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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF AND SAFETY VALVE TESTING

NUREG-0737, ITEM II.D.1

FACILITY OPERATING LICENSE NO. DPR-51

ARKANSAS POWER AND LIGHT COMPANY

ARKANSAS NUCLEAR ONE, UNIT NO. 1

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ABSTRACT

Light water reactors have experienced a number of occurrences of improper performance of safety and relief valves installed in the primary coolant system. As a result, the authors of NUREG-0578 (TMI-2 Lessons Learned Task Force Status Report and Short-Term Recommendations) and subsequently NUREG-0737 (Clarification of TMI Action Plan Requirements) recommended that programs be developed and completed which would reevaluate the functional performance capabilities of Pressurized Water Reactor (PWR) safety, relief, and block valves and which would verify the integrity of the piping systems for normal, transient, and accident conditions. This report documents the review of these programs and their results by the Nuclear Regulatory Commission (NRC) and their consultant, EG&G Idaho, Inc. Specifically, this report documents the review of the Arkansas Nuclear One - Unit 1 Licensee response to the requirements of NUREG-0578 and NUREG-0737. This review found the Licensee provided an acceptable response, which would reconfirm that the General Design Criteria 14, 15, and 30 of Appendix A to 10 CFR 50 were met.

CONTENTS

1. INTRODUCTION

1.1 Background

Light water reactor experience has included a number of instances of improper performance of relief and safety valves installed in the primary coolant systems. There were instances of valves opening below set pressure, valves opening above set pressure, and valves failing to open or reseat. From these past instances of improper valve performance, it is not known whether they occurred because of a limited qualification of the valve or because of basic unreliability of the valve design. It is known that the failure of a power operated relief valve (PORV) to reseat was a significant contributor to the Three Mile Island (TMI-2) sequence of events. These facts led the task force which prepared NUREG-0578 (Reference 1) and, subsequently, NUREG-0737 (Reference 2) to recommend that programs be developed and executed which would reexamine the functional performance capabilities of Pressurized Water Reactor (PWR) safety, relief, and block valves and which would verify the integrity of the piping systems for normal, transient, and accident conditions. These programs were deemed necessary to reconfirm that the General Design Criteria 14, 15, and 30 of Appendix A to Part 50 of the Code of Federal Regulations, 10 CFR, are indeed satisfied.

1.2 General Design Criteria and NUREG Requirements

General Design Criteria 14, 15, and 30 require that (1) the reactor primary coolant pressure boundary be designed, fabricated, and tested so as to have extremely low probability of abnormal leakage, (2) the reactor coolant system and associated auxiliary, control, and protection systems be designed with sufficient margin to assure that the design conditions are not exceeded during normal operation or anticipated transient events, and (3) the components which are part of the reactor coolant pressure boundary shall be constructed to the highest quality standards practical.

To reconfirm the integrity of overpressure protection systems and thereby assure that the General Design Criteria are met, the NUREG-0578 position was issued as a requirement in a letter dated September 13, 1979, by the Division of Licensing (DL), Office of Nuclear Reactor Regulation (NRR), to ALL OPERATING NUCLEAR POWER PLANTS. This requirement has since been incorporated as Item II.D.1 of NUREG-0737, Clarification of TMI Action Plan Requirements, which was issued for implementation on October 31, 1980. As stated in the NUREG reports, each pressurized water reactor Licensee or Applicant shall:

1. Conduct testing to qualify reactor coolant system relief and safety valves under expected operating conditions for design basis transients and accidents.

2. Determine valve expected operating conditions through the use of analyses of accidents and anticipated operational occurrences referenced in Regulatory Guide 1.70, Rev. 2.

3. Choose the single failures such that the dynamic forces on the safety and relief valves are maximized.

4. Use the highest test pressure predicted by conventional safety analysis procedures.

5. Include in the relief and safety valve qualification program the qualification of the associated control circuitry.

6. Provide test data for Nuclear Regulatory Commission (NRC) staff review and evaluation, including criteria for success or failure of valves tested.

7. Submit a correlation or other evidence to substantiate that the valves tested in a generic test program demonstrate the functionability of as-installed primary relief and safety valves. This correlation must show that the test conditions used

are equivalent to expected operating and accident conditions as prescribed in the Final Safety Analysis Report (FSAR). The effect of as-built relief and safety valve discharge piping on valve operability must be considered.

8. Qualify the plant specific safety and relief valve piping and supports by comparing to test data and/or performing appropriate analysis.

2. PWR OWNER'S GROUP RELIEF AND SAFETY VALVE PROGRAM

In response to the NUREG requirements previously listed, a group of utilities with PWRs requested the assistance of the Electric Power Research Institute (EPRI) in developing and implementing a generic test program for pressurizer safety valves, power operated relief valves, block valves, and associated piping systems. Arkansas Power & Light (AP&L), the owner of Arkansas Nuclear One - Unit 1 (ANO-1), was one of the utilities sponsoring the EPRI Valve Test Program. The results of the program, which are contained in a series of reports, were transmitted to the NRC by Reference 3. The applicability of these reports is discussed below.

EPRI developed a plan (Reference 4) for testing PWR safety, relief, and block valves under conditions which bound actual plant operating conditions. EPRI, through the valve manufacturers, identified the valves used in the overpressure protection systems of the participating utilities and representative valves were selected for testing. These valves included a sufficient number of the variable characteristics so that their testing would adequately demonstrate the performance of the valves used by utilities (Reference 5). EPRI, through the Nuclear Steam Supply System (NSSS) vendors, evaluated the FSARs of the participating utilities and arrived at a test matrix which bounded the plant transients for which over pressure protection would be required (Reference 6).

EPRI contracted with Babcock & Wilcox (B&W) to produce a report on the inlet fluid conditions for pressurizer safety and relief valves in B&W designed plants (Reference 7). Since ANO-1 was designed by B&W, this report is relevant to this evaluation.

Several test series were sponsored by EPRI. PORVs and block valves were tested at the Duke Power Company Marshall Steam Station located in Terrell, North Carolina. Additional PORV tests were conducted at the Wyle Laboratories Test Facility located in Norco, California. Safety relief valves (SRVs) were tested at the Combustion Engineering Company, Kressinger

Development Laboratory, which is located in Windsor, Connecticut. The results of the relief and safety valve tests are reported in Reference 8. The results of the block valve tests are reported in Reference 9.

The primary objective of the EPRI/C-E Valve Test Program was to test each of the various types of primary system safety valves used in PWRs for the full range of fluid conditions under which they may be required to operate. The conditions selected for test (based on analysis) were limited to steam, subcooled water, and steam to water transition. Additional objectives were to (1) obtain valve capacity data, (2) assess hydraulic and structural effects of associated piping on valve operability, and (3) obtain piping response data that could ultimately be used for verifying analytical piping models.

Transmittal of the test results meets the requirements of Item 6 of Section 1.2 to provide test data to the NRC.

3. PLANT SPECIFIC SUBMITTAL

A preliminary assessment of the adequacy of the overpressure protection system was submitted by AP&L on July 28, 1982 (Reference 10). An initial assessment of the Pressurizer Safety and Relief Valve Piping was transmitted November 30, 1982 (Reference 11). A request for additional information (Reference 12) was submitted to AP&L by the NRC on December 18, 1984. AP&L responded to this request on May 7, 1985 (Reference 13). A second request for additional information was sent to AP&L on January 8, 1987 (Reference 14), to which the Licensee responded on June 12, 1987 (Reference 15).

The response of the overpressure protection system to Anticipated Transients Without Scram (ATWS) and the operation of the system during feed and bleed decay heat removal are not considered in this review. Neither the Licensee nor the NRC have evaluated the performance of the system for these events.

4. REVIEW AND EVALUATION

4.1 Valves Tested

ANO-1 utilizes two safety valves, one PORV, and one block valve in the overpressure protection system. The safety valves are Dresser Model 31759A. The PORV is a Dresser Model 31533VX-30. Neither the safety valves or the PORV have loop seals. The block valve is a 2-1/2 in. Velan F9-454B-13MS gate valve with a Limitorque SMB-00-10 operator

The Dresser 31759A safety valve used at ANO-1 was not one of the valves tested by EPRI. The 31759A valve falls between the two valves tested, the 31739A and 31709NA, with respect to size. It is closer in size to the 31739A valve, the smaller of the two valves tested. The 31759A valve differs from the test valves in the size of the inlet and outlet flanges and in the orifice size. These differences do not affect valve operability. These considerations, and the fact that all Dresser valves are similar in configuration and design philosophy, indicate the test valves are representative of the ANO-1 valves.

The Dresser PORV installed at ANO-1 was originally a dash 1 (31533VX-30-1) design with a bore diameter of 1-3/32 in. The test valve was a dash 2 design with a bore size of 1-5/16. The dash 2 design resulted from a need to improve the seat tightness and included modifications to the internals, the body, and the inlet flange. The body and flange modifications were not of a nature that would affect operability. The ANO-1 valve was modified to incorporate the changes to the internals of the dash 2 design. The difference in bore diameter will only affect capacity and not operability. The test valve is, therefore, considered an adequate representation of the in-plant valve.

The Velan block valve used at ANO-1 is a 2 1/2 in. gate valve Model Number F9-454B-13MS, and has a Limitorque SMB-00-10 operator. Two Velan valves, both 3 in. gate valves, Model B10-3954-13MS, were tested by EPRI (Reference 9). One was tested with a Limitorque operator SB-00-15 and the other tested with a Limitorque operator SMB-000-10. The plant and test

valves are of the same style, internal design, and operation. They differ in size, pressure rating, and valve ends, which have no affect on operability. The 3 in. test valve requires a larger force to operate and the SMB-000-10 operator is a smaller operator with the same starting torque as the plant valve, so the tests with this operator on a 3 in. valve are a conservative demonstration of the operability of the plant valve. The block valve at ANO-1 is installed in a vertical position while the EPRI tests were performed with the valve in the horizontal position. Since the plant valve and the test valves are designed for use in either orientation, the horizontal tests are considered applicable to the vertical configuration.

Based on the above, the valves tested are considered to be applicable to the in-plant valves at ANO-1 and to have fulfilled that part of the criteria of Items 1 and 7 as identified in Section 1.2 regarding applicability of test valves.

4.2 Test Conditions

The valve inlet fluid conditions that bound the overpressure transients for B&W designed PWR plants are identified in Reference 7. The transients considered in this report include FSAR, extended high pressure injection (HPI), and cold overpressurization events. Reference 7 addresses those transients listed in Regulatory Guide 1.70, Rev. 2, which potentially challenge the PORV or safety valves in B&W plants. The conditions in the report that are applicable to ANO-1 are those identified for B&W 177-FA plants.

For the SRVs only steam discharge was calculated for FSAR type transients. The peak pressure was 2677 psia and the maximum pressurization rate was 175 psi/s. According to Reference 16, the maximum backpressure developed during FSAR accidents and transients for ANO-1 is 595 psia. Therefore the test on a Dresser 31739A valve with a peak backpressure of 617 psia bounds the maximum backpressure predicted to occur at ANO-1. Since ANO-1 does not have loop seals upstream of the SRVs, testing of the Dresser safety valves with the short inlet piping is applicable.

Six steam tests with a short inlet pipe were performed with the 31739A valve which had a peak pressure of 2703 psia and a peak pressurization rate of 333 psi/s. Tests with backpressures as high as 866 psia were run. With the larger 31709NA valve, five steam tests were run with a peak pressure and pressurization rate of 2697 psia and 322 psi/s, respectively. One test was run with a backpressure of 530 psia. These conditions bound those expected at ANO-1.

For extended HPI events the safety valve will initially open on steam with transition to subcooled water calculated. A peak pressure of 2515 psia was calculated with liquid temperatures ranging from 400 to 640°F. A peak liquid surge rate of 11,500 lbm/min at 640°F will occur. Pressurization rates from 0 to 65 psi/s are expected.

For the 31739A valve, testing included a steam to water transition test at 2489 psia and saturated conditions. Three water tests at pressures ranging from 2389 to 2749 psia and with water temperatures of 414 to 608°F were run. During these tests, the 31739A valve passed at least 1128 GPM (~80,000 lbm/min). For the 31709NA valve, the test series included two steam to water transition tests at pressures of 2530 and 2545 psia and saturated conditions and four water tests with temperatures from 415 to 625°F and pressures from 2393 to 2558 psia. During three of these tests, the 31709NA valve passed at least 1646 GPM (~11,666 lbm/min), during the fourth test, with 415°F water, the valve chattered and no data was obtained. The transition and water tests for both valves were run with pressurization rates from 1.8 to 3.2 psi/s. Although these represent the lower end of the range of pressurization rates calculated for B&W plants, they are adequate to represent expected inlet conditions at ANO-1. These conditions are sufficiently close to the conservatively selected bounding conditions to adequately demonstrate valve performance.

For the PORV, FSAR events result only in steam discharge. Although Reference 7 indicated the PORV should be tested at a peak pressure higher than the opening set point, 2465 psia, the valve opens quickly enough that the increase in pressure during the opening cycle is minimal. Additionally, the peak pressure listed in Reference 7 was based on an analysis in which the PORV was assumed to be inoperable. Testing with saturated steam at set pressure is, therefore, considered adequate. The Dresser PORV is a pilot operated valve and the back pressure developed at the outlet is of potential importance to valve operability. The ability of the valve to operate at backpressures at least as high as those expected in service should be demonstrated. The expected backpressure for the PORV was not reported by AP&L. However, the PORV discharge pipe routing is similar to the safety valves. The PORV rated flow, 119,000 lbm/hr, is 30% of the rated flow of the safety valve, 391,000 lbm/hr. The 4 inch discharge pipe of the PORV has approximately 44% the flow area of the 6 inch pipe for the safety valves. From these data the conclusion is reached that the expected backpressure for the PORV is less than the 595 psia which bounds the safety valve. Testing of the valve (Reference 8) included numerous steam tests with opening pressures close to the ANO-1 set pressure and backpressures as high as 760 psia which adequately bounds the expected conditions for the PORV.

For the extended HPI events, the initial opening of the PORV will be on steam but subcooled liquid could follow. HPI events can, therefore, result in steam to water transition and water (400 to 650°F) discharge at a maximum pressure of 2500 psia (Reference 7). A steam to water transition test and liquid tests with temperatures ranging from 447 to 647°F and pressures of approximately 2500 psia were included in the test series. The tests were run using the same discharge pipe orifice which developed backpressures as high as 450 to 500 psia for the steam tests so that the expected backpressure was adequately represented. The HPI events were, therefore, adequately represented by the tests.

The PORV is used for low temperature overpressure protection (LTOP). For LTOP events the valve is required to open on 565 psia steam. Reference 7 indicates transition and water flow will not occur at ANO-1 during cold overpressurization events. Opening on steam is considered to be adequately represented by the full pressure steam tests discussed above.

For the block valve only full pressure steam, 2480 psia, tests were performed (Reference 9). The block valve, however, is required to open and close over a range of steam and water conditions. The required torque to open or close the valve depends almost entirely on the differential pressure across the valve disk and is rather insensitive to the momentum loading and, therefore, is nearly the same for water or steam and nearly independent of the flow. The full pressure steam tests, therefore, are adequate to demonstrate operability of the valve for low pressure steam and the required water conditions.

The test sequences and analyses described above, demonstrating that the test conditions bounded the conditions for the plant valves, verify that Items 2 and 4 of Section 1.2 were met, in that conditions for the operational occurrences were determined and the highest predicted pressures were chosen for the test. The part of Item 7, which requires showing that the test conditions are equivalent to conditions prescribed in the FSAR, is also met.

4.3 Determination of Safety Valve Ring Settings at Arkansas Nuclear One - Unit 1

Determination of the applicability of a particular EPRI test to a plant submittal usually included a comparison of the plant valve ring settings to the ring settings used in the test. This comparison was needed to assure the plant valve will respond in a manner similar to that observed in the test. This comparison was not made in Section 4.2 because of the different approach used by AP&L in the ANO-1 submittal. For ANO-1 the setting for the middle ring, which controls most of the important valve performance

parameters in Dresser valves, was determined by use of the COUPLE code (References 16 and 17). COUPLE was developed during the EPRI tests by Continuum Dynamics, Inc. (CDI) to model the dynamics of spring loaded safety valves like the Dresser valves. In Reference 16, COUPLE was shown to reliably predict the valve performance observed during the EPRI tests for both Dresser valves tested as a function of the middle ring setting.

The ability of the COUPLE code to determine a middle ring setting which results in acceptable valve performance was also independently assessed. The GPU Nuclear submittal for Three Mile Island, Unit 1 (TMI-1) used COUPLE to determine the middle ring setting for the Dresser 31739A safety valves used at TMI-1. The Dresser 31739A valve was one of the valves tested by EPRI. Review of the EPRI test results showed that for tests where the middle ring setting bounded that determined by COUPLE for the TMI-1 valves, the 31739A valve had stable performance, passed rated flow, and closed with a reasonable blowdown under conditions similar to those expected at TMI-1 (Reference 18). Therefore, it was concluded the COUPLE code can be used to determine a middle ring setting for Dresser valves which will result in acceptable valve performance.

The ring settings selected for the 31759A valves at ANO-1 were: upper = -48, middle = -93, and lower = +8. The rationale for these settings was discussed in the Rancho Seco Unit 1 submittal by Sacramento Municipal Utilities District (SMUD) in References 19 and 20. Since the Rancho Seco and ANO-1 safety valves and ring settings are the same, it was concluded a similar approach to determining the ring setting was used by the two plants. The upper setting was the same as that used in all the EPRI tests. EPRI testing showed the upper ring in the Dresser design did not have a significant influence on valve performance. The lower ring setting is set to give the quick popping action of the valve as it opens. This ring is usually set when the valve is cold. Setting of the lower ring at +8 when the valve is cold will ensure the lower ring does not expand on heating and contact the disc holder forcing the valve open. It will also put the lower ring a nominal eight notches above the seat. Dresser feels this is adequate for correct operation (Reference 21). Also EPRI tests used lower ring

settings from -13 to +11 which bound the ANO-1 setting. The middle ring setting of -93 was selected based on the most negative middle ring position actually tested with the 31739A valve during EPRI tests. This value was -80 notches from one test, Number 1008. The -93 setting for the 31759A valve corresponds to the same scaled geometric position as -80 for the 31739A valve. As will be shown in Section 4.4, this ring setting resulted in acceptable valve performance as determined by COUPLE.

4.4 Valve Operability

As discussed above, the middle ring setting for the Dresser 31759A valves used at ANO-1 was determined using the COUPLE code. Use of COUPLE to determine valve ring settings and consequent valve performance is considered an acceptable approach for the reasons discussed above.

COUPLE analyses of the ANO-1 valve for steam discharge (Reference 16) showed the valve was stable, achieved 85.4% of rated lift, and passed 100% of rated flow. Valve blowdown was calculated to be 8.6%. The COUPLE analysis indicated that system pressure had to reach 7% accumulation before the lift and flow results noted above could be achieved because of the high backpressure at the plant. Error bounds on the COUPLE results reported in Reference 16 were blowdown, -1.9%, +2.1%, overprediction of stem lift by 2.4%, and underprediction of mass flow rate by 13.9% for the EPRI test data. Plant valve performance within the error bounds of the COUPLE analysis is considered adequate.

The ANO-1 submittal identified one EPRI test as applicable to the plant valves to support the assertion that acceptable valve performance will result with the COUPLE determined ring setting. This was test 1008 run with the smaller 31739A valve. The middle ring setting in test 1008 was the one selected to set the middle ring in the ANO-1 valve. This test was a steam discharge test with a peak pressure of 2680 psia, 275 psi/s pressurization rate, and 617 psia backpressure. This test was run with the long inlet pipe used to characterize loop-seal plants, but this configuration conservatively

bounds the ANO-1 SRV installation without loop seals. In this test the 31739A valve opened within ±3% of the set pressure, reached 80% of rated lift, and passed 111% of rated flow at 3% accumulation. The peak backpressure during this test was 617 psia which exceeds the maximum predicted backpressure of 595 psia for ANO-1. The valve closed with 14.2% blowdown. During the test the valve had stable performance. It should also be noted that during test 618 with the larger 31709NA valve, 123% of rated flow and 101% lift were achieved at 3% accumulation with a peak backpressure of 530 psia. This performance is considered acceptable and provides additional support to the validity of the COUPLE analysis, and shows that the ANO-1 31759A valve will achieve at least rated flow at 3% accumulation.

Additional support for acceptable valve performance during steam discharge is found in Reference 18. This reference reviewed EPRI test results of the Dresser 31739A valve to determine if the test valve gave acceptable results with ring settings similar to those used with the 31739A valves at the TMI-1. As noted in Section 4.3, the ring settings at TMI-1 were also determined with COUPLE. This review is relevant because ANO-1 and TMI-1 are both B&W 177-FA plants and the SRV inlet conditions identified in Reference 7 are the same for both plants. Reference 18 found the test valve gave acceptable performance during steam discharge tests with middle ring settings that bounded those determined by COUPLE for the plant valve. Therefore, it can be concluded acceptable performance for the nontested 31759A valve at ANO-1 will also result with the COUPLE determined ring setting.

As noted in Section 4.2, possible inlet conditions for the safety valves include steam to water transition and water flow. Direct evidence was not provided in the submittal to demonstrate acceptable valve performance with the plant ring settings and transition and water inlet conditions. Indirect evidence is available from several sources that indicates the 31759A valves at ANO-1 will give acceptable performance under these inlet conditions. First, as noted in Reference 13, unstable behavior was uncommon with the Dresser valves tested. Dresser valves only chattered during four tests out of 47. For the 31739A valve, the two unstable tests

were on the long inlet pipe configuration. Therefore, these tests are not applicable to ANO-1. For the 31709NA valve, one test was run in a loop seal configuration the other was a 429°F water test. The 429°F water test is applicable to ANO-1. The test was run with the short inlet configuration and the water temperature was representative of a steam line break at ANO-1. During the test the valve opened and chattered for ~3 s before stabilizing, without manual actuation, and then closed. After the test the valve was disassembled and inspected. Galled guiding surfaces were found and several damaged internal parts were found. Based on this performance, AP&L should inspect the SRVs after any lift involving water discharge at temperatures below 550°F to ensure continued operability of the in-plant valves.

Additional support is found in the supplement to the TMI-1 TER noted above (Reference 18). Reference 18 found that in EPRI transition and water tests with ring settings bounding those at TMI-1, the 31739A valve gave acceptable performance. The transition and subcooled water inlet conditions tested were similar to those expected at ANO-1. Therefore it is concluded that the 31759A valve at ANO-1, with a middle ring setting determined with COUPLE, will have acceptable valve behavior with transition and subcooled water inlet conditions.

Blowdown for the Dresser safety valves tested by EPRI ranged from 4.7% to 20.2% so that the measured blowdown generally exceeded the design blowdown of 5%. A B&W analysis (Reference 22) showed blowdown up to 20% does not impede natural circulation due to hot leg voiding. Therefore, having the observed blowdown exceed the design blowdown is considered acceptable.

The maximum bending moments applied to the discharge flanges of the test valves were 241,730 in.-lbs (31739A) and 473,000 in.-lbs (31709NA). Valve operability was not impaired by the application of these moments. The maximum expected moment at the plant for the 31759A valve is 54,800 in.-lbs. Application of a larger moment in the EPRI tests to the smaller 31739A valve indicates the tests bound the expected plant condition.

For the test performance to be a valid demonstration of plant safety valve stability, the test inlet piping must have a pressure difference at least as great as the plant. The plant valves are mounted directly on a pressurizer nozzle and thus have the minimum pressure drop possible. The test piping included a venturi and a reducing flange and, therefore, a higher pressure difference.

During the 414°F water test the 31739A valve was stable but only achieved partial lift. The valve did not pass enough flow to prevent the test pressure from accumulating. SMUD, in its submittal, pointed out that the flow the 31739A valve passed (which is smaller than the 31759A valves at ANO-1) was 30% more than required for the steam line break (which results in the 400°F liquid flow case). In addition there are two safety valves at the plant, which gives ANO-1 more than sufficient relief capacity. Under conditions typical of the FWLB, 2515 psia, water flow at temperatures of 602 and 640°F, the 31739A test valve on the short inlet configuration passed -20% less (602°F) and -7% less (640°F) than the required flow. ANO-1 does have sufficient relief capacity at these conditions, however, because the plant valve is larger than the test valve, the measured flow was at a pressure less than the 2515 psia used to determine the maximum surge rate in the analysis, and, as noted above, two valves are installed at the plant.

Based on the code and test results discussed above, and the requirement that AP&L shall inspect the SRVs as noted above, demonstration of safety valve operability is considered adequate.

The Dresser PORV opened and closed on demand for all nonloop seal tests. Inspection of the valve after testing at the Marshall Steam Station showed the bellows had several welds partially fail. The failure did not affect valve performance and the manufacturer concluded the failure did not have a potential impact on valve performance. The bellows was replaced and

did not fail during any of the additional test series. A bending moment of 25,500 in.-lbs was induced on the discharge flange of the test valve without impairing operability. The maximum bending moment calculated for the ANO-1 PORV is 16,599 in.-lbs. The EPRI tests, therefore, bound the expected plant condition.

The ANO-1 PORV is a pilot operated valve that uses system pressure to hold the disk tight against the seat. At one point Dresser Industries recommended the block valve be closed at system pressures below 1000 psig to avoid steam wirecutting of the PORV disk and seat. Testing by Dresser later showed the 1000 psig pressure limit to be overly conservative and that the PORV as designed was qualified to system pressures of 100 psig. Below 100 psig the deadweight of the lever on the pilot valve was sufficient to keep the pilot valve open. Dresser recommends that heavier springs be used under the main and pilot disks to ensure closure if the plant is to operate below 100 psig. AP&L stated in Reference 15 that the heavier springs will be installed during the next refueling outage.

Based on the valve performance during EPRI tests, under the full range of expected inlet conditions, and the Licensees commitment to install the heavier springs in the ANO-1 PORV, the demonstration of relief valve operability is considered adequate.

The PORV block valve must be capable of closing over a range of steam and water conditions. As described in Section 4.2, high pressure steam tests are adequate to bound operation over the full range of inlet conditions and as described in Section 4.1, the tests with the 3 in. Velan valve and SMB-000-10 operator conservatively demonstrate the operability of the plant valve. The test valve was cycled successfully at full steam pressure with full flow. It was shown to open and close successfully with torques as low as 82 ft-lbs (Reference 9). In Reference 15, the Licensee stated that the PORV block valve operator torque switch is set to produce a closing torque of 141 ft-lbs which is sufficient to close the valve under all operating and accident conditions.

NUREG-0737 II.D.1 requires qualification of associated control circuitry for the harsh environments the PORV will be exposed to during the accidents and transients listed in Regulatory Guide 1.70, Rev. 2, as part of the safety/relief valve qualification. The Nuclear Regulatory Commission staff agreed, however, that meeting the licensing requirements of 10CFR50.49 for this electrical equipment would satisfy the requirements of NUREG-0737, Item II.D.1. In Reference 13 AP&L stated that the PORV control circuitry was not environmentally qualified and further stated that they did not believe the NRC intended the PORV circuitry to be qualified under 10CFR50.49. In Reference 15, AP&L stated the issue of environmental qualification was thoroughly addressed by the NRC under 10CFR50.49. This included NRC review of several lists of equipment required to be environmentally qualified under 10CFR50.49, lists that did not include the PORV control circuitry. AP&L stated that the determination was made that the environmental qualification of the PORV control circuitry was more than adequate considering a PORV system configuration which includes an environmentally qualified PORV block valve and an environmentally qualified indication of PORV position. This configuration ensures the capability to detect and isolate a stuck open PORV. AP&L noted the PORV is not relied upon for overpressure protection because the safety valves provide the capability to protect the plant from overpressurization. Also, AP&L stated a failure of the PORV control circuitry as a result of exposure to a harsh environment would not cause the PORV to inadvertently open and if the valve was open, failure of the control circuitry would result in the valve closing. If the valve should stick open after a control circuitry failure, the environmentally qualified PORV position indicator and PORV block valve would make the operator aware of the situation and provide him with the capability to isolate the valve. Therefore, it can be concluded that the ANO-1 PORV circuitry meets the qualification requirements of NUREG-0737 Item II.D.1.

The presentation above demonstrates that the valves operated satisfactorily, verifying that the portion of Item 1 of Section 1.2 that requires conducting tests to qualify the valves, Item 5 of Section 1.2 that requires qualification of PORV circuitry, and that part of Item 7 requiring that the effect of discharge piping on operability be considered were met.

4.5 Piping and Support Evaluation

In the piping and support evaluation, the safety/relief valve piping between the valve discharge flanges and the pressurizer relief tank were analyzed for the requirements of the ASME, Section III, Code. The pipe supports were analyzed for the requirements of the AISC Code, 1978. The load combinations and acceptance criteria for piping were equivalent to those recommended by the EPRI piping subcommittee as presented in Reference 23 and meet the NUREG-0800, Section 3.8.4, standard.

The transient conditions analyzed were based on Reference 7 and included discharge of saturated steam or 400°F water at assumed valve opening pressures of 2575 psig (saturated steam) and 2500 psig (400°F water) for the SRVs and 2500 psig (saturated steam and 400°F water) for the PORV. For the saturated steam analyses a pressurization rate of 175 psi/s was assumed in ramping the pressurizer pressure from the set point to the maximum pressure (SRVs open--2662 psig, PORV open--2575 psig). The forces generated from these conditions bound those from all other conditions expected at the plant.

The thermal-hydraulic analysis was performed with the program RELAP5-FORCE. RELAP5-FORCE is a UCCEL, Corp. version of RELAP5/MOD1, Cycle 14, which was modified to include the capability to compute the hydraulic force on each pipe segment. The Licensee stated that verification showed that RELAP5-FORCE preserves the results from RELAP5. Preserving the RELAP5 results with RELAP5-FORCE indicates that the basic code was maintained and the RELAP5 verification work in Reference 24 applies to RELAP5-FORCE to show it is a suitable tool for calculation of valve discharge transients. Furthermore, the ability of RELAP5-FORCE to calculate pipe segment forces was verified through simulations of EPRI/CE SRV tests, and Edward's and Hanson's blowdown experiments (Reference 15).

Details of the RELAP5-FORCE model for the safety and relief valve piping from the valve discharge to the relief tank were provided in Reference 15. In the piping model, the key parameters of time step size, choked flow locations, and valve opening times were reviewed and found to be

acceptable. Because of computer limitations, AP&L stated that a coarser nodalization than recommended in Reference 24 was used in the RELAP-FORCE model of the ANO-1 piping system. To account for the coarse nodalization, a nodalization study was performed to develop force intensification factors for those pipe segments with less than the recommended number of nodes. The intensification factors were applied as multipliers to the tabulated force time histories when these force time histories were input to the structural program. This approach to overcoming nodalization limitations was reviewed and accepted in the Rancho Seco, Unit 1, submittal (Reference 25). To account for uncertainties in valve flow rates, the valve flow area and therefore the flow rate in the piping analysis must be conservatively adjusted. In Reference 13, AP&L stated that a conservative factor of 1.15 was included in the maximum rated valve mass flow rate for the PORV and SRVs. The conservative valve flow rates used in the analysis acceptably account for 10% ASME derating and potential error in the flow rate.

The Licensee stated that the thermal hydraulic analysis for each individual valve and associated discharge piping was performed separately. The effects of simultaneous (or nearly simultaneous) actuation of the valves were considered in the structural analysis.

The piping structural analysis was performed using NUTECH, Inc.'s, computer program PISTAR. The analytical solutions used in PISTAR are based on the well known public domain program SAPIV developed by the University of California at Berkeley. The Licensee stated that PISTAR was verified by comparing computer solutions from PISTAR for a series of benchmark problems to that obtained from manual calculations or other computer programs such as ANSYS and EPIPE. The support loads were analyzed statically using hand calculations and computer programs. The computer programs used in the support analysis were GENSAP, BASEPLATE II, and STARDYNE. GENSAP performs the static analysis of elastic structures. GENSAP was verified in a manner similar to that discussed for PISTAR. BASEPLATE II and STARDYNE together are used to perform the non-linear flexible analysis of baseplates. These programs are available through Control Data Corporation (CDC) and are on the CDC list of safety related computer programs. The Licensee provided

information on the verification of the CDC programs used in the support analysis in Reference 15. This information demonstrated the programs used in the support analysis gave accurate results.

The key parameters of lumped mass spacing and damping were provided in Reference 15. The lumped mass spacing used in the structural model was that required to obtain accurate dynamic responses of the piping system up to 50 Hz cut-off frequency. For earthquake conditions, the damping values were those defined in the FSAR, i. e. 0.5%. For the valve discharge cases, the structural damping values (1% for PORV discharge and 2% for safety valve discharge) were obtained from NRC Regulatory Guide 1.61 and were based on the diameter of the piping and the anticipated stress levels for the loading conditions. The key parameters used are acceptable.

As noted above the thermal-hydraulics analysis for each SRV and PORV discharge line was performed separately. In the structural analyses, the discharge loads calculated from the thermal-hydraulic analysis were applied independently to each discharge piping system. The individual pipe responses were then combined absolutely to obtain the total response of the piping system due to the discharge loads. This ensures that the responses obtained would bound any sequence of valve actuation.

According to the Licensee, the results of the piping and support analysis identified a number of locations where piping and support modifications were needed to relieve overstressed locations. To correct the piping overstress condition, AP&L added or relocated several supports to reduce stresses to within allowable limits. Where support stresses or loads exceeded allowables, appropriate modifications were made. With the modifications to the support and piping systems, all stresses and loads are within their allowables. In the modified system, the maximum calculated piping stress was 18,543 psi versus an allowable stress of 26,028 psi (load combination P-3). AP&L stated the necessary modifications to the piping and support systems were made during the Cycle 5 refueling outage in early 1983.

The selection of a bounding case for the piping evaluation and the piping and support stress analysis, demonstrates that the requirements of Items 3 and 8 of Section 1.2 outlined in this report were met.

5. EVALUATION SUMMARY

The Licensee for ANO-1 provided an acceptable response to the requirements of NUREG-0737, which reconfirms that the General Design Criteria 14, 15, and 30 of Appendix A to 10 CFR 50 were met with regard to the safety valves and PORV. The rationale for this conclusion is given below.

The Licensee participated in the development and execution of an acceptable relief and safety valve test program to quality the operability of prototypical valves and to demonstrate that their operation would not invalidate the integrity of the associated equipment and piping. The subsequent tests were successfully completed under operating conditions which, by analysis, bound the most probable maximum forces expected from anticipated design basis events. The test results showed that the valves tested functioned correctly and safely for all steam and water discharge events specified in the test program that were applicable to ANO Unit 1 and that the pressure boundary component design criteria were not exceeded. Analysis and review of both the test results and the Licensee justifications indicated the performance of the prototypical valves and piping can be extended to the in-plant valves and piping. The plant-specific piping also was shown by analysis to be acceptable.

The requirements of Item II.D.1 of NUREG-0737 (Items 1-8 in Paragraph 1.2) which ensure that the reactor primary coolant pressure boundary will have a low probability of abnormal leakage (General Design Criterion No. 14) were met. In addition, the reactor primary coolant pressure boundary and its associated components (piping, valves and supports) were designed with sufficient margin so that design conditions are not exceeded during relief/safety valve events (General Design Criterion No. 15). Further, the prototypical tests and the successful performance of the valves and associated components demonstrated that this equipment was constructed in accordance with high quality standards, meeting General Design Criterion No. 30.

Based on the performance of the Dresser 31709NA safety valve during test 1311 (a test with 429°F water during which the valve chattered), AP&L should inspect and refurbish the safety valves following any water discharge with a temperature lower than 550°F.

Dated:

Principal Contributor: G. Hammer

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