of the pressure drop due to the acoustic wave created when the valve opens is determined by correcting the measured ΔP for the velocity head at the location of the measurements.

3.5.4 Method of Calculation

For each applicable test, $\Delta P_{measured} = P_0 - P_1$ is taken from PT12 or PT105 data plots.

Design flow rate is calculated using the Napier corrected equation (Reference 6.5) as follows:

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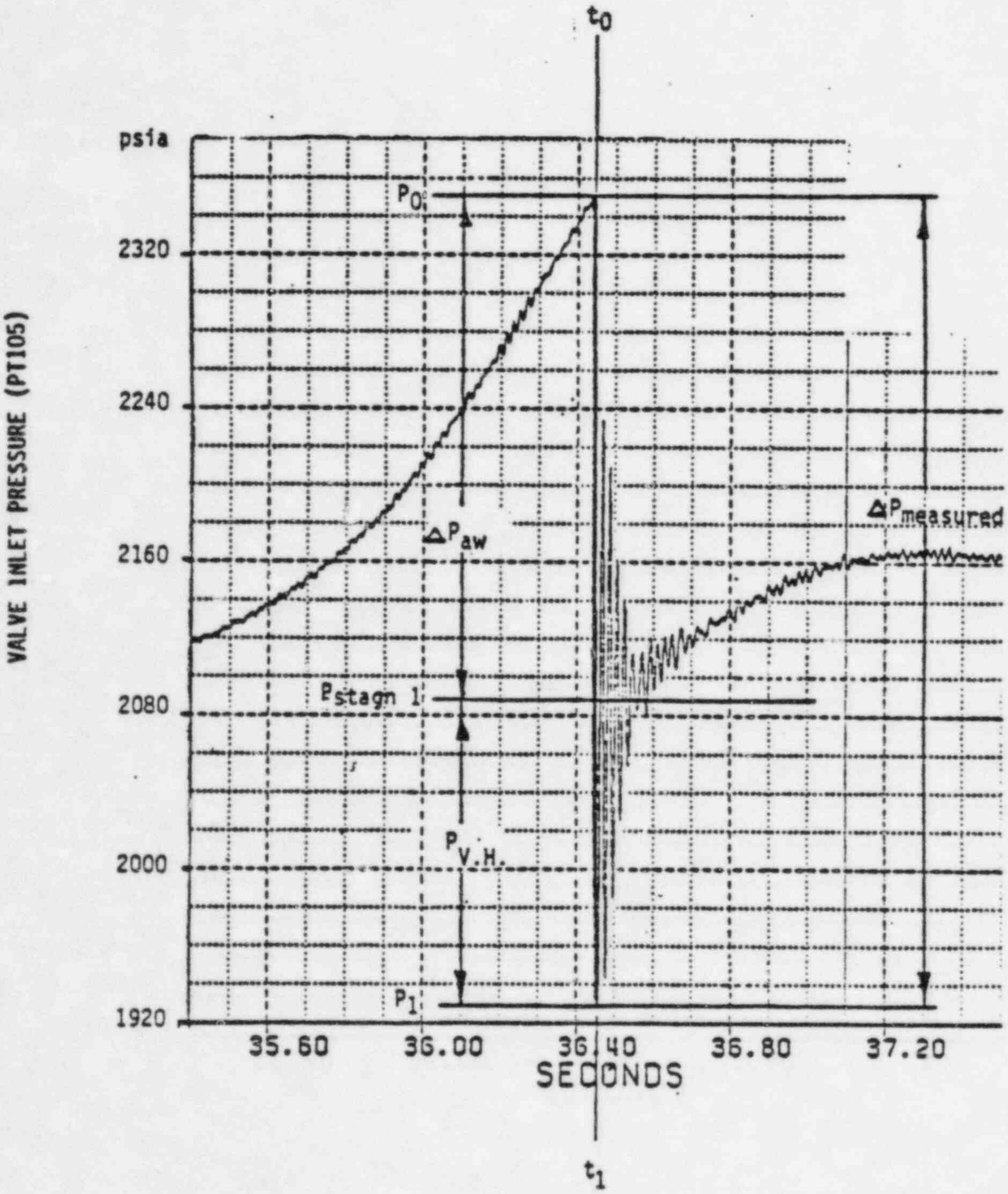
(1) Friction losses are not taken into consideration.

Figure B3-1. Valve Inlet Pressure Response (typical)



$$\dot{M}_o = 51.5 \times A \times Po \times K_N \times K_D, \text{ lbs/hr}$$

Where: A - valve bore area, in^2

P_o - see above, psia

K_N - correction factor (see Reference 6.5); assumed constant and equal 1.075

K_D - valve discharge coefficient, K_D - 0.975 for Dresser valves

The corrected flow rate is calculated, if $t_{aw}/t_{ff} < 1$, as follows:

$$\dot{M}_{corr} = \frac{t_{aw}}{t_{ff}} \times \dot{M}_o$$

In a case when $t_{aw}/t_{ff} \geq 1$, the design flow rate is used.

Pressure differential due to velocity head is calculated using the equation derived from Reference 6.4, as follows:

$$P_{V.H.} = \frac{0.1727 \times 10^{-6}}{\rho} \times \left(\frac{\dot{M}corr}{A_T}\right)^2, \text{ where}$$

A_T - pipe cross-sectional area at pressure transducer location, in^2

ρ - saturated steam density at the pressure Po, lb/cu ft.

Acoustic wave amplitude

$$\Delta P_{aw} = \Delta P_{measured} - P_{V.H.}$$

4.0 DRESSER MODEL 31739A TEST RESULTS AND EVALUATION

4.1 INTRODUCTION

The Dresser Model 31739A safety valve has a 2-1/2 inch inlet, 6-inch outlet, and 2.545 sq. in. bore area. The tests described below were conducted on valve serial number BN-04372. Valve parameters are listed in the Table B4-1. A detailed description of the valve and the associated tests is provided in Reference 6.1, Volume 3.

4.2 INLET PIPING ARRANGEMENT

The Dresser 31739A valve was tested on both short inlet (test series 300 and 1100) and long inlet (tests series 1000) piping configurations, shown in Figures B4-1 and B4-2, respectively.

4.3 TEST CONDITIONS

A total of 22 steam and steam-to-water transition tests were performed on the Dresser 31739A valve. Sixteen tests were conducted with a short inlet piping configuration and six tests with a long inlet. Table B4-2 provides the summary of the tests categorized according to valve adjusting ring settings. A detailed tabulation of the test data is provided in Reference 6.1, Vol. 3, Tables 4-2 thru 4-4. It should be noted that only steam conditions are applicable, as described in Part C.

Test 1107 was the only steam-to-water transition test and was performed with a short inlet. Three tests (Tests 302, 1003, and 1107) were initiated at low pressurization rate (< 4 psi/sec). All other tests had high pressurization rate (275 to 360 psi/sec). Nine tests (see Table B4-2) had low peak back pressure (< 220 psia), the other tests were conducted with high peak back pressure ranging between 477 and 866 psia.

There were nine combinations of adjusting ring settings typical of PWR plants, including the manufacturer's recommended setting (-48, 0, -13)[1].

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(1) Dresser ring settings are designated in the order of upper, middle, and lower ring positions.

TABLE B4-1

DRESSER 31739A TEST SAFETY VALVE PARAMETERS

Manufacturer	Dresser Industries
Inlet Diameter, in.	2-1/2
Outlet Diameter, in.	6
Bore Area, in^2	2.545
Orifice Designation	3
Design Set Pressure, psig	2500
Design Blowdown, %	5
Rated Flow, lb/hr	297,845
Rated Lift, in.	0.450
Inlet Flange Rating, # ANSI	2500
Outlet Flange Rating, # ANSI	600
Curtain Diameter, in(1)	2.110
Full Flow Lift, in(1)	0.384

(1) See Subsection 2.2 for definition.

Figure B4-1. Short Inlet Piping Configuration for Dresser 31739A Safety Valve. Test Series 300 and 1100

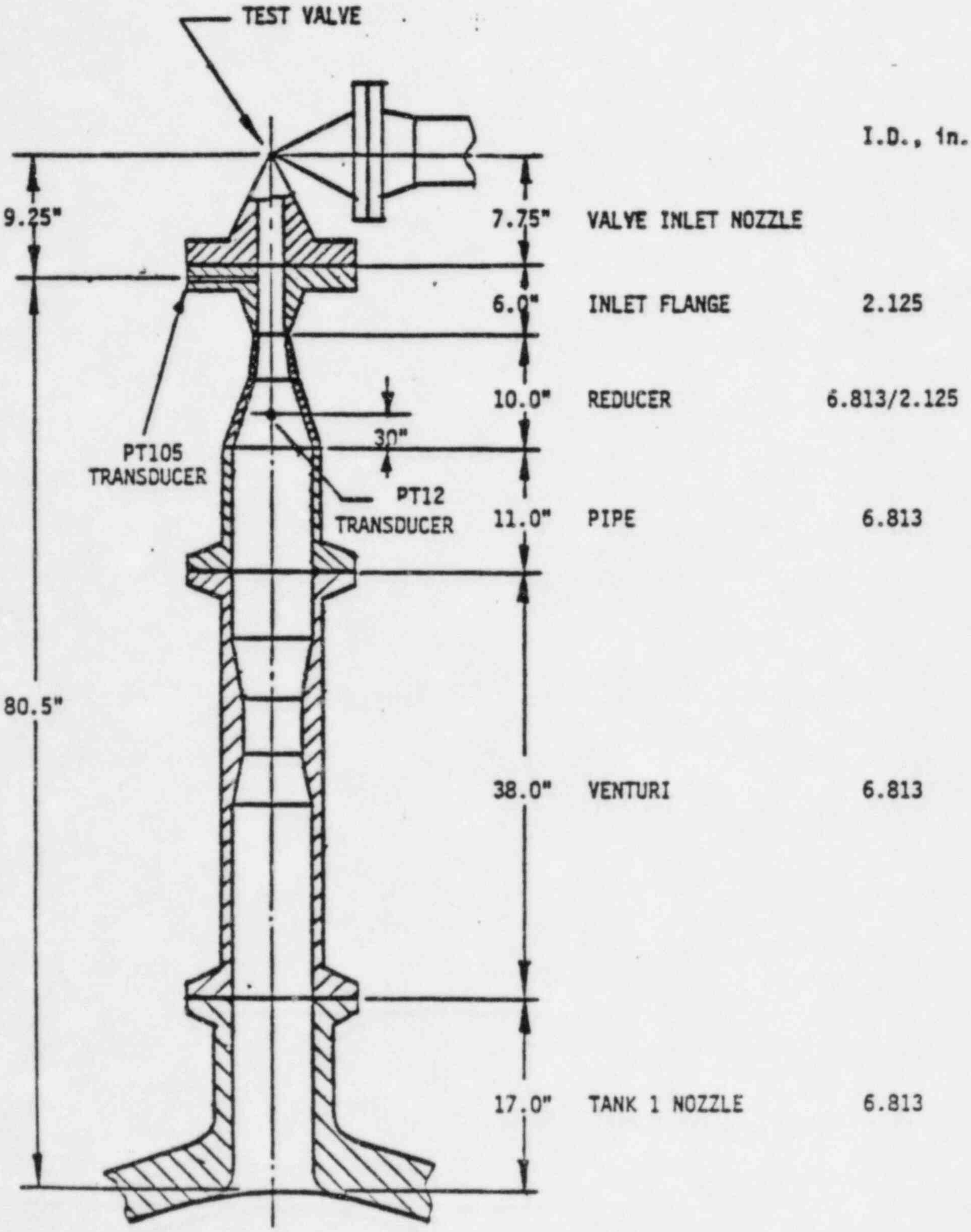
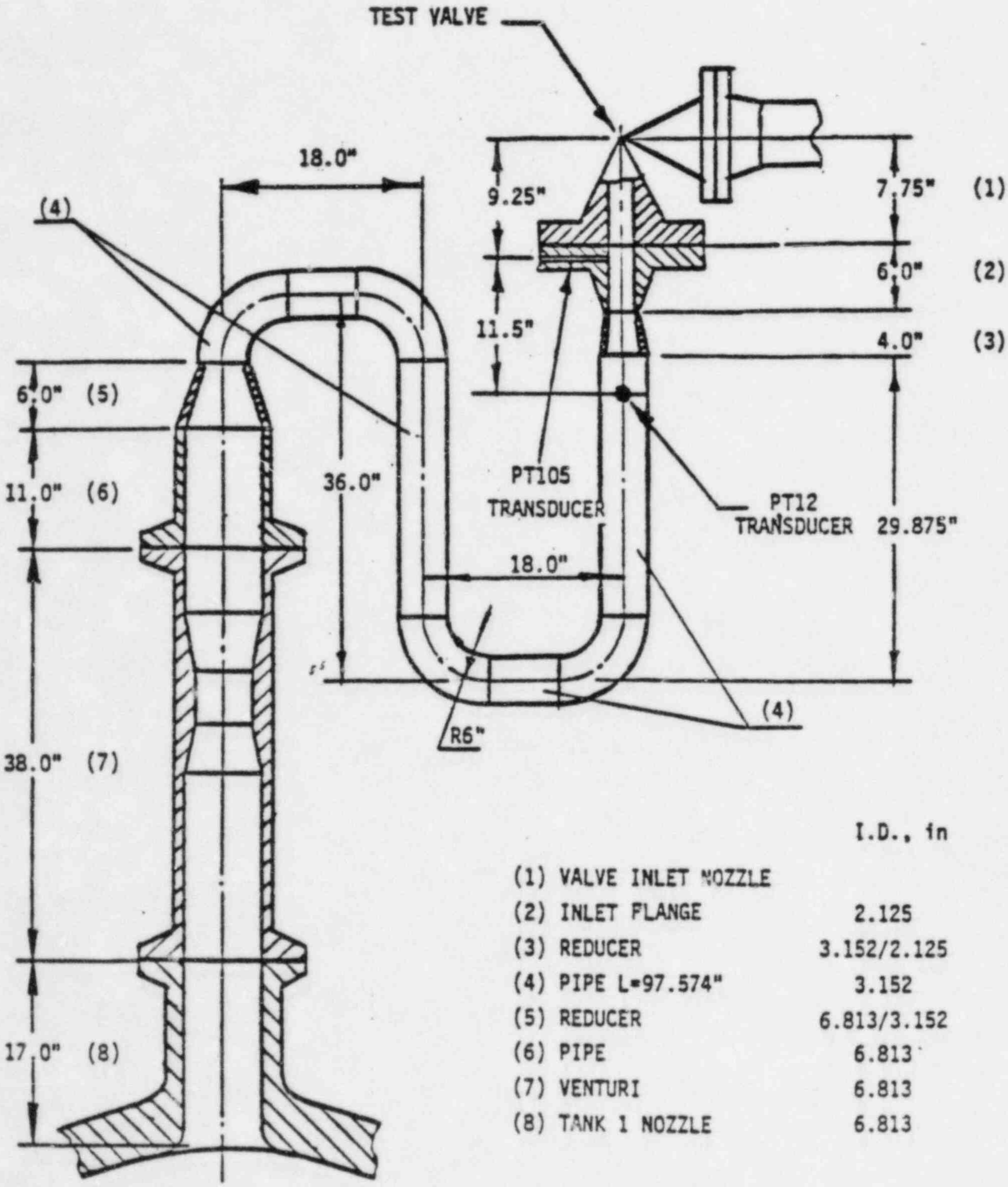


Figure B4-2. Long (loop seal) Inlet Piping Configuration for Dresser 31739A Safety Valve. Test Series 1000



	I.D., in
(1) VALVE INLET NOZZLE	
(2) INLET FLANGE	2.125
(3) REDUCER	3.152/2.125
(4) PIPE L=97.574"	3.152
(5) REDUCER	6.813/3.152
(6) PIPE	6.813
(7) VENTURI	6.813
(8) TANK 1 NOZZLE	6.813

TABLE B4-2

SUMMARY OF TESTS
BASED ON INLET FLUID CONDITIONS
FOR DRESSER MODEL 31739A VALVE

Valve Ring Settings Upper Middle Lower	Test No.	Inlet Piping Configu-ration	Pressure, psig Opening (pop)	Pressure, psig Resealing	BD_{EPRI} (1) %	BD_A (2) %	Peak Tank 1 Pressure, psia	Comments
-48, 0, -13	302	short	2467	2325	7.0	5.8	2483	(3) (4)
	304	short	2511	2355	5.8	6.2	2638	(4)
	306	short	2542	2337	6.5	8.1	2680	(4)
	308	short	2534	2378	4.9	6.2	2677	
	312	short	2518	2378	4.9	5.6	2684	
-48, -1, -9	310	short	2542	2322	7.1	8.6	2680	(4)
-48, -20, (5)	314	short	2527	2305	7.8	8.8	2680	(4)
-48, -40, +3	1012	long	2480	2233	10.7	10.0	2665	
-48, -40, +11	316	short	2575	2172	13.1	15.7	2703	(4)
	318	short	2470	2149	14.0	13.0	2685	(4)
	320	short	2567	2325	7.0	9.4	2667	
	322	short	2520	2222	11.1	11.8	2670	
	1018	long	2443	2196	12.2	10.1	2657	
	1104a	short	2535	2223	11.0	12.3	2720	(8)
	1107	short	2474	2023	19.1	18.2	2489	(3) (7)
-48, -60, 0	1003	long	2445	2308	7.7	5.6	2460	(3) (4)
	1005	long					2665	(6)
-48, -60, +5	1011	long	2467	2176	13.0	11.8	2676	
-48, -60, +11	324	short	2557	2185	12.6	14.6	2693	
	326	short	2487	2077	16.9	16.5	2697	(4)
	328	short	2515	2245	10.2	10.7	2690	
-48, -80, +11	1008	long	2435	2145	14.2	11.9	2680	

(1) Blowdown used in the EPRI program (Reference 6.1). See Subsection 3.2 for definition.
(2) Valve manufacturers definition of blowdown. (See Subsection 3.2).
(3) Test w/low pressurization rate (< 4 psi/sec). All other tests are w/high rate (275 to 360 psi/sec).
(4) Test w/low peak back pressure < 220 psia). All other tests are w/high peak back pressure (477 to 866 psia).
(5) The setting was between -13 and +11.
(6) The valve chattered on closure.
(7) Steam-water transition test.
(8) The valve experienced low amplitude chatter following closure.

4.4 TEST RESULTS

4.4.1 Introduction

All tests listed in Table B4-2 (with the exception of Tests 1005 and 1104a) exhibited stable performance. Test 1005 was terminated when the test valve was manually opened to stop chatter. In Test 1104 the valve experienced low amplitude chatter following closure.

4.4.2 Short Inlet Configuration Tests

4.4.2.1 Steam Tests

Fourteen steam tests exhibiting stable performance were conducted with five different ring settings at both high and low pressurization rates and both high and low peak back pressures.

With the exception of Test 310, tests 302 thru 312 used the manufacturer's recommended ring setting (-48, 0, -13), resulting in blowdowns of 5.6 to 8.1 percent. In general, opening pop pressures exceeded the design set pressure of 2500 psig (by a maximum of 0.7%). The valve stem achieved 69 to 85 percent of full flow lift (0.384 in.) at opening. Opening pop time was between 26 and 40 msec.

Following the initial series of tests, alternate ring positions were tested to obtain full flow lift. With a setting of (-48, -40, +11) - Tests 316, 318, 320 and 322 - blowdown ranged between 9.4 and 15.7 percent. Opening pop pressures exceeded the design set pressure by no more than 3% in three of four tests. Full flow lift was achieved in all tests. Opening pop time ranged from 12 to 21 msec.

At the ring setting of (-48, -60, +11) - Tests 324, 326, and 328 - blowdowns ranged from 10.7 to 16.7 percent, while stem reached full flow position. The maximum opening pop pressure exceeded the design set pressure by 2.3%. Opening pop time ranged from 12 to 16 msec.

In three of twelve of the above mentioned tests (one at each ring setting) the actual opening pop pressure was less than the design set pressure. The maximum difference was 1.2%.

4.4.2.2 Transition Test

Test 1107 was performed with low pressurization rate. The valve opened on steam at 2474 psig (~ 1% below the design set pressure) and closed on water at 2023 psig. The blowdown of 18.2 percent, listed in Table B4-2, refers to a full steam-to-water transition cycle. The valve had stable performance.

4.4.3 Long Inlet Configuration Tests

Five drained loop seal steam tests exhibited stable performance with five different ring settings (Tests 1003, 1008, 1011, 1012, and 1018). The ring setting of (-48, -60, 0) used in Test 1003 resulted in a blowdown of 5.6 percent. The test was performed with a low pressurization rate and low back pressure. The valve stem reached full flow lift at opening, then dropped down to about 86 percent of full flow lift and popped again exceeding full flow lift. It should be noted that at the same ring setting the valve chattered in Test 1005 (see Subsection 4.4.1).

In tests 1008, 1011 and 1012 (each with different ring settings) the valve stem, after having reached full flow position, experienced a limited flutter for about 120, 60 and 130 msec, respectively. However, the valve behavior in the tests was considered to be stable by EPRI (Reference 6.1, Volume 3, Subsection 3.2.2.1). The valve opened within 2.6, 1.3 and 0.8 percent below the design set pressure with opening pop times of 14.16 and 21 msec, respectively. The full flow stem position was maintained for about 6.8, 7.5 and 2.8 sec, respectively, with a blowdown ranging from 11.9 to 10.0 percent. High pressurization rate and high peak back pressure were developed in all three tests.

Test 1018 was performed at a (-48, -40, +11) setting with a high pressurization rate and high back pressure. Valve closure occurred at a blowdown of 10.1%. Opening pop pressure was 2.8 percent below the design set pressure and opening pop time was 24 msec. The stem reached full flow position.

4.4.4 Valve Inspection

Typical wear patterns on seat surfaces were observed during inspections performed after the steam tests. The seat surfaces were lapped prior to reassembly and continued testing to minimize seat leakage.

4.4.5 Valve Discharge Flange Bending Moment

The maximum bending moment of 241,738 in-lbs was measured in Test 1011. The bending moment did not impair the operability of the valve.

4.5 EVALUATION OF TEST RESULTS

The plots in Figure B4-3 demonstrate that blowdown decreases as peak back pressure increases. This dependence becomes stronger with the adjustment of the middle ring to a lower position (-60). The plots in Figure B4-4 show that moving the middle ring down from the seat plane (0 to -60 notches) causes an increase in blowdown. The increase is greater at low peak back pressures.

Valve opening and closing characteristics are presented in Figure B4-5.

Table B4-3 shows the acoustic wave amplitudes in applicable tests. For Dresser 31739A valves the full flow lift to rated lift ratio is equal to 0.853. The pipe cross-sectional areas at the pressure transducer locations are as follows:

- PT105 location in both short and long inlets: A_T = 3.546 sq. in.;
- PT12 location in short inlet: A_T = 19.5 sq. in.;
- PT12 location in long inlet: A_T = 7.8 sq. in.

Figure B4-3. Dresser 31739A Valve, Blowdown vs. Peak Back Pressure

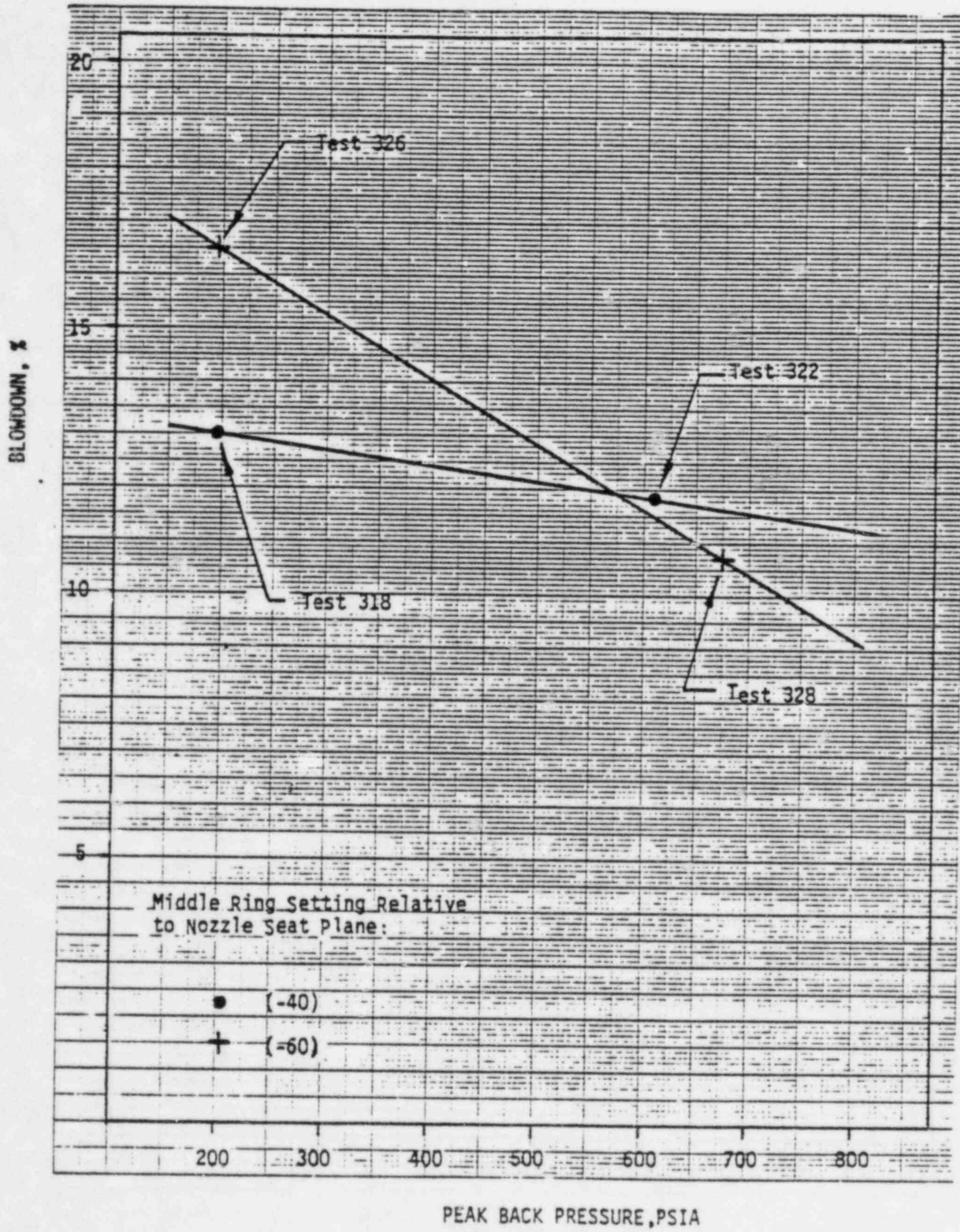
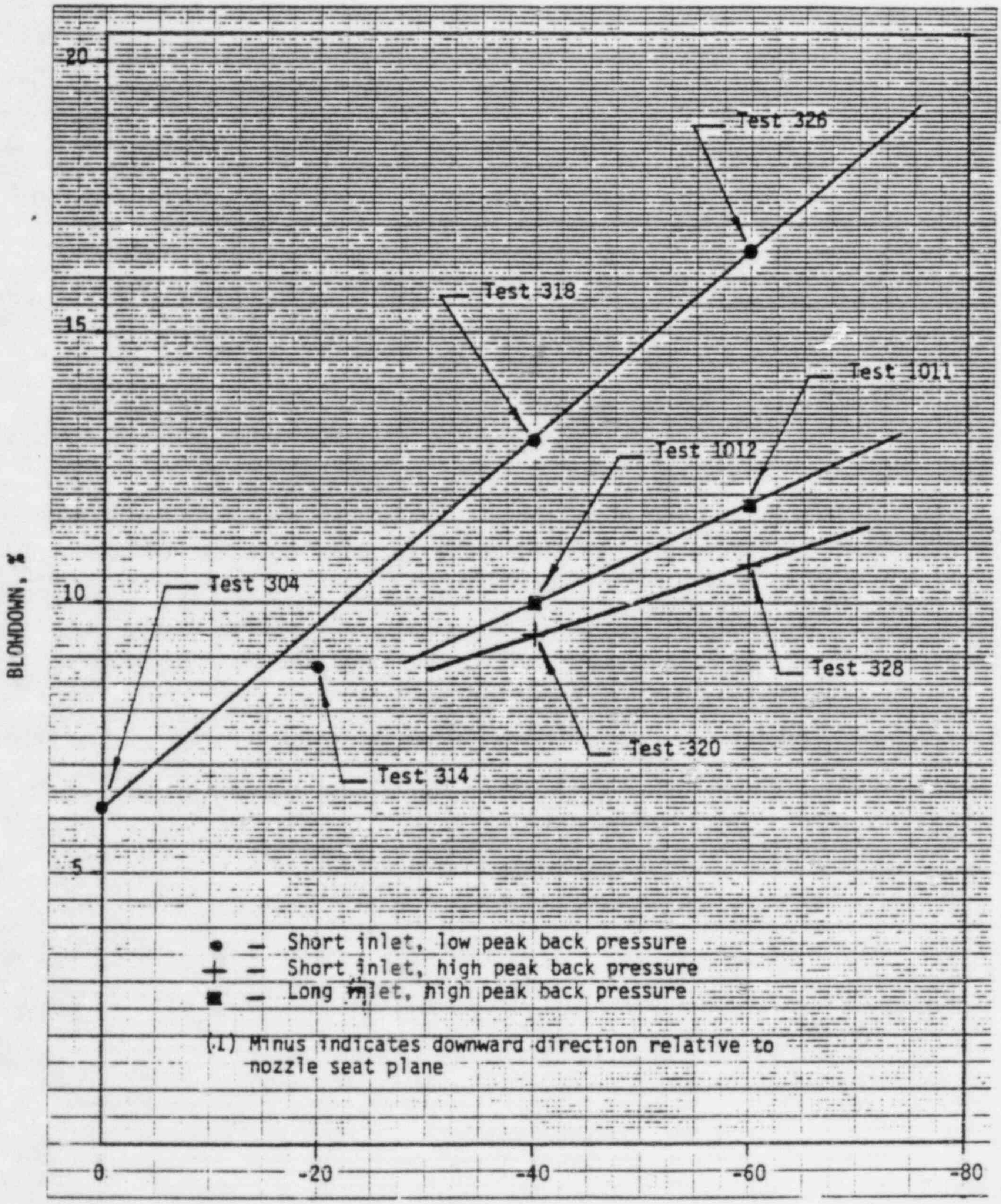


Figure B4-4. Dresser 31739A Valve, Blowdown vs. Middle Ring Setting



MIDDLE RING SETTING, NOTCHES (1)

Figure B4-5. Dresser 31739A Valve Operating Characteristics

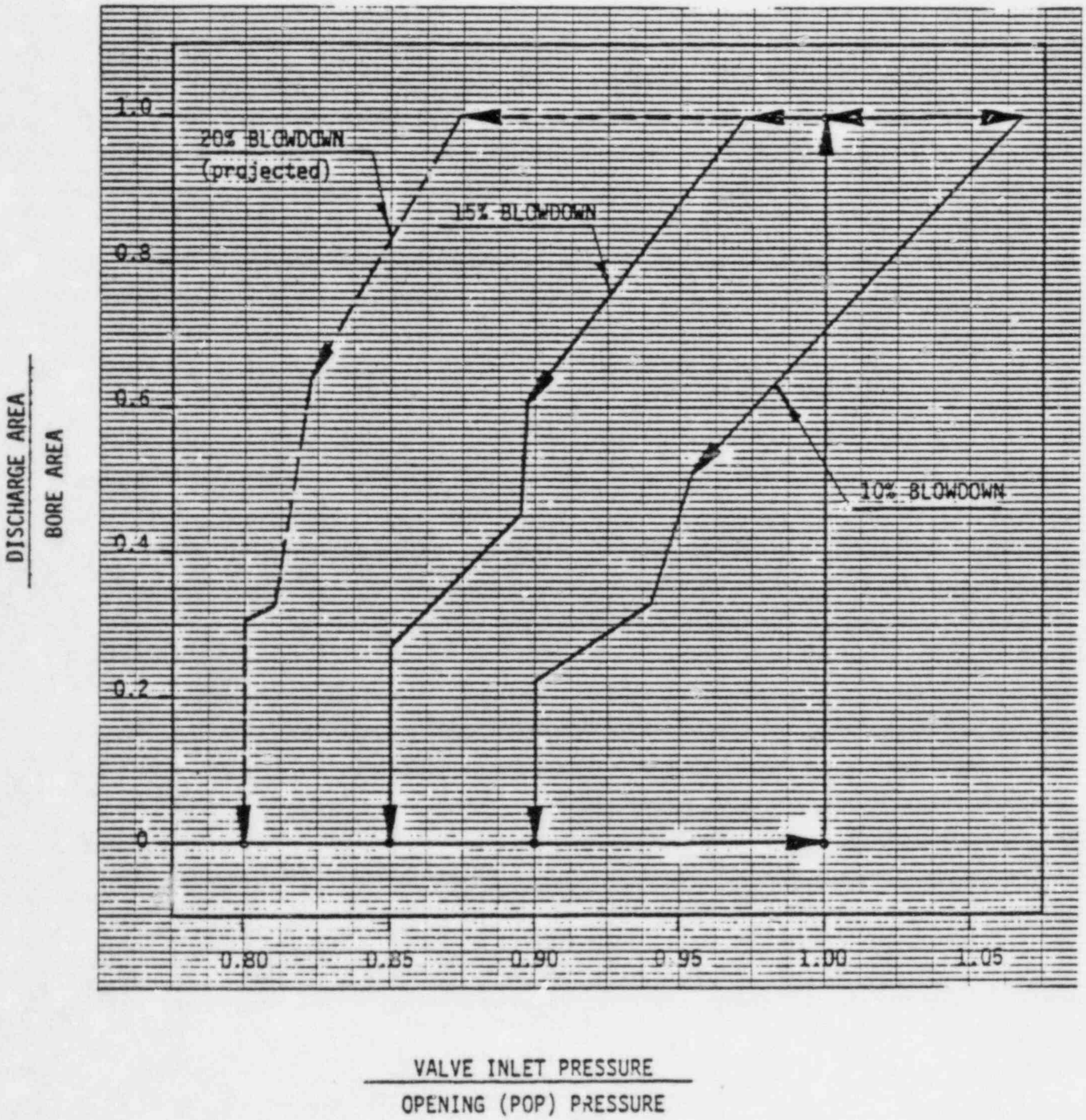


TABLE B4-3

DRESSER MODEL 31739A VALVE

ACOUSTIC WAVE AMPLITUDE IN APPLICABLE TESTS

Test No.	ΔP Measured psi	t_{ff} msec	t_{aw} msec	t_{aw}/t_{ff}	ΔP_{aw} psi	% Full Flow Lift at Opening
302	141	24.7	10.4	.4211	103	69
304	65	34.1	10.4	.3050	45	72
306	110	22.2	10.4	.4685	64	85
308	111	29.0	10.4	.3586	84	79
310	146	21.3	10.4	.4883	96	91
312	89	29.0	10.4	.3586	62	77
314	182	20.5	10.4	.5073	127	96
316	420	10.2	10.4	>1.0	204	130
318	283	17.9	10.4	.5754	213	130
320	359	12.8	10.4	.8128	219	122
322	372	12.8	10.4	.8047	235	130
324	420	11.1	10.4	.9279	236	131
326	410	10.2	10.4	>1.0	199	131
328	370	13.6	10.4	.7574	248	132
1107(2)	280(1)	15.4	10.4	.6753	248	101
1003	430	12.8	21.7	>1.0	219	135
1008	258(1)	11.9	21.1	>1.0	215	139
1011	219(1)	13.6	21.1	>1.0	176	139
1012	227(1)	17.9	21.1	>1.0	183	138
1018	241(1)	20.5	21.1	>1.0	198	140

(Continued on Following Page)

TABLE B4-3 (Continued)

Notes:

(1) Based on PT12, all other tests based on PT105.

(2) This is a transition test that only considers opening.

Nomenclature:

ΔP measured -	measured valve inlet static pressure drop at valve opening.
t_{ff} -	time for valve stem to reach full flow position.
t_{aw} -	acoustic wave travel time from PT12 (or PT105) transducer location to Tank 1 and back.
ΔP_{aw} -	acoustic wave amplitude

PART C - CALVERT CLIFFS PRESSURIZER SAFETY VALVE

OPERABILITY - PLANT-SPECIFIC EVALUATION

PART C - CALVERT CLIFFS PRESSURIZER
SAFETY VALVE OPERABILITY - PLANT-
SPECIFIC EVALUATION

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PART C - CALVERT CLIFFS PRESSURIZER SAFETY VALVE OPERABILITY - PLANT-SPECIFIC EVALUATION

1.0 GENERIC AND PLANT-SPECIFIC INFORMATION

1.1 INTRODUCTION

The plant-specific evaluation of the Calvert Cliffs Units 1 and 2 safety valve operability is presented in this portion of the report. The evaluation is based on comparison of the in-plant installations and fluid conditions with the test data presented in Part B. Specifically, comparisons include valve model and installation, inlet fluid conditions, inlet transient pressure drop at valve opening, valve stem lift, back pressure, and valve discharge flange bending moment.

Tests which envelope the Calvert Cliffs Units 1 and 2 conditions are considered to be directly applicable. The valve adjusting ring settings used in these tests are thus designated as "qualified" ring settings for the plant safety valves, provided the blowdown measured for the particular ring setting is within acceptable limits.(1)

1.2 INLET FLUID CONDITIONS

The EPRI test program based the tested valve inlet fluid conditions on FSAR/Reload Analyses of pressurization transients which result in safety valve actuation. The transients and associated fluid conditions are summarized in Reference 6.2. It should be noted that the peak pressurizer pressure and pressure ramp rates derived from the analyses are conservatively high, since the analyses do not credit PORV operation or non-safety grade systems such as pressurizer spray to mitigate the transients. Extended high pressure injection transients are not applicable for Calvert Cliffs

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(1) See Subsection 1.5, Part C, for further clarification.

Units 1 and 2 since the HPSI pump shutoff head is below the safety valve setpoints, as well below normal operating pressure. Hence, the HPSI pumps are incapable of challenging the safety valves.

The Calvert Cliffs Units 1 and 2 safety valve inlet fluid conditions were based on Cycle 5 and Cycle 4 Reload Analyses, respectively. The calculated highest peak pressurizer pressure of 2538 psia occurs for the Loss of Load event. The pressure ramp rates for the Calvert Cliffs events which actuate the safety valves range from 27 to 64.4 psi/sec; the highest rate is associated with the Loss of AC event. The above values apply to both, Unit 1 and Unit 2. In all cases, the valve inlet fluid is limited to saturated steam.

1.3 INLET TRANSIENT PRESSURE DROP

As previously noted (Part B, Subsection 3.5.1), the inlet transient pressure drop due to the acoustic expansion wave developed upon valve actuation is an important parameter characterizing safety valve opening stability. The derivation of the in-plant pressure drops is presented in Appendix C-1. The acoustic wave amplitude from a representative test is compared to the value calculated for the plant-specific installation. Tests with stable valve operation and amplitudes greater than, or equal to, the in-plant value are considered applicable. The comparison indicates that valves having as-tested ring settings would operate with a greater margin for opening stability in the plant installation than in the EPRI test installation. This is justified since the inlet transient pressure response at the valve inlet for the in-plant piping is less severe than that measured in the test.

1.4 BACK PRESSURE

The evaluation of test data provided in Part B demonstrates the effect of the peak back pressure on blowdown for Dresser 31739A safety valve. The greater the builtup back pressure, the lower the value of blowdown (i.e. the valve tends to close at a higher inlet pressure because of the increased forces acting on its disc). The builtup back pressure is a function of the flow rate (number of valves discharging) and the flow resistance of the discharge piping.

As the tests with the Dresser 31739A valve demonstrated, the actual opening pressures could differ as much as 140 psi (at the same set pressure). If the valves are set at staggered pressures, the difference may be even greater. Therefore, it is possible that during mild transients, only one valve could be challenged. The lower steam flow associated with one safety valve discharging would result in a lower builtup back pressure, and, therefore, a greater blowdown than when the full complement of relief valves (safety valves and PORVs) discharge. Even if the valves open simultaneously, they would not necessarily close simultaneously. For the case of staggered valve closing, when the first valve closes under a relatively high back pressure, the steam flow would decrease, thus causing a reduction in the back pressure against which the second valve was discharging. As a result, the second valve would discharge against a reduced back pressure resulting from the lower flow in the discharge piping. Therefore, operation of the plant safety valves is considered for back pressures which bound the range expected in the plant.

The ranges of the Calvert Cliffs Units 1 and 2 safety valve builtup back pressures of 640 to 670 and 456 to 476 psia, respectively, were determined on a plant-specific basis and provided by the utility. It is noteworthy that the lower values refer to the cases with one safety valve discharging, the higher values refer to cases with both safety valves discharging.

1.5 BLOWDOWN

The EPRI tests demonstrated that stable safety valve operation is generally associated with blowdown above 5 percent. Prior to 1975, the ASME Code, to which the safety valves were designed and built, required that blowdown not exceed 5 percent. However, beginning with the Summer 1975 Addenda to the 1974 ASME Code (paragraph NP-7614.2) blowdown in excess of 5 percent is permitted if appropriate justification is provided.

The concern with an extended blowdown of the plants' safety valves is that the pressurizer pressure might decrease sufficiently below the pressure corresponding to the pressurizer liquid saturation temperature. The reduction in pressure would then cause flashing and an excessive increase in the pressurizer level. If the two-phase level reaches the elevation of the safety valve nozzle, the valve could encounter either a two-phase mixture or solid water conditions at the inlet. Accordingly, it is desired to limit the level swell to below the pressurizer safety valve nozzle since the discharge piping and supports are not designed for two-phase or water relief, nor are the safety valves designed to operate with these fluid conditions.(1)

The Calvert Cliffs Units 1 and 2 analysis which demonstrates the pressurizer level response for blowdown up to 20 percent is provided in Reference 6.13. The analysis shows that discharge through the safety valves is limited to steam, while RCS loop subcooling is maintained throughout the associated blowdown.

1.6 VALVE DISCHARGE FLANGE BENDING MOMENT

The effect of discharge piping loads on safety valve operability is determined by comparing the calculated bending moment on the valve discharge flange for the in-plant installation to the maximum measured moment for the applicable tests.

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(1) Transition to water conditions does not imply valve, piping, or support failures, but only that additional design impacts may need to be considered should transition to two-phase or water occur.

In the analysis of the structural adequacy of the Calvert Cliffs Units 1 and 2 safety valve discharge piping the calculated maximum bending moments on the valve discharge flanges are 12,727 and 20,561 in-lbs., respectively.

2.0 OPERABILITY EVALUATION

2.1 SAFETY VALVES AND INSTALLATION

The Calvert Cliffs 1 and 2 reactor coolant systems are each provided with two Dresser Industries Model 31739A pressurizer safety valves with staggered set pressures of 2550 and 2485 psig. A general description of a Dresser safety valve is provided in Part B, Subsection 2.1. The Dresser 31739A test valve parameters are listed in Part B, Table B4-1. The Calvert Cliffs 1 and 2 valve parameters are identical, with the exception of the design set pressures which are 50 psi greater for the first valve and 15 psi lower for the second valve than the test valve set pressure and outlet flange rating which is a 300 pound instead of a 600 pound design.

The Calvert Cliffs safety valves are connected by inlet piping to the top of the pressurizer, as shown in Figures C2-1 and C2-2. The piping is 4" sch 120 and 2 1/2" sch 160 with 4" x 2 1/2" reducer between them. The total length from the inside of the pressurizer to the valve inlet flange mating surface is 6.13 ft. for Unit 1 and 7.91 ft. for Unit 2.

2.2 APPLICABILITY OF TESTS

The total of twenty steam and steam-to-water transition tests exhibiting stable valve operation were performed on the Dresser Model 31739A safety valve (see Part B, Tables B4-2 and B4-3). The applicability of these tests to the Calvert Cliffs Units 1 and 2 safety valves is justified below.

FIGURE C2-1
CALVERT CLIFFS UNIT 1 PRESSURIZER
SAFETY VALVE INLET PIPING CONFIGURATION

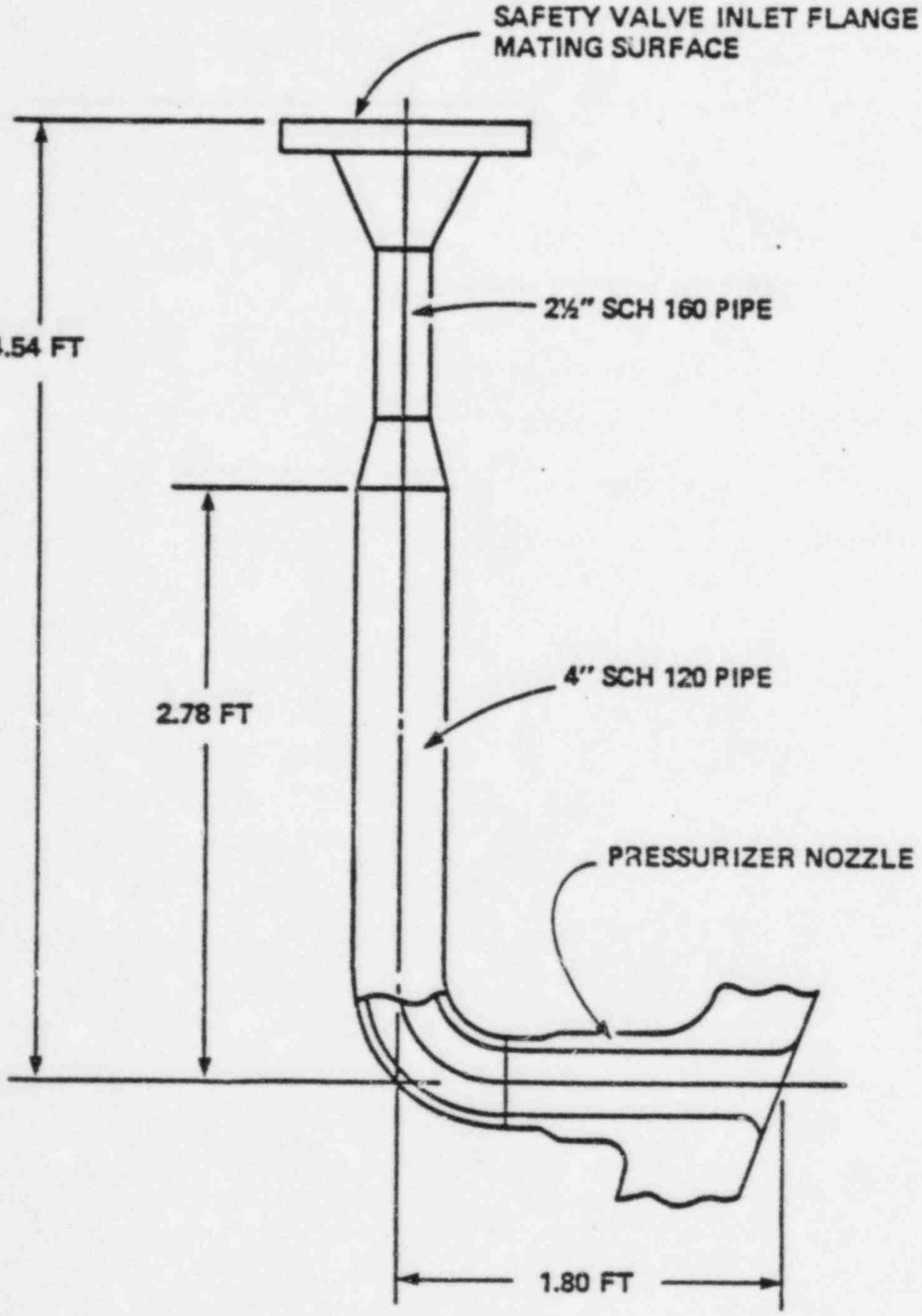
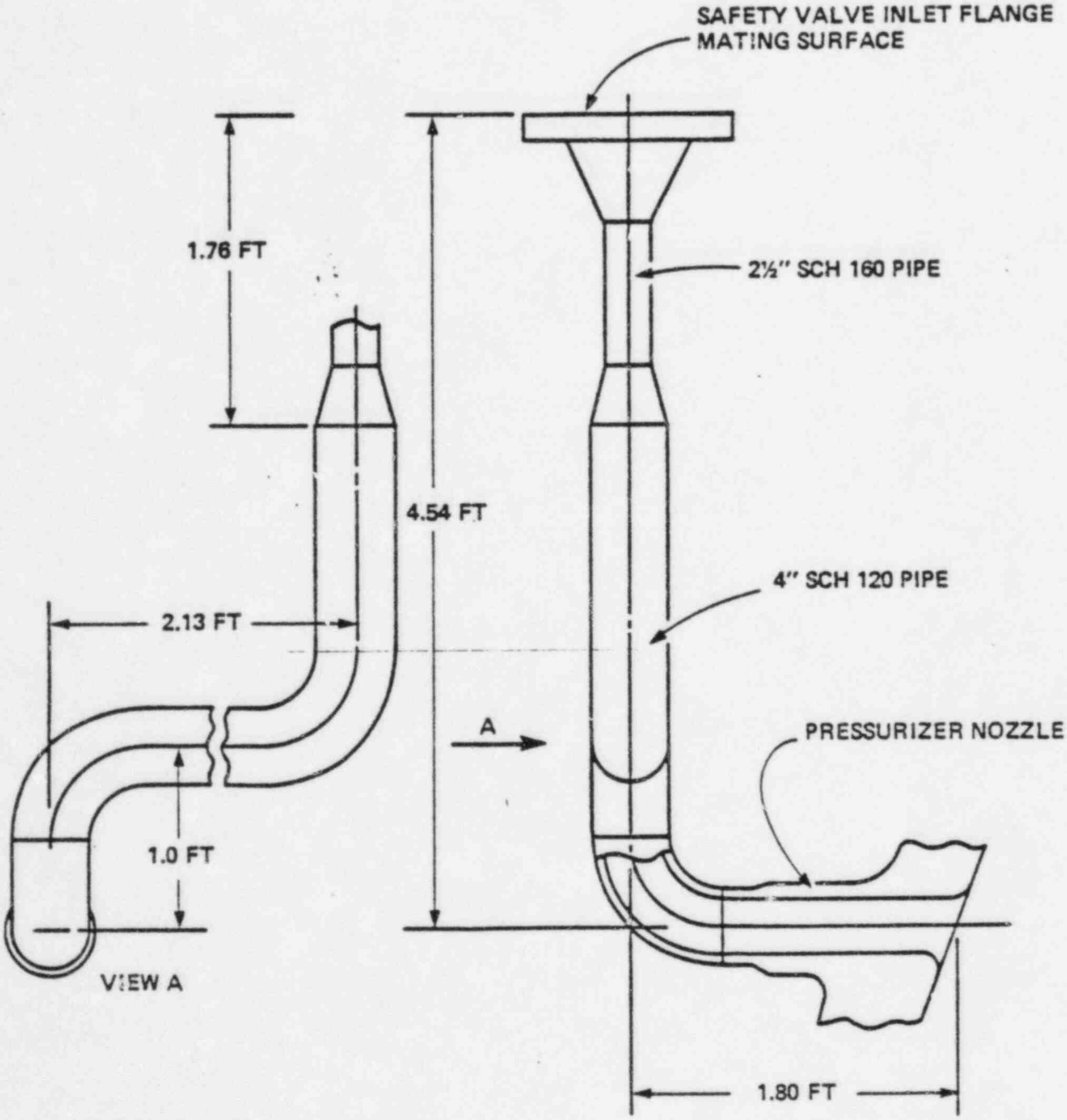


FIGURE C2-2
CALVEPT CLIFFS UNIT 2 PRESSURIZER
SAFETY VALVE INLET P'PING CONFIGURATION



In all tests, the test valve opened on steam. The range of peak pressures measured in Tank 1 during these tests (2460 to 2703 psia) enveloped the calculated Calvert Cliffs Units 1 and 2 peak pressurizer pressure of 2538 psia, with the exception of three tests (with measured pressure from 2460 to 2489 psia). The tests were initiated with pressure ramp rates from 2.3 to 360 psi/sec that enveloped the Reload Analyses range of 27 to 64.4 psi/sec. In thirteen tests, the valve stem reached full flow lift at opening (see Table B4-3).

Thus, the inlet fluid conditions for the above tests are considered to be representative of the plant conditions. However, only tests in which the valve stem achieved full flow lift are considered applicable to the Calvert Cliffs Units 1 and 2 safety valves. Since transition to water does not occur in the Calvert Cliffs plant, Test 1107 is not applicable. It is noteworthy, however, that the test valve remained stable when transition occurred during the test.

The range of builtup (peak) back pressures measured in the applicable tests (195 to 866 psia) enveloped the ranges of the calculated plant back pressures of 640 to 670 psia for Unit 1 and 456 to 476 for Unit 2.

It was demonstrated (Appendix C-1) that the acoustic wave amplitudes measured in the Dresser 31739A valve tests conducted on long inlet piping configuration (Test Series 1000) exceeded those estimated for the Calvert Cliffs Units 1 and 2 installations. Thus, at the PT12 transducer location, the amplitude measured in reference test No. 1008 is equal to 215 psi (Table B4-3). At the corresponding point in plant inlet piping and with the same opening conditions as in the test, the estimated amplitudes are as follows: for Unit 1 - 152 psi and for Unit 2 - 205 psi (Appendix C-1). That means that the test inlet piping configuration envelopes that of the plant. Therefore, Test Series 1000 tests are applicable to the plant as far as opening stability is concerned.

It should be noted, that the Dresser 31739A valve tests performed on short inlet piping configurations (Test Series 300 and 1100) are not applicable to the plant from an opening stability viewpoint. The amplitudes measured in the tests were lower than those estimated for the plant which makes the short inlet configuration less limiting than that of the plant.

Plant-specific calculations show that the safety valve discharge flanges will be subjected to loadings which are significantly less than their tested loading capability. The maximum bending moment on the valve discharge flange was calculated to be less than the maximum bending moment of 241,800 in-lbs measured during the EPRI tests. The measured bending moment did not impair the operability of the valve.

2.3 EVALUATION

The analysis presented in Subsection 2.2 resulted in identifying the tests which are directly applicable to the plant safety valves. They are Test Series 1000 steam tests (see Table B4-3, Part B). The following evaluation of the operability of the Calvert Cliffs Units 1 and 2 safety valves is based on these test results.

In Test 1003, the adjusting ring setting was (-48, -60, 0). The test was performed at low peak back pressure (220 psia) and resulted in a flowdown of 5.6 percent. It is expected, based on evaluation of the Dresser 31739A valve tests results, that the valve blowdown would have been further reduced at higher back pressures. For the back pressures expected in the Calvert Cliffs Units 1 and 2 the low blowdown may result in an unstable valve operation with this ring setting. Therefore, the ring setting of (-48, -60, 0) is not considered appropriate for the Calvert Cliffs Units 1 and 2 safety valves.

The next three tests, 1008, 1011 and 1012, were performed with different adjusting ring settings and at high peak back pressures. In all three tests, the valve stem, after having reached the full flow position, experienced a limited flutter of short duration. During discharge and closing, the valve demonstrated stable operation. According to EPRI, overall valve behavior was considered to be stable in the tests. Analysis of the test results shows that any combination of adjusting ring settings associated with the tests would result in blowdowns within 10 to 15 percent at the Calvert Cliffs Units 1 and 2 ranges of peak back pressures.(1) Therefore, the ring settings of (-48, -80, +11), (-48, -60, +5) and (-48, -40, +3) are considered to be qualified for the Calvert Cliffs Units 1 and 2 valves.

Test 1018 demonstrated stable valve operation at opening, closing and discharge. The ring setting was (-48, -40, +11), and the resulting blowdown was 10.1 percent. It was also a high peak back pressure test. The ring setting would also result in blowdown within 10 to 15 percent at the plant ranges of peak back pressures. Hence, the ring setting of (-48, -40, +11) is qualified for the Calvert Cliffs Units 1 and 2 valves.

Thus, four combinations of adjusting ring settings are considered to be qualified for the Calvert Cliffs Units 1 and 2 safety valves.

At the request of Baltimore Gas and Electric one of the qualified combinations of adjusting ring settings was to be selected for the

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(1) See Subsection 2.2, Part C for magnitudes.

Calvert Cliffs safety valves. Based on an additional analysis of valve operability at the qualified settings it is concluded that the recommended ring setting for both Unit 1 and Unit 2 is identified as (-48, -40, +11). The reasons are provided below.

1. The recommended setting was employed, also, in a number of short inlet configuration tests (Test Series 300) which demonstrated satisfactory valve operation under different conditions.

2. The valve test results show that blowdown decreases as the middle ring is adjusted to a higher position. Therefore, it is expected that the middle ring being at a higher position (-40, as recommended, compared to -60 and/or -80) wold reduce blowdown.

3. Two tests were performed with peak back pressures enveloping the plant ranges of back pressures for both units. In one of them - Test 320 - performed with the highest peak back pressure of 866 psia the ring setting was identical to the recommended, and the value demonstrated satisfactory performance.

2.4 SAFETY VALVE FLOW MODEL

The analytical model used to depict safety valve discharge in the Calvert Cliffs Units 1 and 2 safety analyses is shown in Figure C2-3.

Based on the analysis of the test results, the operating characteristics for the Dresser 31739A valve were developed (see Figure B4-5, Part B). The characteristic curves corresponding to 10 and 15 - percent blowdown are representative of the Calvert Cliffs safety valves, adjusted to the recommended ring setting identified in the previous subsection. Figure C2-4 shows the 10 and 15% - blowdown characteristic curves and the valve flow model curve

Figure C2-3

CALVERT CLIFFS UNITS 1 AND 2

PRESSURIZER SAFETY VALVE FLOW MODEL

USED IN FSAR ANALYSES

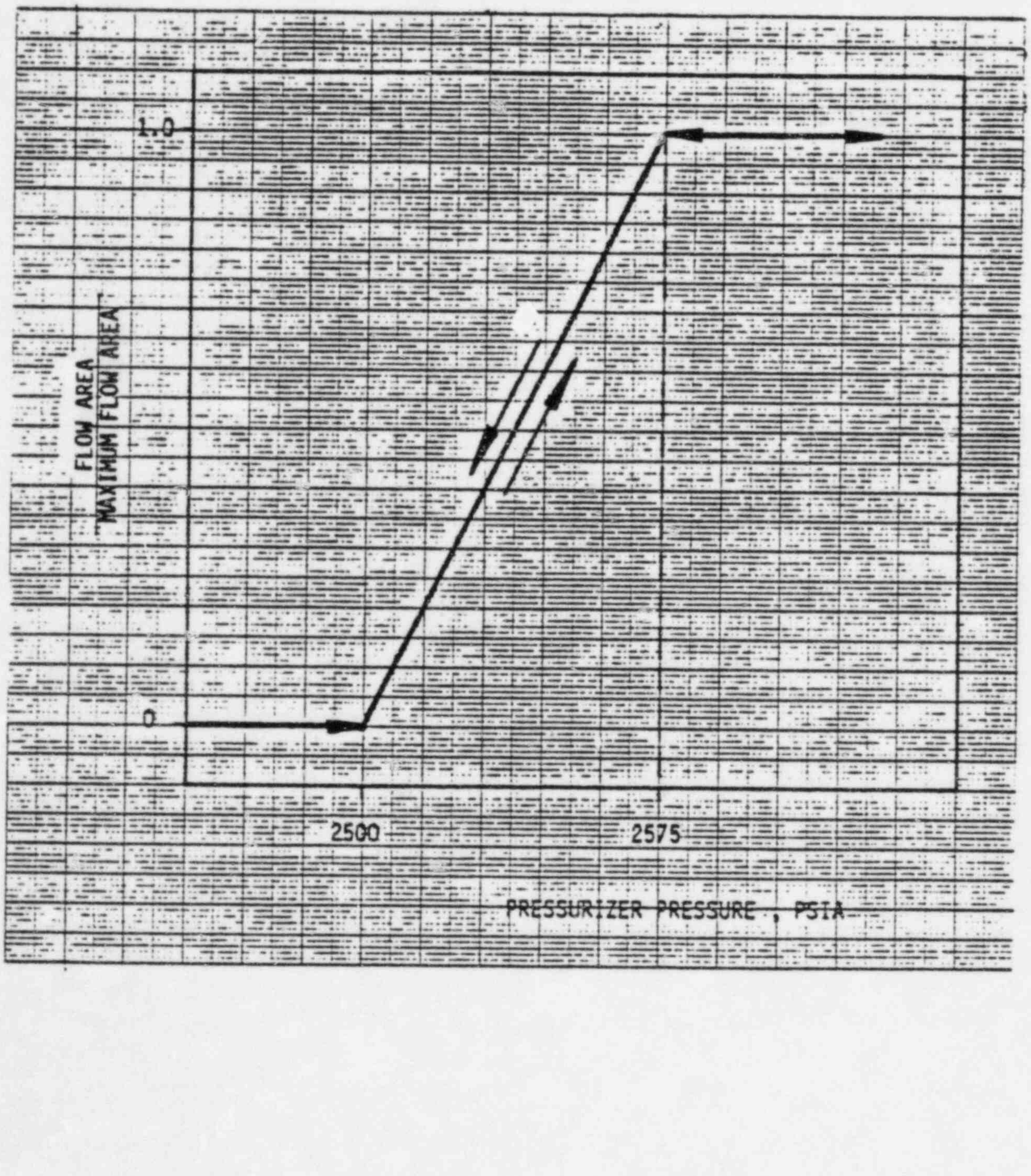
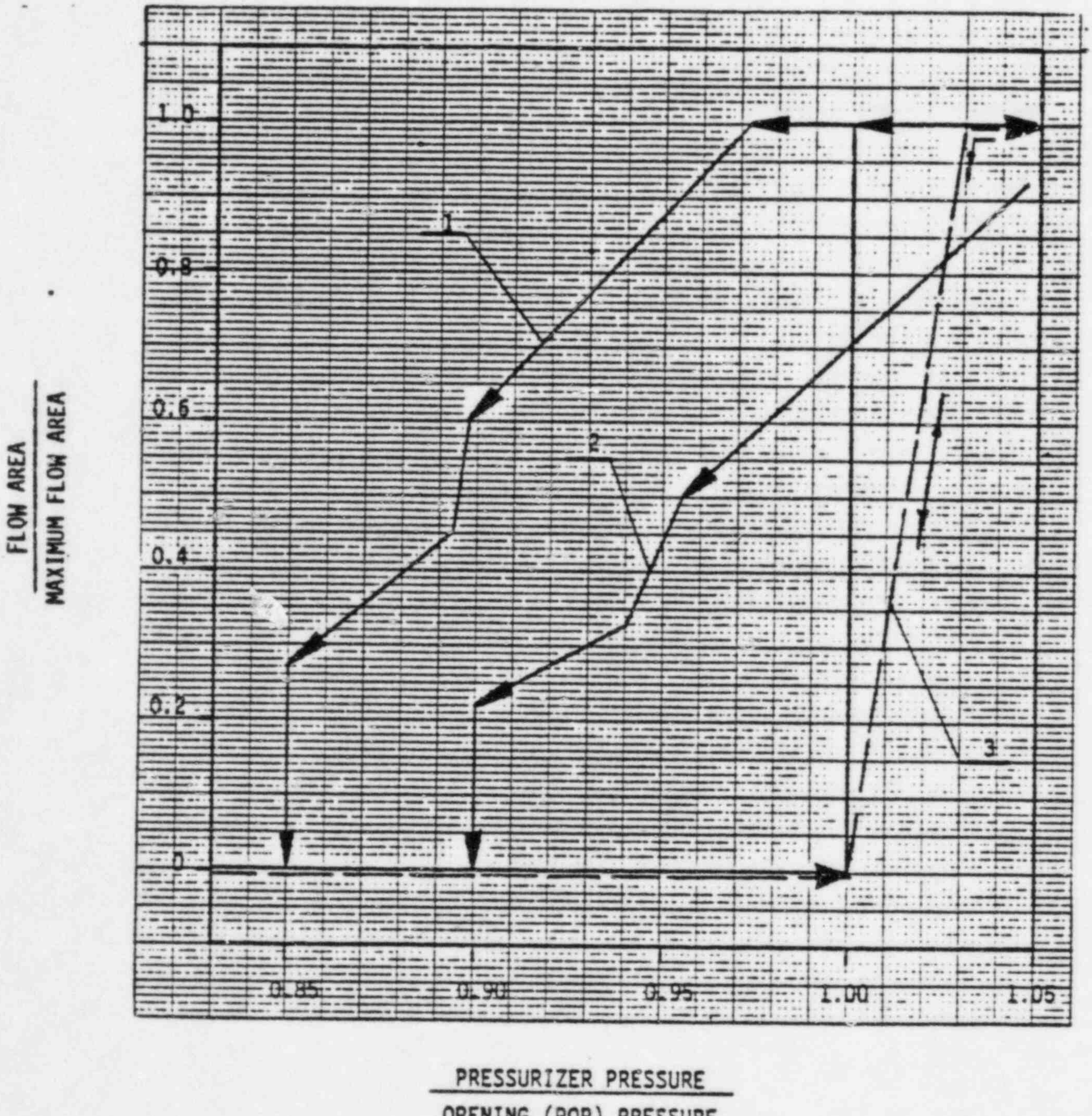


Figure C2-4

COMPARISON OF THE CALVERT CLIFFS UNITS 1 AND 2

FSAR SAFETY VALVE FLOW MODEL AND DRESSER 31739A VALVE

OPERATING CHARACTERISTICS OBSERVED IN EPRI TESTS



Notes: 1 - Operating characteristic observed in tests (at 15% blowdown)

2 - Operating characteristic observed in tests (at 10% blowdown)

3 - FSAR assumptions

superimposed for comparative purposes. The curves demonstrate the capability of the safety valve to relieve overpressure. However, the FSAR analyses assume that the valve linearly ramps to achieve the maximum flow area when 3% overpressure is reached. The comparison, therefore, illustrates the conservatism in the FSAR analyses assumption since the tests demonstrate that the safety valves open to the maximum flow area at the set pressure. Thus, the peak pressurizer pressures determined in the safety analyses are not adversely impacted by the actual valve characteristics observed in the EPRI tests.

2.5 CONCLUSION

The EPRI test results for the Dresser 31739A safety valve, applied to the Calvert Cliffs Units 1 and 2 specific conditions, demonstrated that four combinations of valve adjusting ring settings, (-48, -40, +11), (-48, -40, +3), (-48, -60, +5) and (-48, -80, +11), result in satisfactory operation.

It is concluded that the (-48, -40, +11) setting is recommended for use in Calvert Cliffs Units 1 and 2 since stable operation was demonstrated, test conditions bounded the conditions in the plant, adequate valve lift was achieved, the resultant blowdowns are acceptable, and the bending moments imposed by the discharge piping did not impair valve operability.

APPENDIX C-1

PRESSURIZER SAFETY VALVE STABILITY EVALUATION

Pressurizer Safety Valve Stability Evalution

Purpose

The purpose of this evaluation is to determine the Calvert Cliffs Unit 1 and Unit 2 stagnation transient pressure drops at the safety valve inlet under steam discharge conditions. This will enable the two objectives of this evaluation to be fulfilled.

The two objectives of the evaluations presented in this appendix are as follows:

- o To determine plant - specific safety valve stability upon valve actuation under steam conditions.
- o Assist in determining acceptable plant - specific valve ring settings.

Introduction

During the conduct of the EPRI Safety Valve Test Program, there were instances where tested valves experienced unstable behavior. In some cases this occurred during valve opening when forces on the valve disc could not sustain the valve in the open position, and subsequently a cyclic open/close motion of the valve developed. Measurements in the EPRI program demonstrated that when safety valves initially open, there is a transient pressure drop at the valve inlet. The pressure recovers after upstream fluid is accelerated toward the valve. Prior to pressure recovery, the fluid force on the valve is reduced. Whether or not a safety valve will perform in a stable manner is dependent on the valve characteristics, ring setting, inlet piping configuration, and fluid condition.

Evaluations of Calvert Cliffs Unit 1 and Unit 2 configurations were undertaken to determine valve performance during opening on steam actuation. As indicated in Reference 1, only steam conditions are applicable to C-E designed plants. Therefore, only steam conditions valve actuation "pops" are considered in this analysis.

Approach

The approach taken to evaluate the plant specific valve/inlet piping combinations is one of direct comparison with EPRI Safety Valve Program test results. The method focuses on the forces acting on the valve disc during valve opening. This is accomplished through a relative comparison of the transient stagnation pressure loss within the inlet piping. Specifically, the calculated plant valve inlet pressure drop at opening is compared with an EPRI test measured pressure drop for the same valve model. If the plant pressure drop is found to be less than the measured pressure drop, stable plant valve operation can be expected, since the selected EPRI test resulted in stable valve performance.

To accomplish this task of comparison, the first step is to establish the EPRI reference test based on the following criteria:

- Stable safety valve performance of the tested valve model.
- Fast valve opening time.
- Full flow stem lift achieved.
- Tested valve identical to plant-installed model.

Some valves were tested with different inlet piping configurations. The EPRI reference test is based on the inlet piping configuration most closely resembling the plant specific inlet piping. Once the EPRI reference test is chosen, the measured static pressure drop at the valve inlet is obtained from the inlet pressure measurements [2] and the corresponding stagnation pressure drop is calculated using the PIPES computer code. It should be noted that the transient pressure drop corresponds to the pressure difference at the valve inlet location at two different points in time, as opposed to the pressure difference between two different locations at a single point in time.

The magnitude of the transient stagnation pressure loss is greater for faster valve "pop" times. Consequently, the reference test is chosen from a group of applicable tests (defined in Part C, Section 2.2 of this report) which demonstrated stable valve performance under steam discharge and had a relatively fast valve opening "pop" time. This provides conservative values for the transient pressure loss, which are used to judge the valve stability in the plant by comparing with the measured pressure loss of the reference test. Even though plant valve stability is being evaluated relative to the reference test, other applicable tests, having less severe results, can be chosen as the basis for selecting the plant valve ring setting.

Following establishment of the reference test, the next step is to calculate the plant stagnation pressure drop. This is accomplished by a computer dynamic analysis, (PIPES Code) [3].

The PIPES computer code employs the method of characteristics to solve the equations of conservation of mass, momentum, and energy. Computations of fluid conditions are made for a large number of discrete points within the piping system. The code can track the propagation of pressure waves in a complex piping network following a system perturbation such as a valve opening.

The code inputs required for plant specific analysis are as follows:

Valve Opening Function from Reference Test.
Pressurization Rate from Reference Test.
Valve Nozzle Coefficient (Cd).
Inlet Piping Configuration.
SV Nozzle Geometry.
Initial Fluid Conditions from Reference Test.

Before simulating the plant inlet piping transient pressure response, the reference test or applicable test (as described in Part C, Section 2.2 of this report) is simulated to benchmark the code. This procedure accomplishes two tasks; calibration of the code against the reference test, and establishment of the difference between the analytical and measured pressure transient. Subsequently, the plant SV/piping combination is simulated and the corresponding plant transient stagnation pressure drop is conservatively adjusted, if required, to reflect the difference between the analytical and measured pressure transient from the reference test. Since the PIPES code overpredicted the EPRI test pressure drop, adjustment of the plant predicted pressure drop was unnecessary.

Results

Calvert Cliffs Unit 1 and Unit 2 each have two Dresser 2.5 x 6 (Type 31739A) primary safety valves with Unit 2 having a longer inlet piping than Unit 1.

The EPRI reference test for both units is Test #1008. The drained loop seal inlet piping configuration associated with this test is considered to be the most similar to the plant piping. This specific steam discharge test demonstrated stable safety valve performance and had the lowest value of valve opening "pop" time from the Dresser 2.5 x 6 SV test series with the drained loop seal inlet piping configuration.

Figure 1 illustrates the PIPES code schematic piping diagram for Test #1008 where the safety valve nozzle, inlet piping configuration, and accumulator tank are represented. The simulated valve opening function is based on the ZE17 stem position time history. Only the initial rise in valve stem position is included for the valve opening function, while subsequent minor fluctuations in safety valve stem position for Test #1008 are omitted. This is due to the fact that the initial stem position rise generated the largest transient pressure loss as the recorded pressure response indicates. Figure 2 illustrates the PIPES code analytical pressure response for Test #1008 at the PT12 location while Figure 3 shows the corresponding experimental pressure transient. It can be seen that the analytical and experimental pressure transients are similar (i.e., the simulated response overpredicts the experimental delta-P by 20 psid).

Figure 4 and Figure 6 illustrate the schematic PIPES code piping diagram for Calvert Cliffs Unit #1 and Unit #2, respectively. These piping configurations were analyzed with the same fluid conditions and valve characteristics used for the Test #1008 simulation. The simulated inlet piping pressure responses at the same distance from the valve inlet flange as the PT12 probe insertion in Test #1008 are shown in Figure 5 and Figure 7. Since the PIPES code simulation for Test #1008 overpredicted the inlet piping transient pressure drop, it is conservative not to account for this difference for the plant ΔP. Thus, the simulated ΔP for the Calvert Cliffs Unit #1 and Unit #2 inlet piping is probably greater than actual as evidenced by the simulated versus experimental pressure transient for Test #1008, but no accounting of the phenomenon is being made.

Since the ΔP of the plants (205 psid for Unit #2 and 152 psid for Unit #1) is less than the reference test ΔP (235 psid), stable safety valve operation is expected for Calvert Cliffs Units #1 and Unit #2.

References :

(1) EPRI Research Project V102-20, "Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Combustion Engineering Designed Plants", Interim Report, April 1982.

(2) EPRI Research Project V102-2, "EPRI/C-E Safety Valve Test Program", Interim Report, July 1982.

(3) PIPES, "A Program for Calculating Dynamic Hydraulic Forces in Piping Systems", Trans. Am. Nucl. Soc., Pg. 300 (November 1980).

EPRI/CE SAFETY VALVE TEST PROGRAM

DRESSER 2.5X6 - LOOP SEAL INLET CONFIGURATION

INPUT SCHEMATIC DIAGRAM FOR PIPES CODE ANALYSIS

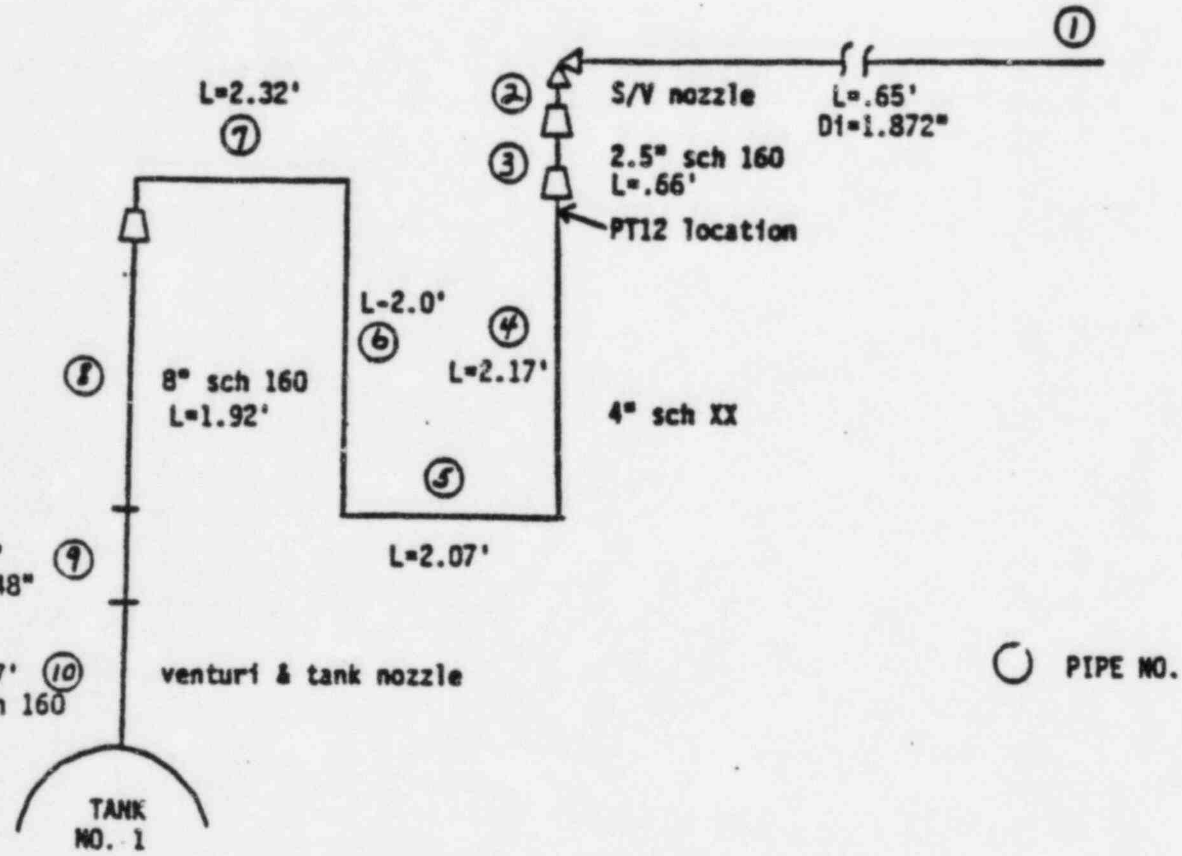
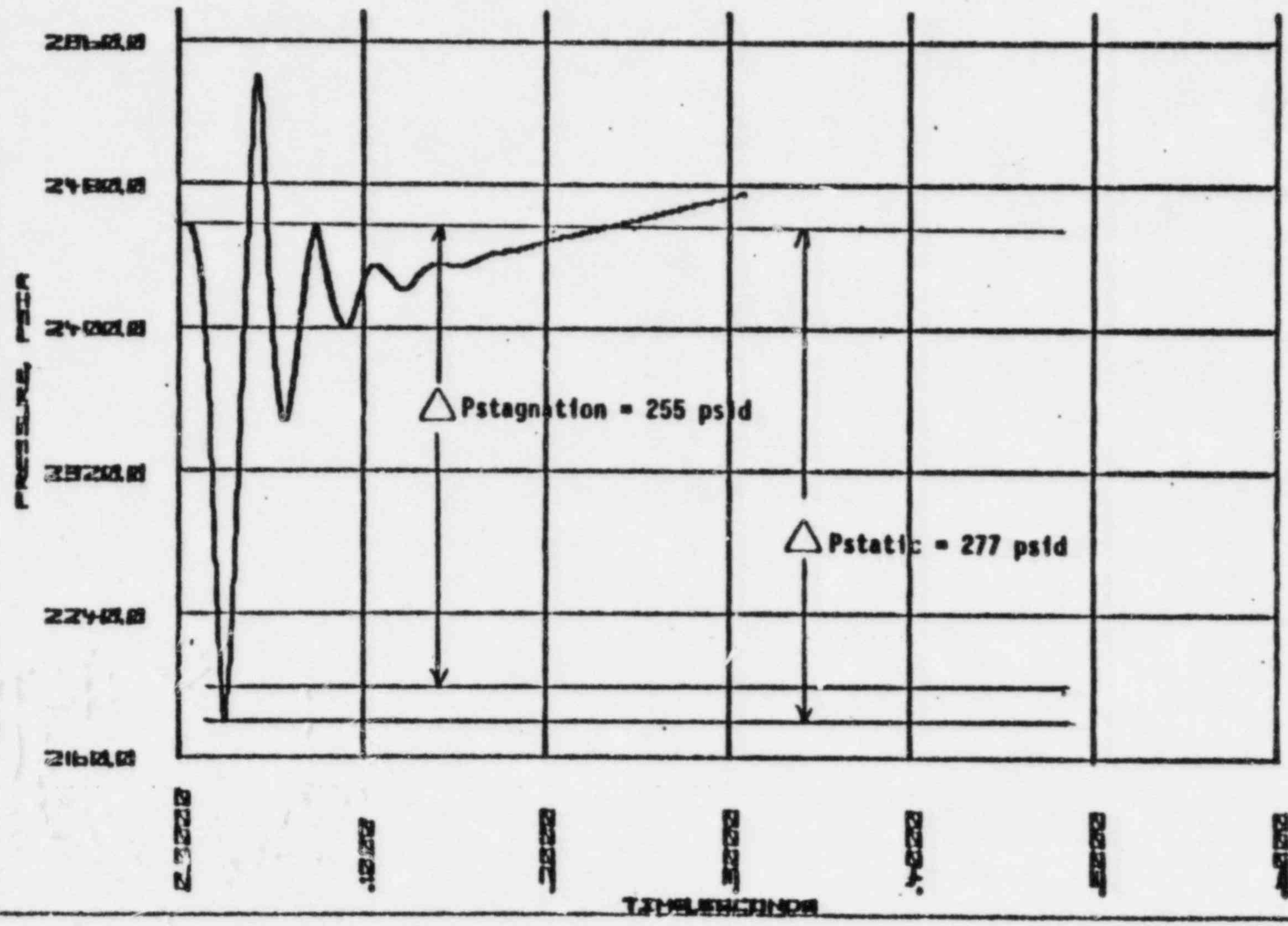


FIGURE 1

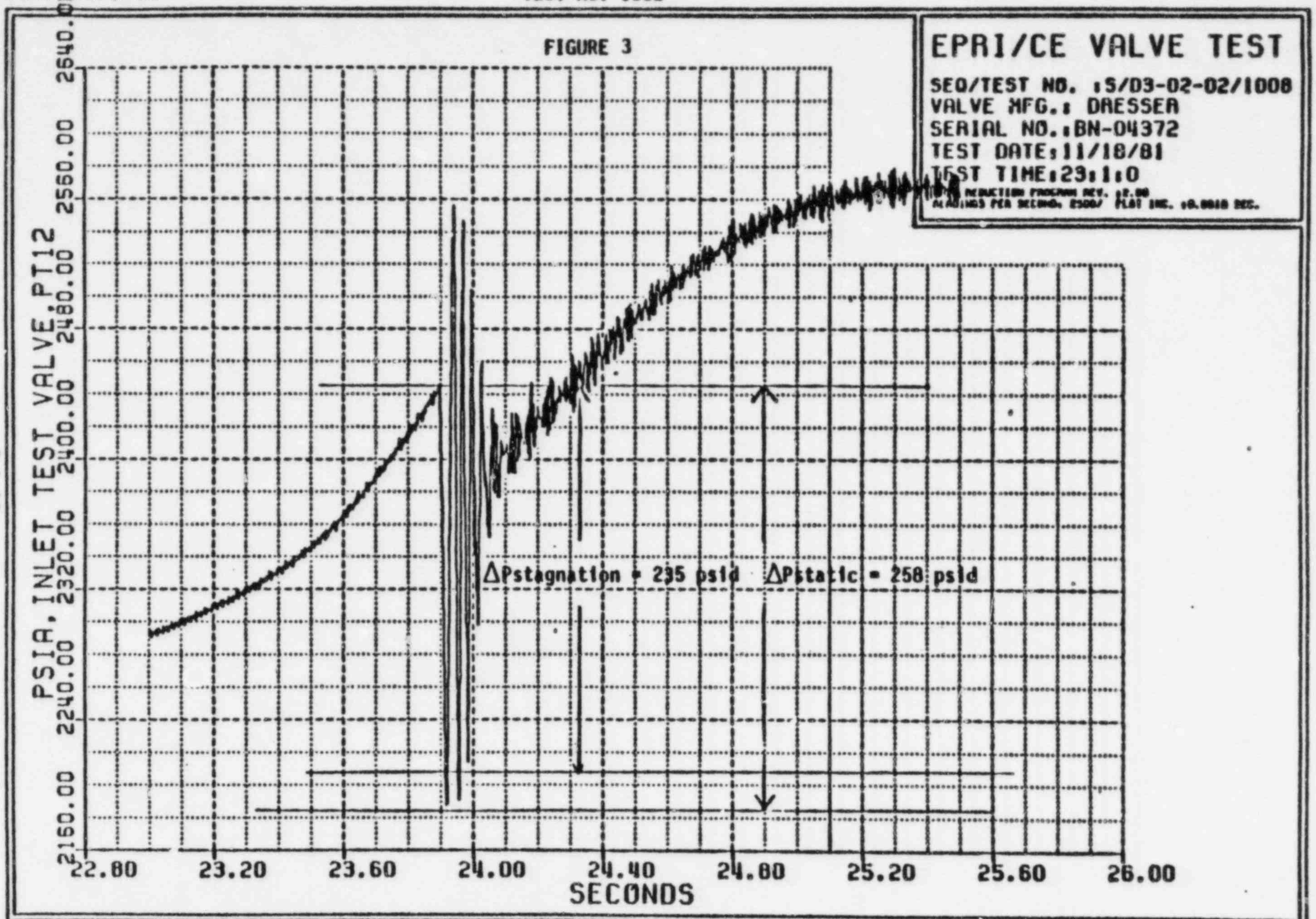
ANALYTICAL SAFETY VALVE INLET PIPING
PRESSURE TRANSIENT FOR TEST NO.
1008 AT THE PT12 LOCATION
PRESSURE AT OUTLET TO PIPE NO 4

FIGURE 2



DATE :3/28/82
TIME : 4/1/16

EXPERIMENTAL SAFETY VALVE INLET
PIPING PRESSURE TRANSIENT FOR
TEST NO. 1008



POWER SYSTEMS

EPRI

PIPES CODE SCHEMATIC DIAGRAM
FOR CALVERT CLIFFS UNIT 1
PRESSURIZER SAFETY VALVE INLET PIPING CONFIGURATION

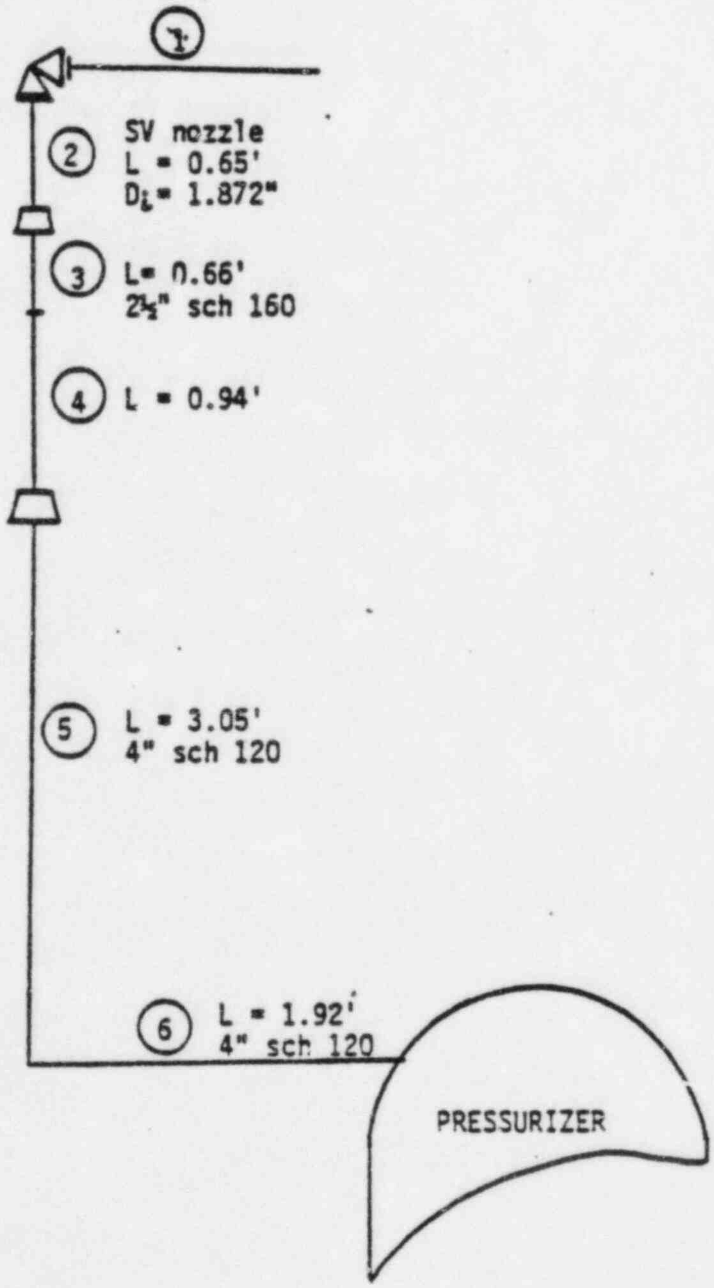
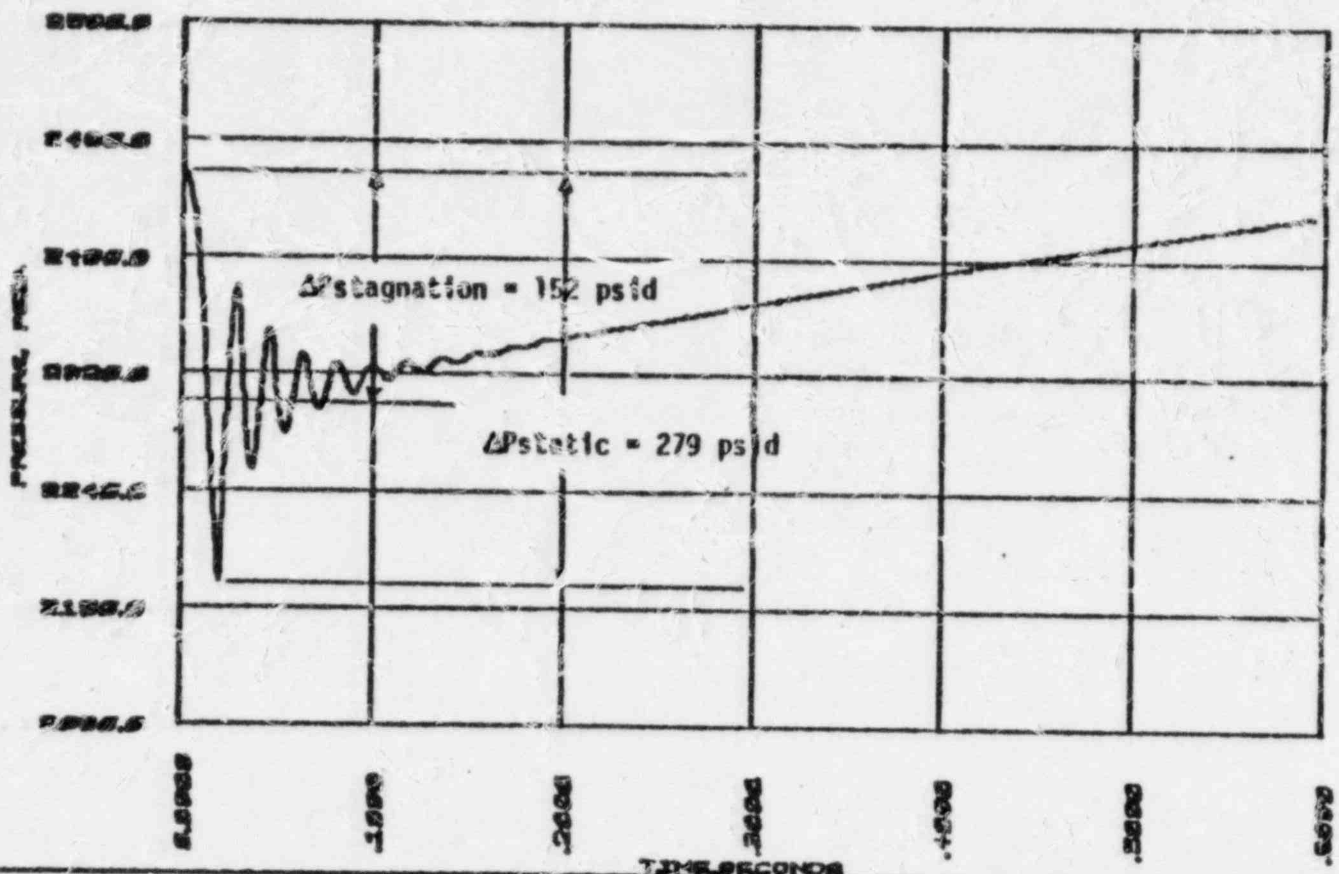


FIGURE 4

ANALYTICAL SAFETY VALVE INLET PIPING ANALYSIS
PRESSURE TRANSIENT FOR CALVERT CLIFFS UNIT 1
PRESSURE AT OUTLET OF PIPE 4

FIGURE 5



PIPES CODE SCHEMATIC DIAGRAM
FOR CALVERT CLIFFS UNIT 2
PRESSURIZER SAFETY VALVE INLET PIPING CONFIGURATION

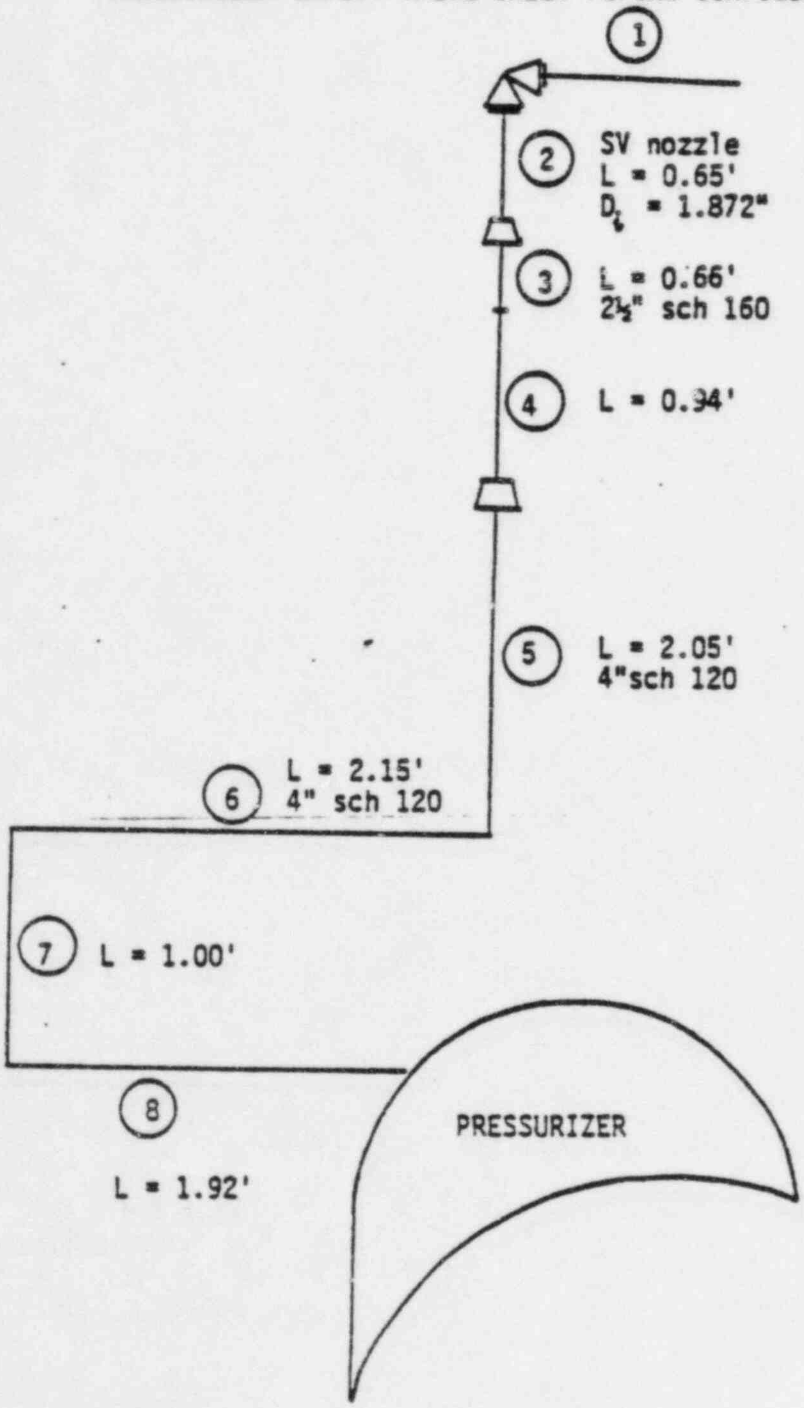


FIGURE 6

ANALYTICAL SAFETY VALVE INLET PIPING ANALYSIS
PRESSURE TRANSIENT FOR CALVERT CLIFFS UNIT 2
PRESSURE AT OUTLET OF PIPE 4

FIGURE 7