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SUBJECT: Submits supplemental response to GL 96-06, "Assurance of Equipment Operability & Containment Integrity During Design-Basis Conditions."

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August 1, 1997

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Subject: Oconee Nuclear Station
Docket Nos. 50-269, 50-270, 50-287
Supplemental Response to Generic Letter 96-06:
Assurance of Equipment Operability and Containment
Integrity During Design-Basis Conditions

Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Conditions", was issued on September 30, 1996. GL 96-06 requested licensees to determine if containment air cooler cooling water systems are susceptible to either waterhammer or two-phase flow conditions during postulated accident conditions and to determine if piping systems that penetrate containment are susceptible to thermal expansion of fluid that could lead to overpressurization of piping. Duke Energy Corporation (Duke) responded to GL 96-06 in submittals to the NRC dated October 29, 1996, January 28, 1997, April 15, 1997, and June 30, 1997. To assist the staff in their review of GL 96-06 issue pertaining to waterhammer, a summary of Duke's activities through June 30, 1997, is provided in Attachment 1.

In the April 15, 1997, submittal, Duke committed to perform additional thermal-hydraulic analyses to assess the waterhammer issues in GL 96-06. Duke stated that the results of these thermal-hydraulic analyses, along with a schedule for completion of the piping structural analyses and any modifications which may be necessary, would be submitted to the staff by August 1, 1997.

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Because of the complexities associated with the waterhammer analyses, Duke has performed two independent thermal-hydraulic analyses to predict the conditions within the LPSW piping. The results of these analyses are provided in Attachment 2. Duke is currently evaluating differences in the predictions between these two independent methods and will be proceeding with the structural analyses for the subject piping. Attachment 3 contains a schedule for completion of the LPSW piping structural analyses and associated potential modifications.

The analyses to date continue to support operability of the RBCUs. As further analyses are completed, Duke will continue to assess operability and proceed towards ultimate resolution of this issue.

Please address any questions to D. A. Nix at (864) 885-3634.

Very truly yours,

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Attachments

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Attachment 1

History of Generic Letter 96-06 Activities to June 30, 1996

On September 30, 1996, the NRC issued Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity during Design-Basis Accident Conditions". Among others, this GL identified a concern that cooling water systems serving containment air coolers could potentially experience waterhammer during certain design basis accidents.

As a result, Oconee began work on a thermal-hydraulic evaluation to determine if any portions of the Low Pressure Service Water (LPSW) System piping which serve the air cooling units in the Oconee reactor buildings may be susceptible to waterhammer.

During a loss of coolant accident (LOCA) or steam line break (SLB) concurrent with a loss of offsite power (LOOP), LPSW flow to the Reactor Building Cooling Units (RBCUs) is required to remove energy from the reactor building. The Oconee reactor building contains three safety-related RBCUs and four non-safety auxiliary air coolers (RBACs). During normal operation, the four non-safety RBACs are in service along with two of the three safety-related RBCUs. Following an engineered safeguards (ES) signal, LPSW flow is isolated to the four non-safety RBACs and the third safety-related RBCU is placed in service.

During a LOOP, flow is temporarily interrupted in the LPSW system, which causes water flashing and resultant drainage of the LPSW piping from high points in the reactor building. Upon restoration of power and LPSW flow, there is a potential for column-rejoining waterhammer to occur in the voided sections of the LPSW piping.

Duke's initial thermal-hydraulic evaluation of the LPSW System with no RBACs isolated, as provided in a letter to the staff dated January 28, 1997, concluded that the potential waterhammer loads to the safety-related RBCUs would not challenge the integrity of the LPSW piping to the RBCUs. This evaluation also investigated the possibility of waterhammers in the LPSW piping associated with the four non-safety-related RBACs. The initial evaluation of the LOCA/LOOP scenario predicted conditions which were potentially conducive to condensation-induced waterhammer in the LPSW piping associated with the non-safety RBACs.

As an immediate conservative corrective action, Duke isolated and drained portions of the affected RBAC LPSW piping prior to starting up each Oconee unit in January and February of 1997. These actions were taken as a precaution to eliminate the possibility of condensation-induced waterhammer while further analyses were performed.

An engineering evaluation was also performed to address the operability of the temporary RBAC LPSW configuration. The engineering evaluations performed in late January and early February, 1997, concluded that the LPSW System was not susceptible to condensation-induced waterhammer in the temporary RBAC LPSW configuration, and that the LPSW System was operable. This operability evaluation was described in a January 28, 1997, submittal to the staff.

On February 22, 1997, Duke performed a test which interrupted LPSW flow to the RBCUs on Unit 3. This test recorded the presence of column-rejoining waterhammers. Following this LOOP test, LPSW System piping was examined and no structural damage was observed.

In a June 30, 1997, letter to the staff, Duke stated a failure modes and effects analysis had been completed which confirmed that the most limiting cases had been considered in the operability evaluation described in Duke's January 28, 1997, submittal to the staff.

To thoroughly assess a given LPSW System configuration for waterhammer, it is first necessary to perform a thermal-hydraulic analysis to determine the peak pressure and forcing functions which are created by certain bounding accident scenarios. Second, the peak pressure and forcing functions are used as inputs to a detailed piping structural analysis to determine whether or not the affected piping can withstand the pressure and the loadings.

Duke employed a vendor, ALTRAN, to perform a bounding thermal-hydraulic analysis of the LPSW System configuration with RBACs unisolated. In addition, Duke performed an analysis with the RBACs isolated to validate the conclusions from the initial thermal-hydraulic evaluation. Based on discussions with the vendor, Duke's waterhammer methodology was revised. With the revised methodology, the potential for condensation induced waterhammers near the RBCUs was identified. The ALTRAN and Duke analyses are summarized in Attachment 2, along with a summary of the operability evaluation.

Attachment 2

Summary of ALTRAN and Duke Thermal-Hydraulic Analyses and Operability Conclusions

Because the thermal-hydraulic analysis are complex, Duke elected to perform two independent analyses to quantify the thermal-hydraulic conditions in the LPSW System. One analysis was performed inhouse by Duke and the other analysis was performed by a vendor (ALTRAN). ALTRAN has performed thermal-hydraulic analyses for the GL 96-06 waterhammer issue for several other utilities.

The primary focus of these analyses was to further investigate and evaluate concerns related to two-phase phenomena in the LPSW System. Scenarios without high-energy line breaks inside containment concurrent with a loss of offsite power (LOOP), and scenarios with high-energy line breaks inside containment concurrent with a LOOP, were considered. High-energy line breaks inside containment included the main steam line break (SLB) and large break loss of coolant accident (LOCA) transients. The LOOP, LOCA/LOOP, and SLB/LOOP scenarios were selected to bound the spectrum of the potential heat transfer from containment to the LPSW System.

ALTRAN's Thermal-Hydraulic Analysis

ALTRAN employed techniques that were used for several other nuclear utilities in determining the magnitude for both condensation-induced waterhammers and column rejoining waterhammers as addressed in GL 96-06. A mathematical model, prepared as an EXCEL spreadsheet, was used to predict the thermal transients. The waterhammer magnitudes were calculated using the Joukowski equation. ALTRAN performed analyses of the Units 1&2 LPSW System, and the Unit 3 LPSW System. The Unit 3 LPSW System was the bounding case. The following waterhammers were identified by ALTRAN:

Accident Scenario	Waterhammer Type	Peak Pressure (psig)
LOOP	Column rejoining	170
LOCA/LOOP and SLB/LOOP	Column rejoining	330
LOCA/LOOP and SLB/LOOP	Condensation induced	200

In conclusion, the ALTRAN thermal-hydraulic analysis determined that the worst waterhammer possible in the Oconee LPSW System with the RBACs unisolated is a column rejoining waterhammer occurring while the system is draining following a postulated LOCA/LOOP event. This potential waterhammer results in a peak pressure pulse of 330 psig. The ALTRAN analysis was performed with the Oconee LPSW System in its normal alignment with RBACs unisolated. Based on ALTRAN's analysis, it is expected that the peak pressures would be less severe in the current LPSW System configuration with the RBACs isolated.

Duke's Thermal-Hydraulic Analysis

Duke's investigation of the various accident scenarios and the resulting waterhammers was performed by modeling the LPSW System to the RBCUs using the RELAP5 computer code for all three Oconee Units. A review concluded that Unit 3 LPSW System presented the most limiting case due to higher expected LPSW flow rates. The Unit 3 LPSW System exhibits higher flow rates since it is an independent system with two pumps, whereas the Units 1&2 LPSW System is a shared system with three pumps. Therefore, the Unit 3 LPSW System was modeled in detail with RELAP5. The results of RELAP5 were then reviewed for identification of locations where waterhammers were probable. The following waterhammers were identified from Duke's thermal-hydraulic analysis:

Accident Scenario	Waterhammer Type	Peak Pressure (psig)
LOOP	Column rejoining	150 to 356
LOCA/LOOP	Column rejoining	118 to 467
LOCA/LOOP	Condensation induced	758

In conclusion, the Duke thermal-hydraulic analysis determined that the worst waterhammer possible in the Oconee LPSW System in its current configuration with the RBACs isolated is a

condensation-induced waterhammer occurring while the system is draining following a postulated LOCA/LOOP event. The location of this potential waterhammer is in an 8" horizontal supply or return line connected to an RBCU, resulting in a waterhammer pressure pulse with a conservatively estimated magnitude of 758 psig.

Piping Stress and Structural Analysis Evaluation

The waterhammer scenarios modeled by ALTRAN are similar to those experienced during the LOOP tests conducted at Oconee. No structural damage was noted after these LOOP tests. Based on industry experience, the structural response of the LPSW System would be similar during the LOCA/LOOP scenario and the SLB/LOOP scenario. Although plastic deformation of some of the LPSW system supports could potentially occur during both accident scenarios, it was concluded that the structural integrity of the LPSW System would be maintained.

A preliminary evaluation was also performed assuming the peak pressures from the thermal-hydraulic analyses, and using the system geometry, sectional properties, and material properties. This evaluation concludes that there are no challenges to pressure boundary integrity. Based on a review of the range of maximum waterhammer pulse pressures from both the ALTRAN and Duke analyses, it was concluded that hoop stresses remain below acceptable limits.

Therefore, based on engineering insight gained from both the ALTRAN and Duke thermal-hydraulic models, it has been determined that the LPSW System is operable.

Further investigations will be performed to address the differences between the Duke analysis and the ALTRAN analysis. Once these differences have been sufficiently evaluated, Duke will develop a force-time history. After development of the force-time history, it will be applied to a lumped mass linear elastic structural finite element model of the LPSW System. Results of that analysis will be compared to operability limits. The results are expected to show that while some plastic deformation of the piping supports may occur, the pressure boundary integrity of the piping system will be maintained, and thus the system would remain operable.

Attachment 3
GL 96-06 Reactor Building Cooling Unit (RBCU)
and Reactor Building Air Coolers (RBAC)
Waterhammer Resolution Schedule

Action Item #	Action Item	Expected Completion Date
1	NRC notified that Duke plans to complete the requested Generic Letter (GL) 96-06 actions and submit the requested information within the requested time period.	10/29/96 Complete
2	Duke provided response to GL 96-06. Oconee committed to provide schedule of any required piping structural analyses and modifications by August 1, 1997.	1/28/97 Complete
3	Performed test procedure TT/3/A/0251/63, LPSW Pump Loss of Offsite Power (LOOP) Simulation, which recorded column rejoining waterhammer loads in the RBAC piping as an LPSW pump was stopped for 33 seconds and then restarted.	2/22/97 Complete
4	Duke notified NRC that a failure modes and effects analysis (FMEA) would be performed and that the results of the additional waterhammer analysis for the Low Pressure Service Water (LPSW) System would be submitted to the NRC by 6/30/97.	4/15/97 Complete
5	Completed Oconee Calculation #6932, Evaluation of LPSW Two-Phase Phenomena. Determined waterhammer loads with RBACs valved out (Current System Configuration) to support the present operability. Calculation included an FMEA analysis.	6/26/97 Complete
6	Duke updated the NRC that the detailed analysis verified the previous operability evaluation.	6/30/97 Complete
7	Complete an analysis with RBACs valved in with "B" RBAC fan off .	8/31/97
8	Perform interim operability evaluation using waterhammer loads with "B" RBAC fan off to evaluate RBAC and/or RBCU piping pressure boundary integrity.	8/31/97
9	Complete an analysis with RBACs valved in and all RBAC fans on.	10/31/97

Action Item #	Action Item	Expected Completion Date
10	Perform interim operability evaluation using waterhammer loads with all RBAC fans on to evaluate RBAC and/or RBCU piping pressure boundary integrity.	10/31/97
11	Review piping and hanger loads based on force time histories and determine if code allowables have been exceeded for Unit 1 with all RBACs valved in and all RBAC fans on.	9/30/98
12	Review piping and hanger loads based on force time histories and determine if code allowables have been exceeded for Unit 2 with all RBACs valved in and all RBAC fans on.	9/30/98
13	Review piping and hanger loads based on force time histories and determine if code allowables have been exceeded for Unit 3 with all RBACs valved in and all RBAC fans on.	5/31/98
14	If necessary, modify Unit 1 RBCU and/or RBAC piping supports.	1EOC-18 3/99
15	If necessary, modify Unit 2 RBCU and/or RBAC piping supports.	2EOC-17 10/99
16	If necessary, modify Unit 3 RBCU and/or RBAC piping supports.	3EOC-18 3/00