REPORT DETAILS

1. Inspection Objectives

Numerous problems identified at various operating plants in the United States have called into question the ability of SWSs to perform their design function. These problems have included inadequate heat removal capability, biofouling, silting, single failure concerns, erosion, corrosion, insufficient original design margin, lapses in configuration control or improper 10 CFR 50.59 safety evaluations, and inadequate testing. NRC management concluded that an in-depth examination of SWSs was warranted based on these problems.

The team focused on the mechanical design, operational control, maintenance, and surveillance of the SWS and evaluated aspects of the quality assurance and corrective action programs related to the SWS. The inspection's primary objectives were to:

- Assess SWS performance through an in-depth review of the system's mechanical functional design and thermal-hydraulic performance including the content and implementation of SWS operating, maintenance, and surveillance procedures, and operator training on the SWS.
- Verify that SWS functional design and operational controls could meet the thermal and hydraulic performance requirements, and that SWS components were operated in a manner consistent with their design bases.
- Assess the licensee's planned and completed actions in response to Generic Letter 89-13, "Service Water System Problems Affecting Safety Related Equipment," July 1989, and
- Assess SWS unavailability resulting from planned maintenance, surveillance, and component failures.

The specific areas reviewed are described in paragraph 2 of this report. The observations and concerns identified are described in paragraphs 3 through 10 of this report. Personnel contacted and those who attended the exit on December 14, 1993, are identified in Appendix A.

2. Inspection Areas of the SWSs Associated with Oconee

The SWSs at Oconee encompassed numerous systems. These were the LPSW; HPSW; ASW; CCW (including the ECCW subsystem); the EDG cooling, HVAC cooling, steam generator cooling, and submersible pump subsystems of the SSF; and most of the mechanical systems of the Keowee hydroelectric station.

The team reviewed the mechanical design of each SWS, including the design bases, functional requirements, design assumptions, calculations, boundary conditions, analyses and models to determine if the design met licensing commitments and regulatory requirements. Each SWS's capability to meet the thermal and hydraulic performance specifications during accident and

abnormal conditions was reviewed. The design features associated with the loss of the Jocassee and Keowee Dam were evaluated. Single and common mode failure vulnerabilities, selected modifications and proper reflection of SWS design in plant operations, testing, and maintenance procedures were reviewed. The team reviewed maintenance history on selected equipment, maintenance procedures, completed work packages, preventive maintenance schedules, preventive maintenance procedures, and associated LERs. The availability records of the LPSW system for the past two years was compared to the licensee's PRA submittal. Plant walkdowns were conducted on all SWSs to assess present operating configurations, conformance to design documents, housekeeping and material conditions. Normal, abnormal and emergency operating procedures were reviewed for adequacy. Simulator scenarios involving the LPSW system were evaluated. The team reviewed preoperational test procedures, surveillance procedures, and the IST program implementation to determine if sufficient testing had been conducted to confirm system design requirements and system operability. Also reviewed were the licensee's procedures, controls, and other activities associated with the calibration of instrumentation in the SWSs. The team reviewed the licensee's self-assessment of the LPSW system and select corrective action documents associated with the SWSs. The minutes of off-site committee meetings were reviewed for conformance to Technical Specification requirements. Also, the team evaluated the adequacy of the licensee's GL 89-13 actions associated with all the SWSs.

3. <u>Generic Letter 89-13 Implementation</u>

The NRC issued GL 89-13, "Service Water System Problems Affecting Safety Related Equipment," requesting licensees to take certain actions related to their SWS. These actions included establishing biofouling surveillance and control techniques, monitoring safety-related heat exchanger performance, establishing a routine inspection and maintenance program, reviewing the design to assure intended safety functions could be accomplished, and training personnel in the operation, maintenance, and testing of the SWS.

The licensee's docketed responses to the GL of January 26, 1990, and May 31, 1990, were broad in nature and not specific to each system addressed. Also, the licensee's response indicated the GL actions had been performed without taking exceptions.

However, the licensee's GL actions almost exclusively focused upon the LPSW system and its support systems. The licensee's actions in response to GL 89-13 did not address all the applicable GL systems. The SWS associated with the Keowee hydroelectric station was not considered. A number of GL actions were not considered for the ASW and the SWS portion of the SSF. Also, a number of GL actions were not performed by the licensee for the HPSW system due to the classification of the system as nonsafety-related. Failure to apply the GL actions to all the applicable systems is Deviation 50-269, 270, 287/93-25-01, "Failure to Adequately Perform SWS GL Actions."

The licensee had performed extensive corrective actions to the LPSW system, but one LPSW design deficiency identified during self-assessment activities was not properly rectified. Also, corrective actions associated with the support functions provided by the CCW system had not been performed in a timely manner and/or did not fully address the deficiencies identified.

Heat exchanger performance monitoring was adequate for the LPI coolers and the smaller LPSW system coolers. The RBCU performance monitoring had established relative changes in the fouling factor between monitoring intervals but had not determined the true fouling factor. Also, some of the inputs associated with RBCU performance monitoring were questionable, in that the licensee was continuing to improve the hydraulic model for LPSW. See Appendix B for details on each GL 89-13 Action Item.

4. Low Pressure Service Water System

The LPSW system provided cooling to the RBCUs, LPI coolers, the motor and turbine driven EFW pump coolers, HPI pump motor coolers, the control room chilled water system, numerous room coolers, and nonsafety related turbine building loads. Units 1 and 2 shared three 15,000 gpm pumps with one pump capable of being powered from two separate safety related busses. The Unit 3 LPSW system had two 15,000 gpm pumps. The LPSW pumps took a suction from the 42" CCW discharge header within the turbine building. The Unit 1/2 LPSW pumps discharged into a common header that split into two supply lines; one supply line for each unit. The unit supply lines further divided into two separate headers supplying the two trains of safety related equipment. The two equipment supply lines then interconnected into a common line which entered containment. This common line then split into three parallel lines, each line supplying one RBCU. These three RBCU supply lines then reconnected into one line on the discharge side of the RBCUs before exiting containment. Also, branching from the common discharge header was a supply line to the turbine building loads. The turbine building supply line then split to provide cooling to each unit's turbine building equipment. The Unit 3 RBCU and turbine building cooling arrangement was similar. A normally closed crosstie line allowed either LPSW system to supply the discharge header of the other LPSW system.

Inspection findings related to the LPSW system were:

a. Turbine Building Isolation

(1) Design

The licensee's design for isolating the nonseismic turbine building line from the seismic portion of the LPSW system was inadequate. A single, motor operated butterfly valve was provided, even though the two LPSW trains were designed and operated as one interconnected system. The isolation valve for

Units 1/2 was LPSW-139, and LPSW-45 for Unit 3. The valves did not have an auto-closure feature, but could be electrically closed by operator action from a station just outside the control room. The isolation valves had not been originally specified as seismic but were seismically qualified as a resolution to a 1987 SITA finding on the LPSW system.

The licensee had performed calculations to determine the effect an earthquake would have on the LPSW systems. In the case of a nonseismically supported turbine building line failure without turbine building isolation, the calculation indicated the LPSW system would not be able to supply adequate cooling to the required safety related loads.

FSAR Section 9.2.2.2.3 stated in part, "The LPSW system provides sufficient flow to the Low Pressure Injection coolers and Reactor Building Cooling Units to ensure sufficient heat transfer capability following a design basis accident and a single active failure. The worst case design basis accident involves a LOCA/loss of offsite power with seismic event."

The licensee stated that failure of a seismic/non-seismic interface valve was outside the licensing basis for the facility. The team disagreed. This is Unresolved Item 50-269, 270, 287/93-25-02, "Turbine Building Isolation Single Failure Vulnerabilities."

(2) Testing

The isolation valves had not been VOTES tested in response to GL 89-10, "Safety Related Motor Operated Valve Testing and Surveillance." LPSW-45 was scheduled for VOTES testing at the next refueling outage. LPSW-139 was scheduled for VOTES testing at the next outage of both Units 1 and 2. In response to the team's request for design calculations supporting the closing capability of these valves, the licensee performed calculation OSC-4019, Valve LPSW-139 and 3LPSW-45, "Closure Against Maximum Delta P," indicating that adequate closing thrust could be developed.

Stroke testing of the valves had been limited. LPSW-45 was stroke tested once per refueling outage. Due to operating constraints associated with closing LPSW-139, it had been stroke tested only once since initial operation.

D. LPSW Pump NPSH Considerations

Calculations extrapolating system testing results identified several configurations involving loss of instrument air where LPSW flow demand was greater than design. The most severe configuration was

simultaneous operation of both LPI coolers on a shutdown unit and a LOCA on the other unit with the LOCA unit's MTOTC temperature control valve bypassed. For this case, there was insufficient NPSH for the excessive LPSW flow demand causing significant cavitation of the LPSW pumps. The licensee established procedural controls to throttle LPSW flow within 30 minutes through operator actions, thereby eliminating the cavitation. The inadequate NPSH condition was evaluated by the licensee and considered acceptable.

(1) The licensee's NPSH acceptability evaluation was based upon accepting the manufacturer's best judgement that no significant pump degradation would occur during and following the inadequate NPSH condition. Neither the licensee nor the pump manufacturer performed any testing validating this judgement. Also, the pump manufacturer did not warrant the LPSW pumps for operation with insufficient NPSH. Therefore, the licensee failed to adequately validate this critical design assumption. 10 CFR 50, Appendix B, Criterion III, "Design Control," requires that adequate measures be established for the selection of equipment. Also, as committed through Duke Power Company Topical Report 1-A, Table 17.0-1: ANSI 45.2.11-1974, "Quality Assurance Requirements for the Design of Nuclear Power Plants," requires NPSH be considered as a design input in Section 3.2.11. This is considered an example of Violation 50-269, 270, 287/98-25-08A, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

(2) One of the operator actions to reduce flow demand within 30 minutes was throttling the LPI cooler isolation valves until reaching 3000 gpm. The cooler isolation valves were gate valves and, generically, not used for throttling. The licensee had evaluated and tested these valves for throttling flow and determined the valves could be throttled. However, after throttling, the valves may not go full open or closed due to internal damage suffered while throttled. This could result in the inability to isolate a leaking LPI cooler subsequent to the throttling activities.

c. The Hydraulic Model

(1) The licensee's hydraulic computer model for predicting LPSW system response during an accident used the manufacturer's pump curves. The manufacturer's pump curves did not include pump degradation. Quarterly inservice pump testing allowed for up to 10 percent pump degradation without declaring the pump inoperable. There were no procedural controls to evaluate the inservice pump test results against the hydraulic model's flow inputs. Although the situation was not identified during the inspection, an acceptable inservice pump test could invalidate the LPSW pump flow inputs to the hydraulic computer model.

Contrary to the requirements of 10 CFR 50, Appendix B, Criterion III, "Design Control," the licensee failed to provide the adequate procedural controls to ensure the LPSW hydraulic model was not invalidated. This is an example of Violation, 50-269, 270, 287/93-25-03B, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

(2) The manufacturer's pump curve indicated the possibility of deadheading a degraded pump when the LPSW pumps were operating in parallel. Trending of the one point flow/pressure check used in the IST program was not the most reliable method of detecting pump degradation. The development of an individual pump curve would more accurately predict this condition. However, the current testing method was consistent with regulatory requirements.

(3) In 1992, the licensee reviewed Unit 1 and 2 hydraulic computer model results and determined a waterhammer would occur during a design basis LOCA with a single failure. The hydraulic model predicted a LPSW pressure of -13.5 psig downstream of the RBCU discharge throttle valves. Containment temperature would exceed 200°F in response to the design basis LOCA. The combination of the low pressure (-13.5 psig) and the high temperature (200°F) would cause the LPSW water to flash to steam. Upon condensation of the steam, a waterhammer would ensue. Under condition adverse to quality report PIP 92-484, the licensee evaluated the effects the waterhammer would have on LPSW flow within the piping and the reduction in RBCU cooling in calculation OSC-4982, "LPSW Woods Model Flowrate Correction through RBCU's Due to Cavitation," issued September 25, 1992. The licensee did not evaluate the effects the waterhammer would have on the structural integrity of the RBCUs and the discharge piping. 10 CFR 50, Appendix B, Criterion XVI, "Corrective Actions," requires conditions adverse to quality to be promptly identified and corrected. This is considered an example of violation 50-269, 270, 287/93-25-04A, "Inadequate Evaluation of Conditions Adverse to Quality by Engineering."

d. RBCU Operability Determination

A combination of LPSW flow test data and computer modeling of RBCU air flow were used to determine if the RBCUs had adequate accident condition heat removal capability. There were two questionable inputs used in that determination as follows:

(1) Accuracy of the installed orifice used to measure LPSW flow

A reduction in the diameter of the piping in the area of the orifice would result in higher indicated LPSW flow than was actually occurring. Documentation and photographs showed fouling

had occurred at various points within the LPSW piping. Anomalous results in previous flow testing, though possibly due to other reasons, could be explained by the flow instrumentation reading high. The licensee was aware of the potential problem and planned to replace the RBCUs and associated piping, including the section containing the flow orifice, at the next refueling outage for each unit.

(2) Validity of the RBCU non-uniform air flow distribution predicted by the computer modeling

The calculation of the air side fouling factor was highly sensitive to variations in the air flow distribution. The computer code had been benchmarked by a vendor. However, an airflow test performed in 1987, indicated airflow was substantially less than expected. When questioned about the results, the licensee stated this test was invalid due to significant air side fouling. Further testing was not conducted.

These two concerns placed RBCU results in question. Further licensee actions to determine the accuracy of these two inputs into AN RBCU operability determination is considered an Inspector Follow-up Item 50-269, 270, 287/93-25-06, "Additional Validation of RBCU Evaluation Inputs." Also, a detailed discussion of RBCU operability determination is contained in Appendix B, section II.

e. Use of Belzona for RBCU Leak Repair

The licensee had used Belzona to repair various plant components including the pressure retaining braze joints on the RBCUs. The commercial grade evaluation, CGD 2021.01-01-0001, specifically addressed the use of Belzona as a pressure retaining material for "pinhole" leak repairs on the Unit 2 RBCU coils. While the licensee's calculation found that the shear stress was acceptable; the licensee failed to evaluate or obtain test data to show that the RBCU repairs would withstand accident conditions. Failure of the Belzona presently installed in Unit 2 coincident with a LOCA would significantly increase containment leakage. 10 CFR 50, Appendix B, Criterion III, "Design Control," requires adequate suitability of application of materials reviews be performed. This is considered an example of Violation 50-269, 270, 287/93-25-03C, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

f. Simulator Observations

(1) During a LOOP/LOCA with failure of one LPSW pump on the shared Unit 1/2 system, the operator stopped one of the two operating LPSW pumps when no pump amperage was indicated. Redundant, independent instrumentation was not used prior to stopping the pump and was considered a performance weakness. Although

expected and consistent with the facility's design, LPSW pump suction valve position indication was lost. Indication was powered from a nonsafety related electrical bus which de-energizes in response to the LOOP. These valves were normally aligned open and do not receive an ESF signal. The lack of indication contributed to the operator's decision to stop the pump.

(2) With one operating LPSW pump supplying both units, the LPI cooler flows required by the emergency procedure could not be achieved. None of the licensee's procedures were applicable to this situation. The operators used their judgement and secured LPSW flow to the LPI coolers, isolated cooling to the control room, and isolated numerous nonessential loads. After transferring LPI pump suction to the containment sump due to depletion of the BWST, the LPI coolers were returned to service at flows less than required by the emergency procedure.

The lack of specific procedural direction was due to a deficiency within the abnormal procedure for total loss of LPSW. The entry condition for using this procedure was no LPSW pump operating; instead of inadequate LPSW flow. The licensee acknowledged this deficiency. Actions to improve operator response to inadequate LPSW flow is considered part of Inspector Follow-up Item 50-269,270, 287/90-25-08A, "Actions to Improve Operator Responses to Abnormal Events."

(3) After the simulator demonstration, the ramifications of reduced LPI flow and the bases of the procedurally required 3000 gpm LPI cooler flow was discussed. This parameter directly involved maintaining containment temperature less than equipment environmental qualification temperature limits. Licensee responses were focused exclusively on reactor core cooling. The 3000 gpm bases for LPI cooler flow was not fully understood by the individuals. This was due to the limited training on containment temperature concerns during an accident. The licensee responded that containment temperature ramifications would be the responsibility of the Technical Support Center. This is considered a training weakness.

(4) The simulator was certified. However, there was no simulation of the HPI and LPI pump motor coolers, no deviation in LPSW flow to the RBCUs in response to the ESF actuation, and no simulation of the Unit 3 LPSW system crosstie.

g. SITA Actions

In 1987, the licensee conducted a technical audit of the LPSW system. The audit was thorough with a substantial number of findings. Some of the corrective actions directly associated with the LPSW system were adequately dispositioned. Examples included the replacement of the unreliable radiation monitoring system for effluents from the LPSW system, development of a hydraulic computer model, and the generation of a substantial number of calculations to support LPSW design. However, concerns by the licensee associated with some of the corrective action resolutions, especially dealing with support systems, prompted an October-November 1992 review of the SITA process and revisiting a number of those outstanding issues. Subsequently, a SWS Steering Committee was formed and charged with resolution of all SWS issues.

The team concurred with the licensee's assessment that there had been untimely progress of some critical SITA issues prior to the Fall, 1992. The SITA process review in the Fall, 1992, was a good initiative. Also, the resulting SWS Steering Committee had a number of positive aspects including centralization of the issues and the ability to focus the diverse sections of the Oconee organization on resolution of a particular issue. However, resolution of some of the outstanding issues was inadequately addressed. Examples included the LPSW turbine building isolation, and HPSW piping seismic capability.

h. System Availability

Recent system availability data compared favorably with the availability assumed in the IPE report. Also, the material condition of the LPSW system was good except for fouling of small diameter piping. Recent machinery history records indicated the majority of the repetitive corrective maintenance focused on unplugging fouled instrument impulse lines. Also, flow testing of the Unit 3 HPI pump motor cooler, the Unit 1 LPSW A pump's cooling line, and the TDEFW pump cooling lines indicated fouling resulting in stainless steel piping replacements in those areas.

5. Circulating Cooling Water System

The CCW system was common to all three units and took suction from the Lake Keowee intake canal. Twelve pumps (four per unit) supplied a common cross-connected 42-inch discharge header from which numerous other SWSs took suction. From this header, cooling water passed through the three condensers. Upon leaving the condensers, the water discharges through six lines (two per unit) and returns to Lake Keowee upstream of the intake canal.

A subsystem of CCW was the ECCW system. If the CCW pumps lost power ECCW actuated establishing siphon or gravity flow from the intake canal to the 42-inch header and through the condenser sections. Emergency condenser discharge lines connect the condensers with the Keowee Hydroelectric station's tailrace and due to elevation differences, this was gravity/siphon flow operated. Prior to entering the tailrace all the discharge lines connected into one line. ECCW actuation involved the automatic closure of the condensers' normal outlet valves, opening of the condensers' emergency outlet valves and opening emergency discharge valve to the Keowee tailrace, CCW-8, located in the common discharge piping. The high points of the ECCW piping were connected to a vacuum priming system which would remove air entrapped within the system that could impede siphon operation. The licensee considered CCW supplying the LPSW pumps as the first siphon and CCW passing through the condensers as the second siphon.

The CCW system performed two distinct safety functions during the LOCA/LOOP event: First, it provided a suction source for other systems including the safety-related LPSW system, and second it provided cooling water to the condenser to remove decay heat in the emergency condenser cooling water (ECCW) mode. The CCW pumps contributed to these safety functions in two ways: First, when power is lost and they are not operating, they provided a siphon conduit from the intake canal to the CCW piping from which the LPSW takes suction, and to the condenser for the ECCW system. Second, at the time when the pumps can be restarted (up to 1/2 hours per emergency procedures), they continue to provide water for these same functions. Since dissolved air will tend to come out of solution when the system is in the siphon mode, at least one of the CCW pumps must be operated after power is restored in order for the water to continue to be supplied to the CCW piping.

Within the intake canal is an underwater dam which can trap approximately 17,000,000 gallons of water if Lake Keowee were to fall below the 776-foot level. With the CCW pumps operating the system is capable of recirculating water from this impounded area, through the condensers, through the condenser emergency discharge lines and through normally closed valve, CCW-9, which discharges into the intake canal.

Findings associated with the CCW system were:

a. The Siphons

(1) The 1987 SSFI identified numerous support systems associated with the first siphon which did not meet safety related standards such as the non-seismically qualified vacuum priming system. The original SSFI response did not refute the finding, but considered such requirements as outside the licensing basis of the facility. Eventually, the safety related aspects of these support systems were evaluated in a design study. Through a combination of the design study and a DPC steering committee the vacuum priming

issue was addressed by isolating the vacuum priming system in the Fall, 1989. Outgassing of air was addressed by establishing minimum CCW pump combinations for particular Lake Keowee levels. Licensee actions on this matter were untimely. Another support system, HPSW, for the first siphon is discussed in section 6.

(2) The CCW pump components necessary to support siphon operation to the LPSW system (the first siphon) performed a safety related function but, were not classified as safety related. For the first siphon to operate, the physical interface between the pump casing and the CCW piping must be leaktight, and the pump mounting/structural supports must be capable of withstanding an earthquake without allowing air inleakage. Examples of the effects of the improper classification were as follows:

(a) Following failure of an ECCW flow test the licensee determined the cause of the test failure to be air inleakage between the pump casing and the CCW piping. In response the licensee issued OE # 4872 dated 6/3/91 which authorized installation of a rubber seal at this interface. Though the design change appeared technically adequate, it was designated as nonsafety related.

(b) During the inspection period, the overhaul/repair of the 2B CCW pump was being performed using nonsafety related procedures.

(c) Whenever a CCW pump was disassembled, as with the 2B pump, the pump casing seal was disturbed. The subsequent post maintenance test to confirm leak tightness was performed without written procedural direction. Following discussions with the licensee the test method appeared adequate but, the conditions for testing, the instrumentation, the acceptance criteria, etc. were not being appropriately controlled.

Independently, the licensee recognized the error and was classifying the components as safety related in the most current draft revision to the Quality Standards Manual. The failure to properly classify the components is considered Violation 50-269, 270, 287/90-25-01, "Inadequate Classification of Siphon Support Equipment for LPSW Supply." However, based upon the corrective actions in progress, the licensee's self identification of the matter, no similar violations associated with the misclassification of the first siphon's support equipment, the lack of willfulness, and the nonescalated enforcement nature of the violation, this is considered a non-cited violation authorized under 10 CFR 2, Appendix C, Section VII.B.2.

(3) The licensee did not consider the equipment associated with the second siphon as safety-related. Therefore, some of the equipment associated with the condenser cooling mode did not meet safety-related design requirements.

The vacuum priming support system was not seismically supported. A number of valves were not powered from safety-related sources including some of the condenser emergency discharge valves, midpoint vent valves, and the emergency discharge valve to the Keowee tailrace.

Also, the single discharge valve to the Keowee tailrace was not seismically protected. This valve was located in a concrete and steel structure at elevation 750 feet. The top of this structure was covered with unrestrained metal deck plates. In a seismic event, the plates could fall damaging the valve or the associated electrical cables below.

Unresolved Item, 269,270, 287/90-13-03, "ECCW System Design and Testing," had already been established as ascertaining the licensing basis of the ECCW system, including the condenser cooling mode. Therefore, the design aspects of the condenser cooling mode discussed above have been encompassed by this unresolved item. Resolution of this unresolved issue is contingent upon further NRC review.

(4) Nonconservatisms existed within the calculations supporting ECCW design and testing. Examples included:

(a) Calculation OSC-2340, "CCW Intake Piping Degassing in the ECCW Mode", Rev 1, May 21, 1990, was performed to show that the CCW system had the capability of providing the required flow rate even with air inleakage and outgassing of dissolved air from the water, both of which would tend to break the siphon. The calculation also provided the acceptance criteria for the intake piping water level for the "Emergency CCW System Flow Test," PT/1/A/0251/07, and the equivalent performance tests for Units 2 and 3.

The following discrepancies and nonconservatisms existed in this calculation:

- The maximum flowrate analyzed was 30,000 gpm. However, for the LOOP case, the maximum flowrate may include the maximum tailrace flow through the condenser and the CCW-8 emergency discharge valve (in the range of 30,000 gpm), plus the flows to the LPSW pumps (design flow of 15,000 gpm per pump, 5 pumps). The various LPSW pump combinations had not been analyzed, but initial evaluation indicated that as many as four pumps could

be operating. Therefore, the actual flow could be significantly higher than what was analyzed, producing more outgassing due to the higher mass flow rate. Additionally, higher flow would require a higher minimum level in the piping to overcome the increased flow resistance.

- The atmospheric pressure used was 14.7 psia. Per "Atmospheric Pressure for Design Calculations," S. L. Nader, File OS-3C, 7/23/87, the correct atmospheric pressure for Oconee was 14.0 psia.

Conservatisms in the calculation and differences from the actual operating configuration which would tend to offset the non-conservatisms were as follows:

- The calculation assumed an outgassing rate of 100 percent. The actual rate would be less.
- Actual testing was done on one unit at a time with four CCW pump flow paths open. The calculation assumed only one open pump flow path.
- The duration of the analyzed SBO event was longer than the LOOP event (4 hours versus 1.5 hours).

It was not clear which will dominate, the conservatisms or the non-conservatisms, without rigorous re-performance of the analysis. Failure to reconcile the competing assumptions compromised the calculation on which the adequacy of the ECCW design requirements and test acceptance criteria were based in part.

(b) Calculation OSC-2300, "ECCW System Performance Evaluation," Rev 3, February 17, 1988, was generated to show that the condenser had the capacity to transfer the required decay heat without exceeding the condenser pressure limitations or causing flashing in the CCW piping which could cause loss of the siphon. This calculation formed the basis for the acceptance criteria of the Technical Specification required system flow test.

(1) The methodology used to derive the heat transfer capability of the siphon/condensers was nonconservative as follows:

- The calculation did not account for the potential for outgassing of the CCW which would tend to decrease the heat transfer capability of the condenser. Such outgassing would be driven by the

decrease in pressure in the CCW system due to the siphon and by the increase in temperature of the CCW as it passes through the condenser tubes.

- The atmospheric pressure used in the calculation was 14.7 psia. Per "Atmospheric Pressure for Design Calculations," S. L. Nader, File OS-3C, July 23, 1987, the correct atmospheric pressure for Oconee was 14.0 psia.

- The calculation did not account for the decrease in heat transfer area as a result of condenser tubes that were presently plugged and may be plugged in the future.

- The calculation did not account for the decrease in heat transfer area due to plugging of the tubes by the Amertap balls. The balls were continuously recirculated through the condensers for tube cleaning during normal operation. Due to the very low differential pressure across the condenser during siphon operation, the balls would stick inside the tubes.

(2) The calculation did not address, as one of its acceptance criteria, the requirement that the condenser capacity in the ECCW mode should be such that the main steam relief valves would not be open except in the initial pressure spike transient. This criteria should have been included to show that the system could perform one of its primary functions, minimizing the release of radioactivity and conserving condensate inventory by condensing steam in the condenser rather than exhausting it to the environment through the relief valves. Although the calculation was deficient in this regard, the licensee was subsequently able to demonstrate this capability.

(3) The calculation derived a minimum initial flow rate of 4,800 gpm to each unit's condenser to meet the heat transfer requirements. Flow through the three condensers was assumed to be equally split. Upon this assumption, acceptance criteria for the Technical Specification required flow test was derived. However, the unit specific flow paths (the piping from the condenser waterbox outlets to the common discharge line) were different in length and configuration. Also, there was not a flow analysis demonstrating the equal flow split. Therefore, the assumed equal flow distribution had not been validated.

10 CFR 50, Appendix B, Criterion III, "Design Control," requires that measures shall be established to assure that design bases are correctly translated into design documents and to verify the adequacy of design. Contrary to this requirement, the licensee did not adequately translate the requirements for the ECCW system into the analyses and test acceptance criteria which demonstrated the system's capability to meet those requirements. This is an example of Violation 50-269, 270, 287/90-25-05, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

(5) ECCW Test Procedure

Procedure PT/1/A/0261/07, change 8, August 8, 1991, "Emergency CCW System Flow Test," was the periodic Technical Specification required test of the ECCW system flow capability. The flowrate of the siphon was determined by measuring the distance between the exit nozzle of the ECCW piping and the middle of the flume's impact point with the tailrace. There were distance markings at two foot increments painted on the tailrace for taking this measurement.

Through licensee interviews, the probable width of the flume at the point of impact was approximately three feet, and the center of the flume was estimated to the nearest foot. Therefore, determination of the flume's impact point entailed an error of as much as ± one foot, which represented an error of approximately ± 2,000 gpm in the acceptance criteria. This potential error was not accounted for in the test acceptance criteria. 10 CFR 50, Appendix B, Criterion XI, Test Control, requires that, "Test procedures shall include provisions for assuring that....adequate test instrumentation is available and used..." This is considered an example of Violation 50-269, 270, 287/90-25-06, "Inadequate Testing Methods for Testing SSS Equipment."

(6) Although the ECCW calculations and the test procedure were inadequate, the most current test results of ECCW flow appeared to support system operability. This was due to:

(a) The current test procedure verifying the ECCW mode capability, PT/1/A/0261/07, change 8, August 8, 1991, was based on the more conservative analysis in Rev. 2 of the calculation which required an initial flow rate of 6,000 gpm per unit instead of 4,000 gpm per unit. This procedure's acceptance criteria started at 18,000 gpm flow and decreased with time based on an implied assumption that flow through the three unit condensers would be evenly distributed.

(b) Total ECCW flow was approximately 20,000 gpm.

(7) Under Minor Modification ON # 5534 dated September 14, 1998, the licensee deleted the condenser cooling water mode or the "second siphon" from the CCW system design basis document, Specification OSS-0254.00-00-0003, Rev 2, March 31, 1998. The licensee's safety evaluation justifying the deletion, considered the condenser cooling mode of decay heat removal as only required for the total loss of power (onsite and offsite) event discussed at original licensing. In the more recent SSF submittal approved by the NRC (SER dated January 28, 1988), the decay heat removal pathway described was via lifting main steam relief valves, and not the condenser cooling mode. Therefore, the licensee considered the SSF submittal as superseding the original requirements.

Deletion of the condenser cooling mode was not justified because:

- Technical Specifications 3.4.5 required the ECCW system. The Technical Specification bases stated "Normally, decay heat is removed by steam relief through the turbine bypass system to the condenser. Condenser cooling water flow is provided by a siphon effect from Lake Keowee through the condenser for final heat rejection to the Keowee Hydro Plant tailrace." It also stated that, "Decay heat can also be removed from the steam generators by steam relief through the main steam safety relief valves." Therefore, both the ECCW condenser cooling mode and the SSF submittal method were credited for decay heat removal.

- Section 9.2.2 of the current FSAR, "Cooling Water Systems," stated that the CCW system, "...serves as the ultimate heat sink for decay heat removal during cooldown of the plant. Following a design basis event involving loss of the CCW pumps, the Emergency Condenser Circulating Water System...provides flow through the condenser for decay heat removal." It further stated, "The CCW system has an emergency discharge line to the Keowee hydro tailrace... Under a loss-of-power situation, the emergency discharge line will automatically open and the CCW system will continue to operate as an unassisted siphon system supplying sufficient water to the condenser for decay heat removal and emergency cooling requirements." Additionally, it stated, "...the "second siphon" provides flow through the condenser to remove decay heat." And finally it stated, "In a loss of off-site power situation, the ECCW System is required to function until a CCW pump can be manually restarted by the control room operator."

- The licensee's SSF submittal did not request elimination of the ECCW condenser cooling mode from the licensing basis. The NRC's SSF SER did not state relief was granted from

previous condenser cooling mode licensing requirements, nor did it state that the condenser cooling mode was only required for a total loss of power event.

- On page 9, item 6, of a May 23, 1988, Notice of Violation, the NRC stated, "The ECCW system is required to provide both a suction source to the Low Pressure Service Water (LPSW) pumps and cooling water through the main condenser for decay heat removal if the Condenser Circulating Water (CCW) pumps are unavailable."

- In a February 11, 1987, letter concerning an enforcement conference for failure of an ECCW system test, the NRC's position was summarized on Page 3 of Enclosure 1 as, "The NRC discussed the event in detail with DPC and expressed concern that the load shed test had not been appropriately conducted in the past to insure that the required gravity flow (which relies upon a siphon) for the ECCW System was available and effective upon demand." On this page, the siphon referred to was defined as the "second siphon" in a statement that, "The ECCW System relies upon a siphon effect to lift water from Lake Keowee and then exit by gravity flow to Lake Hartwell at a lower elevation."

The licensee stated that present practices (operation, maintenance, testing, etc.) were not changed as a result of deleting the condenser cooling mode from the design basis document. However, the team considered that at a minimum, future modifications could be impacted. Also, the minor modification's safety evaluation became the basis for a licensee request to delete ECCW from the Technical Specifications. The Technical Specification change request was under review by NRR. Resolution of the team's concerns associated with the licensing bases of the condenser cooling mode and the prudence of the licensee's actions are contingent upon NRR's decision (either approval or denial) of the Technical Specification change request and completion of NRC's review of Unresolved Item 50-269, 270, 287/90-13-03, "ECCW System Design and Testing."

D. The CCW Pumps

(1) The active components associated with CCW pumps were not classified as safety-related. However, the licensee credited CCW pump operation 1/2 hour after accident occurrence to provide the suction supply to the LPSW system. Therefore, the pumps were improperly classified. Independently, the licensee recognized the error and was classifying the pumps as safety related in the most current draft revision to the Quality Standards Manual.

Unresolved Item 50-269, 270, 287/93-13-08, "ECCW System Design and Testing," already identified concerns regarding the licensing basis of the CCW pumps.

(2) The only documentation discussing CCW NPSH requirements was a letter from the pump vendor which stated that the pump "...will operate satisfactorily at a low water condition of elevation 770 feet." This letter did not address the temperature of the water on which this judgement was made. The design temperature for the CCW pumps at the time of this letter is given in Table 9-12 of the original FSAR as 75°F. Since then, the design maximum lake temperature was raised to 80°F by Calculation OSC-2508, Revision 0, July 24, 1987. Also, the letter did not discuss operation below the 770 foot elevation, the top of the intake canal's underwater weir, which would be the initial conditions for the loss of Keowee Dam event. Subsequently, the intake canal level would decrease due to leakage and evaporation. Finally, the intake canal temperature would steadily increase due to decay heat and other heat input from the three units.

Prior to and during the inspection the licensee was attempting to acquire the necessary information from the pump manufacturer. Acquisition of the information is Inspector Follow-up Item 50-269, 270, 287/93-25-09, "CCW Pump NPSH Information." The lack of CCW pump performance evaluation during the loss of Keowee Dam event is another facet of the inadequate Keowee Dam failure analysis discussed in paragraph d. below.

(3) The power and control cables for all of the CCW pumps and the pump discharge valves as well as all of the piping for the NPSH supply to the pump seals and coolers were located in a common trench at the CCW structure. This trench was covered with heavy steel deck plates which were not bolted in place. In response to a seismic event the plates in the horizontal portions of the trench would not dislodge due to stiffeners welded to the plates. However, there were sections of the trench running at approximately 45° from horizontal, and the plates covering these sections could be dislodged by a seismic event potentially damaging the cables below. The licensee was able to demonstrate that only the cables in the upper cable tray (powering the Unit 3 CCW pumps), and the cables in the bottom of the trench (powering and controlling the CCW pump discharge valves) could be damaged. Due to armored sheathing on the cables, damage could not spread to adjacent cables from the resultant electrical faults. Although CCW pump performance could be degraded, the total CCW function of supplying water to the LPSW system and the condensers would not be lost. The licensee initiated a work request to bolt the covers in place.