c. Keowee Loss of Dam Event

Part of the licensing bases for Oconee involved the ability to withstand a loss of Lake Keowee as an ultimate heat sink. Section 10.4 of the original FSAR, "Condenser Circulating Water System" stated, "In the unlikely event that the water level in Lake Keowee should fall below 770 feet, an underwater weir in the intake canal would act as a dam capable of retaining a large amount of water (87 million gallons) to serve as an emergency cooling pond. By operator action, the condenser circulating water system normal discharge paths would be closed and an emergency discharge conduit, provided for this contingency, would be opened, permitting cooling by recirculation of the cooling pond water. The capacity of this cooling pond is adequate to provide core decay heat cooling indefinitely as long as electric power is available to run the condenser cooling pumps in the intake structure." Therefore, for the dam break event, the impounded intake canal would become the plant's ultimate heat sink.

Numerous weaknesses in the licensee's ability to respond to the Keowee Dam failure were identified as discussed below.

(1) The licensee did not have analyses demonstrating the "...capacity of this cooling pond is adequate to provide core decay heat cooling indefinitely..." Such analyses should have addressed the heatup rate, the water inventory losses due to leakage, evaporation, etc., and the effects of the increased temperature and the decreased water inventory on the CCW system and the various systems being served. Therefore, the licensee failed to demonstrate the ability of the intake canal to perform as the ultimate heat sink as described in the FSAR.

10 CFR 50, Appendix B, Criterion III, "Design Control," requires in part that measures shall be established to assure that design bases are correctly translated into design documents and procedures. This is considered an example of violation 50-269, 270, 287/93-25-03, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

(2) Case B of Abnormal Procedure AP/1/A/1700/13, "Loss of Condenser Circulating Water Intake Canal/Dam Failure," described the actions to be taken in the event of a failure of the Keowee Dam without loss of the CCW intake canal. In Step 5.5.1, the operator was directed to align the LPSW system to recirculate the water back to the CCW crossover header between the units from which it also takes suction in order to conserve circulating water inventory.

In this closed loop condition, the temperature of the system would rise very rapidly to the point where its ability to perform its decay heat removal safety function would significantly

degrade. The licensee had no analyses supporting operation in this recirculation condition. Without such an analysis LPSW system operation was inconsistent with system design requirements.

10 CFR 50, Appendix B, Criterion III, "Design Control," requires in part that measures shall be established to assure that design bases are correctly translated into design documents and procedures. This is considered an example of Violation 50-269, 270, 287/93-25-03F, "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

(3) Procedure AP/1/A/1700/13, Case B, "Dam Failure Without Loss of Intake Canal", required the operator to actuate ECCW by pressing the "CCW DAM FAILURE" pushbutton. This action tripped the CCW pumps and opened the emergency discharge valve to the Keowee tailrace, CCW-8, to establish the ECCW flow. Upon restoration of power to the CCW pumps the operator was directed to start a CCW pump, verify that CCW-8 closed, and verify the emergency discharge to the CCW intake canal structure valve, CCW-9, opened.

However, as a consequence of the Keowee Dam failure valve CCW-8 would be submerged. Per Calculation FERC Project Number 2503 dated December 10, 1992, "Final Summary of Analysis to Determine the Extent of Inundation Due to Catastrophic Dam Failure for Keowee Hydro Project," for the dam failure event, the water level at the valve would reach a maximum of 770 feet for the "sunny day" failure and 785 feet for the "postulated maximum flood" failure. Valve CCW-8 was located within the flooded area in a concrete and steel enclosure. According to this calculation, the valve would be submerged by as much as 55 feet, and 12 hours would elapse before the water would recede below the valve. Even with the receding water, the water, mud and debris trapped within the enclosure could impact valve operation.

The licensee's analysis had not considered the consequences of the dam failure affecting valve CCW-8. Subsequent licensee review concluded that all operator actions associated with the valve's cycling would be accomplished prior to the flood water reaching the valve. However, the procedure and previous operator training did not indicate that these actions were time dependent. Also, the calculation establishing the time available for operator action was not very precise. Therefore, the ability to perform the necessary actions without such procedural direction/training was questionable.

(4) Procedure AP/1/A/1700/13, "Loss of Condenser Circulating Water Intake Canal/Dam Failure," had other weaknesses including:

- Pressing the "CCW EMR FAILURE" pushbutton without considering CCW pump power availability in Case 8. This action tripped the CCW pumps and opened the emergency discharge to the Keowee tailrace valve, CCW-8, to establish the ECCW flow. However, tripping the CCW pumps with power available was not necessarily the most appropriate action at that time.

- Not providing a caution to ensure a CCW pump was ready for immediate restart prior to closing the CCW discharge valves. Closure of the discharge valves would break the ECCW siphon. Therefore, the CCW pumps must be immediately ready for starting to maintain a viable decay heat removal path through the condenser.

The licensee stated that procedure AP/1/A/1700/13 would be reviewed to ensure procedural content was appropriate. Review and revision of this procedure is considered part of Inspector Follow-up Item, 50-269,270, 287/90-25-01, "Actions to Improve Operator Responses to Abnormal Events."

6. <u>High Pressure Service Water System</u>

The HPSW system was the site's fire protection system and constantly supplied cooling and sealing water to the CCW pumps. The system was capable of supplying cooling water to specific components normally cooled by the LPSW system, such as the HPI pump motor coolers and the TDEFW pump coolers. The system could also provide backup cooling to the Unit 1, 2, and 3 LPSW systems, though at reduced capacity, through interconnections at the discharge of the LPSW pumps.

The system was composed of three pumps, an elevated water storage tank (EWST), and interconnecting piping to fire protection deluge valves throughout the site and to the CCW pumps. The three HPSW pumps, two with 6000 gpm capacity each and one jockey pump, took suction from the 42 inch CCW discharge header. The jockey pump was normally in service maintaining HPSW system pressure. The other two pumps were in standby to automatically makeup lost water inventory to the 100,000 gallon capacity elevated storage tank.

HPSW must remain operational for the CCW system to accomplish its safety related function of supplying water from the intake canal to the suction of the LPSW pumps. The CCW system relied upon HPSW as a necessary support system in both the siphon mode and CCW pump operating mode. The interface between the CCW pumps and the CCW piping must be leaktight to prevent air inleakage which would break the siphon. Seal water from HPSW performed this function. Also, in order for the CCW pumps to operate, cooling water must be supplied to pump motor bearing coolers. Cooling water from HPSW performed this function. This sealing and cooling water was supplied by the HPSW system normally through operation of the HPSW jockey pump, and

during accident conditions involving a loss of power, from the elevated water storage tank. The HPSW pumps also performed an accident mitigation support function since EWST replenishment would be necessary to maintain long term cooling and sealing flow to the CCW pumps.

The original NRC Safety Evaluation Report discussed the HPSW as a backup to the LPSW system and "...concluded that the LPSW and HPSW systems will provide all needed normal and emergency services and are acceptable." Neither the SER nor the original FSAR discussed the HPSW support function for the CCW system. In the more recent licensee SSF submittal and the subsequent NRC SER, HPSW gravity flow cooling of CCW from the EWST for up to four hours was assumed. Without continual gravity flow, air inleakage would form voids requiring extensive fill and venting actions prior to CCW pump restart. Therefore, to allow immediate pump restart after four hours, the assumed duration of the SBO, HPSW gravity flow had to be maintained.

Inspection findings associated with HPSW were:

a. The HPSW system was not classified, constructed, tested or maintained commensurate with its importance to safety. This determination was based upon:

(1) The HPSW system was not designated or constructed to the seismic standards of the FSAR, but to conventional commercial fire protection structural standards of the late 1960s. Failure in virtually any portion of the system in a loss-of-power event would cause loss of CCW sealing and cooling water due to diversion of flow out the faulted piping section depleting the EWST water source. Consequently, through the loss of the siphon or the CCW pumps, the LPSW and CCW decay heat removal capabilities to all three units would be lost.

(2) The safety function of critical HPSW valves were not tested following maintenance.

During a LOOP/LOCA, SBO or any LOOP, the HPSW pump check valves, HPSW-2, 5, and 8, must not leak or the EWST inventory would drain into the CCW suction header. Such leakage would directly impact the duration of EWST cooling and sealing flow to the CCW pumps.

Maintenance records indicated that the only post maintenance testing on these check valves was an external leakage observation and did not include a reverse flow test. Normal system operation would only indicate gross leakage of the main HPSW pumps' valves and would not indicate any leakage of the jockey pump valve since it operated continuously.

Maintenance records for the last 13 years contained 5 work requests associated with the check valves. Three involved the NPSW jockey pump valve, NPSW-8. The first of these three was written in 1982 to repair a seat leak on NPSW-8. Although the original work request was lost, a replacement work request was closed out on November 20, 1986, with a note to the effect that the valve was checked out by Operations, and no problems were found. However, on the next day, the second work request was written to investigate and repair NPSW-8 because of indications it was not seating. Under this work request, the disk was found installed backwards and the disk nut and washer found to be broken off. Since there were no replacement parts available, the valve was reassembled and placed back into service on November 25, 1986, without a disk "...to enable [sic] the sys. to be used." Under the third work request, a replacement valve was installed on January 23, 1987. Therefore, [illegible] cooling/sealing capability to the CCW pumps was questionable for an extended period of time. It also appeared that during the last two months of this period, the inoperable status of this valve was recognized by plant personnel without any compensatory measures taken.

The other two work requests in the maintenance records were to disassemble, inspect, and refurbish valves NPSW-6 and NPSW-2 respectively in 1986. A responsible Maintenance Supervisor was asked if this work were being done today, would current procedural requirements have specified post-maintenance back-leakage testing for these valves. He responded that it would not have.

(3) Although the system performed a safety-related function, it was not classified as safety-related in the licensee's safety classification document, the Quality Standards Manual.

One of the ramifications of the lack of safety-related designation was not including NPSW within the IST program. Therefore, the stringent, periodic reverse flow testing of the NPSW check valves was not required. Also, the NPSW system was not included in much of the SWS GL actions since the GL was only applicable to safety-related SWSs.

(4) CCW pump cooling flow indication was not properly maintained. Consequently, operators may not be alerted to a low flow condition jeopardizing siphon operation when required. Also, one of the indications of inadequate motor bearing cooling flow was not properly maintained.

Each of the 12 CCW pumps was instrumented with 2 rotameters. A larger rotameter with a scribe mark was installed for cooling flow and a smaller one without a scribe mark for cooling flow.

These rotameters were input devices to low flow annunciators in the control room. Also, operators took local rotameter readings as part of their normal rounds.

Examples of improperly maintaining the rotameters were:

(a) The instrument procedure, IP/0/B/0604/004, used to calibrate the low seal and cooling flow alarms, directed setting the alarms nonconservatively with respect to the applicable vendor information. The procedure directed setting the low seal water alarm setpoint at 2.5 gpm ± 0.5 gpm decreasing, but the CCW pump vendor manual required a seal water flow of 3 to 5 gpm. The procedure directed setting the low bearing cooling water alarm setpoint at 1.6 gpm ± 0.2 gpm decreasing, but the pump motor vendor drawing required a bearing cooling water flow of 2.5 gpm.

Additionally, inconsistent with the rotameter's vendor document, OM 207-0179, the procedure directed reading the float from the bottom instead of from the scribe line on the float or from the top if there was no scribe line.

(b) The material condition of some of the rotameters was poor. Pump 2C's bearing cooler flow meter tube was installed backwards with the scale in a difficult place to read. Pumps 2A and 2D flow tubes, float, and guide rod for the seal water flow meters were heavily coated with organic contamination (slime). This would tend to reduce the accuracy of the instruments.

(c) The operator rounds sheet for taking local rotameter readings contained no guidance on how to read the reference marks. The Shift Manager was asked how the operators read these gauges. He responded consistent with vendor guidance on the larger rotameters with a scribe mark. However, he stated that "It was the consensus of opinions of the unlicensed operators that the float should be read to the center of the cylindrical portion" for the smaller non-scribe mark types. As discussed earlier this was not the correct reference point.

The seismic and safety classification concerns of the HPSW system were encompassed in an outstanding unresolved item documented in NRC inspection report 50-269, 270, 287/93-13. This unresolved item concerned the licensing bases of the CCW pumps, the ECCW subsystem, and their support systems. Resolution of this unresolved issue is contingent upon further NRC review.

b. Through various means (DBD effort, attempts to resolve outstanding SITA issues on ECCW, and SDD submittal preparation) the licensee's engineering organization recognized the safety significance of the HPSW system. This was evident by the licensee's decision to evaluate HPSW for seismic acceptability, adding the HPSW valves necessary for ECCW pump cooling and sealing to the most current draft revision of the safety classification document and establishing a periodic disassembly and inspection of the HPSW pump discharge check every fourth refueling outage.

However, based upon interviews with operations and maintenance personnel, this heightened safety emphasis on the HPSW system had yet to be fully conveyed to the rest of the organization. Also, two of the engineering actions associated with HPSW were not adequate or of sufficient scope. The two actions are discussed below.

(1) In the licensee's most current draft revision to the Quality Standards Manual, the safety classification document, some HPSW components were included, but not the HPSW pumps or their discharge check valves.

(2) The licensee recognized the lack of seismic qualification while attempting to resolve ECCW siphon support system concerns during design study ONMS 327 and PIP 92-004. The licensee concluded that the HPSW system was structurally adequate because it was "inherently rugged." Inherently rugged was defined by the licensee to mean that the system, in general, conformed to the criteria in EPRI Report NP-5617, "Recommended Piping Seismic Adequacy Criteria Based on Performance During and After Earthquake," January 1988, which had yet to be endorsed or accepted by the NRC. The licensee's evaluation criteria from the EPRI report were:

- A system walkdown has verified qualitatively that piping and equipment in the system are adequately supported.
- A system walkdown has verified that no large pipes are restrained by small pipes.
- A qualitative evaluation of the system has concluded that corrosion does not threaten its structural integrity.

However, the licensee's evaluation failed to consider the actuation of any of the fire deluge functions of the system due to a seismic event, which would have the same effect as a pipe break with regard to loss of water. Therefore, full identification of the adverse condition and assurance of adequate corrective action was not accomplished. 10 CFR 50, Appendix B,

Criterion XVI, "Corrective Actions," requires conditions adverse to quality be promptly identified and corrected. This is considered an example of violation 50-269, 270, 287/93-[illegible], "Inadequate Evaluation of Conditions Adverse to Quality by Engineering."

Also, the licensee's evaluation involved these weaknesses:

- The determination of adequate support was of a qualitative nature. The team observed some of the HPSW piping at the CCW intake structure to be supported by simple threaded rod hangers at relatively long intervals, and the hangers were attached to the concrete by simple expansion bolts.

- The conclusion by the licensee that corrosion did not threaten the structural integrity of the system was inferred from observations made in the similar LPSW system, and can be challenged by direct evidence of corrosion deterioration in the HPSW system. Although through wall leakage had not been observed, excessive flow restriction in the small bore HPSW piping to the CCW pumps caused the piping material to be upgraded to stainless steel in Exempt Change [illegible]. The licensee's safety evaluation for this change stated, "Recently failures have occurred in the small diameter piping, showing that the corrosion has reached the condition of causing us to question the integrity of the pipe." Also, though it did not render the system inoperable, corrosion had been identified in the LPSW system.

- Only the portion of the system from the HPSW water source to the CCW pumps was included in the walkdown.

The seismic and safety classification concerns of the HPSW system were encompassed in an outstanding unresolved item documented in NRC inspection report, 50-269, 270, 287/93-13. This unresolved item centered around the licensing bases of the CCW pumps, the ECCW subsystem, and their support systems. The lack of seismic qualification for the HPSW system was specifically discussed in the report. The concept of "inherently rugged" as an acceptable substitute for seismic qualification is another aspect of this unresolved issue. Resolution of this unresolved issue is contingent upon further NRC review.

c. There were numerous weaknesses in the management controls that assured the HPSW system was capable of performing as indicated in the licensee's [illegible] submittal.

The SBO submittal discussed gravity flow cooling of the CCW pumps from the EWST for up to four hours so the CCW pumps could be restarted immediately upon restoration of offsite power. Without continual gravity flow, air inleakage would form voids requiring extensive fill and venting actions prior to starting the CCW pumps.

The management control weakness are discussed below.

(1) The ability to perform cooling via the EWST to the CCW pumps and other necessary equipment for four hours was tested annually using test procedure PT/0/A/0200/30, "Elevated Water Storage Tank Drain Test." Per Section 5.2 of the procedure and the design specification for HPSW, OSS-0254.00-00-1032, the normal level of the EWST was 90,000 gallons or greater. Per Enclosure 13.3 of the procedure, Step 3.0, the capacity of the tank in minutes was calculated by dividing the EWST level at the beginning of the test by the adjusted HPSW outleakage flow rate. The result must be greater than 240 minutes (4 hours) to be acceptable. However, using the level at the beginning of the test for the calculation rather than the minimum full level of 90,000 gallons, only verified that the tank had sufficient capacity at that particular time, not for any other time when the level may be lower but still in the normal range above the "full" 90,000 gallons level. For the last six tests (March 21, 1997-August 7, 1998) the tank level varied between 97,000 gallons and 99,100 gallons. Therefore, the procedure failed to establish the appropriate initial test conditions. The licensee's submittal of January 28, 1999, states that adequate test procedures will be established to ensure system performance during a SBO. This is Deviation 50-269, 270, 287/98-25-10, "Inadequate HPSW SBO Test."

(2) The EWST drain test procedure had additional problems including:

- It allowed test re-performance if the original test failed due to HPSW discharge check valve leakage. Prior to test re-performance the procedure directed the applicable pump be isolated (closing its discharge valve) thus isolating the leaking check valve. Following completion of this second test, the isolated pump could be returned to service with an annotation on the operator turnover sheets to isolate the applicable pump on a loss of power event to prevent excessive losses of the EWST.

  This method of assuring EWST cooling capability by isolating the pump was not directed by emergency procedures, did not provide for verification of the completed action and could be forgotten or overlooked due to the numerous other tasks associated with a LOOP or SBO event. Also, assuming the operator action was performed, there was no provision in the test's acceptance criteria to account for the EWST inventory

lost through the leaking check valve prior to isolating the pump. Therefore, the procedure allowed an equipment deficiency that directly affected the test's acceptance criteria to be excluded without proper compensation.

- It directed the user to inform the operating manager for leakage rates greater than 500 gpm, rather than the maximum acceptable leakage rate of 375 gpm. Also, there was no direction as to what action the operating manager was to take upon being notified of the excessive flowrate. In an interview with an operating manager, he did not know what the appropriate response would be.

(3) For over seven months, the four hour gravity feed capability lacked validation. On February 27, 1988, PT/0/A/250/3 was performed and the system failed to meet the 240 minute acceptance criteria by 45 minutes. Subsequently, the licensee recognized that the procedure did not account for several water loss points from the system which automatically isolate for a loss-of-power event. The procedure was revised to account for these inventory losses on April 27, 1988. However, even when accounting for these losses, the test on February 27, 1988, would not have met the acceptance criteria. On August 7, 1988, the test was successfully re-performed. The team could not ascertain what (system maintenance, improper recording of data, change in equipment performance, etc.) caused the difference between the adjusted test results of February 27th and August 7th test results. The licensee was unable to provide any insights.

(4) Five of the CCW seal water rotameters and all of the bearing cooling water flows (3A's was solid against the upper stop at 8+ gpm) were greater than the values used to calculate the four hour availability of the EWST. Also, the operator rounds sheets contained no upper limit for these flows.

7. Standby Shutdown Facility

The SSF was a separate onsite building housing the necessary equipment to maintain all three units in a safe shutdown condition following turbine building flood, fire, sabotage, certain classes of tornados or station blackout. The ASW portion of the SSF was composed of a high head, low capacity pump and interconnecting piping to all steam generator EFW discharge lines, solenoid operated flow control valves in the discharge lines to the steam generators, a pump and piping to cool a tandem diesel with a common generator, two pumps with a condenser unit to cool the HVAC within the SSF and a moveable submersible pump. The SSF ASW, HVAC and EDG pumps took suction from the Unit 2's CCW pumps discharge header. The HVAC

and EDG pumps discharged to the CCW header. There was an option to divert the EDG pump discharge water to the yard drainage system when high temperature constraints warranted. The submersible pump allowed replenishment of the CCW header from the intake canal.

a. Jocassee Dam Failure

In the licensee's IPE submittal for an event outside the facility's licensing bases, the SSF was discussed as the system to mitigate the consequences of a Jocassee Dam failure. This dam was located upstream of the Oconee site and formed the uppermost boundary of Lake Keowee. The IPE flood evaluation concluded that the Oconee site would be under 4.71 feet of water. With the exception of the SSF, this would render all decay heat removal cooling systems inoperable. To assure the SSF would not be affected by the flood, a 5-foot (4.71-foot plus 0.29-foot) high waterproof flood wall was constructed around the ground level entrances to the SSF. The review of the SSF to withstand this postulated flood was as follows:

(1) Contrary to the IPE submittal, the SSF could not withstand the postulated flood. Therefore, core damage of all reactor units would occur as a consequence of such a postulated flood.

In response to questions from the team regarding initial lake height assumptions, the licensee stated that a recently completed reanalysis of the Jocassee Dam failure for another regulatory agency resulted in a flood height at least 10 feet above the SSF wall. The change in flood height was due to modeling a bridge abutment downstream of the Keowee tailrace in the most recent flood analysis. The abutment acted as a flow constriction causing the flood waters to backup over the Oconee site. From a PRA perspective the probability of core melt from the Jocassee Dam failure as calculated by the team increased ten fold to 1.50E-05.

Licensee correction of the this error and subsequent corrective actions as a result of the error are considered a part of Inspector follow-up Item 50-269, 270, 287/93-25-11A, "Jocassee Dam Failure IPE Inaccuracies."

(2) Another aspect of the IPE submittal was in error. IPE Submittal report, Section 3, Subsection 13, indicated there was an 8-foot waterproof flood wall around the SSF ground level entrances. The wall was 5-foot in height.

Licensee correction of the this error and subsequent corrective actions as a result of the error is considered a part of Inspector follow-up Item 50-269, 270, 287/93-25-11B, "Jocassee Dam Failure IPE Inaccuracies."

(3) A watertight gate was installed in the flood wall to allow access to and from the SSF. The gate was observed on more than one occasion with the watertight dogs not properly secured.

b. SSF Calculations

(1) Following plant modifications performed in previous years, some of the applicable calculations were not updated. Examples included:

- OSC 2030, Standby Shutdown Facility HVAC Load Calculations

  The calculation conclusion section stated:

  "The SSF Air Conditioning System can maintain design conditions in the safety related areas (Control Room and Battery Rooms) with the following actions:

  (A) Start second condenser circulating water pump to provide 41 GPM condenser water flow with both pumps operating.

  (B) Shed security computer load by the time control room temperature reaches 85 F or temperature of condenser water reaches approximately 93 F."

  However, an electrical interlock had been installed preventing simultaneous operation of the two condenser circulating water pumps. The condenser circulating water pumps were of different sizes, and their simultaneous operation would cause flow instability and eventual pump runout. This interlock could not be bypassed. Also, the SSF HVAC system had been modified excluding portions of the security complex and portions of the HVAC had been rerouted.

  Prior to the conclusion of the inspection the licensee re-performed the HVAC calculation with acceptable results. The design document had not reflected the as-built condition of the facility at the time of the inspection.

- OSC-3233, SSF Service Water System Hydraulic Model

  The last revision of the model was January 23, 1989. Since then, the HVAC pump motors had been changed from 1700 rpm to 3600 rpm motors, pressure breakdown orifices had been installed, the 3 way valves located upstream of the SSF HVAC condensers had been replaced, and the SSF ASW impellers had been changed twice. Other calculations were performed which

partially encompassed the changes to the hydraulic model but, did not reconcile those results with the total hydraulic model. Therefore, this design document did not reflect the as-built condition of the facility.

The administrative controls for updating calculations, EDM-101, Engineering Calculations/Analysis, Section 2.4.4 only required these calculations be updated in a timely manner, rather than establishing a definitive length of time. 10 CFR 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," require appropriate acceptance criteria for determining that quality related activities have been satisfactorily accomplished. This is an example of Violation 50-269, 270, 287/93-25-12A, "SNS Procedure/ Drawing Content or Procedure Implementation Inadequacies."

(2) Calculation OSC-4171, "SSF ASW Pump Minimum Flow Line Design Inputs Calculation," contained invalidated or nonconservative assumptions as follows:

- Each unit or steam generator pair had only one flow instrument associated with it. Calculation OSC-3303, "SSF ASW Flow and SSF ASW Pump Suction Pressure, Instrument Accuracy Calculation: CCW FT0225," determined the methodology for calculating the instrument loop error for the flow instruments. The result was +/- 54 gpm for an individual flow instrument. The three flow instruments errors were averaged through the square root sum of the squares method resulting in an error of +/- 31 gpm. The instrument error used in calculation OSC-4171 was +/- 31 gpm.

  However, if just one of the flow instruments were at or near it's negative maximum error that particular unit's minimum required flow would be inadequate. According to accepted industry methodology, the square root sum of the squares methodology is used to combine dependent and independent variables to calculate loop uncertainties. In this instance the methodology was misapplied, in that it was used to reduce an individual error contribution and not calculated loop uncertainties. The use of this nonconservative assumption resulted in a flow to a pair of steam generators that was 23 gpm below the minimum analyzed flow. During the inspection period the licensee indicated that a calculation was being prepared that would lower the minimum required flows such that the 23 gpm difference would not invalidate the conclusion of OSC-4171. However, the calculation was not ready for NRC review. 10 CFR 50, Criterion III, "Design Control," requires the design basis and applicable regulatory requirements be translated into appropriate

documents. This is considered an example of Violation [illegible]. 270, 287/[illegible], "Failure to Perform Adequate Calculations and Evaluations to Support Facility Design."

- Calculation OSC-4171 assumed the flows were equally balanced between all six generators. That assumption had never been validated.

- Calculation OSC-4171 and numerous other calculations assumed certain flow distributions among the three SSF operating pumps (SSF ASW, HVAC, and [illegible] cooling water pump). Also, the discharge flow of the operating HVAC pump was assumed to equally split between the two parallel SSF HVAC condenser coolers. These two assumptions had not been validated.

c. SSF Testing

(1) Post-construction Testing

Post-construction SSF testing in the mid-1980s did not adequately confirm critical functional requirements of the SSF design and was not performed in accordance with committed quality standards. Examples included:

(a) The flushing procedure provided by the licensee for the discharge lines was a gravity fill and drain from [illegible] prior to the piping being connected at the SSF ASW pump discharge or in the penetration rooms. There was no acceptability criteria for the flush in the procedure. This fill and drain did not provide assurance that the lines were not blocked or partially restricted.

(b) The calculations supporting SSF design assumed certain flowrates and flow distributions to the steam generators. No documentation existed validating that flow could be achieved to any of the steam generators. The licensee verbally confirmed that there was no flow testing performed which involved the discharge lines beyond the test line connection. Therefore, flow control valve capabilities were not verified, and assumptions associated with equalizing flow to units and steam generator pairs were not verified.

(c) The calculations supporting SSF design assumed certain flow distributions among the three SSF operating pumps (SSF ASW, HVAC and [illegible] cooling water pump). The three pumps were not tested simultaneously to confirm the assumed flow distributions and that the equipment would perform as predicted.

The preoperational testing portion of ANSI N45.2.8-1975, Section 5.2, dealing with assurance of operation in accordance with SSF design and proper flow alignments was also applicable to this aspect of the facility's design.

10 CFR 50, Appendix B, Criterion XI, "Test Control," requires a preoperational testing program demonstrating facility acceptability to the design requirements. Also, the licensee was committed to ANSI N45.2.8-1975 and ANSI N45.2.1-1973 through Duke Power Company Topical Report 1-A, Table 17.0-1. ANSI N45.2.8-1975 and ANSI N45.2.1-1973 requires in part that flushing procedures with velocities and acceptance criteria based on filter, turbidimetric or chemical analyses. The preoperational testing portion of ANSI N45.2.8-1975, Section 5.2, states in part "This testing involves the operation of all items in a system ... to assure that operation is in accordance with the design criteria and functional requirements. The testing shall include, but not be limited to, ... service requirements for initial operation such as flow alignments ..." Therefore, critical aspects of the SSF's design were not demonstrated prior to placing the facility into service. This is an example of Violation 50-269, 270, 287/93-25-08, "Inadequate SSF and ECCW Testing."

(2) Periodic Testing

(a) The periodic testing program for the SSF was accomplished through component specific testing. There were specific tests for the SSF ASW pump, HVAC pump, etc., which were performed at different test intervals. The periodic SSF ASW pump test discharged through a test line connection and not through the full extent of the steam generator discharge lines. Therefore, the deficiencies of the post-construction testing previously discussed in paragraph c.1 above were not rectified by the periodic test program.

b. Beyond the post-construction testing deficiencies discussed in paragraph c.1, the sum of the component specific periodic testing did not constitute an integrated test. Certain aspects of system design could only be provided by the licensee through the completion of actions during emergency response drills. An example of this was the unwinding and connecting of the submersible pump's electrical cable to its emergency bus and operating the pump. These actions were not part of any periodic test program and had only been accomplished once during an emergency response drill.

c. Emergency Procedure AP/0/A/1700/25, Standby Shutdown Facility Emergency Operating Procedure, Enclosure 6.1, Step 2.5 and 2.12 instructed the operator to start the SSF ASW

pump with no preparatory action beyond aligning a flow path to the designated unit. The periodic pump operability test, PT/0/A/0400/06, directed an additional action of pump venting in Step 12.2 just prior to starting the pump in Step 12.4. This action preconditioned the pump, possibly masking air entrapment within the pump which would affect pump performance. 10 CFR 50, Appendix B, Criterion XI, "Test Control," requires test procedures direct the establishment of suitable environmental conditions when performing the test. This is considered an example of Violation 50-269, 270, 287/93-25-08, "Inadequate SSF and ECCW Testing."

d. Other Observations

(1) There were few material condition deficiencies observed. Preventive and corrective maintenance was effective. Repetitive corrective maintenance actions were not evident. Most work requests were completed in one to three months.

(2) Operator training met normal industry standards and emphasized strict adherence to procedures. The information supplied by training matched the information in the procedure.

8. <u>Auxiliary Service Water System</u>

ASW was originally designed for a non-design bases event, the loss of the intake canal/structure. However, following NUREG 0737 review of the facility for tornado vulnerabilities, the system was discussed in the July 28, 1989, NRC Safety Evaluation Report to mitigate the consequences of the most severe classes of tornadoes. For these severe tornados the ASW system in conjunction with the HPI system were required to maintain the units in a safe shutdown condition by providing adequate decay heat removal via the steam generators and RCS makeup.

ASW was a shared system common to all three units. It consisted of a suction connection at the Unit 2 CCW pump discharge piping, a low head, high capacity pump, piping with manual valves connected to the EFW discharge piping of all three units for cooling all the steam generators, and piping with manual valves connected to the LPSW piping for cooling the HPI pump motor coolers. The ASW pump was operated from the tornado protected, safety related AuxService Water Switchgear.

The only other actions necessary in the severe tornado event was operation of the HPI pump. Since normal HPI pump power was not tornado protected, one HPI pump motor per unit could be manually connected to the AuxService Water Switchgear through spare power cables staged for this purpose.

Inspection findings associated with the ASW system were:

a. Emergency Procedure EP/1,2,3/A/1800/01, Section 502, Step 10.1

required approximately 200 gpm be provided to each steam generator by the ASW pump. The step further stated that if one steam generator was isolated, flow should be increased to approximately 400 gpm to the un-isolated steam generator. The ASW discharge lines or the interconnection with the EFW system to the steam generators did not contain any flow instruments. Therefore, there was no way to verify the directed actions had been accomplished. 10 CFR 50, Appendix B, Criterion V, "Instructions, Procedures and Drawings," requires adequate written procedures be provided for activities affecting quality. This is an example of Violation 50-269, 270, 287/93-25-12, "SSS Procedure/Drawing Content or Procedure Implementation Inadequacies."

b. To support the licensee submittal that ultimately led to the tornado SER, Calculation OSC-2262, Tornado Protection Analysis, was generated. The calculation indicated that ASW system operation must be accomplished in about 40 minutes to prevent core uncovery.

(1) Job performance measures existed for the alignment of ASW to the steam generators, alignment of ASW to the HPI pump motor coolers, and establishment of electrical power to a HPI pump motor. Documentation indicated that the tasks could be accomplished in approximately 30 minutes after the operators recognized the need for ASW. No integrated drill/test verifying that all the tasks could be accomplished within the requisite time had been performed.

(2) There was no abnormal procedure specifically for a tornado event. Entrance into the emergency operating procedures for inadequate secondary side heat transfer would eventually direct use of the ASW system. These procedures attempted to establish normal feedwater, emergency feedwater, and SSF service water prior to initiation of ASW. However, there was only 10 minutes available for the operator to direct initiation of ASW in lieu of these other systems (10 minutes to decide to use ASW + 30 minutes to initiate ASW from training documentation = 40 minutes before core uncovery). The procedure provided the system options, but system selection was based on operator judgement depending upon the extent of the tornado damage. No test or drill had been devised confirming the operator's ability to make this judgement within the 10 minutes available.

(3) Other procedures associated with flow through the EFW header to the steam generators included a caution to limit flow to less than 1000 gpm to reduce tube vibration. Procedures associated with ASW operation did not contain such cautions and the hydraulic model indicated that flow to the Unit 3 steam generators would exceed 1000 gpm in certain conditions. The licensee indicated that flows of this magnitude would be for a short period and the tube integrity concerns due to vibration

were only a factor in extended operation. However, the licensee decided to review this item and determine if procedural guidance should be included.

Licensee initiatives to improve operator guidance for response to a severe tornado are considered a part of Inspector Follow-up Item, 50-269.270, 287/93-25-06C, "Actions to Improve Operator Responses to Abnormal Events."

c. Certain equipment associated with the ASW system were not included within a periodic testing program. However, licensee actions associated with the SSD effort identified the situation and appropriate corrective actions were being taken. Examples included:

- Cooling water flow to the HPI pump motors had never been established using the ASW system. However, a test procedure was being developed to establish and verify flow to the HPI motor coolers.

- Certain check valves within the LPSW system which must close to establish HPI flow were not tested in the closed direction per the IST program. This lack of reverse flow check valve testing had been previously identified by the licensee. Corrective actions were in progress to revise the IST program and develop testing procedures for the valves. This is Violation 50-269, 270 287/93-25-13, "Omissions of LPSW Check Valves from IST Program." However, based upon the corrective actions in progress, the licensee's self identification of the matter, no similar violations associated with omissions in the IST program, 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.

- The discharge check valves to the steam generators were being incorporated into a test/inspection program for the first time.

d. Some of the calculations associated with the ASW system lacked rigor. Examples included:

(1) Calculation OSC-4000, Auxiliary Service Water Flow Model, did not model cooling water flow to the HPI pump motors. The licensee performed preliminary calculations indicating flow would be sufficient. Also, complete bench marking of the ASW hydraulic flow model had not been performed.

(2) In the formal ASW pump NPSH analysis and in a subsequent informal analysis the licensee used incorrect assumptions. These were:

(a) Calculation OSC-5125, ASW NPSH Analysis, assumed siphon flow from the intake canal to the ASW pump suction would be in operation following the tornado. Consequently, an administrative minimum level, 780', associated with Lake Keowee was selected as the minimum suction height for the NPSH calculation. However, the ECCW siphon lacked tornado protection, and would not be operational. Therefore, the minimum suction height was contingent upon the inventory losses in the CCW piping as a result of ASW pump operation.

(b) Once the incorrect assumption was identified to the licensee, the licensee re-evaluated the situation and determined the minimum NPSH for the ASW pump was -2.22 psig and NPSH considerations did not restrict pump operation. A required NPSH of -2.22 psig meant that the pump could draw water from 5.12 feet below the pump's impeller eye and still have adequate NPSH. However, the licensee failed to consider the actual configuration of the CCW piping going to the suction of the ASW pump. Therefore, when the water in the CCW piping dropped to a height of 770.46 feet, inadequate NPSH would occur.

Subsequently, the licensee performed preliminary calculations on the water volume between 791 feet, the assumed initial suction height of the calculation, and 770.46 feet. Results indicated that a substantial amount of water inventory still existed allowing ASW operation for an extended period. Therefore, the assumed replenishment of the ASW supply source before reaching 770.46 feet appeared reasonable. Issuance of a revised calculation is considered an Inspector Follow-up Item 50-269, 270, 287/93-25-14, "Review of Revised ASW Pump NPSH Calculation."

(3) Abnormal Procedure AP/1,2,3/A/1700/11, Loss of Power, Enclosure 6.3, Aux Service Water to HPI Pump Motor Coolers, required the recirculation test line valve, CCW-287, be opened approximately 2 turns prior to starting the ASW pump. This flow path through the test line was also the minimum flow pathway to prevent deadheading the pump. No data or calculations existed showing that enough flow could be achieved with CCW-287 throttled to protect the pump. Subsequently, the licensee performed preliminary calculations indicating a flow between 400 and 480 gpm could be achieved with valve CCW-287 in the throttled position. The 400 gpm flow appeared acceptable for minimum flow protection. However, the licensee decided to completely open CCW-287, fully assuring minimum flow protection, prior to starting the ASW pump.