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TECHNICAL EVALUATION REPORT OF THE OVERPRESSURE PROTECTION SYSTEM FOR ARKANSAS NUCLEAR ONE, UNIT 1

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TECHNICAL EVALUATION REPORT OF THE OVERPRESSURE PROTECTION SYSTEM FOR ARKANSAS NUCLEAR ONE, UNIT 1

July 1982

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ABSTRACT

This report documents the technical evaluation of the low temperature overpressure protection system of the Arkansas Nuclear One, Unit 1. The criteria used to evaluate the acceptability of the system are those criteria contained in NUREG-0224 as appended by the Branch Technical Position (RSB 5-2).

FOREWORD

This report is supplied as part of the "Steam Generator Transients and Operating Reactors Evaluation for Reactor Systems Branch" being conducted for the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Division of Systems Integration, by EG&G Idaho, Inc., Reliability and Statistics Branch.

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Steam Generator Transients and Operating
Reactors Evaluation for Reactor Systems Branch
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TECHNICAL EVALUATION REPORT OF
THE OVERPRESSURE PROTECTION SYSTEM
FOR
ARKANSAS NUCLEAR ONE, UNIT 1

1. INTRODUCTION

Several instances of reactor vessel overpressurization have occurred in pressurized water reactors in which the technical specifications implementing Appendix G to 10 CFR Part 50 have been exceeded. The majority of cases have occurred during cold shutdown while the primary system was in a water-solid condition. By letter to the Arkansas Power and Light Company (AP&L), owner and operator of Arkansas Nuclear One, Unit 1 (ANO-1), dated August 13, 1976 (Reference 1), the U.S. Nuclear Regulatory Commission (NRC) requested an evaluation of ANO-1 to determine susceptibility to overpressurization events and an analysis of these possible events, and required AP&L to propose interim and permanent modifications to the systems and procedures to reduce the likelihood and consequences of such events.

By letter dated November 15, 1976 (Reference 3), AP&L submitted to the NRC the interim measures that they had taken to minimize the probability of a low temperature-overpressure transient at ANO-1. For plants where Babcock & Wilcox (B&W) is the Nuclear Steam System Supplier (NSSS), a primary factor concerning overpressure protection is that they always (except during hydro tests) maintain a steam or gas volume in the pressurizer which retards the pressure increase and allows time for operators to take action to terminate the pressure increase prior to exceeding any limits. On December 3, 1976, AP&L submitted their final hardware change (Reference 6) along with an attached B&W Generic Analysis. The final hardware change involved the installation of a dual setpoint on the pressurizer pilot actuated relief valve (PORV). This dual setpoint feature will enable the setpoint of the PORV to be reduced to 550 psig upon reducing the reactor coolant system pressure to 525 psig and system temperature to 280°F. The NRC asked AP&L to answer further questions on their proposed Overpressure Protection System (Reference 8 and 12), and AP&L responded to these questions and proposed additional modifications in their subsequent submittals (Reference 10 and 13).

This is a report of the evaluation of the compliance of the licensee's Overpressure Protection System with the design criteria established by the NRC.

2. DESIGN CRITERIA

The NRC formally addressed reactor vessel overpressurization in August 1976 and requested that the utilities provide a solution to the problem. The design criteria were subsequently identified through meetings and correspondence with utility representatives. NUREG-0224, "Reactor Vessel Pressure Transient Protection for Pressurized Water Reactors" with appended Branch Technical Position (RSB 5-2) formalizes the staff requirements for the overpressure mitigating system. This NUREG also includes a thorough discussion of the background of this problem and technical discussions pertaining to vessel stresses and other aspects of vessel overpressurization.

3. SYSTEM DESCRIPTION AND EVALUATION

The ANO-1 Overpressure Protection System consists of both an active and a passive subsystem. The active subsystem utilizes the pressurizer pilot actuated relief valve (PORV) which provides high pressure protection during normal plant operation. The PORV actuation circuitry has been modified to provide a second setpoint (550 psig) that is used during low temperature operations. The low setpoint is manually enabled at 280°F by positioning a key-operated switch in the Reactor Control Room. An alarm will sound in the Reactor Control Room if the reactor coolant temperature falls below 280°F and the key-operated switch is not selected for low temperature operation or the PORV isolation valve is not open. The passive subsystem is based on the plant design and operating philosophy that prevents the plant from being in a water solid condition (except for system hydrotests). The ANO-1 Reactor Coolant System always operates with a steam or gas space in the pressurizer; the steam bubble is replaced with nitrogen during plant cooldown when system pressure is reduced. The vapor space in the pressurizer greatly retards the increase in RCS pressure, as compared to a water solid system, for all mass and heat input transients. Retarding the rate of pressure increase during transients provides the operator with time to recognize that a pressure transient is in progress and take action to mitigate the transient.

3.1 Pilot Actuated Relief Valve

The pilot actuated relief valve is an electromatic valve that uses system pressure, controlled by an electric solenoid valve, to a pilot mechanism to open the valve and a spring to close it. Characteristics of this valve at the lower setpoint are:

Open setpoint	550 psig
Close setpoint	500 psig
Steam capacity at 550 psig	25,985 lb/hr
Equivalent liquid insurge rate	2,650 gpm
Liquid capacity at 550 psig	500 gpm
Nitrogen capacity at 550 psig	32,420 lb/hr
Equivalent liquid insurge rate	2,350 gpm

3.2 Electrical Controls

The electrical, instrumentation, and control system aspects of the Arkansas Nuclear One, Unit 1 low temperature overpressure protection system have been reviewed and reported in a separate technical evaluation (Reference 19).

3.3 Testability

The staff position requires that a test be performed to assure operability of the system electronics prior to each shutdown and that a test for valve operability, as a minimum, be conducted as specified in the ASME Code Section XI. The ANO-1 pilot actuated relief valve can be tested during the plant cooldown to demonstrate its operational capability. This can be done by either (1) opening and closing the valve using the remote controls in the control room, or (2) with the lower setpoint enabled, input a simulated high pressure signal to confirm that the valve automatically opens at the lower setpoint.

We conclude that the ANO-1 OPS meets the testability criteria except that there are insufficient administrative controls to implement the testing procedures and schedule. When adequate technical specifications are submitted and approved as discussed in Section 4.2, the ANO-1 OPS will completely satisfy the testability criteria.

3.4 Single Failure Criteria

The specified single failure criteria for the overpressure mitigating system is that it should be designed to protect the vessel given a single failure in addition to the failure that initiated the pressure transient. ANO-1 meets this criteria for all events that were evaluated except for an inadvertent actuation of the High Pressure Injection System (HPI). For an inadvertent HPI actuation, with the failure of the PORV being the single active failure, the 10 CFR 50 Appendix G limit would be exceeded in approximately 4.5 minutes. The staff position is that no credit can be taken for operator action until 10 minutes after the operator is aware that a pressure transient is in progress. This event does not provide sufficient time for operator action to terminate the transient prior to exceeding the pressure limit.

The two sub-systems (or methods) of the ANO-1 Overpressure Protection System are sufficiently independent and diverse so that there is no known failure mode which could defeat both subsystems. A loss of offsite power will not affect the pressurizer steam bubble or the operator's action ability. A loss of off-site power also will not affect operation of the pilot actuated relieve valve. Power for the instrumentation which controls the pilot actuated relief valve and other parameter indications and alarms will be supplied either by the diesel generator or storage batteries during a loss of offsite power. A seismic event will not affect the pressurizer steam bubble or the operator's action ability. A seismic event also should not affect operation of the pilot actuated relief valve (refer to Section 3.5 for further discussion).

The most limiting failure for the ANO-1 OPS is failure of the single PORV. Given this failure, the steam or gas volume in the pressurizer provides a time delay before the pressure increases to the Appendix G limit. This time period would be greater than 10 minutes, which meets the staff position for taking credit for operator action to terminate the pressure transient, for all events analyzed except for the inadvertent HPI actuation discussed above. AP&L states that they have procedural and administrative controls that make an inadvertent HPI actuation an incredible event at ANO-1. These include: (a) bypassing the Engineered Safeguard Actuation of the HPI System at 1650 psig, (b) locking out and tagging the circuit breakers for the four HPI motor operated valves with the valves in the closed position prior to going below 280°F, and (c) securing and locking out the operating makeup pump, as soon as the remaining reactor coolant pumps are shut down, to reduce the time the makeup pump is running while the plant is less than 280°F. An alarm will actuate in the control room if RCS pressure drops below 1650 psig and the operator has not bypassed the ES signal to the HPI during cooldown. Also, an alarm will sound in the control room if the RCS temperature drops below 280°F and any of the four HP injection valve breakers has not been locked out.

We conclude that ANO-1 meets the staff single failure criteria for all events except for inadvertent HPI actuatio . We also conclude that the criteria will be satisfied for inadvertant HPI actuation if acceptable Technical Specifications are submitted that require that the three steps mentioned in the previous paragraph are implemented. AP&L is presently preparing a Technical Specification submittal on this subject.

3.5 Seismic Design

The specified seismic criteria is that the Overpressure Protection System should be designed to function during an Operating Basis Earthquake (OBE). Detailed stress analyses have been performed for the pilot actuated relief valve in accordance with ASME Section III, Class 1 requirements. The valve design has been found to be adequate for Class 1 application. Stresses are shown to be within the allowables as specified in ASME Section III, 1971 Edition. Through conservative calculations, the natural frequency is shown to be greater than 500 Hz, well above seismic excitation frequencies, and the maximum axial plus bending stress in the pilot assembly connection pipe due to seismic motion of 3.0 g horizontal and 3.0 g vertical is significantly lower than the allowable. Testing with simulated seismic loadings has not been performed as this was not a requirement at the time this plant was designed and constructed.

We conclude that the ANO-1 Overpressure Protection System meets the seismic criteria. Even if it is assumed that the relief valve, connection pipe, or actuation circuitry failed due to a seismic event, the nitrogen blanket in the pressurizer and the control room operator would provide protection for postulated low temperature overpressure events.

3.6 Analysis Results

The analyses are divided into two general categories of pressure transients: mass input from sources such as charging pumps, safety injection pumps, and core flood tanks; and heat input, which causes thermal expansion, from sources such as steam generators and decay heat. All events involving insurge to the pressurizer were evaluated with the pressurizer and makeup tank initially at high water levels. For the pressurizer, an initial water level at the high level alarm setpoint was used for initial pressures above 100 psig and an initial water level at the high high alarm setpoint was used for an initial pressure of 100 psig or below. The relationship of these levels to the other pressurizer water level setpoints is:

0-320 in.	Level indicating range
275 in.	High high level alarm
220 in.	High level alarm
180 in.	Normal level
160 in.	Low level alarm
40 in.	Low level interlock (heater cut-out) and alarm

The initial pressurizer level used for the event does not affect the peak pressure reached; it only affects the rate of pressure increase. For the makeup tank, which is the normal suction source for the makeup/HPI pump, a water level at the high level alarm setpoint was used. The relationship of this level to the other makeup tank level setpoints is:

0-100 in.	Level indicating range
86 in.	High level alarm
73 in.	Normal level
55 in.	Low level alarm

3.6.1 Mass Input Cases

The mass input events analyzed in the B&W Generic Analysis are:

a. Makeup control valve (makeup to the RCS) fails full open.

b. Erroneous opening of the core flood tank discharge valve.

c. Erroneous actuation of the High Pressure Injection (HPI) System.

d. Erroneous addition of nitrogen to the pressurizer.

AP&L subsequently re-evaluated some of these events using plant specific parameters and more realistic conditions.

According to the AP&L submittals, the most limiting credible mass input transient results from failure full open of the makeup control valve. The makeup control valve is used to regulate the makeup flow rate to the RCS and is normally automatically controlled by the pressurizer level controller. If this valve failed full open, the makeup flow would exceed the letdown flow which would result in an increase in the pressurizer level and RCS pressure. The pressure response for this event has been evaluated using the computer code DYSID with the following assumptions and initial conditions.

a. 220 in. pressurizer water level for 250 psig initial pressure.

b. 275 in. pressurizer water level for 100 psig initial pressure.

c. 86 in. makeup tank water level.

d. 32 gpm total seal injection flow to RC pumps.

e. 45 gpm letdown flow from the RCS to the makeup tank.

f. No spray into the pressurizer (normally there would be spray during cooldown).

The DYSID Code analysis showed that, assuming no operator action, the RCS pressure would increase to 550 psig in approximately 10.5 minutes at which time the pressurizer pilot actuated relief valve would lift to reduce the system pressure. System pressure overshoot, the pressure increase after reaching the PORV setpoint of 550 psig, is almost nonexistent due to the rapid action of the electromatic PORV and the relatively slow rate of pressure increase due to the steam or nitrogen volume in the pressurizer.

For the transient that would result from the makeup valve failing full open, the most limiting single failure is a failure of the single PORV. Given this failure, the steam or nitrogen volume in the pressurizer will allow at least 10 minutes after the operator is alerted to the problem by the makeup line high flow alarm before the pressure reaches the Appendix G limit.

AP&L also evaluated the remaining three mass input mechanisms. They stated that inadvertent opening of a core flood tank discharge valve and inadvertent actuation of the HPI system are not credible events due to the administrative controls established and the low probability chain of events required to initiate the transients. The administrative controls in use to prevent an inadvertent HPI actuation are discussed in Sections 3.4 and 4.0. AP&L considers inadvertent opening of a core flood tank discharge valve not credible because the valves are closed and the circuit breakers for the motor operators are "racked out" during the plant cooldown before the RCS pressure is decreased to 600 psig. The analysis shows that the final RCS pressure for this event is 450 psig which is less than the 550 psig limit. The erroneous addition of nitrogen to the pressurizer does not pose a threat due to the 50 psig regulator used in the system and the relief valve, set at 75 psig, that provides protection in the event of a regulator failure.

We conclude that the ANO-1 Overpressure Protection System will adequately mitigate all mass input cases except the inadvertent actuation of the HPI system. As discussed in Section 3.4 of this report, the ANO-1 system may be judged acceptable if adequate technical specifications are submitted and approved implementing the necessary controls that minimize the probability of an inadvertent initiation of the HPI system and minimize the probability of exceeding the bounding conditions utilized in the analysis.

3.6.2 Heat Input Cases

The three events analyzed that involve heat input into the primary coolant system are:

a. All pressurizer heaters erroneously energized.

b. Temporary loss of the Decay Heat Removal System's capability to remove decay heat from the RCS.

c. Thermal expansion of RCS after starting an RC pump due to stored thermal energy in the steam generator.

Of these three events, only one, temporary loss of the Decay Heat Removal System's capability to remove decay heat, could credibly result in exceeding a pressure limit. All pressurizer heaters erroneously energized is not a significant hazard because of the slow rate of pressure increase. Even with the worst case initial conditions such as a pressurizer level of 50 inches, the rate of pressure increase is so slow that 550 psig is not reached until 52.5 minutes after energizing the heaters. This time period should be adequate to allow the control room operator to recognize that a pressure transient is occurring and terminate it by de-energizing the heaters.

In the analysis of thermal expansion of the RCS after starting an RC pump due to stored thermal energy in the steam generator, AP&L reported on the evaluation of two specific conditions:

a. Filling of the once through steam generator (OTSG) secondary side with hot water with subsequent start of an RC pump, and

b. Restart of an RC pump during heatup following a period of stagnant (no flow) conditions.

The results of these analyses using conservative initial conditions are a maximum pressure of 430 psig for case "a" and 523 psig for case "b". These values are below the PORV setpoint of 550 psig. Other conditions of primary and secondary temperatures which may exist prior to starting an RC pump have been evaluated and are bounded by the above analyses.

A loss of the Decay Heat Removal (DHR) System capability could be caused by loss of flow in the DHR system or in the cooling water system serving the DHR system. A loss of DHR System capability was analyzed using the following conditions:

a. Event occurs during plant cooldown after shutdown of steam generators.

b. Pressurizer level at 275 inches (high high level alarm).

c. All decay heat absorbed by reactor coolant, no heat absorbed by the metal components or by the steam generators.

d. 32 gpm total seal injection to RC pumps.

e. 45 gpm initial letdown from RCS to makeup tank.

f. No spray into the pressurizer.

g. Cooldown rate of 100°F/hr until DHR system "cut-in" temperature, this produces the maximum decay heat generation rate.

The analysis determined that if no operator action were taken the RCS pressure would increase to the PORV setpoint in approximately 15.7 minutes. At that point, the PORV should open and limit the RCS pressure to 550 psig. Given a failure of the pressurizer PORV, the 15.7 minutes should be sufficient time to allow the operator to detect the problem and take action to correct it. The operator should be alerted to the loss of DHR capability by a flow alarm indicating either a loss of flow in the DHR System or a loss of flow in the cooling water system serving the DHR System.

In the heat input analysis, the 10 CFR 50 Appendix G limits are not exceeded; therefore, the performance of the ANO-1 Overpressure Protection System is judged to be adequate for heat induced transients.

4. ADMINISTRATIVE CONTROLS

To supplement the hardware modifications and to limit the magnitude of postulated pressure transients to within the bounds of the analysis provided by the licensee, procedural and administrative controls should be provided by the licensee. Those specific conditions required for the plant to be operated within the bounds of the analysis and requirements for enabling and testing the OPS should be spelled out in the plant Technical Specifications.

4.1 Procedures

A number of provisions for the prevention of pressure transients are incorporated in the plant operating procedures. Some examples of these provisions are given below:

1. The ANO-1 Overpressure Protection System is to be manually enabled prior to the reactor coolant system temperature dropping below 280°F during plant cooldown. An alarm will sound in the control room if the system is not enabled or if the PORV isolation valve is not open when the RCS temperature drops below 280°F.

2. The plant is to be operated with a steam or nitrogen blanket in the pressurizer at all times except for system hydrostatic tests. The pressurizer water level is maintained at or below the high level alarm at system pressures above 100 psig and less than the high high level alarm for pressures less than or equal to 100 psig.

3. The makeup tank water level is to be less than the high level alarm. During periods when the PORV has been removed from service, the makeup tank level will be maintained at or below the "normal" level of 73 inches.

4. The core flood tank discharge valves are closed and the circuit breakers for the motor operators are "racked out" before the RCS pressure is decreased to 600 psig.

5 During a plant cooldown the Engineered Safeguard Actuation of the HPI System is bypassed at 1650 psig. If this function is not performed by the operator, he will receive an alarm. Prior to going below 280°F, the circuit breakers for the four HPI motor operated valves are "locked out" with the valves in the closed position. This is accomplished by opening and tagging the selector switch in the Control Room and locking and tagging the breakers located at the Motor Control Center. The operator will receive an alarm in the Control Room if the RC temperature drops below 280°F and any of the breakers to the four HP injection valves have not been "locked out".

6. The HPI test procedure ensures that only one (1) HPI pump is tested at a time and that no other HPI pump is operating during the test.

4.2 Technical Specifications

AP&L has not yet submitted technical specifications that relate specifically to the operation of the ANO-1 OPS or establish requirements that decrease the probability of occurrance of an initiating event that could result in a pressure transient.

We consider it necessary for AP&L to submit technical specifications that cover this system in order for the ANO-1 OPS to be acceptable. These technical specifications should, as a minimum, contain requirements that cover each of the items in Section 4.1 of this report. In addition, the technical specifications should include requirements for testing the ANO-1 OPS, setting system setpoints, and enabling the system alarms. AP&L is presently formulating a technical specification change proposal for ANO-1 that addresses these items. We will consider the administrative controls acceptable for ANO-1 if adequate technical specifications are submitted and approved.

5. CONCLUSIONS

The administrative controls and plant modifications proposed by Arkansas Power and Light Company provide protection for Arkansas Nuclear One, Unit 1 from pressure transients at low temperatures by reducing the probability of initiation of a transient and by limiting the pressure of such a transient to below the limits set by 10 CFR 50 Appendix G. We find that the Arkansas Nuclear One, Unit 1 Overpressure Protection System meets GDC 15 and 31 and that AP&L has implemented the guidelines of NUREG-0224 except as noted in Sections 3.3, 3.4, and 4.2 of this report. Pending resolution of these items, the Arkansas Nuclear One, Unit 1 Overpressure Protection System is judged as an adequate solution to the problem of low temperature overpressure transients.

6. REFERENCES

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5. NRC internal memorandum (Eisenhut to Goller), dated November 19, 1976.

6. AP&L letter (Phillips) to NRC (Ziemann), dated December 3, 1976.

7. AP&L letter (Rueter) to NRC (Ziemann), dated December 9, 1976.

8. NRC letter (Reid) to AP&L (Phillips), dated December 13, 1976.

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12. NRC letter (Davis) to AP&L (Cavanaugh), dated November 7, 1977.

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14. "Reactor Vessel Pressure Transient Protection for Pressurized Water Reactors", NUREG-0224, September 1978.

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