SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

MULTI-PLANT ACTION ITEM B-4

OVERPRESSURE PROTECTION SYSTEM

DUKE POWER COMPANY

OCONEE NUCLEAR STATION, UNITS NOS. 1, 2 AND 3

DOCKETS NOS. 50-269, 50-270 AND 50-287

I. INTRODUCTION

Incidents identified as "pressure transients" have occurred in pressurized water reactors where the pressure limit in the Technical Specifications for a given temperature is exceeded. These incidents generally occur at relatively low temperatures where the reactor vessel material toughness, i.e., resistance to brittle fracture, is reduced from that which exists at normal operating temperature and where the primary system is completely filled with water, i.e., in a "water-solid" condition.

The "Technical Report on Reactor Vessel Pressure Transients" in NUREG-0138 (Ref. 1) summarizes the technical considerations of this matter, discusses the safety concerns and existing safety margins of operating reactors, and describes the regulatory actions taken to resolve this issue by reducing the likelihood of future pressure transient events at operating reactors.

On August 11, 1976, the U.S. Nuclear Regulatory Commission (NRC) requested that the Duke Power Company (DPC) evaluate Oconee Units 1, 2, & 3 to determine their susceptibility to overpressure events (Reference 2). It also requested an analysis of possible overpressure events and required DPC to propose interim and permanent modifications to the systems and procedures to reduce the likelihood and consequences of such events.

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By letter dated October 14, 1976 (Reference 3), Duke Power submitted to the NRC the interim measures that they had taken to minimize the probability of a low-temperature overpressure transient at Oconee Units 1, 2, & 3. In this letter Duke Power also submitted their final hardware change proposal along with the 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 temperature to 325°F. 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. This retards the pressure increase and allows time for operators to take action to terminate the pressure increase prior to exceeding any limits. The NRC asked Duke Power to answer further questions on their proposed Overpressure Protection System (References 4, 5, and 6), and Duke Power responded to these questions and proposed additional modifications in their subsequent submittals (References 7, 8, and 9). This evaluation is of only the physical and operational aspects of the Oconee, Units 1, 2, & 3 low temperature overpressure protection systems. The evaluation of the electrical, instrumentation, and control aspects is not included. Also not included is the evaluation of DPC's proposed change of the pressure-temperature limit curves. This and the consequences of it will be treated as a separate issue.

II. REVIEW 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" (Ref. 10), with appended Branch Technical Position RSB 5-2 (Ref. 11) states the staff's requirements for the overpressure protection system.

III. DESCRIPTION

The Oconee Overpressure Protection System (OPS) consists of both an active and a passive subsystem. The active subsystem uses 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 325°F by positioning a key-operated switch in the Reactor Control Room. The passive subsystem is based on a plant design and operating philosophy that precludes the plant from being in a water solid condition (except for system hydrotests). The Oconee's 1, 2, & 3 Reactor Coolant Systems are always operated with a steam or gas space in the pressurizers; the steam bubbles are replaced with nitrogen during plant cooldowns when system pressures are reduced. The vapor spaces in the pressurizers greatly retard 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.

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	550 gpm
Nitrogen capacity at 550 psig	32,420 lb/hr
Equivalent liquid insurge rate	2,350 gpm

IV. EVALUATION

A. System

1. 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 Oconee Units 1, 2, & 3 pilot actuated relief valves are tested during every plant startup to demonstrate their operational capability. This is done by positioning the key operated switch to "open" and then verifying that the valve opens by observing various parameters and then closing the valve. The PORV setpoint is verified annually. The contactors for the Oconee Units 1, 2, & 3 OPS relief valves are wired directly to the safety grade 125 V. D.C. power supply. There are nc complicated electronics involved. The only functional test that can be made on this system prior to shutdown without having the relief valve open is to verify that 125 V. D.C. power is available at the contactors. DPC does not intend to operate the valve during cooldown because it might stick open. Since the block valve would be closed and in this event could not be opened, this would take away the low temperature overpressure protection.

We find that a check of the availability of the 125 V. D.C. power at the contactors for the solenoid valves prior to enabling the OPS's during cooldowns is an acceptable functional test and that all of the testing requirements are met.

2. Single Failure Criteria

The specified failure criterion 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. 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.

The two subsystems (or methods) of the Oconee Overpressure Protection System are independent and diverse. A loss of offsite power will not affect the pressurizer steam or nitrogen bubble or the operator's action ability. A loss of off-site power also will not affect operation of the pilot actuated relief valve. Power for the instrumentation which controls the pilot actuated relief valve and other parameter indications and alarms will be supplied either by the emergency system or storage batteries during a loss of offsite power. A seismic event will not affect the pressurizer steam or nitrogen bubble or the operator's action ability. However, since Oconee Units 1, 2, & 3 each have only one PORV, to meet the single failure criteria it has to be assumed that they fail in the closed position.

In Oconee Units 1, 2, & 3 the worst overpressurization event with a failed close PORV is an inadvertent actuation of the High Pressure Injection (HPI) system. In this event the 550 psig setpoint could be exceeded in about 5 minutes. Since this is less than the required 10 minutes, DPC has agreed to incorporate Technical Specifications which require that the four HPI motor operated valves be locked out in the closed position prior to cooling the Reactor Coolant System (RCS) below 325°F.

The next worst overpressurization event with a failed closed PORV is a makeup valve failing full open with a charging pump running when the RCS temperature is below 325°F. DPC's analysis of this event is described in Section IV.B. (pages 6-8) of this report, where it is found that starting at the High Pressurizer Level alarm set point (260"), which is the most conservative assumption, the operator would have 10.1 minutes to stop the pressure increase after the makeup pump fails full open. Since this complies with the staff position, we find that a failed, full-open makeup valve with a single OPS failure will not cause an overpressurization at Oconee Units 1, 2, & 3.

Since all other overpressurization events with a single failure will not cause the RCS pressure to increase above the 550 psig setpoint, we conclude that the Oconee Units 1, 2, & 3 low-temperature overpressure protection systems meet the single failure criteria.

3. 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 Oconee Units 1, 2, & 3 low-temperature overpressure protection systems meet the seismic criteria. Even if it is assumed that the relief valve, connection pipe, or actuation circuitry failed due to a seismic event, the steam or nitrogen blanket in the pressurizer and the control room operator would provide protection for postulated low-temperature overpressure events.

B. Analysis

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:

0-400 in.	Level indicating range
315 in.	High high level alarm
260 in.	High level alarm
220 in.	Normal level
200 in.	Low level alarm
80 in.	Low level interlock (heater cut-out) and alarm

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

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.

Duke Power subsequently re-evaluated some of these events using plant specific parameters and more realistic conditions.

The makeup control valve in item a 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. 260 in. pressurizer water level for 250 psig initial pressure.

b. 315 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).

Since the assumed initial pressures are at alarm points, these are conservative initial conditions.

The DYSID Code analysis showed that, assuming no operator action, the RCS pressure would increase to 550 psig in approximately 10.1 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. These analyses also show that item b, the erroneous opening of the flood tank discharge valve, and item c, the erroneous actuation of the HPI system, could cause an overpressurization when the RCS temperature is below 325°F. To prevent this DPC has agreed to procedural controls which would prevent a core flood tank discharge or a HPI system injection when the RCS temperature is less than 325°F. We will require that these procedures be incorporated into the Technical Specifications.

Item d, the erroneous addition of nitrogen to the pressurizer, does not pose a threat because of the 125 psig regulator and the relief valve in the system. The relief valve will open at 150 psig to provide protection in the event of a regulator failure.

We conclude that the Oconee Overpressure Protection System will adequately mitigate all mass input cases.

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 the 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 90 inches, the rate of pressure increase is so slow that 550 psig is not reached until 47 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, Duke Power 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 530 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 260 inches (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 initial letdown from RCS to makeup tank.

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 29 minutes. At that

point, the PORV should open and limit the RCS pressure to 550 psig. Given a failure of the pressurizer PORV, the 29 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 System or a loss of flow in the cooling water system serving the DHR System.

In the heat input analysis, the 550 psig limit is not exceeded; therefore, the performance of the Oconee Overpressure Protection System is judged to be adequate for heat induced transients.

C. Administrative Controls and Technical Specifications

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

a. The Oconee Overpressure Protection System is to be manually enabled prior to the reactor coolant system temperature dropping below 325°F during plant cooldown.

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

c. The makeup tank water level is to be maintained below the level corresponding to the high level alarm.

d. 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.

e. During a plant cooldown, the Engineered Safeguard Actuation of the HPI System is bypassed at 1750 psig. Prior to going below 325°F, the circuit breakers for the four HPI motor operated valves are "locked out" with the valves in the closed position.

f. The operating makeup pump is to be secured when the last reactor coolant pump is secured.

These six items shall be required by Technical Specifications. There shall also be a Technical Specification on a NRC approved PORV set point.

V. CONCLUSIONS

The administrative controls and plant modifications proposed by the Duke Power Company provide protection for Oconee, Units 1, 2, & 3 from pressure transients at low temperatures by limiting the pressure of such a transient to below the limits set by 10 CFR 50 Appendix G. We find that with the addition of Technical Specifications, as stated above, the Oconee, Units 1, 2, & 3 overpressure protection systems meet GDC 15 and 31 and that DPC has implemented the guidelines of NUREG-0224. The Oconee, Units 1, 2, & 3 overpressure protection systems are judged to be adequate solutions to the problem of transients at low pressure and temperature.

The following personnel contributed to the preparation of this evaluation:

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