3.2 Review of Design

3.2.1 Civil and Electrical Structural Evaluation

The design basis of Keowee was described in the licensee developed documents, Keowee Emergency Power Design Basis Document (DBD), OSS-0254.00-00-2005, Revision 1, dated December 3, 1992 and in Design Basis/Test Acceptance Criteria for Keowee Emergency Power System DBD, Dwg. No. KTC-0-0113-0001-001, Revision) dated January 28, 1991. These documents were used by the team to evaluate Keowee's design. The DBDs for the Keowee mechanical systems and the 125VDC systems are scheduled but not yet issued.

The design and licensing documents associated with seismic qualification of the safety related electrical systems and equipment were reviewed by the team. Documentation supporting equipment qualification was available for that equipment identified as seismic per the UFSAR (Table 3-68). However, the UFSAR omitted four transformers (1X, 2X, 1E and 2E) for which specific qualification documentation was not available. 1X and 2X provide 600 VAC auxiliary power to operate their respective turbine generator loads. 1E and 2E provide excitation for their respective turbine generators. Prior to the end of the inspection the licensee provided qualification documentation for comparable transformers. The licensee also plans to include these transformers in their SQUG program. The team concluded that the structural qualification of the Keowee electrical components was appropriate.

3.2.2 Mechanical Systems

The team reviewed the design and licensing documents for the Keowee mechanical support systems. This included the turbine generator cooling, turbine guide bearing oil, high pressure oil and governor air systems. The mechanical systems were designed and erected to conventional industry standards for hydro-electric facilities.

The team inspected the majority of the supporting systems which were required for the Keowee hydro units to perform their function. As stated in the Keowee mechanical DBD, these systems were designed and constructed to meet the industry grade equipment standards in existence at that time when the plant was constructed. The balance of the piping systems were constructed to B31.1-1967. Several of the safety related support systems contained significant quantities of brass and/or copper piping. Examples were noted of non-safety piping where components were located over important safety related equipment. One example which was apparently not addressed by previous Keowee audits was the presence of fire protection and vacuum system piping installed above the Keowee governor cabinets.

All systems appeared to have been constructed to the requisite industry standards except for the turbine generator cooling system. The coolers (turbine guide bearing oil, generator thrust bearing and generator air)

associated with this system were not protected from overpressurization due to thermal expansion of the water in an isolation mode (both upstream and downstream valves closed). No relief valves were installed to protect the piping.

The UFSAR Report 3.2.2.2 established the design criteria for this piping as USAS B 31.1.0. USAS B 31.1.0 section 101.4.2, "Fluid Expansion Effects," requires overpressure protection. The licensee was informed of this discrepancy and initiated PIP 0-093-0197 to address the problem. The appropriate course of action was under determination at the conclusion of the inspection. Failure to provide overpressure is identified as an example of a deviation (DEV 50-269,270,287/93-02-03).

The Keowee mechanical systems were not designed to seismic qualifications. Prior to the inspection the licensee had initiated a design study, ONDS-025B, addressing the seismic issue. The licensees Self Initiated Technical Audit (SITA) audits had identified some problems related to seismic issues on battery room Heating, Ventilation and Air Conditioning (HVAC) and cable supports. These specific cases were reviewed under the licensee's condition adverse to quality system with no problems identified. The comprehensive corrective action to this matter will be through the SQUG program as part of the resolution to USI A-46. At the conclusion of the inspection the licensee was completing a determination of what components were to be included in the SQUG program.

During the reviews, the team noted that the design and licensing documents associated with the mechanical systems omitted the noted aspects of the design. Examples included:

- No specific descriptions of how the Keowee mechanical systems function in the UFSAR.

- Omission of the portion of the cooling water line and manual valve that is common to both turbine generators in UFSAR section 8.3.1.2.

- Seismic Design Criteria, OSDC-1093.01-00-0001, did not specifically address the mechanical systems or how the design criteria apply to the mechanical systems.

Prior to this inspection the licensee identified numerous deficiencies in the documentation and had initiated corrective actions including preparation of a mechanical design basis document and flow diagrams for the different systems.

The team utilized the recently developed Keowee Flow Drawings (KFD) during walkdowns of the systems. Several discrepancies between the KFDs and the actual plant conditions were noted. These included differences in piping arrangements and valve numbering. In some cases, valves contained two conflicting labels because a previous tag had not been removed following installation of a revised label. During the

inspection, efforts were in progress to address the errors. The team also noted many examples of Keowee electrical drawings which contained safety related equipment which were not marked as "safety related" or as "QA Condition 1". Since the drawings of the electrical systems are not very user friendly, many of the drawings contained important information which had been penciled in. System drawings for the air system did not exist and some errors were identified on the recently developed KFDs. Detailed walkdowns of the loading configuration of one AC and one DC load center indicated that the drawings accurately reflected the existing equipment arrangement. Additional review of the documentation identified minor deficiencies. The specific drawing inaccuracies were documented on PIP 0-093-0197 so they could be corrected at the next drawing revision. (See Appendix A, Finding 3) Deficiencies involving testing of the mechanical systems are discussed in paragraph 3.4.2.4 of this report.

3.2.3 Separation and Sharing of Systems

The team noted several areas in which the two Keowee units were not totally independent. Various licensing documents discuss the common penstock. The team reviewed the controls associated with the headgate and concluded that appropriate measures were in place to prevent inadvertent blocking of the penstock by the headgate. A small portion of the cooling water system (supply line from the penstock) which contains one manual isolation valve was common to both units. Rigorous separation between the control and electrical cables of the units was not employed. In many cases, cables for the two units occupy the same trays. However, armored cables are used with voltage and current carrying ratings in excess of that required. Although many of the primary components for the units are separated physically, for 10 CFR 50 Appendix R criteria, Keowee is considered as one fire area. The fire protection systems are common to both units. The potential consequences of a failure of fire protection piping will be addressed by an internal flooding study scheduled for completion by March 31, 1993.

The batteries for the Keowee units were separated by a partial length block wall which contained several unsealed penetrations. Efforts were made to provide some separation between the emergency power paths. ACBs 3 and 4 (underground feeder path breakers from each Keowee unit) were separated from the other switchgear but were located in the same structure with only several feet of open space separating their cabinets. The air supply system for all four ACBs was connected together and check valves on small reservoirs at the breakers were relied upon to function if a break occurred in any section of the piping. Several other supporting air systems which were not required for the Keowee units to accomplish their intended safety function (if other systems perform as required) were shared by both units. The team concluded that under normal conditions and alignments, the failure of one of these air systems would not adversely affect both units. With one exception, the team did not identify any specific scenarios in which the potential

vulnerabilities noted above would present a likely failure of the Keowee units. The exception was that plugging of the common generator cooling water supply line had occurred once in the past.

3.2.4 Electrical Calculations and Analyses

Many of the electrical calculations associated with the Keowee Hydro System were reviewed to determine if the existing analyses, studies, and tests were sufficiently comprehensive. The following major issues were examined:

- Adequacy of the analyses and tests necessary to demonstrate the capability of Keowee to start, accept, and accelerate its worst case design load, within required times, without degradation of the connected safety loads.

- Assessment of the licensee's evaluations involving the potential vulnerabilities associated with a single Keowee unit powering all redundant safety groups of an Oconee unit following a DBE. Specifically, the team reviewed potential vulnerabilities associated with operation of both units to the grid and their hydro units' control systems.

- Adequacy of Keowee generator's electrical protection to prevent degradation of the Oconee auxiliaries during anticipated operational occurrences. This item was reviewed because the licensee has issued several LERs related to this subject as the result of unanticipated operational occurrences.

The licensee had generated a significant number of associated calculations as part of a design basis effort over the last three years. Because a single Keowee unit powers all redundant safety groups of an Oconee unit following a DBE, the EDSFI focused heavily on review of the licensee's assessment of the Keowee vulnerabilities associated with this arrangement.

3.2.4.1 Single Failure Criteria

The team questioned the licensee's conformance to the single failure criteria as stated in the UFSAR. Section 8.3.1.2 of the UFSAR states, "The basic design criteria of the entire emergency power system of a nuclear unit, including the generating sources, distribution equipment, and controls is that a single failure of any component, passive or active, will not preclude the system from supplying emergency power when required". The team found that the licensee had not fully analyzed the controls consistent with this requirement. The team concluded that the licensee had not adequately analyzed potential single failures within the hydro unit governor control systems. The team identified several other potential single failure vulnerabilities which had not been sufficiently analyzed. This item is identified for further NRC review. This will be identified as IFI 93-02-04.

The team noted that the licensee had completed the appropriate failure analyses of the generating and distribution systems and these had resulted in hardware modifications, setpoint changes and administrative controls. Design Study OSC-5096, Keowee Single Failure Analysis was approved by the licensee on January 21, 1993. The study documents the results of a single failure while both Keowee units are supplying power to the grid. The study applied the single failure criteria as stated in the UFSAR. A LOCA/LOOP was assumed and single active or passive failures, or spurious actuations, were examined down to the component level. The appropriate Keowee controls were included. The study identified that following a trip from full load operation, an overspeed switch in each Keowee unit could make both unavailable. The licensee's evaluation of this resulted in Keowee's power output being administratively limited to 60 Megawatts (MW). Previous load rejection test results were used to determine from what load Keowee could sustain an overspeed without making either unit unavailable. The team concluded that the administrative limits were set at a conservative value. The team verified that the Keowee operators were aware of these administrative limits.

The team noted that the study closely examined the performance of the Loss of Excitation Relay. This relay locks out its respective Keowee unit upon detection of loss of excitation voltage. The potential concern was if both units were running to the grid, both of the relays may actuate as a result of grid instability or an electrical fault. The study substantiated that both relays would not actuate as a result of grid instability or an electrical fault. The team noted that a recommended relay setpoint revision was provided in OSC-4300, dated 3/91 because the existing setpoint could be effected by grid stability response. The team's observations in the field were that the relay settings had not been implemented. The revised setpoint had been evaluated as not effecting operability, and was being tracked in Station Problem Report (SPR)-3426, and was awaiting management work authorization. During the quarterly senior management review, problems are identified to be worked, and to date this had not been selected.

During the review of the Keowee volts/hertz limiter, a design feature, in the voltage regulator was examined. No documented specific failure analysis for this feature existed, but the licensee was able to demonstrate that a single active or passive failure would fail safe. The team concluded that it was possible that a failure of the signal mixer or other features may not have the same result, causing an undetected increase in generator field current and an undetected overvoltage on the Oconee auxiliaries. The licensee responded that it was their licensing position not to analyze the controls and referred to an internal memorandum to File, dated 1/15/93, which stating "that in general it has been the Oconee position not to consider "smart failures" within control systems and the system is assumed to control or design to fail to its designed state". This item is identified for further NRC review. This will be identified as IFI 93-02-04.

The team evaluated the licensee's single failure analysis of the Keowee governor control systems. The licensee provided a copy of an internal Memorandum to File, dated 1/15/93, that documented the results of the single failure review of the governor. The team concluded that this review was not complete, since conclusions were not well supported. An example, the failure of the linkages within the governor and the wicket gate shear pins was evaluated. The review concluded that these were passive failures. Failures of inherently rugged items need not be postulated because normal operation of the unit would reveal actual problems with these units should they occur. The team did not agree with licensee's conc'usions since the shear pins are designed to fail (active) during abnormal conditions. During discussions, the team identified that the licensee had limited this review to the collective experience of the involved personnel (including a technical representative of the governor manufacturer). Searches of LERs, Nuclear Plant Reliability Data System (NPRDS), etc., had not been performed. The team noted that the licensee had submitted LER 83-01 in which a single failure in the Keowee hydro Woodward governor system was identified which could have rendered the associated Keowee unit inoperable.

The licensee indicated that the principle reason that failures of the governor system had not been examined more closely was that undervoltage conditions would cause a governor abnormality to be promptly identified. The undervoltage device (27S) was set at 68% and its operation would result in connection of another power supply automatically. The team agreed the undervoltage relay will eventually detect the problem, however, it was not evident that this would be in sufficient time. The governor failure mechanism is descrited in section 3.6.1. and indicates that its failure could take place over some period of time and not instantaneously. The detection time of the undervoltage condition is critical to establish the connection of the alternate supply to protect Oconee safety loads. The team concluded that additional review was needed in the area of potential failures of the governor control systems. (See Appendix A, Finding 4)

A review of operating experience indicated that the overall Keowee design had been vulnerable to a single failure. Several LERs had been submitted in the past two years addressing single failure vulnerabilities. These were identified and corrected by the licensee. Most were corrected through equipment modifications. The licensee did not consider all credible failure modes for the Keowee governor control system and voltage regulator. (See Appendix A, Finding 5)

The team also reviewed the degree of independence between the onsite emergency power sources and between their distribution systems. The team found the licensee did not consider a single failure concurrent with the initiating event LOCA/LOOP (loss of the 230 kV Switchyard) in the development of Tables 8-3, Single Failure Analysis for Keowee Hydro Station, and Table 8-4, Single Failure Analysis for the Emergency Electrical Power Systems, of the UFSAR. The licensee considers a

portion of the 230 kV switchyard to be part of the onsite, and not the offsite, power system even though it is described and analyzed as the offsite power system in the UFSAR Sectio .2. The team considered that the 230 kV switchyard is part of the off e system until the control logic isolates the switchyard and a single failure should be considered with the initiating LOCO/LOOP.

The licensee's current position regarding their definition of the single failure criteria and how it is applied in reference to the 230 kV switchyard is identified for further NRC review. This will be identified as IFI 93-02-04.

3.2.4.2 Protective Feature Issues

The team had several concerns which involved the electrical protective features associated with the Keowee hydro units. It was concluded that in some areas the features may not be appropriate to the degree of safety commensurate with the fact that redundant safety groups for each Oconee unit are fed from one emergency power supply.

The control logic bypasses all of the Keowee normal automatic electrical and mechanical protective trips on an emergency start. The bypassed trips include generator and turbine bearing overtemperatures, volts/hertz, overspeed, governor oil pressure, generator field ground, and maximum excitation. The licensee was asked to provide analysis/or bases for bypassing these protective trips from the perspective of one Keowee unit powering all three redundant safety groups. The licensee indicated that the bypasses were consistent with NRC Regulatory Guide 1.9. However, the basis for bypassing Keowee trip functions during emergency start of the unit was not fully analyzed or documented. In the Oconee arrangement, all the redundant load groups are powered by a single emergency power supply, and this necessitates the detection and isolation of an adverse condition in sufficient time to connect the alternate emergency supply. The licensee initiated PIP 0-093-0081 to request a study on this subject. (See Appendix A, Finding 5)

The team noted that the Keowee design did not provide for protection and detection of abnormalities such as over or under frequency operation that may be experienced by a single failure of a component in the speed control circuits. The auxiliaries are not protected for overvoltage conditions as might be experienced by an abnormality in the voltage regulator or during a sustained overspeed condition.

3.2.4.3 Keowee Auxiliaries

The licensee had completed a single failure analysis of Keowee auxiliary transformers 1X, 2X, and CX in KC-0082. This analysis resulted in operability requirements which were recently incorporated into TS requirements.

The licensee had performed single failure analyses on the coordination of safety and non-safety 600 volt switchgear protective devices to identify potential losses of redundant functions. The analyses had resulted in hardware modifications and administrative controls.

3.2.4.4 Other Calculations

The team reviewed other engineering calculations and analyses during the inspection. Some findings were noted:

KC-0073, Auxiliary Power System Voltage Level, Rev 1, (3/9/92), a voltage analysis of the Keowee 600V auxiliaries was considered incomplete. Sections 20.2.3.3, 20.2.3.4, and 20.2.3.5 of the DBD refer to KC-0073 as a basis of the voltage adequacy for Keowee auxiliaries when supplied from any of the three potential sources (either the Keowee generators via 1X and 2X transformers, from Oconee Switchgear 1TC via CX , or the 230 kV Switchyard via the 1X and 2X transformers). KC-0073 analyzes the voltages recorded before and after a Keowee start when fed by 1X, 2X, and CX, and also establishes a single baseline reference point. This methodology utilized representative data and did not consider variations in the supplied voltage levels. The results obtained was the normally expected bus voltage. The calculation should have obtained the maximum and minimum expected voltages and evaluated these in view of equipment voltage limitations. The maximum expected voltage is also an input to the short circuit analyses, and higher voltage will result in increases currents. In response to the teams comments, the licensee reviewed the calculation and concluded that no operability concern existed. The licensee indicated that an additional analysis (KC-Unit-1-2-0095) would be performed. (See Appendix, Finding 2)

The Keowee 600 volt cable sizing calculations were found to be generally acceptable. The team noted that technical standards and output documents existed but intermediate calculations were not present. Three examples were reviewed and the cables were found to be sized per the licensee requirements. The licensee provided a comparison of the Oconee cable sizing criteria to the 1990 National Electric Code and Insulated Power Cable Engineers Association (IPCEA) P-46-426 which demonstrated that the cables were oversized when they are routed in conduit, cable trays with maintained spacing, or cable trays with single layer fill. The documentation did not address derating if power cables were routed in overfilled trays along with control and instrument cables as was the case at Keowee. The team could not establish what cables were in what raceways from the documentation. The existing cable tray fill and contents of the trays and sizing was a concern. The licensee indicated that they were going to inventory the cables at Keowee in a manner similar to the process at Oconee.

Calculation, OSC-4328, Revision 2, Operability Evaluation for Keowee Load Centers 1X and 2X in Response to PIR-4-091-0039 (9/23/92), was reviewed. The analysis addresses operability of the Keowee auxiliary equipment power supplies (1X, 2X, and CX transformers). It was noted that in certain scenarios, the safety related electrical auxiliaries for both Keowee units could be supplied from only one Keowee unit. Keowee powers all redundant Oconee auxiliaries during a DBE. It is essential that abnormal voltages and frequencies not degrade redundant equipment. The equipment has voltage and frequency limitations; some critical performance characteristics of the electrical equipment can be adversely affected. The licensee initiated PIR 0-093-0081 on February 11, 1993, to address this issue. (See Appendix A, Finding 2)

This calculation, OSC-4328 is also used as a basis of Keowee 600 volt breaker coordination. The calculation identifies that coordination problems exist between load centers Motor Control Center (MCC) supply breakers and the MCC main feeder breakers and recommends corrective actions. The corrective actions have been implemented. The licensee identified one example that had not been corrected. The problem was miscoordination between the load centers and safety related MCC 1XS and 2XS. The licensee judged this to be of no concern as the MCCs powered a safety load (the standby battery charger), which is not needed at the start of the event. In review of drawing K-702, Rev 14, the team also noted that the Spillway and Intake Power Panels did not coordinate. The two major criteria utilized in the development of the analysis were discussed with the responsible engineer. The first consideration was that all branch circuits feeding safety-related loads shall be coordinated such that no overload or credible fault on a safety-related circuit can disable more than one safety-related power distribution string. The other criteria was that branch circuits feeding non-safety-related loads from safety-related busses shall be coordinated such that no overload or credible fault on non-safety-related equipment can disable any safety-related power distribution string. The team indicated to the licensee that the criteria should be clearly stated in the DBD, as it establishes the reference boundary for the design of this particular feature.

Calculation, KC-0076, Rev 2, dated 8/1/88, Voltage and Duty Cycle Calculation was reviewed, and it was noted that there was no discussion of the results considering the equipment voltage limitations. Other calculations were in progress to examine the adequacy of the emergency start channel (OSC-5077) and the adequacy of the voltage to the generator field, generator supply, and field flash breakers (OSC-5093). The comprehensiveness of the scope of the supplemental calculations to examine voltage adequacy at the component level should be considered by the licensee. It was also noted that KC-0075 was an input to this calculation that was issued subsequent to the issue of KC-0076. As a result,

KC-0076 may require update. The licensee should identify the full scope, and complete individual voltage component calculations for Keowee. (See Appendix A, Finding 2)

OSC-4653, Revision 1, Battery Charger and Safety Related Inverter Sizing Calculation (1/21/93) demonstrates the adequacy of the existing Keowee charger size based on KC-0076, a one hour discharge rate, and supply of continuous load. An improved charger, which the licensee stated was on order, will meet an 8 hour discharge rate and supply continuous load. This charger will more closely comply with accepted industry practices in this area.

Other calculations were reviewed. Their methods, assumptions, results, and conclusions were found to be consistent with the licensing bases. These calculations were: KC-Unit 1-2-0090, 1/22/93, Keowee 600 Volt Distribution Fault Study, KC-Unit 1-2-0084, 7/23/92, Keowee 13.8 kV Breaker Fault Study, and KC-0075, Rev 1, 4/9/91, Keowee 125 VDC Battery Load Test Report.

3.3 Operation of the Keowee Units

3.3.1 Emergency Start Operations

Following a DBE on an Oconee Unit, the hydro units will be emergency started from zero speed, and will accept a single block load with the Keowee voltage and frequency as low as 50% of their rating. The Keowee units may (and often are) operated to generate peaking power to the transmission grid. The practice is to load to the units in excess of 60 MW to limit long term degradation of the hydro impeller due to cavitation. Under these conditions, and following an emergency start, the unit is disconnected from the grid and then reconnected to the Oconee busses if required. This sequence includes tripping of the output breaker, a load rejection, and results in an overspeed condition on the Keowee unit. Connection to the Oconee busses will then occur before full recovery from the overspeed condition. These start and load sequences create voltage and frequency excursions on the Keowee output. Since the Keowee unit powers the required safety related loads for the Oconee unit, the ability of the Keowee generator to maintain voltage and frequency within limits that would not adversely effect the loads is critical.

The team concluded that the licensee lacked sufficient analyses and tests to fully demonstrate that Keowee would perform its function under these conditions. Transient voltage analyses were completed for the underground path and are planned for the overhead path. At the beginning of the inspection there were no analyses, existing or planned, which adequately address frequency performance. As a result, the effects of the frequency transients on the equipment had not been evaluated. The team was not able to establish that Keowee had been emergency started and loaded through the overhead path or that the existing tests fully bound the design. (See Appendix A, Finding 1)

Completion of the overhead voltage analysis and tests to demonstrate the ability of Keowee to start, accelerate and accept load were open items from the DBD effort and documented in a Memorandum to File dated May 14, 1991.

During the EDSFI the licensee supplemented the completed analysis with informal analyses to demonstrate that Keowee would function without degradation of its auxiliaries when started from zero speed. Additionally the licensee provided test data which demonstrated the units' capability to start, accept approximately 35% of the maximum expected LOCA/LOOP block load, and the maximum expected LOOP load, and accelerate with this loading within 18 seconds. Other data was provided which demonstrated that the Keowee units could accommodate approximately 71% of the expected LOCA/LOOP block load,and 44% of the LOOP load, but no time parameters were included in the testing.

These tests were reviewed by the team to establish a level of confidence that the power system will deliver the required Emergency Core Cooling System (ECCS) flows within the required time (48 seconds) via the underground path. No analyses or tests were available to assess the performance of the emergency power system when Keowee feeds Oconee via the overhead path. The team concluded that while emergency starts from zero speed should be bound by the existing analyses, connection from grid operation and from recovery of an overspeed condition require additional evaluation. The effects of the analyses and tests on margins was not determinable. The licensee indicated that these analyses and additional testing would be completed this year.

Chapter 8 of the UFSAR required that Keowee accept full emergency power load as it accelerates from zero to full speed within 23 seconds from receipt of an emergency start signal. The team found this requirement had been translated into the TS as 25 seconds. This was identified in 1989. However, the correct timing requirement was indicated in the test procedure.

3.3.2 Worst Case Loading

The UFSAR states that the capability of the 87.5 MVA Keowee units to continuously carry a maximum load of 21 MVA had been analyzed. The team determined that additional analysis had been performed in this area. The licensee had established the worst case load profiles, considering the transient and steady state, that are in excess of those stated in the UFSAR. The team's review indicated that the LOCA/LOOP and three unit LOOP scenarios represent the worst case loads and these load profiles are significantly higher than the UFSAR loadings. In those load sequences that connect the loads at reduced Keowee voltage and frequency, the initial load peak would be less than the maximum. However, under other accident conditions, the loads can be connected at higher voltage and frequency levels and thus the load peak may be much

greater. The team concluded that since the magnitude of the loads effects the ability of Keowee to meet its functional goals, the specific bounding load profiles should be indicated in the DBD.

3.3.3 Load Sequencing

When Keowee receives an emergency start, the required Oconee electrical loads are supplied power by one of the following load sequences:

- If Keowee was not generating to the grid, and there was a LOCA/LOOP, the load would be connected by the EPSL to the Keowee underground path approximately 11 seconds after the emergency start was initiated. At this time, the voltage and frequency could be as low as 50% of rated. After the load was connected, the unit should continue to accelerate to rated voltage and speed (frequency) within the 23 seconds prescribed in the UFSAR. If the other Keowee unit did not establish voltage in sufficient time, the loads of the non-LOCA Oconee units would also be connected to the underground path as early as 31 seconds after the emergency start. The functional Keowee unit would be at rated speed and voltage at that time. The connection of this load results in a frequency decrease that could last several seconds and affect the performance of the required safety loads at all three of the Oconee units.

- If Keowee was not generating to the grid and there was a LOOP, the Oconee loads are connected in approximately 31 seconds by the MFBMP system.

- If both Keowee units are generating to the grid and an emergency start signal was received, the units are tripped and begin to overspeed. The Units also experience an overvoltage as a result of the load rejection, however, the voltage regulator acts to rapidly restore the voltage. Test data indicates that the overspeed peaks at 195 rpm on Keowee Unit 1 and 188 rpm on Keowee Unit 2. (The actual value varies with lake elevation and Keowee loading.) The loads (for the non LOCA Oconee units) would be supplied by Keowee via the overhead path within 4 to 7 seconds after receipt of the emergency start signal and while the unit was recovering from an overspeed condition. Test results indicate that the Keowee unit would be between 132% and 138% of rated speed and voltage. This overfrequency corresponds to about 79-82 Hz.

Section 15.8.2 of the UFSAR, "Loss of Power Accidents" states that the required Oconee safety related loads can perform through an overfrequency transient lasting 40-50 seconds. Apparently, this information was relied upon to substantiate that the equipment would not be degraded during the above transient conditions. However, the licensee was not able to retrieve the analysis, or provide the technical basis for the statement that the electrical equipment can withstand the transient. (See Appendix A, Finding 2)

3.3.4 Keowee Operational Controls

3.3.4.1 Overall Keowee Operations

The team noted that informal means of control were sometimes relied upon regarding activities within the hydro station. The condensing mode of operation of the Keowee units, which had not been fully analyzed and thus was not authorized, appeared to be fully operable and controlled only by the fact that no specific procedure existed to support such operation. Deficiencies such as problem instruments were not formally tracked for resolution and in some cases were not labeled. The level and pressure in each Keowee unit's governor oil pressure tank was critical to the operation of the hydro units. This level was maintained and monitored (by the operators) through the use of two pieces of duct tape on the tank sight glass. By measurement and reference to the post installation testing data and vendor manuals, the team verified that the tape marks were in fact at the proper levels. The level switch which actuates an annunciator on abnormal tank levels had not been calibrated or tested. The controllers for the heaters in the turbine guide bearing oil systems for the units were set at different values.

Due to several equipment problems and a few recently identified design issues, numerous administrative controls were in effect on the Keowee equipment. The following is a list of the significant items:

- Due to a problem involving short circuit ratings, the alternate feeder breakers to several load centers were tagged to require entry into an Limiting Condition of Operations (LCO) if utilized.

- The disconnects for ACB 2 were tagged/locked open due to a zone relay protection issue and also due the use of a non qualified repair part in the breaker. These issues restrict the flexibility of the normal longterm Keowee alignment.

- When generating to the transmission grid (only unit 1), the Keowee unit was administratively limited to a maximum output of 60 MW due to a potential overspeed trip concern. Automatic Gain Control (AGC) was also not utilized on the unit to help ensure that this limit was not exceeded.

- The Keowee AC auxiliaries are maintained in a required alignment and in the "manual" mode due to problems with the automatic transfer system.

The team did not identify any safety related functions which were directly or adversely affected by the use of these informal administrative controls. Additionally, it should be noted that since the Keowee operating staff consists of five operators and three technicians, more formal methods may not be required regarding most issues. The team observed that procedural compliance, independent verification, and tagging activities during maintenance activities were appropriate. It was also noted that the procedures addressing removal

and restoration of Keowee Station equipment were highly detailed. Additionally, it was noted that the general quality of procedures which had been revised or written within the past two years by Keowee personnel was good. Procedures which had not been recently revised or which were not directly controlled by Keowee personnel, were not as detailed and in several instances, needed upgrading.

During the inspection, it was noted that the knowledge and skills of the Keowee technicians was heavily relied upon. The Keowee operators are limited in their knowledge and capabilities to address abnormal conditions or equipment malfunctions that occur. The common practice under such circumstances was to contact the power system dispatcher and the Oconee Control Room and await the arrival of the technician onsite to address the problem.

3.3.4.2 Material Conditions

Extensive tours of the Keowee facility were conducted. Overall housekeeping and control of combustibles was appropriate. The turbine wheelpit areas contained excessive corrosion products on the walls and on equipment mounted on the walls. Some small debris was noted under the switchgear in the battery room. The team inspected the interior of several critical control cabinets, the governor enclosures, several ACB compartments, and both generator enclosures. In all of the areas, no discrepancies were noted. The interior of the upper portion of the governor cabinets was noted to be particularly well maintained.

3.3.4.3 Keowee Setpoint Controls

A single controlling document for the setpoints of Keowee equipment does not exist. (Electrical relays are an exception and are listed in OSC-4300).

While recently revised procedures under the control of the Keowee staff contain the necessary setpoints, most other procedures do not contain the setpoints. The partial listings of setpoints do not contain tolerance acceptance bands. Personnel performing activities refer to drawings and sometimes rely on personal knowledge to determine setpoints. Often, the as found or as left setpoints were not recorded in the procedure. One example was the setting of Permanent Magnet Generator (PMG) speed switch number 4. These speed switches play a role in the generator's response during an emergency start. The switches had been set to actuate at 50 rpm by reference to a vendor provided listing. Questioning by the team led to the identification that the setpoint was listed as 65 rpm on two of the licensee's drawings. The licensee acknowledged that this problem existed and plans were being made to correct the problem. However, the team could not locate a PIP that identified this issue. (See Appendix A, Finding 3)

3.4 Testing of Keowee

3.4.1 Review of Voltage and Frequency Analyses and Tests

The DBD states that the voltage adequacy for the Oconee safety bus loads when fed from the underground power path was documented in calculation OSC-2444 and OSC-3696. The licensee advised that OSC-2444 presents the worst case analyses. Keowee analysis (OSC-2444) was performed using Continuous System Modeling Program (CSMP) to analyze the transient voltage performance at Oconee when fed by Keowee via the underground path. Similar analyses, addressing the transient voltage performance at Oconee when fed by Keowee via the overhead, were scheduled for completion in the spring of 1993. The licensee had concluded that the underground path was the worst case voltage response as there was more impedance in the underground circuit. The team concluded that this was appropriate if Keowee was started at zero speed. However, connection from grid operation could result in an overvoltage condition that was not bounded by the underground analysis.

Insufficient analyses exist to determine the frequency response of Keowee under different conditions. In response to team questions, the licensee addressed the effects of abnormal frequency when powering Oconee via the underground path. The DBD did not consider the frequency response of Keowee and its potential effects on Oconee.

The existing transient voltage analysis assumed that the 13.8 kV generator was an infinite bus with terminal voltage constant at 13.2 kV, and the frequency constant at 60Hz. These assumptions did not appear to be valid as they did not reflect that the voltage and frequency could be as low as 50% of rated when the loads were initially connected. In response to the team's observations, the licensee pursued a dynamic voltage and frequency analysis using the underground path. The dynamic analysis was performed with a new software program that still required validation in accordance with the licensee's QA program. Both the existing dynamic analysis and analysis performed during the EDSFI had limitations. The CSMP could not model the voltage regulator or speed control dynamics and the software used in response to the EDSFI concerns would not accept other than rated voltage and frequency as the starting point. The final results of the analyses did not enable the licensee to obtain actual voltage and frequency versus time profiles.

The results of this dynamic analysis were provided to the team along with evaluations of equipment performance when experiencing both voltage and frequency below acceptable limits. The licensee substantiated that fuses would be able to sustain the current inrush associated with the undervoltage transients. Additionally the licensee evaluated the effects of the transients on safety related loads (HPIP, EFW, LPI, LPSW and RBS pumps motors) and concluded the voltage to be adequate. The evaluation of the induction motor performance resulted in more margin than the previous analyses because the volts/hertz control feature of the voltage regulator limits the ratio to 1.06. The licensee informed the team that the Keowee voltage regulator would follow the speed

(frequency) and maintain the ratio at 1.06. As the starting torque of a motor was directly proportional to the volts/hertz ratio squared, the net effect was that the motor provides 1.12 torque to load ratio and starts faster. The team concluded that this analysis was appropriate as long as the voltage did not drop below a point that results in the motor torque being less than the load torque. The licensee stated that the voltage would dip below 13.2 kV for a maximum of 36 cycles. The team noted that the analyses demonstrated that the recovery could take as long as 200 cycles. The licensee then provided further clarification that the recovery occurs within 36 cycles provided the generator comes up to speed with no load. As this was not the actual case, the team concluded that further review of this issue may be warranted by the licensee. This would ensure that the voltage not dip low enough to cause the motor torque to be less than its load and result in spurious tripping of the Oconee loads.

During review of the dynamic analysis, it was noted that the frequency of the Keowee supplied power was below rated for 40 to 50 seconds. The team concluded that the effects of this decreased frequency on the performance of the ECCS loads may need to be evaluated. The licensee provided the team with a copy of the B&W topical 10103A, Revision 3, dated July, 1977 "ECCS Analysis of B&W'S 177-FA Lowered-LOOP NSS," that indicated that the time delay for providing power to ECCS pumps was 25 seconds assuming the single failure of a diesel. The licensee provided updated information that substantiated 90% HPI flow was required to the Reactor Coolant System (RCS) within 48 seconds. The B&W analysis took no credit for flow before 48 seconds. B&W was also aware that one of the Keowee units supplied all of Oconee's emergency loads. The licensee correlated the B&W requirements with the results of the electrical analysis to establish that there would be adequate flow. The updated B&W report may need to be reviewed to confirm this information. The licensee also addressed the effects of operation below 57 Hz for approximately 10 to 16 seconds (57 Hz is the minimum frequency that an induction motor can run when at rated voltage). The licensee indicated that the increased current for this short duration would not cause the motor to trip or overheat. (See Appendix A, Finding 5)

The licensee stated that the conclusions of OSC-2444 should remain acceptable, except for the voltage adequacy evaluation on some lower voltage busses, which were addressed in part by the above equipment evaluations and OSC-4581. The team did not concur with this conclusion. The team noted that the dynamic analysis results did not agree with the UFSAR 23 second time requirement and more accurate consideration of the control logic would aggravate this concern. A more accurate representation of the actual voltage and frequency response may be required to assess agreement with the UFSAR. The licensee provided information indicating that the Keowee unit will continue to accelerate while accepting load due to the action of the speed control system. They were also able to provide test results with times to support these statements. In the pre 1987 Emergency Start Test, PT/1/A/0610/01J, shutdown loads were block-loaded onto the Keowee Unit in the same manner that would occur in an event. The test data

showed that the Keowee Unit accepted a block load of approximately 2 MVA and reached rated speed and voltage within 18 seconds. The data also demonstrated the actual frequency response was not what would be provided by the dynamic simulation. Further analysis may be warranted in this area. The team concluded that the licensee should define acceptable voltage and frequency limitations for the Keowee electrical auxiliaries and the emergency power system. Additional, acceptable recovery times from voltage and frequency excursions should be identified. (See Appendix A, Finding 5)

3.4.2 Keowee Performance Tests

3.4.2.1 Start and Load Acceptance Tests

The net results of these start and load acceptance tests should establish the capability of the unit to start and accept load within prescribed periods of time. These tests should also demonstrate that the frequency and voltage can be maintained within acceptable limits. The team concluded that the test results reviewed to date do not fully bound the design. The licensee has agreed to perform supplemental testing.

The DBD, KTC-0-0113-0001-003, requires verification of each Keowee units ability to supply a block load equivalent to the Oconee emergency load requirements. The licensee implemented this requirement by paralleling each unit to the grid and assuming load at the maximum practical rate.

Performance test procedure PT/0/A/0620/16, Keowee Hydro Emergency Start, verifies on an annual basis that the Keowee units will start and accelerate to rated speed and voltage within a designed time upon receipt of an emergency start signal. The unit is loaded after reaching rated voltage and speed. In section 8.3.1.1.1 of the UFSAR it indicates that Keowee starts, accepts load, and accelerates within 23 seconds. This feature is no longer tested. (See Appendix A, Finding 1)

During each Oconee unit refueling outage (approximately two units per year), performance procedure PT/0/A/0610/01J, Emergency Power Switching Logic Functional Test, tests the logic which aligns the Oconee loads to the Keowee underground feeder. This test ensures proper breaker operation.

A completed test in accordance with procedure PT/0/A/0610/01J which was performed prior to 1987 was provided. This test demonstrates Keowee's ability to start and accelerate a 2 MVA load block via the underground path. Subsequent to the exit the licensee provided the specific results of such a test performed on 10/1/86. That test connected the 2 MVA load at 11 seconds which was fairly close to the expected loading during a DBE. The test resulted in the starting and acceleration of 2 MVA load to rated speed and voltage within 18 seconds. The requirements of performance procedure PT/0/A/0610/01J had been relaxed from those in the pre-1987 procedure. The test is currently performed with a 2 MVA block load connected to Keowee after it reaches rated speed and voltage.

The most rigorous test appears to be the October 19, 1992 event. The licensee provided information concerning the loading of Keowee during this event. This event demonstrated the ability of Keowee to accept a 4 MVA block load, subsequently accepted a block load of 1.8 MVA with the 4 MVA running, and an additional 1 MVA block load with 5 MVA running. Comparison of the loading of this event with the design demonstrated that the unit can start and accelerate with 71% of the maximum LOCA/LOOP initial block load and 42% of the maximum LOOP initial block load. However, no times were available.

The licensee also provided a summary of testing performed at the Jocassee Pump Storage Station. The units at that pump storage station located near Oconee were very similar to the Keowee units. On a regular basis, one of the Jocassee units was utilized to start another Jocassee unit as a motor. The licensee concluded that a 140 MVA generator was starting a 140 MVA motor. Further questioning identified that the unit being started as a motor was being accomplished with the gate closed. The actual load corresponds to that of the inertias of both the motor and water wheel rotors and was expected to be approximately 2% of the machine rating. This was a reference value of power required to motorize a hydro unit. In response to further questioning by the team, the licensee also advised that it took 2-3 minutes to start and accelerate that load. This test did not appear to be as rigorous as other tests or events.

The team concluded that the existing tests collectively do not bound the design requirements. The licensee stated that additional testing would be performed in 1993 to demonstrate that Keowee can be loaded through the overhead as required by the design. (See Appendix A, Finding 1)

3.4.2.2 Rated Load Tests

The team reviewed these tests to ensure that they adequately demonstrate the capability and availability of the units to carry the continuous loads required by the DBE.

The units are routinely paralleled with the grid at loads much greater than those required by the DBE. These operations are performed on a frequent (often daily) basis. During the EDSFI, the team observed that the unit aligned to the overhead path was generally run at 60 MW on a daily basis.

The longest continuous time period of Keowee operation was thought to be three days. The team noted that the Keowee DBD stated that the Keowee unit may be required to run continuously for longer than three days. |

3.4.2.3 Load Rejection Tests

These tests were reviewed to assess the ability of the Keowee units to reject a full load without electrical or mechanical damage to the unit or the connected loads. These tests were completed in 1971 and included

scenarios in which one or both units were initially generating to the grid. The maximum overspeed recorded was 195 rpm. Electrical parameters were not recorded.

3.4.2.4 Keowee Support and Control System Testing Issues

Several concerns were noted regarding testing of other safety related components necessary for the operation of the Keowee units. By virtue of the fact that the Keowee units are frequently operated to supply power to the transmission grid, significant portions of the Keowee units are functionally tested at frequent intervals. The team focused on those systems not required to perform their function during operation for power generation, but necessary for emergency operations. Inspection was centered on those specific components which could either prevent an emergency start or could result in the loss of unit under emergency start conditions. The team noted that the TS did not contain testing requirements for Keowee mechanical support systems.

Weaknesses were identified involving the testing of several lubricating oil systems essential to the operation of the hydro units. Although some testing of the DC powered turbine guide bearing oil pumps were being conducted, it was not complete to ensure those pumps would function properly to support Keowee operation when required. The pumps would be required to operate in case of a loss of the Keowee auxiliaries (AC power) or loss of the AC powered oil pump. Several safety related level switches in the oil systems which could affect the operability of the Keowee units under emergency start conditions had not been calibrated nor functionally tested. Discussions with involved personnel indicated that at least one of these testing inadequacies had been previously recognized and a testing procedure was under development. During a review of all PIPs and PIRs involving the Keowee facility, the team noted that this problem was not addressed in the system. The team was informed that the procedure for testing of the switches was under development.

During reviews of circuitry and devices involved in the emergency lockout feature (actuation of the 86E relay results in tripping and lockout of the unit under emergency start conditions), the team identified another discrepancy. A pressure switch in the carbon dioxide fire protection system (63FX) which should actuate the 86E relay if a fire occurs in the generator, had not been calibrated nor functionally tested. The circuitry from the switch to the 86E relay had not been tested. It was noted that during testing in accordance with Procedure MP/0/A/2000/59 several annunciators would be activated by this same pressure switch but those alarms were not checked during the test. Spurious activation or inoperability of this circuitry could adversely effect the performance of the Keowee generating units under emergency start conditions. This issue was discussed with licensee management on February 11 1993. At the close of the inspection, the licensee was investigat[illegible] methods for testing the switch. (See Appendix A, Finding 6)

It was noted that performance monitoring testing was not routinely performed on the safety related mechanical components (coolers and pumps) at Keowee. Design study ONS-0275, completed on December 31, 1990, listed all pumps and valves at Keowee which should be tested. Actions were still in progress to develop the necessary program. (See Appendix A, Finding 6)

During the inspection, the team identified several valves which were required to change position for Keowee to provide emergency power, which were not included on the Keowee active valve list (KC-0085). These valves were; 1 and 2 OG-7 (the governor oil tank float valves) and the four check valves on the ACB air accumulators. Since that list was used to determine testing requirements, it should be complete.

During review of the testing associated with ACBs 1, 2, 3, and 4, procedural weaknesses were noted. MP/0/A/2001/2: Inspection and Maintenance of Keowee ACBs and associated Disconnects and Bus, did not provide sufficiently detailed instructions for testing of several important components. The check valve on the air accumulator in each breaker are relied upon to seat if a problem occurs anywhere in the ACB air system which was common to all four ACBs. Step 11.1.12 of the procedure states "Inspect the check valve" and "repair or replace if it is sticking." The team's review of the associated vendor manual (KM-303-26) did not identify any guidance for testing of these valves. Through discussions with I&E personnel who perform the ACB work, the team concluded that the actual testing performed was adequate to identify a malfunctioning check valve. Despite the lack of specific guidance provided in the procedure, the workers were knowledgeable of how to inspect the check valves after the test. The procedure also did not contain adequate guidance regarding testing of two air pressure switches which actuate an alarm on decreasing air pressure. The team confirmed that the switches were tested in accordance with the guidance provided in the vendor manual.

3.5 Keowee Modification Review

The design input calculations for several modifications were reviewed. The team concluded that the licensee did not establish adequate design input prior to proceeding with the modification and existing DBD did not identify specific design data.

OSC-4757, Rev 1, Electrical Design Input and EQ Verification for Urgent Modification On-52917, Replacement of "X" relays on Keowee Westinghouse "DB" Breakers (1/12/93) was reviewed. This calculation was found to be incomplete. The review indicated that the modification was incorrect in that if implemented as proposed, it would have defeated both the manual and remote operation of the breaker. The error was identified and corrected during implementation. The team concluded that the error was the result of not fully considering the performance of the equipment as required by the calculation. The licensee only considered performance with the anti-pump feature of the breaker and did not consider the performance during manual and remote closure operation of the breaker.

OSC-4077 is the design input calculation supporting NSM-52855/00. This modification resolved a potential overload condition as a result of not tripping reactor coolant pumps which would be operating prior to automatically connecting Keowee to Oconee via the overhead path following a LOCA/LOOP. The team concluded that the problem was the result of the existing DBD lacking appropriate reference bounds for voltage and was not adequately supported by analysis (i.e. overhead path analyses were planned). OSC-4077 required that ACB-1, ACB-2, and PCB-9 trip on switchyard isolation and added a four second time delay before reclosure of ACBs 1,2 and PCB-9. The 10 CFR 50.59 evaluation for this modification was completed in OSC-4080, dated 8/10/90. The modification appropriately considered the timing interfaces with the RCPs. Load rejection tests and an understanding of the volts/hertz feature of the voltage regulator show that changing this timing significantly increases the magnitude of the initial voltage and frequency at the time of breaker closure. Analyses or tests to demonstrate that the previous control scheme would work without degradation of the auxiliaries or causing spurious trips had not been developed. Allowable magnitudes and durations of voltages and frequency were not identified in the DBD. The team concluded that this information should have been developed prior to implementing the modification.

3.6 Review of Corrective Actions at Keowee

3.6.1 Loss of Switchyard Event (October 1992)

As a result of detailed reviews of the Keowee systems involved in the October 1992 event, the team concluded that in some areas, the licensee's corrective actions had not been commensurate with the significance of the event.

Although the development of an abnormal procedure for an emergency start condition addressed some concerns regarding the actions of Keowee operators, the team noted a weakness in the procedure. A significant issue identified as a result of the October event was that the Keowee operators relied excessively on the "on-call" Keowee technician. Review of the procedure and discussions with Keowee operators indicated that the operator would not restore the Keowee AC auxiliaries (even if lost due to a simple problem) without obtaining permission from the Keowee technician. The procedure was subsequently revised to correct the problem.

The operation of the Keowee hydro units' governor system without AC power or adequate control oil pressure/level was reviewed by the team in detail. This issue played a significant role in the October event and should have been fully analyzed by the licensee. Questioning by the team led to a better understanding of the failure mode of the Keowee turbine wicket gates under the postulated conditions. It was concluded that the gates would eventually fail (on a loss of oil level and continued operation of the unit) to a "neutral" or intermediate position. This position would be where the forces of the water flow (as directed by the flow vanes) are balanced out. The licensee's

discussions with the vendor indicated that this position would be just below the "speed-no-load" gate position. Keowee testing data indicates that this position would not support the required Oconee electrical loads. More importantly, since the ability of the governor to control the wicket gate position would be defeated (very soon after the oil level in the Governor Oil Pressure Tank (GOPT) went too low) the gates would initially remain in a fixed position despite any loading changes placed on the unit. The frequency and voltage levels of the electrical power being supplied to all of the Oconee emergency loads would not be controlled. The degraded Keowee unit may not automatically trip and permit the other available unit to provide power. Information indicates that if all air pressure were suddenly lost on the governor system, the gates would very rapidly (within seconds) fail to the "balanced" position. The team concluded that additional review by the licensee is ...ed based on the final understanding of the failure mechanism.

During the October event, the oil level in both of the governor tanks was observed by the Keowee technician to be about 4 inches on the sight glass. This level approximately corresponds to the level at which the float valve inside the tank would shut and the governor then becomes inoperable. The team concluded that the failure of the licensee to fully review this potential failure mechanism and understand the results of such a failure was a significant weakness.

During the inspection, the team noted the absence of an overall management plan addressing the incorporation of the Keowee hydro staff into the Oconee operations organization. Although numerous activities were in progress which addressed the change of organization and some objectives had apparently been informally established, no overall controlling plan or proposed timeline had been established. The team noted that extensive corrective actions were in progress in some areas. Significant effort was being dedicated to the establishment of Job Task Analysis (JTAs) on Keowee activities. Discussions with management indicated that the Oconee outage manager had recently been tasked with developing such an overall plan. The team concluded that the lack of an overall management plan limited the effectiveness of the resolution of identified discrepancies.

3.6.2 Review of Keowee PIPs and PIRs:

The team reviewed all PIPs and PIRs (since 1989) which involved the Keowee hydro station. Several problems were identified involving PIPs which did not become escalated to PIRs.

- Of the 32 total PIPs classified as Less Significant Event which were reviewed, only four had been closed. Many of the PIPs appeared to remain open unnecessarily long since corrective actions had been completed.

- Many of the open PIPs were open well beyond their "due" dates. Numerous reports did not have due dates assigned. The team noted that in some cases, the corrective actions required were very broad in nature and did not consider those open PIPs to be weaknesses.

- PIPs were not found for several items which had been previously identified by the licensee and appeared to meet requirements for generation of a PIP (or a PIR). Examples include:

  - inadequate testing of the oil system level switches and pumps,

  - lack of a controlling Keowee setpoint document,

  - and revision of the abnormal procedure for Keowee emergency start to correct excessive reliance on the on-call Keowee technician.

The review of the Keowee PIRs led to the following major conclusions:

- The majority of the DBD and SITA identified issues were the result of the licensee reviewing the electrical systems in a critical manner and often involved the recognition of single failure vulnerabilities.

- In 1992, there were a total of nine PIRs involving component failures. Even without the rash of the "X-relay" issues, that was a significant increase over the 1-2 component failure PIRs reported in each year prior to 1992. Some of the equipment failures at Keowee are related to aging of the system/component.

- The PIRs indicate that repetitive problems had occurred involving the ACBs, the AC auxiliaries, and the voltage regulators.

- The 1992 PIRs had not only increased in number but also seem to involve more significant problems than those addressed in previous years. It was noted that a smaller fraction of the 1992 PIRs were initiated as a result of formal review programs than in previous years.

3.6.3 Operational Experience Review

The team reviewed applicable NRC Information Notices and Bulletins to assess if they had been reviewed by the licensee for applicability to Keowee. The SITA had identified (May, 1992) that Bulletin 79-02 "Pipe Support Base Plates Designs using Concrete Expansion Anchor Bolts," had not been reviewed. The licensee resolved the situation through the condition adverse to quality system with no anchor bolt problems

identified. The licensee attributed the exclusion of Keowee from Bulletin review to a lack of clear definition of safety classifications for Keowee mechanical support systems.

In December, 1992, the licensee initiated a comprehensive review of operating experience documents (Bulletins, Information Notices, Generic Letters, etc.) for applicability to Keowee. The review is targeted for completion by June 30, 1993. This was addressed as an example of Finding 3.

3.7 Reliability and Availability of Keowee and Lee

The team reviewed the availability data for the emergency AC power system for the years 1989 to 1992. The licensee tracks total LCO time for the Keowee units. In 1992, the Keowee units were unavailable for a total of 382.37 hours which corresponds to an unavailability of 4.4%. The station goal for 1992 was 150 hours or 1.7%. In 1991 the keowee units were unavailable for a total of 179.89 hours or 2.1%. In 1990 the Keowee units were unavailable for a total of 135.23 hours or 1.5%. In 1989 the Keowee units were unavailable 266.43 hours or 3%.

The licensee does not currently officially trend/track start failures on the Keowee units. The licensee is establishing a Keowee hydro emergency power source reliability program and a draft procedure has been developed. The draft program incorporates availability and reliability trending and establishes trigger values for start failures on a Keowee unit. The program will require that increased testing be performed if certain trigger values are exceeded.

The team reviewed licensee memorandums to file concerning Keowee hydro station operating data for the years 1980 through 1988. The data was obtained by review of the Keowee operator logs by licensee personnel. The data indicated that in the eight year period reviewed, a Keowee unit failed to start 22 times and 14 of the failures were considered valid failures. A valid failure indicating that the unit would not have started when an emergency start signal was generated. The data indicated that the Keowee units experienced 5 failures while operating to the system grid and 2 of these failures were considered valid failures. A valid operating failure indicated that the unit would have failed to continue operating if an emergency start signal was present. The data indicated that the Keowee hydro station experienced 16 valid failures of the Keowee unit during the 9 year period reviewed or approximately 1.78 failures per year.

Review of LERs by the team determined that Keowee Unit number 2 overhead emergency power path was inoperable for an undeterminate period of time prior to September 29, 1992 due to an undetected failure of an undervoltage relay. The failed relay was found during a post-modification test for a modification unrelated to the undervoltage

relay. The relay in question had never been functionally tested and may have been failed for an extended period of time prior to discovery during the post-modification test performed on September 29, 1992.

The team noted that an integrated test has never been performed on the Keowee overhead emergency power path and that on October 19, 1992 when the overhead power path was called upon to function during a loss of offsite power event the actuation resulted in a failure of the overhead path and a loss of Keowee auxiliaries on the Keowee unit supplying the underground path.

The data used in the PRA analysis for computing overall Keowee reliability is primarily composed of events and tests which involve Keowee starts and subsequent loading to the grid. This data, while useful in determining the hydro units ability to start and generate electricity, does not necessarily reflect the units ability to provide power to the Oconee emergency busses.

The team reviewed availability data for the three Lee gas turbines located at the Lee Steam Station which is approximately 30 miles from the Oconee site. The gas turbines are not safety related. However, a Lee gas turbine can be aligned to the Oconee standby busses through a dedicated transmission line to meet certain TS action statement requirements. The team reviewed availability data for the years 1990, 1991, and 1992. The team determined that at least one Lee gas turbine was available to energize the Oconee standby busses during this three year period except for a 16 hour and 59 minute period on March 20, 1990. All three Lee gas turbines were unavailable due to a transmission line problem.

3.8 Root Causes of Deficiencies Identified in the Electrical Distribution System

The team reviewed Licensee Event Reports (LERs) from 1988 through 1992. The LERs were reviewed in three functional areas, Oconee Switchyard, Oconee 1, 2, & 3, and Keowee.

The team reviewed facility generated LERs concerning the Oconee Switchyard since 1988 and have identified that twelve LERs have been submitted to the NRC. Of these twelve LERs, three of these were generated due to the Design Basis Document (DBD) process, one was generated due to the Loss of Offsite Power in October of 1992, and the remaining eight LERs were due to other various reasons. Of these twelve LERs, seven were due to design deficiencies, two were due to testing/maintenance problems, and three were due to operational inadequacies (i.e. procedural problems).

The team reviewed facility generated LERs concerning the Oconee Nuclear Station since 1988 and have identified that seven LERs have been submitted to the NRC. Of these seven LERs two of them were due to the DBD process, one was due to an engineering review, and the remaining four LERs were due to other reasons.

The team reviewed facility generated LERs concerning the Keowee Hydro Station since 1989 and have identified that twelve LERs have been submitted to the NRC. Of these twelve LERs two of them were due to the DBD process, two were due to the SITA process, two were due to the Operating Experience Program process, and the remaining six were due to other various reasons. Of these twelve LERs, eight were due to design deficiencies, one was due to testing problems, one was due to operational inadequacies and two were due to component failures.

Conclusion:

In 1992, there were five LERs associated with the Keowee Hydro Units concerning design deficiencies. The majority of these issues were identified as a result of the critical review of the Keowee Hydro Units by the licensee. Most of the deficiencies identified were original design deficiencies.

In general, based on the team's review, it was determined that the LERs generated by the licensee were due to the following:

- Most deficiencies identified were original design deficiencies identified during a programmatic review conducted by the licensee. Examples of these are: Potential closure of E-breakers on degraded grid voltage, incorrect relay setpoints causing lockout of the yellow bus, and single failure of protective relay inops. both the underground and overhead paths.

- The overall original design was not fully understood by engineering or operations. Examples of this are: Breaker Ferroresonance affecting CT2, EPSL Logic inoperable due to fuse removal during breaker maintenance, Lee line inoperability when adding Motor Driven Emergency Feedwater (MDEFW) pumps, and overloading of the Keowee Hydro units due to an RCP not tripping.

- The EDS is complicated and unique. Physical separation is present but not electrical independence. An example of this is that all safety busses for all three units are tied together when fed by the standby busses through CT-4.

- Testing of all safety related components has not been accomplished on a periodic basis. The following are examples of components not being tested: MG-6 relays, Keowee CO_2, Keowee governor oil level Switch, Yellow bus isolate function.

- Keowee Hydro organization was functionally independent of Oconee Nuclear Station. (Overall design of the electrical system was not fully understood.)