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LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Oconee Nuclear Station, Unit 1	05000269	1 of 14

TITLE (4)
Building Spray System Outside Design Basis due to Design Inadequacy

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER(S)
10	01	98	1998	- 12	- 00	11	02	98	Unit 2	05000270
									Unit 3	05000287

OPERATING MODE (9)	N	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR (Check one or more of the following) (11)			
POWER LEVEL (10)	100	20.402(b)	20.405(c)	50.73(a)(2)(iv)	73.71(b)
		20.405(a)(1)(i)	50.36(c)(1)	50.73(a)(2)(v)	73.71(c)
		20.405(a)(1)(ii)	50.36(c)(2)	50.73(a)(2)(vii)	OTHER (Specify in
		20.405(a)(1)(iii)	50.73(a)(2)(i)	50.73(a)(2)(viii)(A)	Abstract below and
		20.405(a)(1)(iv)	X 50.73(a)(2)(ii)(B)	50.73(a)(2)(viii)(B)	in Text, NRC Form
		20.405(a)(1)(v)	50.73(a)(2)(iii)	50.73(a)(2)(x)	366A)

LICENSEE CONTACT FOR THIS LER (12)

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COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS		CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	

SUPPLEMENTAL REPORT EXPECTED (14)			EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
X	YES (If yes, complete EXPECTED SUBMISSION DATE)	NO		12	02	98

ABSTRACT (Limit to 1400 spaces, i.e. approximately fifteen single-space typewritten lines) (16)

On September 21, 1998, an Engineer reviewing a revised calculation noted there was no NPSH calculation for operation of the Reactor Building Spray (BS) System with suction from the Borated Water Storage Tank following a LOCA. A Problem Investigation Process report was initiated on September 28, 1998. At 1855 hours on October 1, 1998, an evaluation concluded that the BS pumps might not perform their safety function due to runout and cavitation. The BS pumps were declared inoperable on all three Units and Technical Specification (TS) 3.0 entered. Units 1 and 2 were at 100% and Unit 3 was at 45% prior to a refueling outage. An ENS call was made at 1928 hours to report operation outside the design basis of the plant. TS 3.0 was exited at 0148 hours on October 2, 1998, when a procedure was revised to require dedicated operators to throttle the BS flow within five minutes of an Engineered Safeguards actuation. Until a more permanent resolution is implemented, dedicated operators are assigned in each control room whenever the BS system must be operable. The root cause of this event is an historical design inadequacy. Contributing deficiencies are incomplete Design documentation and ineffective corrective action.

EVALUATION:

Background

Oconee Nuclear Station is a three unit site. Babcock and Wilcox (B&W) designed the Nuclear Steam Supply System. Oconee Units 1, 2, and 3 were licensed and began operation in 1973-74.

The Reactor Building Spray (BS) System [EIIS:BE] is an Engineered Safeguards (ES) System [EIIS:JE] that performs two functions in the event of a Design Basis Accident. First, in conjunction with the Reactor Building Cooling (RBC) [EIIS:BK] and the Low Pressure Injection (LPI) Systems [EIIS:BP], the BS System removes heat (both sensible and latent) from the Reactor Building atmosphere. Secondly, the BS System also removes iodine from the post-accident containment atmosphere (credit taken only during a Maximum Hypothetical Accident). The BS System is designed for long term post-accident operation (i.e. until the Reactor Building atmospheric temperature is reduced below 125°F).

The BS pumps are normally aligned in standby to take suction from the Borated Water Storage Tank (BWST) at the onset of the event. Upon initiation by the ES System on high Reactor Building pressure, the BS pumps start and spray borated water into the Reactor Building atmosphere. The BWST supply will be depleted approximately thirty minutes into an event (depending on the exact scenario). Upon depletion of the BWST, the BS pumps are realigned to take suction from the Reactor Building emergency sump.

Both water supplies to the suction of the BS pumps are shared with the LPI System. The BS System must be capable of taking suction from either source with or without the LPI pumps running. To ensure adequate pump NPSH, the Emergency Operating Procedure (EOP) contains steps to throttle the flow rate of both the LPI and BS Systems to limit total flow in the common suction piping. This requirement is documented in both the LPI and the BS system design basis documents. Operator action is required to initially throttle BS flow from the BWST to 1500 gpm as indicated by flow instrumentation and to subsequently throttle to 1000 gpm just prior to realigning suction to the emergency sump.

Description of Event

During the period of November 10, 1997 through December 11, 1997, the Duke Power (Duke) Nuclear Generation Department Regulatory Audit Group conducted the on-site portions of a Self-Initiated Technical Audit (SITA) to assess the operational readiness and functionality of the High Pressure Injection (HPI) [EIIS:BG] and Low Pressure Injection (LPI) systems and interconnecting systems at the Oconee Nuclear Site. This internal audit identified a number of findings and recommendations and, as part of the audit process, the team initiated Problem Investigation Process (PIP) entries to address the issues.

The inspection team concluded that the subject systems were capable of performing their safety functions, but some potentially incomplete and non-conservative inputs may have been used in some design calculations. The SITA report stated:

> "These errors could have significant cumulative impact... but typically the errors had small impact on the validity of the calculations"

The SITA team and Systems Engineering reviewed the issues and Systems Engineering concluded that their apparent significance did not justify an operability evaluation at that time.

Subsequently, as more detailed investigations of the issues were conducted as part of the evaluation for proposed resolutions, two related problems were identified which specifically impacted the operability of the Emergency Core Cooling System (ECCS) and Building Spray System (BS). These resulted in Licensee Event Report (LER) 269/98-04.

During the preparation of LER 269/98-04, one of the problems recognized was that a weakness existed in the review process for calculations affecting Emergency Operating Procedure (EOP) setpoints. As a result, a corrective action was created for a review of all EOP setpoints for accuracy and completeness. Calculation inputs were to be verified as current and appropriate.

On September 21, 1998, as result of the corrective action from LER 269/98-04, a Mechanical Systems Engineer was reviewing a revision to one of these calculations (OSC-2820). While performing the review, he discovered that there was no referenced calculation that addressed the adequacy of NPSH during operation of the BS System with the suction aligned to the Borated Water Storage Tank (BWST) following a Loss of Coolant Accident (LOCA).

The engineer confirmed that there was no approved Duke calculation on file to document the available NPSH in the injection mode or to justify the suitability of a requirement in the EOP to throttle flow to 1500 gpm.

A calculation was initiated to determine BS NPSH margin as a function of BWST depletion. Operations personnel were consulted to verify the elapsed time to reach the step in the EOP that throttled the BS pumps. The elapsed time was determined (based, in part, on performance during past simulator training) to be less than fifteen minutes. Therefore, the calculation assumed that operator action would be taken to throttle the pump flow at fifteen minutes after the initiation of the event. Preliminary calculation results raised a concern that the pumps may reach runout conditions, with cavitation, during the period between the onset of the event and the throttling of the pumps. This situation applied to all three Oconee units.

Information on the pump operating conditions from the preliminary calculation was provided to the pump manufacturer, Ingersoll-Dresser Pump Company (Ingersoll), for their evaluation. On September 24, 1998, Ingersoll provided a letter documenting the ability of the pumps to run a short time (less than one hour) with limited available NPSH.

Up to this point in the analysis, the method used was considered very preliminary and conservative. On September 24, 1998, Engineering began developing a computer model to more accurately quantify the operating performance of the system. On September 28, 1998, the initial results using the earliest version of the model confirmed the results from the previous method.

Therefore, a PIP report was initiated on September 28, 1998. As part of the PIP process, an operability evaluation was initiated to address this operating mode.

On October 1, 1998, a revised set of operating conditions was provided to Ingersoll. An Ingersoll representative stated that, under the revised conditions predicted by the preliminary calculation, the pump would experience lower than the available NPSH previously communicated, and that there was no available test data for performance of the pumps under these conditions for this length of time (fifteen minutes). Based on the test data and operating experience that was available, the Ingersoll representative stated that it was their opinion that the pump could survive this type of event, but this opinion involved extrapolation of test data from short (3-4 minute) runs. They recommended that the only way to assure the pump would survive would be to perform more extensive testing. This opinion was telecopied to Oconee on October 1, 1998.

At 1855 hours on October 1, 1998, the operability evaluation concluded that the Reactor Building Spray pumps were inoperable on all three Oconee units. At that time, Units 1 and 2 were at 100% and Unit 3 was at 45%, coasting down prior to a refueling outage. All three Oconee Units entered the action statement of Technical Specification (TS) 3.0, which requires the affected units to come to hot shutdown within 12 hours. An Emergency Notification System notification was made at 1928 hours to report operation outside the design basis of the plant.

The operability evaluation included verification that the LPI Pumps have been evaluated for operation in this mode and were shown to be completely operable.

A follow-up analysis was performed to evaluate operating conditions that would be acceptable. This analysis demonstrated that the NPSH available at the pumps is adequate to satisfy Ingersoll's requirements if the operators throttle the pump discharge valves within the first five minutes of the event. Compensatory actions were initiated to allow the Units to exit TS 3.0. These included the posting of a dedicated operator in each control room with instructions provided to throttle BS flow to

1500 gpm within five minutes of any BS start due to actuation of Engineered Safeguards (ES).

Due to the expected prompt implementation of the compensatory actions, Operations did not begin power reductions. At 0148 hours on October 2, 1998, the compensatory actions were in place and the Units exited TS 3.0.

The compensatory instructions were formalized on October 2, 1998 by a change to the EOP. Subsequently, several simulator drill scenarios were run to validate that the required steps could be performed within the required time frame using the revised procedure.

Engineering is expeditiously pursuing efforts to eliminate the need for a dedicated operator. Testing of a BS pump at a test laboratory is scheduled. Comprehensive NPSH calculations are being developed. Also, plant changes to increase the resistance in the discharge piping are being evaluated.

During the continued reviews of the calculations and the flow models used to support the calculations, a series of enhancements were made to the analysis. At the time this report was finalized, the calculation indicates that, although the BS pumps might be exposed to NPSH less than the recommended minimum prior to operator action at 15 minutes, the available NPSH conditions, and the duration of operation, would be within the bounds of operation that Ingersoll could support based on existing tests.

Duke will continue to evaluate this issue, taking actions as described above and in the Corrective Action section below, and will provide supplemental information following completion of testing and completion of an approved calculation package.

An investigation was initiated to determine the root cause of this event.

An historical calculation was found in the Babcock and Wilcox (B&W, the Nuclear Steam Supply System vendor) files. This 1968 calculation credited that containment pressure would limit the predicted BS and LPI flow rates following a LOCA. As containment pressure and BWST level

decrease, available NPSH would decrease and would soon become less than the required NPSH. A B&W letter dated February 14, 1969 stated:

> "The BS pumps will cavitate beginning about 15 minutes after a LOCA. The LPI pumps will cavitate for approximately 2 minutes before manual throttling of the discharge of the BS and LPI pumps. This throttling is performed just prior to manual switching of the pump suctions to the emergency sump. From information obtained from the pump vendor, this amount of cavitation will not damage either set of pumps."
>
> "...the BS pumps will cavitate at some time after 15 minutes after the LOCA depending on operational conditions. ...Reference 3 states that the BS pumps will not be harmed by running in cavitation prior to the throttling at 32 minutes after a LOCA (time of switching suction to sump)."

This calculation appears to apply specifically to a postulated large break event from full power. When this calculation was originated, the large break from full power scenario was considered to be the worst case for many analyses. However, since that time, the industry has found that this assumption was not valid. For example, many additional scenarios were analyzed following the Three Mile Island (TMI) event. The Duke calculation currently being developed recognizes that, with respect to NPSH and pump runout considerations, smaller breaks, or large breaks from lower power, might be large enough to cause BS initiation, yet result in lower containment pressures. This could produce pump runout sooner in the event, or result in slower reduction of BWST level. Therefore, the duration of cavitation might be longer, or the cavitation more severe, for smaller breaks or lower initial power levels. The Duke calculation currently being developed takes no credit for flow being limited by building pressure.

Other letters and memos from the 1968-1973 time period discuss the applicability of Regulatory Guide 1.1 (then known as Safety Guide 1), "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps." Initial speculation was that this guide would NOT apply to Oconee due to the fact that construction was already in progress. Subsequent letters focused on the issue of credit for

containment pressure in the recirculation mode. This issue appears to have overshadowed any concern over the issue of marginal NPSH for the relatively short duration of the injection mode. LER 269/1998-11 discussed that Oconee did take credit for some containment pressure in order to satisfy NPSH requirements for the BS pumps in recirculation mode.

The original Oconee Final Safety Analysis Report (FSAR) and Safety Evaluation Report (SER) also focused on the NPSH margin during the recirculation phase of a LOCA. NPSH margin during the injection phase was not specifically addressed in these documents. It appears that the recirculation phase analysis was considered to bound the injection phase analysis.

B&W Topical Report 10103, "ECCS Analysis of B&W's 177-FA Lowered Loop NSS" dated 1977, states in section 10.2:

> "Operator actions are required to verify and sustain long-term cooling, and these actions may be initiated as soon as reasonable operator response can be assumed. Reasonable response time for the operator is defined as 15 minutes after the LOCA."

The Anticipated Transient Operating Guideline (ATOG) document, dated February, 23, 1982, in CP-101 (the ATOG Large Break LOCA cooldown guideline), reads "Throttle LPI valves LP-12 and LP-14 and building spray valves BS-1 and BS-2 as necessary to prevent pump cavitation." ATOG Part II Volume 1, p. 218: Section 3.2 "Reactor Building Spray" has the following statements: "When drawing water from the BWST, the maximum pump flow rate is 1800 gpm to avoid reactor building spray pump run out. When drawing water from the reactor building sump the maximum pump flow rate is 1000 to meet spray pump NPSH requirements." The NRC SER on ATOG is Generic Letter 83-31, dated September 14, 1983.

Section 15.14.6.5 of the current Oconee Updated FSAR (UFSAR) states that operator action is required fifteen minutes after initiation of a LOCA in order to support long term core cooling. This section does not specify exactly which actions are necessary in this time period. Similar wording has been included in the UFSAR since 1982.

The Reactor Building Spray System Design Basis Document (originally issued October 1, 1993) states:

> "To ensure adequate BS pump NPSH, both the LPI and BS Systems shall provide throttling capability since flow through each system must be throttled to limit total flow in the common suction piping."

The Reactor Building Spray System Design Basis Document also contains the following as a system limit and precaution:

> "If a high flow alarm is activated, the operator should manually throttle valve(s) 1BS-1 and/or 1BS-2. As RB pressure diminishes, the BS System flows will increase. If not controlled, the flows could reach pump runout conditions when the BS pumps are aligned to the BWST. At this high flow condition, pump NPSH requirements may not be satisfied which could lead to cavitational damage to the pumps."

Each BS injection header contains flow instrumentation that feed signals to a High/Low Flow control room alarm. However, for the operability evaluation, no credit was taken for operator response to this alarm, due to the large number of alarms that would be expected during a LOCA event.

CONCLUSIONS

The root cause of this event is an historical design inadequacy. It appears that, based on 1968 calculations, both Babcock & Wilcox (B&W) and Duke Energy (Duke) concluded that it was acceptable to operate for a period of time during the injection phase with the available NPSH to the Building Spray (BS) pumps less than the manufacturer's recommended minimum NPSH as documented on the pump performance curves. Communications from the pump vendor were referenced, indicating that the pump vendor also concurred. Therefore, it appears that this was an informed decision, based on the data available and industry practices of the time.

A number of documents indicate that operator action to throttle flow in the Low Pressure Injection (LPI) and BS systems while still in the injection phase was a recognized part of the Oconee Design Basis. While these documents did address the timeliness of some required actions, they did not specifically address how soon throttling was required. However, no documentation could be found to indicate that the NRC was informed that credit was being taken for operation with available NPSH less than the vendor's minimum NPSH curves. Therefore, based on currently available information, it appears that Oconee may have operated outside its Design Bases.

The analytical bases for required actions, were contained in historical B&W calculations. No Duke controlled calculation was generated to document the NPSH margin for the BS pumps during the injection phase of a LOCA. Over the years, many of the calculations and assumptions that would be used as inputs to the NPSH calculation have been updated. If a controlled calculation had been generated and updated, the NPSH margins would have been better understood. The need to better address the available NPSH and timeliness of operator action would have been more apparent. Appropriate actions could have been taken when changes in inputs resulted in decreases in available margins. Therefore, a deficiency contributing to this event is Design Deficiency, for incomplete documentation.

Historically, there have been at least two specific reviews for this type of missing or incomplete documentation:

As an expanded self initiated follow-up to observations of the 1986 NRC Safety System Functional Inspection of the Oconee Emergency Feedwater [EIIS:BA] System, Design Engineering at Duke performed a technical review of all nuclear safety related mechanical calculations. On October 2, 1987 this technical review identified the absence of a design calculation on the High Pressure Injection pump NPSH from the Reactor Building emergency sump which resulted in Licensee Event Report (LER) 269/88-06. The LER stated: "The method of discovery (a review of nuclear safety related mechanical calculations) is a corrective action which should ensure that any other incident of a similar nature would have been detected." However, the review failed to discover the absence

of a design calculation on the BS pump NPSH from the Borated Water Storage Tank (BWST).

In 1989 Oconee initiated a six year long Design Basis Documentation (DBD) project, which provided a common document format to describe the design basis for Oconee structures, systems, and components. It also provided a reference section listing applicable calculations or other documents. A secondary intent of the DBD project was to identify instances where documentation did not exist to adequately describe the Design Basis. The program called for reconstitution of the design basis only where necessary. Where a decision was made that a missing document was not to be regenerated, the program called for an explanation to be documented. The project identified a number of systems where needed calculations did not exist or where existing calculations were outdated or incomplete. A number of these deficiencies were placed on an action register and were tracked to completion. The BS DBD was completed in 1993, but did not identify the absence of a design calculation on the BS pump NPSH from the BWST.

In addition, at several locations, the format of the DBD contains a field for the applicable calculation number. A number of these locations, including the page addressing the BS High/Low Flow Alarm, have the calculation field marked NONE or N/A. It appears that pump NPSH calculations would be necessary to support several of these requirements. Therefore, the absence of a calculation on required NPSH appears to be an omission, which should have been identified prior to this event.

The fact that this issue was not identified by these earlier review efforts contributed to the duration of this event. Therefore, a contributing deficiency is ineffective corrective action. It was noted that the problem discussed in this report was discovered as a result of more recent corrective actions.

On September 17, 1998, Oconee submitted LER 269/98-11, which addressed the fact that a 1991 NPSH calculation credited a limited amount of reactor building overpressure to assure adequate available NPSH for the BS pumps in recirculation mode. The root cause of this condition was an incorrect

interpretation of the Oconee licensing basis. Although LER 269/98-11 addresses an event similar to the current event, they are not considered recurring due to the differences in root cause and the significantly different time period in which the root cause occurred.

This event did not result in personnel injuries, radiation overexposures, or releases of radioactive materials. There were no equipment failures associated with this event.

CORRECTIVE ACTION:

Immediate:

1. Upon determination that the BS pumps should be considered inoperable, Operations was notified and Technical Specification 3.0 was entered.

2. Compensatory guidance, including a revision to the Emergency Operating Procedure, was provided to Operations.

3. Operations provided a dedicated operator in each control room to throttle the BS pumps within five minutes of an Engineered Safeguards actuation. Dedicated operators will continue to be assigned in each control room, when the BS system is required to be operable, until a more permanent resolution is identified.

Subsequent:

1. Simulator drill scenarios were run to validate that the required steps could be performed within the required time frame using the revised procedure.

Planned:

1. Engineering will determine the suitability of installing valve stops on Reactor Building Spray (BS) pump discharge valves to limit BS pump flow.

2. Engineering will conduct Net Positive Suction Head (NPSH) testing of a similar model pump at a test laboratory.

3. Engineering will complete the calculation of available NPSH for the BS pumps when pumping from the Borated Water Storage Tank.

4. Based on the results of Planned corrective actions 1, 2, and 3, Engineering will determine a permanent resolution to this problem.

5. A review will be performed to assure that NPSH calculations for safety related systems are appropriately addressed.

6. This Licensee Event Report (LER) will be revised to reflect the results of Planned corrective actions 1, 2, and 3. It is expected that this revision will be submitted approximately December 2, 1998.

Immediate corrective action 3 and planned corrective actions 1 through 6 are considered to be NRC Commitment Items. These are the only NRC Commitment items contained in this LER.

SAFETY ANALYSIS:

The Reactor Building Spray (BS) System is an Engineered Safeguards (ES) System that performs two functions in the event of a Design Basis Accident.

First, in conjunction with the Reactor Building Cooling (RBC) and the Low Pressure Injection (LPI) Systems, the BS System is capable of removing sufficient heat (both sensible and latent) from the containment atmosphere to maintain the Reactor Building post-accident conditions (i.e., pressure, temperature, etc.) within design limits. Analysis has shown BS is not needed to prevent peak building pressure from exceeding the Reactor Building design pressure following a Loss Of Coolant Accident. Rather it provides cooling to control the rate of depressurization, to reduce the driving force for leakage of radioactive materials from the Reactor Building, and to aid in maintaining the conditions with the Environmental Qualifications guidance for equipment inside containment.

Secondly, the BS System also removes iodine from the post-accident containment atmosphere to meet the criteria established by Reference 10CFR100, Reactor Site Criteria, concerning offsite doses from radiological releases following the design basis Maximum Hypothetical Accident (MHA).

During the continued reviews of the calculations and the flow models used to support the calculations, a series of enhancements were made to the analysis. At the time this report was finalized, the Duke calculation for available Net Positive Suction Head (NPSH) when in injection mode and the supporting flow models were still undergoing refinement and enhancement. Therefore, conclusions based on its output are subject to change. However, the current calculation indicates that, although the BS pumps might be exposed to NPSH less than the recommended minimum prior to operator action at 15 minutes, the available NPSH conditions, and the duration of operation exposed to those conditions, would be within the bounds of operation that Ingersoll could support based on existing tests. Therefore, the current conclusion is that the BS pumps would have successfully performed their safety function.

Duke will continue to evaluate this issue and will provide supplemental information regarding the safety significance following completion of the testing and an approved calculation package.