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NORTH,P.J. Duke Power Co.
TUCKER,H.B. Duke Power Co.
RECIP.NAME RECIPIENT AFFILIATION

SUBJECT: LER 88-006-01:on 880519,inadequate design analysis of HPIS in ECCS sump recirculation mode.

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U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES: 8/31/88

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Oconee Nuclear Station, Unit 1	0 5 0 0 0 2 6 9	1 OF 1 3

TITLE (4) Inadequate Design Analysis of the High Pressure Injection System in the Emergency Core Cooling System Sump Recirculation Mode

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 NAMES	DOCKET NUMBER(S)
0 5	1 9	8 8	8 8	— 0 0 6	— 0 1	0 9	0 8	8 8	Oconee Unit 2	0 5 0 0 0 2 7 0
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		20.405(a)(1)(i)	50.36(c)(1)	X 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 Abstract below and in Text, NRC Form 366A)
		20.405(a)(1)(iii)	50.73(a)(2)(i)	50.73(a)(2)(viii)(A)	
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ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On May 19, 1988, with all Oconee units operating at 100 percent power, upon completion of a design calculation a deficiency in Oconee Nuclear Station's High Pressure Injection (HPI) and Low Pressure Injection (LPI) systems was discovered. The design deficiency relates to operation of these systems in the Emergency Core Cooling System (ECCS) sump recirculation (piggyback) mode. Specifically, NPSH concerns in all operating scenarios were not adequately addressed in the original system design or operating procedures.

The root cause of this incident was determined to be a design deficiency due to inadequate design documentation. Subsequently, Technical Specifications, operating procedures, and operator training were written which did not adequately address the system limitations and requirements of the HPI piggyback mode.

Corrective actions included: enhancing procedural guidance for Oconee operations personnel to more completely address the piggyback mode of operation, valves LP-15 and LP-16 were locally cycled to verify their manual-local operability, and a Technical Specification Interpretation was issued regarding operability and surveillance requirements for valves LP-15 and LP-16.

IE07

☆ U.S.GPO:1984-0-454-481/18759

SEQUENCE OF EVENTS

October 2, 1987 — A Duke Power Company calculation review identified the absence of a design calculation on pump Net Positive Suction Head (NPSH) when taking suction from the LPI system in the sump recirculation (piggyback) mode.

May 19, 1988 — The HPI pump NPSH calculation is completed results conclude that current system design and operating procedures did not provide sufficient precautions and limitations for HPI pump operation, and system design did not meet single failure criteria.

0900 hrs. - In a conference phone call, Design Engineering notified Oconee Nuclear Station of the deficiencies.

Problem Investigation Reports (PIR) are initiated.

1600 hrs. - Problem was determined to be reportable per 10CFR50.72.

Operating procedures are revised to require valves 2LP-9 and 3LP-9, to be in the open position.

1716 hrs. - Emergency Notification Report to NRC was completed by phone.

May 20, 1988 — 1900 hrs.- Operational Guidance was provided to operators through a letter to Shift Engineers and Duty Engineers.

May 24, 1988 — Design Engineering (Electrical) completed the operability evaluation for the PIR concerning the effect of loss of offsite power simultaneously with a single failure to switchgear (EIIS:SWGR) 2TD and 3TD.

May 25, 1988 — Design Engineering (Mechanical) completed the operability evaluation for the PIR concerning adequate NPSH to the HPI pumps in the piggyback mode.

June 6,1988 — Oconee Nuclear Station Emergency Procedure Guidelines were revised to include limitations and precautions for operation in the HPI piggyback mode.

June 7,1988 — Oconee Nuclear Station operating procedures were revised to include limitations and precautions for operation in the HPI piggyback mode.

July 28, 1988 — Babcock and Wilcox documentation (dated February 22, 1968) was discovered, which documented sizing the HPI piggyback lines based on 300 gpm HPI flow and 500 gpm Reactor Building Spray (RBS) flow.

August 1, 1988 — LER 269/88-06 was submitted.

August 4, 1988 — The acceptability for manual-local operation of valves LP-15, LP-16, and LP-9 as backup to remote operation was recognized.

Oconee Nuclear Station operating procedure were further revised to include guidance for manual-local operation of valves LP-15 and LP-16.

Justification for Continued Operation was completed.

August 5, 1988 — Valves LP-15 and LP-16 were locally cycled to verify manual-local operability.

An Operator Training Package was issued establishing a Limiting Condition for Operation for valves LP-15 and LP-16.

August 11, 1988 — Technical Specification 3.3.1 Interpretation was issued .

August 18,1988 — Oconee Nuclear Station Emergency Procedure Guidelines were revised to open valves LP-15 and LP-16 at the ten-foot level in the BWST.

August 19,1988 — Oconee Nuclear Station operating procedures were revised to open valves LP-15 and LP-16 at the ten-foot level in the BWST.

Background

During a Loss of Coolant Accident (LOCA), the Borated Water Storage Tank (BWST) provides the initial water suction source for the High Pressure Injection (HPI) [EIIS:BQ] and the Low Pressure Injection (LPI) [EIIS:BP] systems as well as the Reactor Building Spray (RBS) [EIIS:BE] system. The BWST contains a Technical Specification required minimum of 350,000 gallons of borated water. As the BWST is depleted the Reactor Building (RB) sump water level will increase.

The LPI and RBS systems are capable of taking suction directly from this sump. The suction of the HPI pumps is not connected directly to the sump. If the Reactor Coolant System (RCS) [EIIS:AB] pressure is above the discharge capability of the LPI system as the BWST approaches depletion, the LPI system is used to supply suction to the HPI pumps. This mode is often referred to as the HPI piggyback (see Figure 1).

Valves LP-15 and LP-16 are the piggyback line isolation valves. In order to align the HPI system in the piggyback mode, at least one of these valves must be opened. Electrical power to these valves is supplied from a highly reliable (non-load shed), non-safety related power supply.

Valves LP-9 and LP-10 are the LPI discharge header crossover valves. Valves LP-9 and LP-10 are not required to be open to align the piggyback mode.

Technical Specification 3.3 delineates the requirements to assure immediate availability of the Emergency Core Cooling, Reactor Building Cooling, and Low Pressure Service Water [EIIS:BI] systems. Section 3.3.1 of this specification addresses the High Pressure Injection system.

Technical Specification 4.5.1.2.2.b defines the periodic testing requirements for the ECCS to assure the manual-local operability of certain LPI system power operated valves in the event that the capability to operate these valves from the control room is lost.

One-time functional tests of the Oconee Units 1, 2, and 3 HPI piggyback mode of operation were successfully completed on January 9, 1973, October 5, 1973, and June 26, 1974 respectively. This test involved operating each HPI pump at 500 gpm individually in the piggyback mode while verifying that adequate NPSH was available to each pump. Although these tests verified adequate NPSH to the HPI pumps in several scenarios, it did not verify adequate NPSH for the worst case scenarios which were allowed by operating procedures prior to May 19, 1988.

DESCRIPTION OF OCCURRENCE

As an expanded self initiated followup to observations of the 1986 NRC Safety System Functional Inspection (SSFI) of the Oconee Emergency Feedwater [EIIS:BA] System, Design Engineering at Duke Power Company performed a technical review of all nuclear safety related mechanical calculations. Duke Power Company committed to performing this review as a response to the SSFI Report.

The safety related calculation review involved a search of files dating back to 1967, indexing of all mechanical safety related calculations, and a technical review of each calculation judging them on completeness. On October 2, 1987, the calculation review identified two areas where no existing calculations were found: (1) Main Steam Relief Valve sizing and (2) HPI Piggyback NPSH. Corrective actions were taken to generate calculations. The first was completed on March 7, 1988 and did not identify any reportable deficiencies. The second was completed on May 19, 1988 (HPI Pump NPSH Calculation From Reactor Building Emergency Sump-Piggyback Mode), which is the subject of this report.

The Calculation performed a detailed flow and pressure analysis of the HPI piggyback mode. A review of operating procedures and single failure modes was included in the calculation to determine worst case operating modes for providing adequate NPSH to the HPI pumps. The calculation identified deficiencies in the current system design and operating procedures. At the completion of the calculation, all units at Oconee Nuclear Station were operating at 100 percent full power.

The first deficiency identified by the calculation was that current operating procedures did not provide sufficient guidance to ensure that adequate NPSH would be provided to the HPI pumps operating in the HPI piggyback mode. The analysis of the calculation indicated that pressure drops through the subject piping and components could deprive the HPI pumps of their required NPSH during high flow scenarios. Calculated large pressure drops from the LPI pump discharge to the HPI pump suction were due to the long runs of three and four inch diameter piping at high flow rates. The operating procedures allowed the LPI and HPI systems to both be injecting simultaneously into the Reactor Coolant System with no flow limitations due to operating in the piggyback mode. In addition, there was no guidance on the use of Reactor Building Spray which could also be aligned to the LPI pump discharge. A precaution was also needed to prevent the throttling of valves LP-12 and LP-14, since the HPI piggyback line is downstream of these valves.

Subsequent investigation identified Babcock and Wilcox (B&W) design information dated February 22, 1968, which sized the HPI piggyback lines assuming 300 gpm flow for HPI and 500 gpm flow for Reactor Building Spray. No justification for these flow rates was included.

The Calculation evaluated worst case scenarios for providing adequate NPSH to the HPI pumps. An example is the scenario of 1000 gpm for HPI and 1000 gpm for Reactor Building Spray simultaneously through one of the four inch diameter piggyback lines, assuming a single failure.

The Calculation found this scenario to be unacceptable in that adequate NPSH to the HPI pumps was not assured. Adequate flow for accident mitigation and NPSH requirements could both be assured with appropriate procedural guidance. To satisfy these concerns, system operating limitations and precautions were required to be incorporated into operating procedures.

The second deficiency originally identified by the calculation was that the electrical design of Oconee Units 2 and 3 did not satisfy the Oconee FSAR Section 15.14.3.3.6, however (that conclusion was incorrect). The Oconee FSAR states that the LOCA analysis of the Oconee Emergency Core Cooling System (ECCS) is based on loss of offsite power with a single failure. The calculation identified that a single failure of switchgear [EIIS:SWGR] TD on Units 2 or 3 during loss of offsite power would prevent the remote alignment of the HPI system in the piggyback mode. Power to LPI pump B and valves LP-9 and LP-15 would not be available after failure of switchgear TD on Units 2 and 3. Backup power to valves 2LP-9 and 3LP-9, which are critical to remote alignment in this scenario, would not be immediately available because this backup power source is automatically load shed during an engineered safety features event.

These originally identified deficiencies were determined to have the potential for rendering the HPI system inoperable in the piggyback mode. In compliance with 10CFR50.72, these deficiencies were reported to the NRC.

A subsequent investigation revealed that the initially identified deficiency of satisfying single failure criteria did not take into account the capability for manual-local operation of valves LP-9, LP-15, and LP-16 as an acceptable redundant means to align the HPI and LPI systems into the piggyback mode of operation. Technical Specification 4.5.1.2.2.b defined the testing requirements for the manual operation of certain valves. Specifically, the specification required that the LPI discharge header crossover valves LP-9 and LP-10 be cycled manually (locally) to verify the manual-local operability of these power-operated valves during each refueling outage. However, the verification of the manual-local operability of valves LP-15 and LP-16 was not addressed in this specification. On August 4, 1988, a justification for continued operation (JCO) was written to address the manual operation of valves LP-15 and LP-16 (Note that the JCO explanation of the qualification of valves LP-15 and LP-16 was misleading. These valves and their actuators are environmentally qualified. It is the electrical power supply that is not safety related as it was provided with non-load shed power). In

addition, an evaluation was performed to verify the acceptability of being able to manually (locally) operate valves LP-15 and LP-16 in response to a design basis accident (loss of coolant accident). The evaluation concluded that the area was accessible, and certain procedural enhancements were implemented to provide the operator with adequate time to manually (locally) operate valves LP-15 and LP-16. To ensure that the operator had at least thirty (30) minutes to manually operate these valves after recognizing their failure to operate remotely, the BWST switchover level was raised from six (6) feet to ten (10) feet on August 19, 1988. Further, as indicated earlier, the remote-manual operation from the control room of valves 2LP-9 and 3LP-9 could have been lost during a loss of offsite power event, assuming worst-case single failure (switchgear TD) since the backup power supply is classified as a load shed power supply. However, it should be noted that the backup power supply to these valves could be reconnected to Oconee's on-site emergency A-C power supply [EIIS:EK] (see Oconee Nuclear Station Final Safety Analysis Report Chapter 8 for discussion of Oconee's on-site emergency A-C power supply). Based on the above discussion, it has been concluded that the second deficiency that was initially identified (a single failure of switchgear TD on Units 2 and 3 during a loss of offsite power which would prevent the alignment of the LPI and HPI systems in the piggyback mode) is no longer considered to be valid.

In discussions between Design Engineering and Oconee Nuclear Station, it was determined that the need for the piggyback mode of operation, with regard to the mitigation of small break LOCAs, was misunderstood. The Oconee emergency procedures included guidance to align the HPI piggyback mode; however, Oconee Nuclear Station did not recognize the significance of the piggyback mode of operation as part of the ECCS. Operator training had emphasized the use of steam generators to mitigate small break LOCAs, with the assumption that long term cooling and LPI alignment would be established prior to BWST depletion. With this assumption, the piggyback mode of operation would not be required. Operations understood the piggyback mode to be one of several other options, such as RCS depressurization, to assist in small break LOCA mitigation. The piggyback mode was addressed in operator training; however, its utilization as an ECCS mode of operation was not addressed. This misunderstanding of the piggyback mode, with regard to the ECCS, may have contributed to the lack of procedural and Technical Specification attention to the manual-local operation of valves LP-15 and LP-16. This incident is reportable pursuant to 10CFR50.73 (a) (2) (v).

CAUSE OF OCCURRENCE:

The root cause of this incident was determined to be a design deficiency due to the failure to provide adequate design documentation for the HPI piggyback mode of operation. The original design assumptions and system capabilities were not adequately documented. Subsequently, operating procedures were written which did not take into account system design limitations. This contributed to a lack of emphasis on the requirements of this mode of operation being placed in the Oconee Technical Specifications and Operator Training.

Results of this design deficiency included:

1) a lack of procedural guidance for ensuring adequate NPSH to the HPI pumps in the piggyback mode;
2) a failure to recognize the requirement that manual-local operability of valves LP-15 and LP-16 must be verified, and;
3) a misunderstanding, by Oconee Nuclear Station, regarding the need to utilize the HPI piggyback mode to mitigate certain small break LOCA scenarios.

After further review, it was determined that the deficiency in single failure criteria for switchgear TD failure on Oconee Units 2 and 3 was not a reportable deficiency since manual-local operability of valve LP-9 was acceptable and addressed in Oconee Technical Specifications.

A review of reportable incidents in the past three (3) years revealed two (2) design deficiencies which were attributed to inadequate design documentation (LER 269/86-02, LER 269/87-05). Both deficiencies were discovered by ongoing programs initiated by Duke Power Company. Similarly, an expanded followup to observations of the 1986 NRC Safety System Functional Inspection, Design Engineering performed a self initiated review of all nuclear safety related mechanical calculations. This review was the method of discovery for the incident described by this report. Discovery of this incident is indicative of the effectiveness of this review, and this review should ensure that any other incidents of a similar nature would have been detected.

This incident did not involve a component failure or malfunction. Therefore, it is not NPRDS reportable. In addition, this incident did not result in the release of radioactive materials, radiation exposure, or personnel injury.

CORRECTIVE ACTIONS

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.

The immediate corrective action was for Design Engineering to notify Oconee Nuclear of the High Pressure Injection (HPI) piggyback mode deficiencies identified by the calculation.

Subsequent corrective actions were to:

1) Change Valves 2LP-9 and 3LP-9 to a normally open position to provide for remote alignment of the HPI system in the piggyback mode after loss of offsite power and single failure of switchgear TD;

2) Write and distribute operational guidance providing the operators with the additional precautions and limitations to maintain adequate NPSH to the HPI pumps if they should be required to operate in the piggyback mode;

3) Revise appropriate operating procedures when the acceptability of manual-local operability of valves LP-15 and LP-16 was identified to ensure the opening (electrical or manual-local) of valves LP-15 and LP-16 prior to Reactor Building Emergency Sump recirculation;

4) Locally cycle Valves LP-15 and LP-16 to verify manual-local operability;

5) Issue an operations Training Package (HPI Piggyback Operation) to delineate the Limiting Conditions for Operation for valves LP-15 and LP-16, as well as corrective actions;

6) Revise the Oconee Nuclear Station Emergency Procedure Guidelines to incorporate the additional precautions and limitations;

7) Revise the appropriate operating procedures to incorporate the additional precautions and limitations to maintain adequate NPSH to the HPI pumps operating in the piggyback mode.

8) Issue an operations Training Package to all Oconee Operations personnel regarding emergency operating procedure changes and the Justification for Continued Operation;

9) Issue Technical Specification Interpretation regarding specification 3.3.1

10) Revise Emergency Operating Procedures on August 19, 1988 to provide guidance for opening valves LP-15 and LP-16, at a Borated Water Storage Tank level of ten (10) feet, in preparation for operation in the HPI piggyback mode. This guidance will allow additional time for manual-local valve operation, should it be required;

11) Reissue the LPI system manual operability test on August 30, 1988 to include testing of valves LP-15 and LP-16.

Planned corrective actions are to:

1) Cover the Oconee Operations Training Package (HPI Piggyback Operation) in the 1988 Segment #5 licensed operator requalification. This will be completed by November 1, 1988;

2) Revise the License Preparatory Senior Operator and License Preparatory Reactor Operator lesson plans to emphasize that the HPI piggyback mode is required for mitigation of certain sizes of small break LOCAs. This revision will include the failure mode and consequences of this scenario. Simulator exercise guides will be revised to describe any limitations that may be seen on the simulator in regard to this scenario. These revisions will be completed by October 7, 1988;

3) Revise Segment #7 or #8 of licensed operator simulator requalification to include a simulator exercise in which the piggyback mode of operation is required for small break LOCA mitigation. This will serve to further emphasize this operating mode to all licensed operators. This will be completed by January 31, 1989.

4) Review to verify the operability of all valves which are required to be available to change position in the Emergency Core Cooling System This will include verifying that these valves are properly addressed in the Oconee Technical Specifications. This review will be completed with particular attention to the requirements of 10 CFR 50.46. This will be completed by December 1, 1988;

5) Revise Oconee Technical Specifications section 4.5.1.2.2 to include the manual testing requirements of valves LP-15 and LP-16 and the results of the review of ECCS valves. This revision will be submitted to the NRC by December 30, 1988.

Analysis of Occurrence

The Emergency Core Cooling System (ECCS), including the High Pressure Injection (HPI) System, is required to meet criteria established in 10CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light Water Reactors. One criterion in this section requires the establishment of long term cooling. This criterion states "After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core." Although the FSAR Chapter 15 LOCA analyses demonstrate ECCS acceptability during the initial phase of the LOCA, it is implied that long term cooling can be established by virtue of the ECCS system design. It is apparent that design limitations inherent to the HPI System were not sufficiently documented prior to this investigation. As a result, long term cooling from HPI piggyback following a small break LOCA was not ensured prior to implementation of the corrective actions described in this report. The conditions for which this requirement was not sufficiently satisfied are as follows:

Following a small break LOCA, the HPI piggyback mode is required to sustain injection flow when the Borated Water Storage Tank (BWST) has been depleted and Reactor Coolant System (RCS) pressure remains above the shutoff head of the Low Pressure Injection (LPI) pumps. Since the HPI System is not directly connected to the emergency sump, fluid recirculation through the LPI System is necessary to maintain the HPI suction supply.

The occurrence of any small break LOCA does not necessarily imply reliance on the HPI piggyback mode of operation. Depending upon break size, the RCS may cool and depressurize to LPI System operating conditions prior to depletion of the BWST and therefore the piggyback mode is not necessary for successful transient mitigation. However, for break sizes in a range of approximately one to four inches in diameter, piggyback may be necessary. For this range of break sizes, RCS pressure

can remain greater than the LPI pump shutoff head when the BWST is depleted and thus HPI piggyback would be required to ensure core cooling. HPI pump damage due to inadequate NPSH during piggyback operation could have potentially resulted in the loss of long term cooling from the HPI pumps. Although appropriate limits and precautions did not exist in the emergency procedure (EP) to ensure adequate HPI pump NPSH during piggyback, failure of the HPI System would not necessarily have followed. Inadequate HPI pump NPSH would have occurred only if one piggyback supply line was available and an adverse combination of Reactor Building Spray flow, LPI flow, and HPI flow existed.

If the piggyback valves had failed to open remotely when required, local operator action would have been required to operate the valves. This action would have required the operators to stop all HPI pumps until LP-15 and LP-16 were opened, since adequate time was not available by procedure to complete this local valve alignment before the BWST emtied. Therefore, the potential existed for a temporary interruption of long term cooling from the HPI System while LP-15 and LP-16 were being opened locally.

There are no redundant systems which would have performed the same function as the HPI System in the piggyback mode. However, several alternatives existed which would have allowed the operator to attempt to depressurize the RCS and obtain ECCS injection from the core flood tanks and ultimately, the LPI System. Depressurization of the steam generators could have induced heat transfer which would depressurize the RCS. In addition, the hot leg and reactor vessel high point vents and the PORV could have been opened in an attempt to depressurize the RCS. Although these options existed in the emergency procedure and may have resulted in RCS depressurization, the effectiveness of these methods is not assured.

Although the HPI piggyback mode of operation is not required for all small break LOCAs and that the HPI System would not have necessarily failed during piggyback operation, the potential for HPI pump failure from inadequate pump NPSH existed prior to May 19, 1988. In addition, inadequate time was available in the operating procedures for manual - local operation of valves LP-15 and LP-16 without interrupting HPI flow. Therefore, continuous operation of the HPI System was not ensured for all small break LOCAs and thus long term cooling as required by 10CFR 50.46 may not have been satisfied. However, corrective actions identified in this report ensure complete operability of the piggyback mode. There have been no incidents which called for use of the HPI System in the piggyback mode, nor were there any releases of radioactive materials, radiation exposures, or personal injuries, as such the health and safety of the public was not affected by this incident.

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6)			PAGE (3)
		YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	
Oconee Nuclear Station, Unit 1	0 5 0 0 0 2 6 9	8 8	0 0 6	0 1	1 3 OF 1 3

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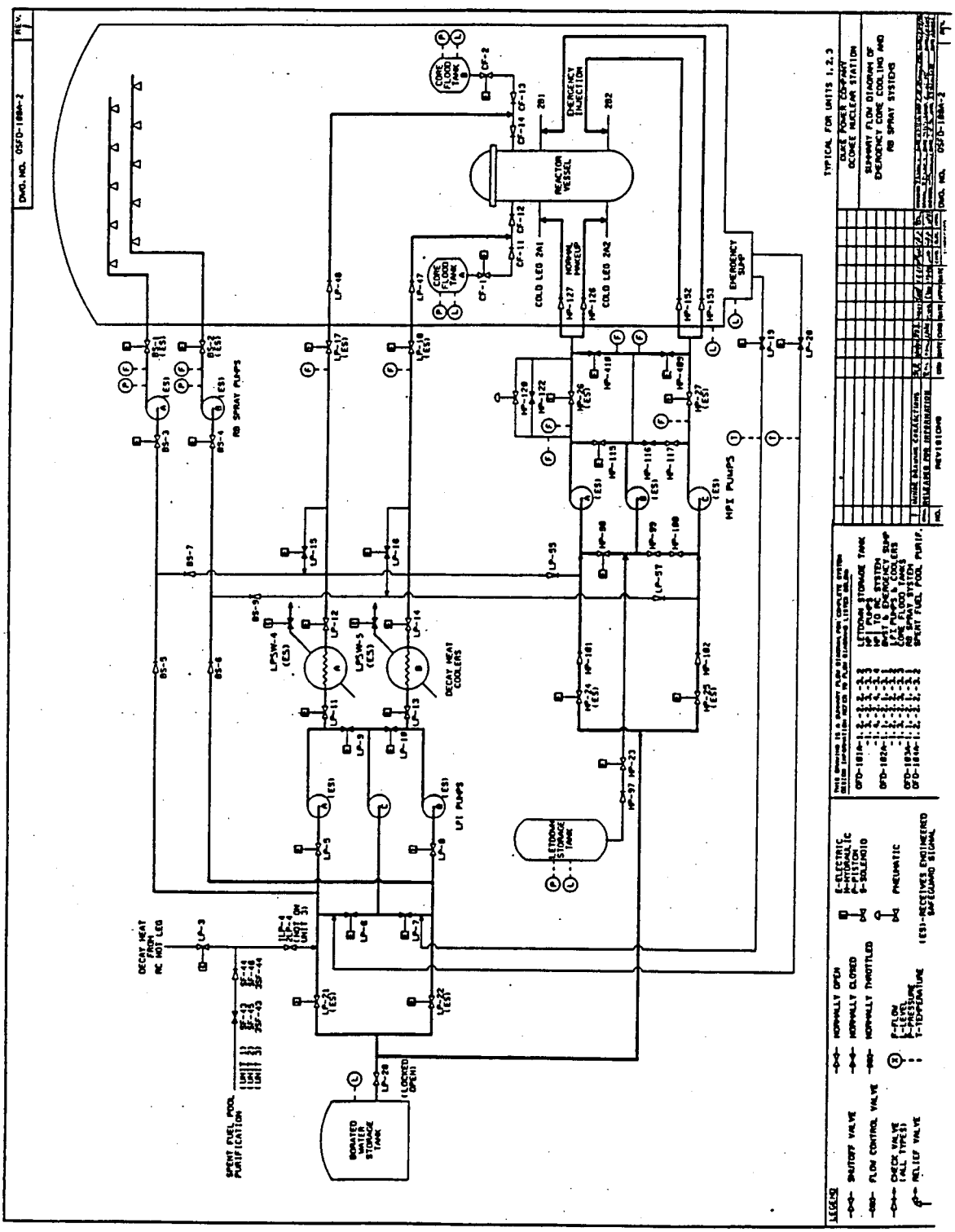

Figure 1
ECCS and Reactor Building Spray System

Duke Power Company
P.O. Box 33198
Charlotte, N.C. 28242

Hal B. Tucker
Vice President
Nuclear Production
(704)373-4531

DUKE POWER

September 9, 1988

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555

Subject: Oconee Nuclear Station
Docket No. 50-269, -270, -287
LER 269/88-06 Rev. 1

Gentlemen:

Pursuant to 10CFR 50.73 Sections (a)(1) and (d), attached is Licensee Event Report (LER) 269/88-06 concerning the inadequate design analysis of the High Pressure Injection System in the ECCS sump recirculation mode. This revision supersedes the originally issued report and incorporates the findings from further investigation.

This report is being submitted in accordance with 10CFR 50.73(a)(2)(v)(D). This event is considered to be of no significance with respect to the health and safety of the public.

Very truly yours,

Hal B. Tucker

Hal B. Tucker

PJN/382/mmf

Attachment

xc: Dr. J. Nelson Grace
Regional Administrator, Region II
U.S. Nuclear Regulatory Commission
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Atlanta, GA 30323

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Ms. Helen Pastis
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Washington, D.C. 20555

Mr. P.H. Skinner
NRC Resident Inspector
Oconee Nuclear Station

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