SUMMARY REPORT
ON THE
OPERABILITY OF THE
SHUTDOWN COOLING SYSTEM
RELIEF VALVES

FOR

PALO VERDE UNITS 1, 2 AND 3

November 1984

Nuclear Power Systems
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1.0 PURPOSE

The purpose of this report is to document the bases for operability of the Crosby 6R10 JO-55 relief valves used in the Shutdown Cooling System (SCS) at Palo Verde Nuclear Generating Station (PVNGS), Units 1, 2, and 3. This report was prepared in response to an NRC request for additional information concerning relief valve operability contained in Reference (1). It documents a C-E presentation which was delivered to the NRC Staff on November 9, 1984. The slides from the presentation are provided in Appendix A.

2.0 SCOPE

This report addresses the operability of the Crosby 6R10 JO-55 liquid relief valves used in the SCS at PVNGS, Units 1, 2, and 3. Each of these valves has a six-inch inlet, a ten-inch outlet and an "R" orifice designation (16.0 square inches). The set pressure for the relief valves is 467 psig; design temperature is 400°F. There is one relief valve installed in each of the two SCS trains for each unit at the station.

The term "operability" is used in this report as a general expression of valve performance to indicate the ability of the valve to open at the required pressure, relieve at the minimum rated capacity and reclose following actuation.

3.0 BASIC OPERABILITY DATA

The operability discussion for the Palo Verde SCS relief valves contained in this report is based on two key pieces of information:

1. Prorated water test data for a Crosby 4P6 JO-45 relief valve with a set pressure of 66 psig. (Reference 2). This valve has a 4-inch inlet, a 6-inch outlet and a "P" orifice designation (6.379 square inches).

2. Production steam tests for Crosby JO series relief valves. These tests were conducted with steam at pressures up to 250 psig and saturation temperatures up to 400°F.

4.0 DISCUSSION OF OPERABILITY

The operability of the Palo Verde SCS relief valves is demonstrated by applying the basic operability data identified in Section 3.0 to the Palo Verde valves. These data are implemented to supplement and support three principal arguments on which the operability of the Crosby 6R10 JO-55 relief valve is based.

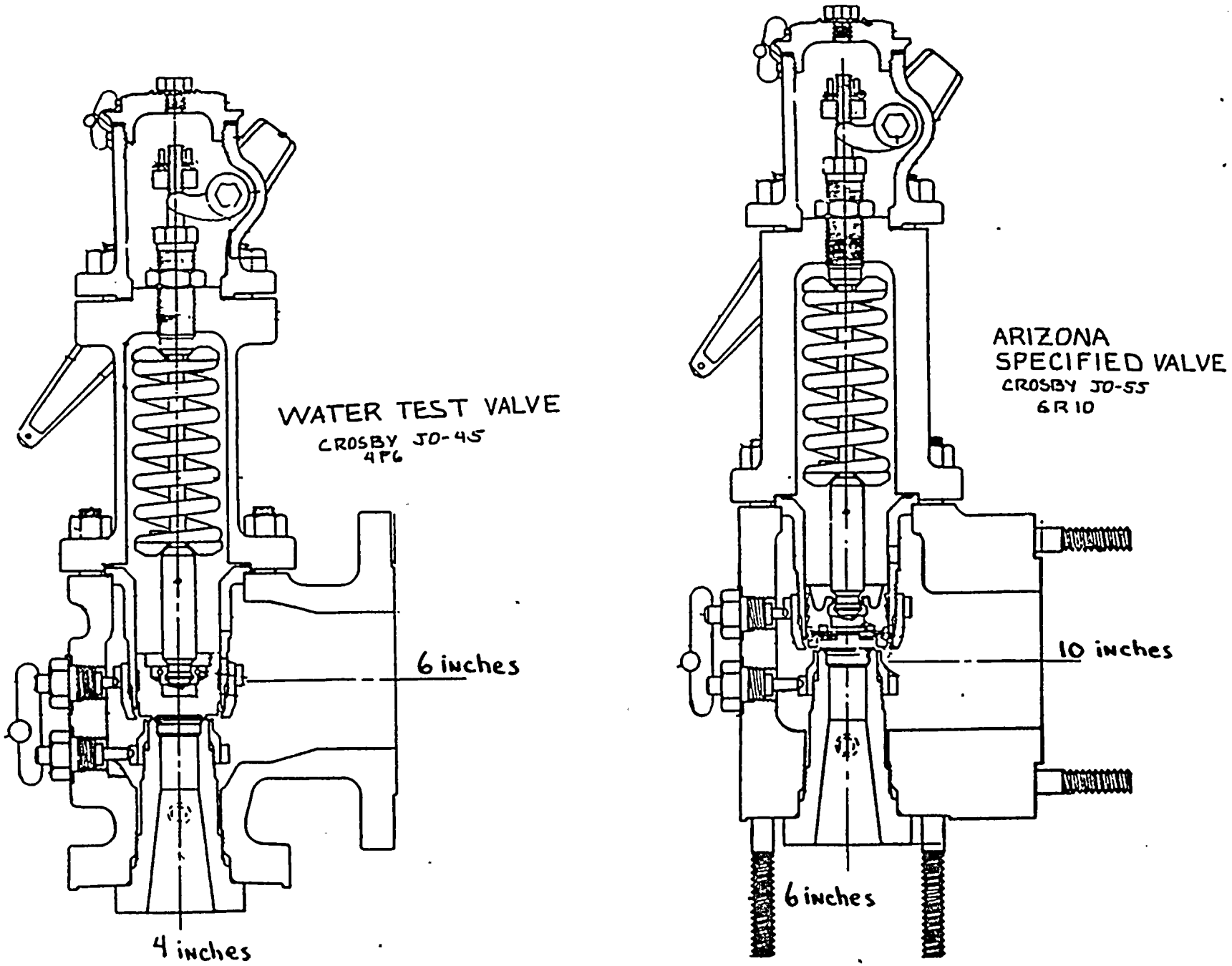
1. Test data for the Crosby 4P6 JO-45 relief valve are applicable to the Crosby 6R10 JO-55 relief valve.
2. Water test data from a 66 psig set pressure test are applicable to 467 psig set pressure operation at the same temperature.
3. Production steam tests for Crosby JO series relief valves provide a basis for operability of the Crosby 6R10 JO-55 relief valve for higher temperature service (up to 400°F).

The following three subsections contain discussions of the three bases for operability identified above. Each of the three bases is considered independently as a component of the overall discussion of operability.

4.1 COMPARISON OF 4P6 AND 6R10 VALVES

The comparison of the 4P6 JO-45 and the 6R10 JO-55 is presented to show that the 4P6 test results are applicable to the Palo Verde 6R10 JO-55 relief valve. The two relief valves which are shown in Figure 4-1 are compared on the basis of 1) physical geometry, 2) materials and 3) functional characteristics.

FIGURE 4-1 CROSBY 4P6 JO-45 AND 6R10 JO-55 RELIEF VALVES



4.1.1 PHYSICAL GEOMETRY

The 4P6 and 6R10 relief valves are both members of a family of similar J0 series valves manufactured by Crosby. Although the 6R10 valve is larger than the 4P6 valve they are very similar in that:

1) the overall dimensions are scaled
2) the nozzle geometry is the same
3) two rings are used for valve blowdown adjustment; and
4) the clearances between the moving parts are comparable and are appropriate for the service conditions.

Other than size, the only differences between the physical geometry of the valves are in the disc design and in the guiding surfaces. The 4P6 has a single piece disc and the 6R10 has a two piece design of disc holder and disc insert. The overall dimensions of these pieces are scaled. The disc insert enhances seat tightness in the larger valve because of thermal considerations and is not considered a significant difference which would affect valve operability. As for the guiding surfaces, the 4P6 has two lands on the circumference of the disc which ride inside the guide. The 6R10 has what is termed a labyrinth geometry which in effect is a larger number of smaller size lands which ride inside the guide. According to Crosby the labryrinth geometry is desireable for guiding larger valves and is expected to result in operability similar to that of the two-land design used in the 4P6.

4.1.2 MATERIALS

The materials in both the 4P6 and 6R10 relief valves were selected to avoid galling and were tested by Crosby for water service. The same seating material was used in each valve. 316 stainless steel material was used for the disc in each valve. The 4P6 guide was also fabricated from 316 stainless steel. ASTM A743 was used for the 6R10 guide to provide better galling resistance for the larger valve.

4.1.3 FUNCTIONAL CHARACTERISTICS

The same design philosophy was used in both the 4P6 and 6R10 valves. The adjustment ring settings have the same basis. Similar functional behavior is expected for the two valves.

4.1.4 SUMMARY OF APPLICABILITY OF 4P6 TO 6R10

The following points summarize the applicability of the satisfactory 66 psig test of the 4P6 to the 6R10 relief valve:

- o The overall dimensons are scaled
- o The geometrical and material differences between the 4P6 valve and the 6R10 valve are for enhancing the 6R10 valve and are not considered significant
- o The same design philosophy was used for each valve
- o The ring settings have the same basis

Therefore, the test of the 4P6 valve is believed applicable to the 6R10 valve used at Palo Verde.

4.2 APPLICABILITY OF PRORATED TEST RESULTS TO FULL PRESSURE OPERABILITY

The following discussion is intended to show that prorated (low pressure spring) tests in general are applicable to relief valve operation at full pressure conditions, given the same fluid state (subcooled liquid) and temperature conditions. That way the water test performance of a relief valve tested at 66 psig can be applied to performance at 467 psig at the same temperature. The comparison of prorated and full pressure operability is made on the basis of 1) mechanical valve operation and 2) valve/fluid interaction.

4.2.1 MECHANICAL VALVE OPERATION

Mechanical valve operation is used here to mean the relative movement of the relief valve internals. Identical mechanical valve operation

is expected for 66 psig and 467 psig. Clearances in the valve internals are not a function of pressure. The same ring settings would be used at prorated and full pressures.

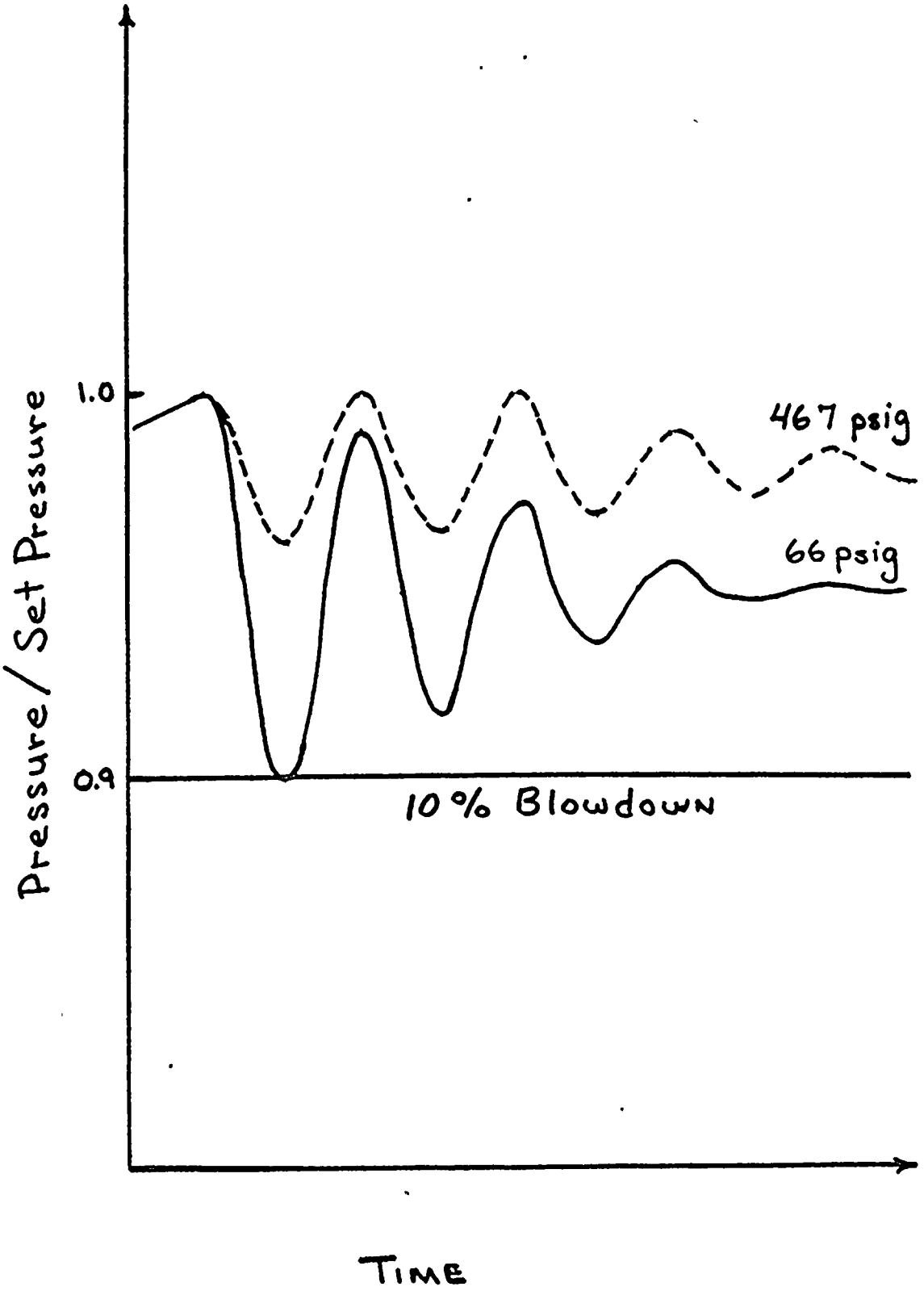
4.2.2 VALVE/FLUID INTERACTION

The manner in which the relief valve reacts to fluid conditions at the valve inlet is expected to be the same. Thus, the relief valve operating characteristics of valve stem position vs. inlet pressure, and valve opening response time are expected to be the same at 66 psig as those at 467 psig. The percent blowdown should be comparable for the same ring settings. A very significant point to be made is that the margin to stability will increase with increasing set pressure for constant percentage blowdown. Figure 4-2 depicts this phenomenon for the general case of a liquid relief valve set at 66 psig and 467 psig. The figure is a plot of valve inlet pressure drop calculated to occur at valve opening for a given valve operating characteristic and inlet piping configuration. As indicated in the figure there will be a drop in inlet pressure when a relief valve opens due to the acceleration of the fluid. When the pressure drop is expressed as a percentage of the set pressure, it is seen that the percentage drop in inlet pressure decreases as the set pressure increases. As for stability, the smaller the percentage pressure drop, the more margin there is between the minimum valve inlet pressure and reseat (or blowdown) pressure. So long as the inlet pressure does not fall below the reseat pressure the relief valve will remain open and will operate in a stable manner. Therefore, prorated tests are a conservative means for assessing valve stability.

4.2.3 SUMMARY OF APPLICABILITY OF PRORATED TEST RESULTS TO FULL PRESSURE OPERABILITY

The following points summarize the applicability of prorated test results to full pressure operability:

FIGURE 4-2 RELATIVE RELIEF VALVE STABILITY VS. SET PRESSURE



- o Low pressure (prorated spring) test results are considered representative of operation at full pressure.

- o A relief valve is more likely to chatter at low pressure if the percentage blowdown is the same. Therefore, prorated tests are a conservative means for assessing relief valve stability.

4.3 JUSTIFICATION OF OPERABILITY AT DESIGN TEMPERATURE

In subsection 4.1 it was shown that the satisfactory test of a 4P6 J0-45 relief valve is applicable to operation of the 6R10 J0-55 relief valve at low pressure with cold water. In other words, both valves are expected to exhibit similar performance with the same fluid conditions. Then in subsection 4.2 the operability argument was extended to full pressure but still with cold water conditions. Subsection 4.3 provides the arguments necessary to complete the overall operability discussion for the Palo Verde 6R10 J0-55 by justifying valve operability over the full range of operating temperatures. These arguments are based on Crosby's experience with production steam tests for J0 series relief valves with steam temperatures up to 400°F as well as on experience gained from the EPRI/C-E PWR Safety Valve Test Program. The considerations of temperature effects on relief valve operability are based on 1) mechanical valve operation and 2) valve/fluid interaction in the same manner used in subsection 4.2.

4.3.1 MECHANICAL VALVE OPERATION

Crosby has performed routine production tests on J0 series steam relief valves over a number of years. These valves are of the same basic design as the J0 series water valve used at Palo Verde and are used in both industrial and utility applications. The valves tested include a 6R10 J0-56 relief valve which is the same size as the Palo Verde 6R10 J0-55 relief valve. For these production tests the valves are equipped with prorated springs if the full set pressure exceeds approximately 250 psig. The valves are tested with saturated steam at

temperatures up to 400°F which is the design temperature of the Palo Verde valves. During the tests the valves opened to substantial lift and then reseated following blowdown. The valves are judged to be acceptable when they meet the test acceptance criteria for set pressure and valve stability. Set pressure must fall within the required tolerances. Instabilities in valve operation such as chatter or flutter are not accepted. These production tests demonstrate proper mechanical valve operation of the J0 series relief valves for temperatures up to 400°F.

4.3.2 VALVE/FLUID INTERACTION

The EPRI safety valve tests (Reference 3) demonstrated that spring-loaded safety valves were more prone to chatter as the degree of subcooling increased. Although the safety valves tested in the EPRI program were designed for steam service, both safety valves and relief valves are fundamentally spring-mass systems for which the principle of valve/fluid interaction is the same. Therefore, prorated tests with cold water are conservative due to the large amount of subcooling and the increased tendency to chatter as fluid temperature decreases.

4.3.3 SUMMARY OF OPERABILITY AT DESIGN TEMPERATURE

The following points summarize the operability discussion for the 6R10 J0-55 relief valve at design temperature:

- Acceptable mechanical valve operation at design temperature is demonstrated by the Crosby J0 series steam tests.
- Valve/fluid interactions are conservatively determined with prorated spring tests at low temperatures.

Thus the valve operability over the range of operating temperatures is bounded by the prorated test of the 4P6 J0-45 valve at cold conditions and the J0 series steam tests at design temperature.

5.0 SUMMARY

The following points are a summary of the discussions contained in this report regarding the operability of the Palo Verde 6R10 JO-55 relief valve:

- o A satisfactory low pressure test of a 4P6 JO-45 relief valve is believed applicable to the 6R10 JO-55 relief valve.
- o Low pressure test results are considered representative of operation at full pressure.
- o A liquid relief valve is more likely to chatter at low pessure if the percent blowdown is the same.
- o Acceptable mechanical valve operation at design temperature is demonstrated by the Crosby JO series steam tests.
- o Valve/fluid interactions over the range of operating temperatures are bounded by the 4P6 JO-45 relief valve test and the Crosby JO series steam tests.

In conclusion, based on the relevant test data and engineering evaluations, acceptable operability is expected for the Crosby 6R10 JO-55 relief valve.

6.0 REFERENCES

1. NRC letter, G.W. Knighton (NRC) to E.E. Van Brunt, Jr. (APS), dated April 18, 1984

2. Crosby Valve and Gage Company Test Report NO. 4053-Revision No. 1, "Report on Seismic Qualification Test of a Crosby 4P6 JO-45 Nozzle Type Relief Valve", dated September 29, 1983.

3. EPRI/C-E PWR Safety Valve Test Report, EPRI NP-2770-LD, Project V102-2 Interim Report, January 1983.

APPENDIX A

Slide Presentation to the NRC Staff
on the
Operability of the Shutdown Cooling System Relief Valves
for
Palo Verde Units 1, 2 and 3

November 9, 1984

PURPOSE OF PRESENTATION

TO DOCUMENT THE BASES FOR OPERABILITY OF THE

CROSBY 6R10 JO-55 RELIEF VALVE.

BASIC DATA

1. PRORATED WATER TEST DATA FOR CROSBY 4P6 JO-45 RELIEF VALVE AT 66 PSIG SET PRESSURE (TEST REPORT NO. 4053, REV. 01).

2. PRODUCTION TEST DATA FOR CROSBY JO SERIES STEAM VALVES. SATURATED STEAM TESTS AT PRESSURES UP TO 250 PSIG (SATURATION TEMPERATURE UP TO 400°F).

BASES FOR OPERABILITY OF THE CROSBY 6R10 JO-55 RELIEF VALVE

1. TEST DATA FOR CROSBY 4P6 JO-45 RELIEF VALVE ARE APPLICABLE TO CROSBY 6R10 JO-55 RELIEF VALVE.

2. WATER TEST DATA FROM 66 PSIG SET PRESSURE TEST ARE APPLICALBE TO 467 PSIG SET PRESSURE OPERATION AT THE SAME TEMPERATURE.

3. STEAM TEST DATA FOR CROSBY JO SERIES RELIEF VALVES PROVIDE A BASIS FOR OPERABILITY OF THE CROSBY 6R10 JO-55 RELIEF VALVE FOR HIGHER TEMPERATURE SERVICE (UP TO 400°F).

COMPARISON OF 4P6 AND 6R10 VALVES

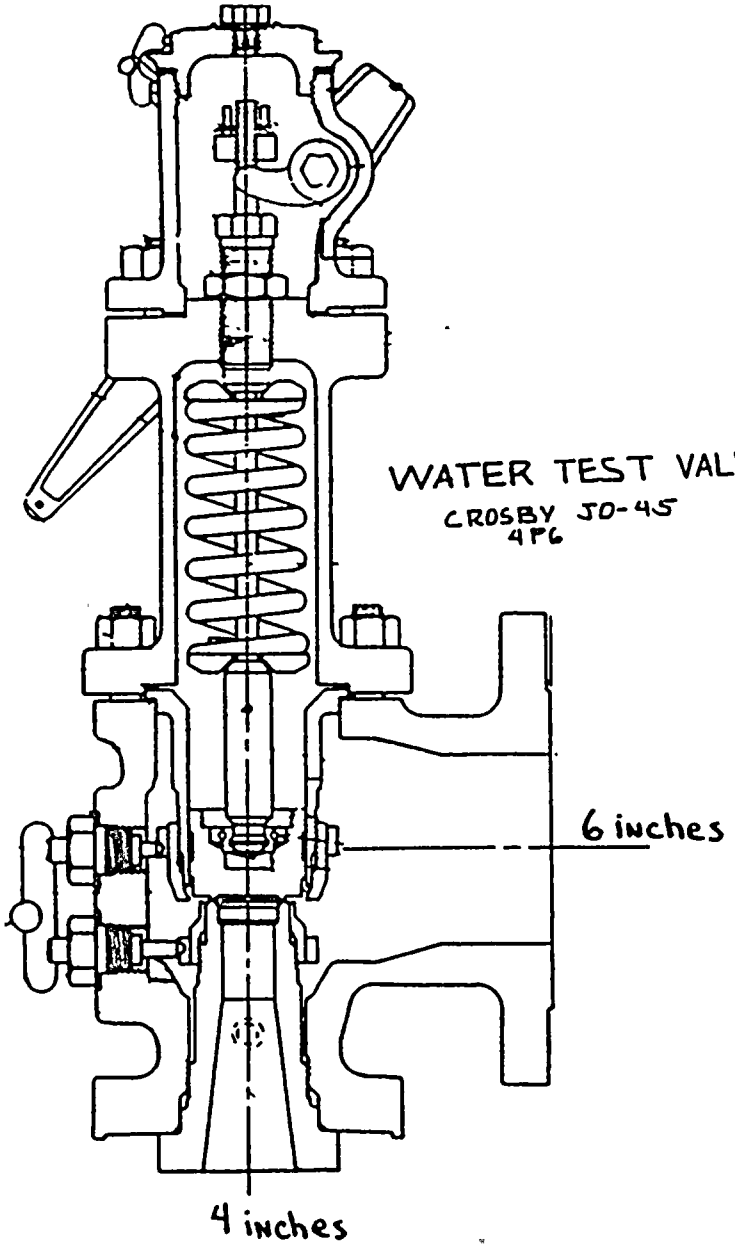
PHYSICAL GEOMETRY

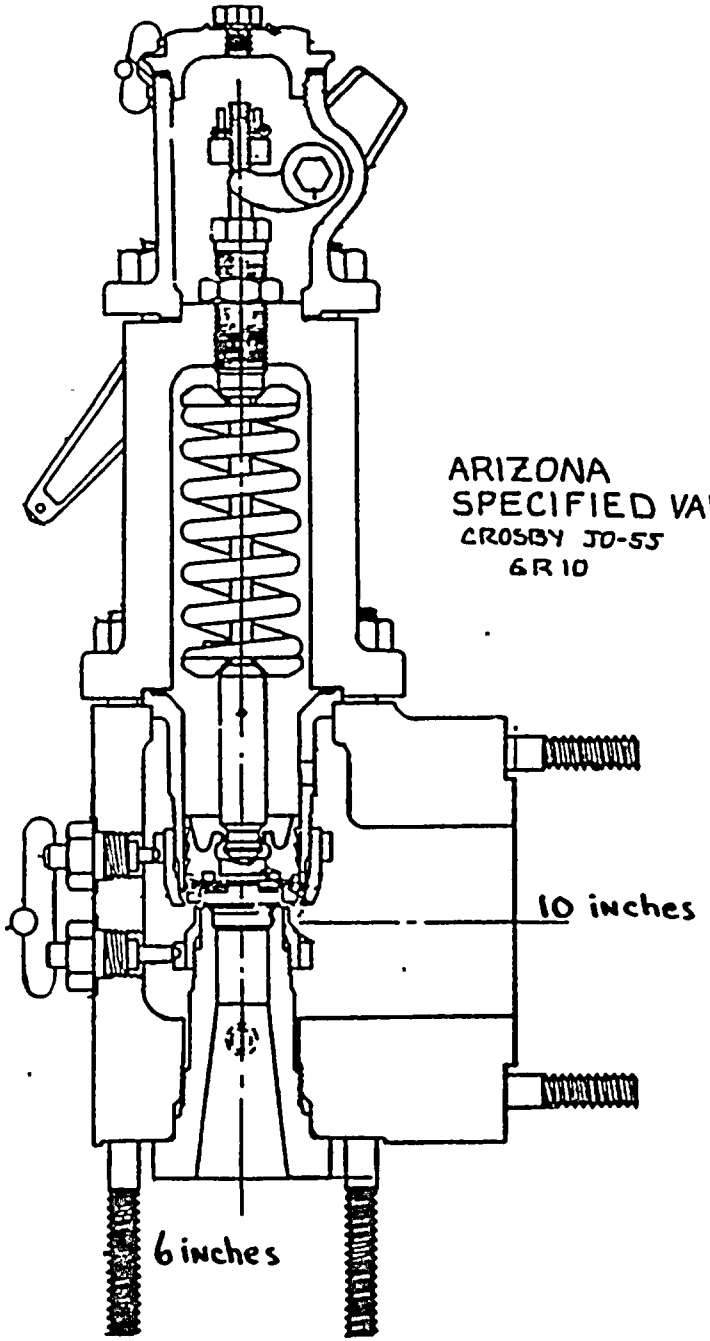
SIMILARITIES -
- OVERALL DIMENSIONS ARE SCALED
- NOZZLE GEOMETRY
- 2-RING CONTROL
- CLEARANCES ARE COMPARABLE AND APPROPRIATE FOR SERVICE

DIFFERENCES	4P6	6R10	SIGNIFICANCE
DISC DESIGN	SINGLE PIECE DISC	DISC INSERT	NEGLIGIBLE OVERALL DIMENSIONS WOULD SCALE - DISC INSERT ENHANCES SEAT TIGHTNESS
GUIDING SURFACES	TWO LANDS ON DISC	"LABYRINTH" GEOMETRY	NEGLIGIBLE "LABRYRINTH" GEOMETRY DESIRABLE FOR GUIDING LARGER VALVES

MATERIALS

- SELECTED TO AVOID GALLING
- TESTED BY CROSBY FOR WATER SERVICE
- SEATING MATERIALS ARE THE SAME
- DISC MATERIALS ARE THE SAME (316 STAINLESS STEEL)
- 6R10 GUIDE ASTM A743 BETTER GALLING RESISTANCE
- 4P6 GUIDE 316 STAINLESS STEEL


WATER TEST VALVE
CROSBY JO-45
4P6
6 inches
4 inches


ARIZONA
SPECIFIED VALVE
CROSBY JO-55
6R10
10 inches
6 inches

FUNCTIONAL CHARACTERISTICS

THE SAME DESIGN PHILOSOPHY WAS USED IN BOTH 4P6 AND 6R10 VALVES.

RING SETTINGS HAVE THE SAME BASIS.

SUMMARY OF APPLICABILITY OF 4P6 TO 6R10

- OVERALL DIMENSIONS ARE SCALED
- THE GEOMETRICAL AND MATERIAL DIFFERENCES BETWEEN THE 4P6 VALVE AND THE 6R10 VALVE ARE FOR ENHANCING THE 6R10 VALVE AND ARE NOT CONSIDERED SIGNIFICANT
- THE SAME DESIGN PHILOSPHY WAS USED FOR EACH
- RING SETTINGS HAVE THE SAME BASIS
- THEREFORE, TEST OF 4P6 VALVE IS BELIEVED APPLICABLE TO 6R10 VALVE

APPLICABILITY OF PRORATED TEST RESULTS TO FULL PRESSURE OPERABILITY

MECHANICAL VALVE OPERATION

- MECHANICAL VALVE OPERATION EXPECTED TO BE IDENTICAL
- SAME RING SETTINGS WOULD BE USED AT LOW AND HIGH PRESSURES

VALVE/FLUID INTERACTION

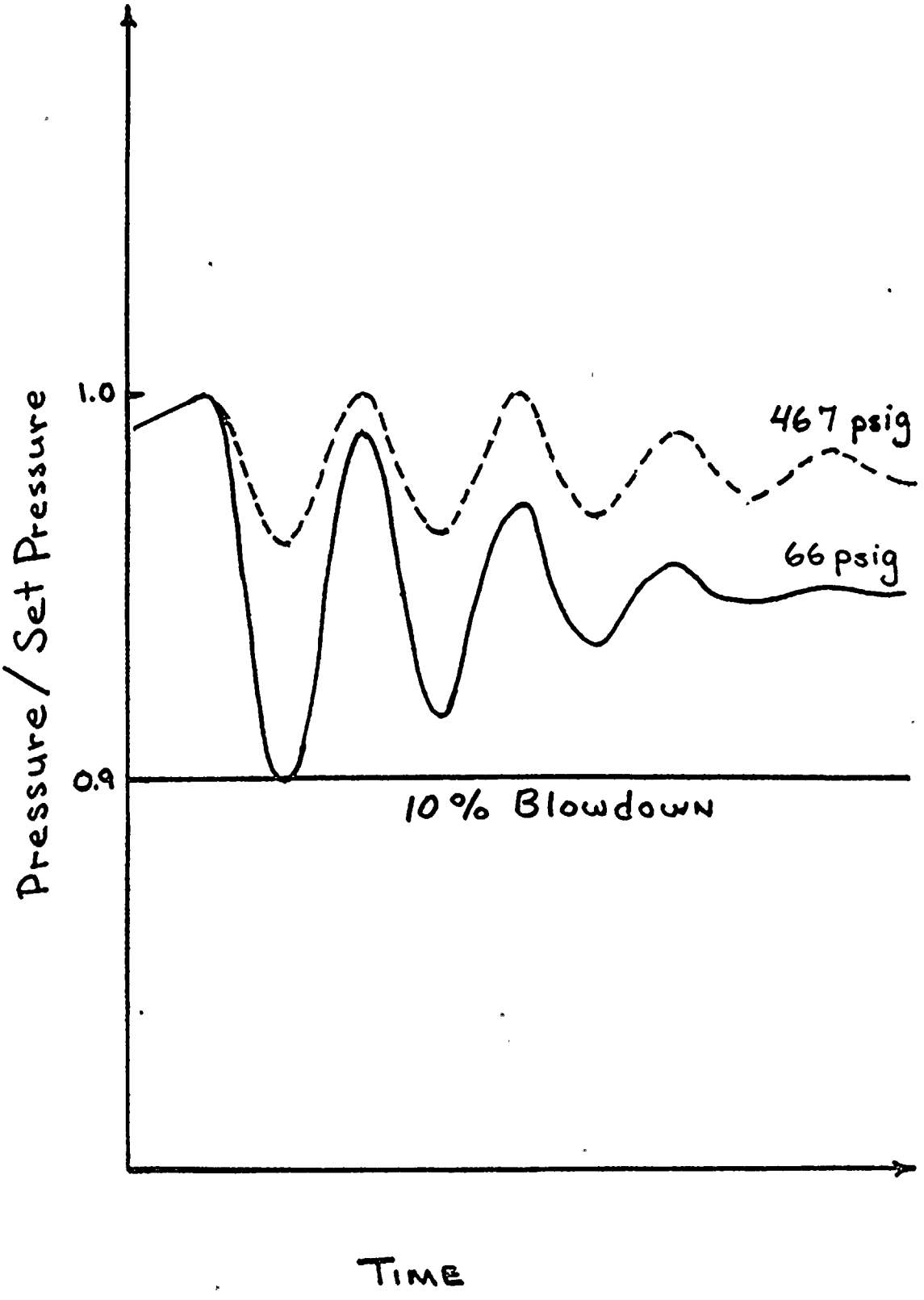
- VALVE/FLUID INTERACTION EXPECTED TO BE THE SAME
- RELIEF VALVE OPERATING CHARACTERISTICS EXPECTED TO BE THE SAME
- PERCENT BLOWDOWN SHOULD BE COMPARABLE
- MARGIN TO STABILITY INCREASES WITH INCREASING SET PRESSURE FOR CONSTANT PERCENT BLOWDOWN

SUMMARY OF APPLICABILITY OF LOW PRESSURE TEST TO FULL PRESSURE OPERATION

LOW PRESSURE (PRORATED SPRING) TEST RESULTS ARE CONSIDERED REPRESENTATIVE OF OPERATION AT FULL PRESSURE.

VALVE IS MORE LIKELY TO CHATTER AT LOW PRESSURE IF PERCENT BLOWDOWN IS THE SAME.

Relative Relief Valve Stability vs. Set Pressure



JUSTIFICATION OF OPERABILITY AT DESIGN TEMPERATURE

MECHANICAL VALVE OPERATION

PRODUCTION TEST DATA FOR CROSBY J0 SERIES STEAM VALVES DEMONSTRATE PROPER MECHANICAL VALVE OPERATION FOR TEMPERATURES UP TO 400°F (DESIGN TEMPERATURE).

J0 SERIES STEAM VALVES ARE OF THE SAME BASIC DESIGN AS J0 SERIES WATER VALVES.

VALVES TESTED INCLUDE J0-46, 6R10 VALVE WHICH IS THE SAME SIZE AS THE PALO VERDE J0-55, 6R10 VALVE.

VALVE/FLUID INTERACTION

EPRI TESTS DEMONSTRATED THAT SPRING-LOADED SAFETY VALVES WERE MORE PRONE TO CHATTER AS THE DEGREE OF SUBCOOLING INCREASED.
THEREFORE, PRORATED TESTS WITH COLD WATER ARE CONSERVATIVE DUE TO LARGE AMOUNT OF SUBCOOLING.

AS TEMPERATURE INCREASES, SUBCOOLING DECREASES. IN THE LIMIT OF ZERO SUBCOOLING, STEAM CONDITIONS OCCUR. CROSBY PRODUCTION STEAM TESTS ON J0 SERIES VALVES DEMONSTRATE OPERABILITY WITH ZERO SUBCOOLING.

SUMMARY OF OPERABILITY AT DESIGN TEMPERATURE

ACCEPTABLE MECHANICAL VALVE OPERATION AT DESIGN TEMPERATURE IS DEMONSTRATED BY CROSBY J0 SERIES STEAM TESTS.
VALVE/FLUID INTERACTIONS OVER THE RANGE OF OPERATING TEMPERATURES ARE BOUNDED BY PRORATED TEST OF 4P6 VALVE AT COLD CONDITIONS AND J0 SERIES STEAM TESTS AT DESIGN TEMPERATURE.

SUMMARY

- SATISFACTORY LOW PRESSURE TEST OF 4P6 RELIEF VALVE IS BELIEVED APPLICABLE TO 6R10 VALVE.

- LOW PRESSURE TEST RESULTS ARE CONSIDERED REPRESENTATIVE OF OPERATION AT FULL PRESSURE.

- RELIEF VALVE IS MORE LIKELY TO CHATTER AT LOW PRESSURE IF PERCENT BLOWDOWN IS THE SAME

- ACCEPTABLE MECHANICAL VALVE OPERATION AT DESIGN TEMPERATURE IS DEMONSTRATED BY CROSBY J0 SERIES STEAM TESTS

- VALVE/FLUID INTERACTIONS OVER THE RANGE OF OPERATING TEMPRATURES ARE BOUNDED BY 4P6 RELIEF VALVE TEST AND CROSBY J0 SERIES STEAM TESTS

THEREFORE, BASED ON RELEVANT TEST DATA AND ENGINEERING JUDGEMENT, ACCEPTABLE OPERABILITY IS EXPECTED FOR THE CROSBY 6R10 RELIEF VALVE.