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Facility Name: Quad Cities Nuclear Power Station, Units 1 & 2

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EXECUTIVE SUMMARY

The Special Inspection Branch of the U.S. Nuclear Regulatory Commission performed a pilot service water system operational performance inspection at the Quad Cities Nuclear Power Station from March 2 through March 20, 1992. The service water system at the station encompassed the residual heat removal service water (RHRSW) and the diesel generator cooling water (DGCW) systems. For these systems, the inspection included a mechanical design review; detailed system walkdowns; review of system operation, maintenance, and surveillance; and assessment of quality assurance and corrective actions. The team also addressed the licensee's implementation of actions required by Generic Letter 89-13, "Service Water System Problems Affecting Safety-Related Equipment," as well as system unavailability.

The team's assessment regarding the operability of the emergency core cooling system (ECCS) pump room coolers, based on calculations, flow test data, and pump performance evaluation, was inconclusive. New calculations, initiated during the inspection, indicated that reasonable assurance existed that the subject coolers would perform their intended safety function, assuming that equipment in the affected rooms can be qualified to temperatures higher than specified in the existing environmental qualification documents and the diesel generator cooling water pumps can sustain operations at 30 percent above pump design characteristics. These technical issues were being addressed by the licensee.

Insufficient engineering and technical support by onsite and corporate organizations was found to be a contributor to the weaknesses and deficiencies identified by the team.

Inadequate technical review by Commonwealth Edison Company (CE) of existing calculations and contractor reports on the service water system contributed to (1) degradation of equipment such as ECCS pump room coolers, residual heat removal service water (RHRSW) pump, and diesel generator cooling water (DGCW) pump vault coolers and (2) lack of assurance that DGCW pump flow distribution meets operability requirements.

Lack of adequate technical support also contributed to several instances of failure to take prompt corrective actions and/or recognize potential safety significant issues affecting operations. For example:

- Indications of partial flow blockage of heat exchangers (room coolers) in the ECCS pump room of Unit 1 did not prompt the licensee to inspect similar equipment for Unit 2.

- Continued indications that the 1/2 (shared between units) diesel generator cooling water pump may not supply the flow required to the Unit 1 ECCS room coolers existed since 1985. To date this condition has not been conclusively resolved.

- Operators were relying on RHR heat exchanger discharge valves for accident mitigation activities, even though the valves had not been environmentally qualified for such service.

The team found that the existing program for the implementation of Generic Letter (GL) 89-13 did not meet the intent of the document. Some redirection of effort and enhancement of proposed and ongoing activities were needed for all Actions of the GL. The team felt that significant improvements were required to successfully accomplish Actions III and IV of the GL.

The team noted several areas of strength: maintenance and operation procedures were generally well written; personnel in these two departments were knowledgeable of the systems; the maintenance training program was task oriented and comprehensive; and the operator training on the RHRSW and DGCW systems was good.

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1.0 INSPECTION SCOPE AND OBJECTIVES

From March 2 through 20, 1992, the U.S. Nuclear Regulatory Commission (NRC) staff performed an announced pilot service water system operational performance inspection at the Quad Cities Nuclear Power Station. The inspection team focused on the mechanical design, operational control, maintenance, and surveillance of the service water system (SWS) and evaluated aspects of the quality assurance and corrective action programs related to the SWS. The primary objectives of this inspection were to:

- assess the performance of the SWS through an in-depth review of mechanical systems functional design and thermal-hydraulic performance; operating, maintenance, and surveillance procedures and their implementation; and operator training on the SWS

- verify that the functional designs and operational controls of the SWS are capable of meeting the thermal and hydraulic performance requirements and that SWS components are operated in a manner consistent with their design bases

- assess the licensee's planned and completed actions in response to Generic Letter 89-13 ("Service Water System Problems Affecting Safety-Related Equipment," July 1989)

- assess the unavailability of the SWS resulting from planned maintenance, surveillance, and component failures.

The team has characterized its findings as deficiencies, unresolved items, or observations. Deficiencies are either the apparent failure of the licensee (1) to comply with a requirement or (2) to satisfy a written commitment or to conform to the provisions of applicable codes, standards, guides, or other accepted industry practices that have not been made legally binding requirements. Unresolved items involve a concern for which more information is needed to determine if it is acceptable or deficient. Items that may require enforcement actions will be reviewed by the appropriate NRC regional office. Observations are items considered appropriate to call to licensee management attention although they have no apparent direct regulatory basis.

2.0 SYSTEM DESCRIPTION

At Quad Cities Station, the residual heat removal service water (RHRSW) system and the diesel generator cooling water (DGCW) system transfer heat from safety-related systems and components to the ultimate heat sink. The RHRSW and DGCW systems take suction on the Mississippi River through the crib house. Water flows through trash rakes, traveling screens, and one of two stationary screens into the RHRSW suction well. For each unit, two RHRSW suction headers, located within close proximity of each other, supply water from the suction well to the suction of four RHRSW pumps. Units 1 and 2 have 3 emergency diesel generators and the three DGCW pumps, one for each Unit and a spared pump. These DGCW pumps also receive water from three of the four RHRSW suction headers. The RHRSW and DGCW systems discharge water back to the Mississippi River through the plant discharge canal.

The RHRSW and DGCW systems are designed as safety-related seismic Category I structures from the suction well to the first isolation valve downstream of the heat exchangers serving the safety-related systems and components. Cross-connections with the low pressure service water system (SWS) that is not safety related are capable of being isolated from the RHRSW and DGCW systems.

The RHRSW and the DGCW pumps are located within pump vaults in the basement of the turbine building. Each pump is equipped with a pump room cooler. The pump room cooler is supplied with cooling water from the discharge of the respective pump, and the cooling water is returned to the pump's suction header. The pump room cooler fans are designed to start automatically when the respective pump is started. The pump room coolers allow from 1 to 5 percent recirculation flow through the pumps.

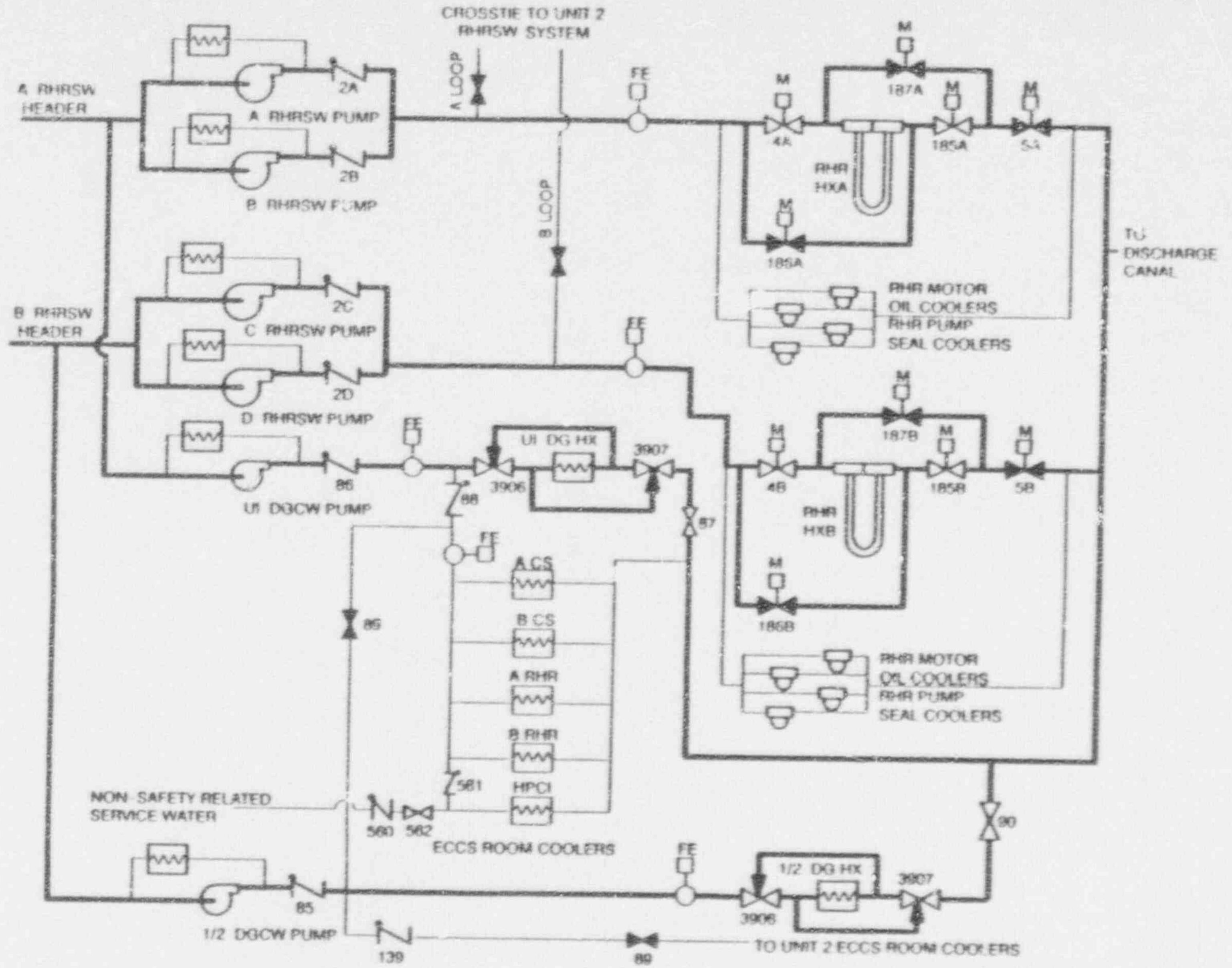
The RHRSW pumps are multistage centrifugal pumps with a rated capacity of 3500 gpm with 760 feet of head. The pumps are horizontally mounted in tandem. The RHRSW pumps are manually started to support the containment cooling and shutdown cooling modes of residual heat removal (RHR) system operation. A single RHRSW pump is capable of providing adequate cooling in the containment cooling mode of RHR system operation.

The DGCW pumps are single-stage centrifugal pumps with a rated capacity of 1304 gpm with 210 feet of head. They are horizontally mounted. All DGCW pumps are designed to start automatically when their respective diesel generator (DG) starts. They also can be started manually.

The essential-service buses for division I and II are supplied by the 1/2 (shared between two units) and unit DGs, respectively. An undervoltage condition sensed on a 4160 V essential-service bus will automatically start and align the associated DG to that bus. A loss-of-coolant accident (LOCA) signal will automatically start the associated unit DG and the 1/2 DG. The 1/2 DG automatically aligns to the unit with a LOCA signal present, or, if no LOCA signal is present, to the first unit to sense a division I undervoltage condition.

The RHRSW pumps for trains A and B are connected to the division I and II 4160 V essential service buses, respectively. The Unit 1 and Unit 2 DGCW pumps are normally supplied with power from the division II 480 V essential-service bus for their respective unit. To satisfy the requirements of Appendix R to 10 CFR Part 50, the Unit 1 and Unit 2 DGCW pumps are provided with an alternate so[illegible] of power from the division II 480 V essential-service bus of the opposite unit. Manual action is required to switch to the alternate power sources. The 1/2 DGCW pump has an automatic bus transfer capability between the division I 480 V essential-service buses of Units 1 and 2. The 1/2 DGCW pump-room cooler fans receive power only through the division I 480 V essential-service bus of Unit 1.

The RHRSW system (shown in Figure 1) consists of two separate trains (A and B) for each unit. Two RHRSW pumps are connected in parallel to supply each train, in addition to supplying their respective RHRSW pump room coolers. Each train of the RHRSW system provides cooling water to one RHR heat exchanger, two RHR pump motor oil coolers, and two RHR pump seal coolers. If necessary, each train of the RHRSW system is capable of supplying cooling water to the corresponding train of the opposite unit through crossties and



QUAD CITIES UNIT 1 RHRSW AND DGCW SYSTEMS associated isolation valves. The RHR heat exchangers have a piping and motor-operated valve (MOV) arrangement that allows reversal of RHRSW flow through the RHR heat exchanger. A normally closed MOV downstream of the RHR heat exchanger outlet provides an RHRSW flow control capability. The RHRSW system also is the alternate source of cooling water for the train B control room air conditioning condenser (not shown).

The three DGCW pumps in the DGCW system (shown in Figure 1) provide cooling water to the three DG heat exchangers and the emergency core cooling system (ECCS) pump room emergency coolers, in addition to supplying their respective DGCW pump room cooler. The high-pressure coolant injection (HPCI) pump room emergency cooler normally receives its cooling water supply from the SWS. During periods when both the DGCW system and SWS are operating, a check valve arrangement allows the higher pressure system to supply the HPCI pump room emergency cooler. The remaining ECCS pump-room emergency coolers are only supplied by the DGCW system. The DGCW system is normally aligned with the Unit 1 and Unit 2 DGCW pumps that supply their respective unit's ECCS pump room emergency coolers, in addition to supplying their respective DG heat exchangers. If necessary, the 1/2 DGCW pump can be aligned to supply cooling water to the 1/2 DG heat exchanger and either unit's ECCS room emergency coolers. To satisfy the requirements of Appendix R to 10 CFR Part 50, an additional design feature allows the Unit 1 DGCW pump to provide cooling water to the 1/2 DG heat exchanger. Each DG heat exchanger also has a piping and valve arrangement that allows reversal of DGCW flow through the heat exchanger.

3.0 GENERIC LETTER 89-13 IMPLEMENTATION

The NRC issued Generic Letter (GL) 89-13, requesting that licensees take certain actions, including establishing the appropriate frequencies for testing and inspecting safety-related heat exchangers over three operating cycles, to ensure the operability of service water systems (SWSs) that are credited for cooling safety-related equipment. Therefore, the licensee has until the end of the Unit 1 Cycle 13 refueling outage to fully develop and formalize its program. The plant is currently in Cycle 12.

The licensee developed a document, "Generic Letter 89-13 Implementation Program," to define its program for addressing the GL actions. The team identified and discussed with the licensee the following weaknesses with regard to the implementation of specific GL actions.

3.1 Biofouling Control and Surveillance Techniques

Action I of GL 89-13 requested that licensees implement and maintain an ongoing program of surveillance and control techniques to significantly reduce the incidence of flow blockage problems as a result of biofouling. The actions requested included intake structure inspections, chemical treatment of service water systems, and periodic service water system flushing/flow testing.

The team reviewed the actions being taken by the licensee to address the generic letter request. Intake structure inspections were being conducted in accordance with procedure QMPM 4400-11, "RHRSW Intake Bay Inspection," and the results were being documented as required by the procedure. The team identified that: 1) the inspection scope was too narrowly focused on RHRSW and did not included an inspection of the complete intake structure, and 2) the inspection procedure did not specifically address biofouling concerns such as the presence of mussels and clams, and the growth of river grass, 3) the 1/2 DGCW supply piping to the ECCS room coolers was not flushed periodically.

At the time of the inspection, the licensee was in the process of installing a modification for injecting biocide into the RHRSW and DGCW systems. The modification was scheduled to be operational prior to startup from the current Unit 2 Cycle 11 refueling outage. Once the modification is complete, the licensee intends to inject biocide into the RHRSW and GDCW systems anytime that these systems are being operated unless biocide is being injected into the circulating water system (state environmental restrictions). The licensee's preliminary plans for biocide injection appeared to be aggressive and responsive to the generic letter request.

3.2 Heat Exchanger Routine Inspection and Maintenance

Generic Letter 89-13 Action II requested that licensees implement a program to periodically verify the heat transfer capability of safety-related heat exchangers. The licensee has implemented a program to periodically inspect and clean safety-related heat exchangers and room coolers. The room coolers and heat exchangers associated with Train A were inspected during the Unit 1 Cycle 11 refueling outage and the Train B heat exchangers were scheduled to be inspected during the Cycle 12 outage. Heat exchangers that did not have train redundancy were scheduled to be inspected during each refueling outage. Inspections would be completed in this manner until the completion of the cycle 13 refueling outage, when the appropriate frequencies for future inspection would be determined based on the results of the initial inspection program (as allowed by GL 89-13). A similar inspection schedule was also established for the Unit 2 heat exchangers. The one exception to this inspection program was the RHR heat exchangers, which were subject to a heat transfer testing program rather than the inspection program.

The team noted the following weaknesses in the program:

- The licensee did not establish specific fouling/clogging acceptance criteria for the heat exchangers that were inspected;
- An evaluation was not completed to determine if any of the heat exchangers or room coolers were marginal and deserved special consideration,
- An evaluation was not completed to assess the actual system heat transfer fouling factor based on observed conditions to ensure that existing heat transfer margins were not being significantly degrades: and
- The program did not have in place a specific requirement to evaluate the adequacy of existing heat exchanger inspection frequencies upon completion of each inspection.

3.3 On-Line Monitoring of Safety-Related Heat Exchanger Performance

The licensee has established a program to routinely inspect and clean all of the safety-related room coolers. In order to provide additional assurance that the room coolers would not become excessively fouled during plant operation, the licensee had installed modifications to allow the differential pressure (d/p) of the service water flowing through the room coolers to be monitored. The licensee's program to periodically monitor the d/p across the room coolers was developed in response to Action II of GL 89-13. Temporary Procedure Change 7549 dated February 19, 1992, was issued to establish a new procedure to monitor the d/p across the ECCS pump room coolers, including the DGCW pump room coolers, on a monthly basis. Procedure Change 7550 dated February 19, 1992, was issued to Procedure QCOS 1000-2, "Monthly RHR Pump/RHR SW Pump Operability Test," for monitoring the d/p across the RHRSW pump room coolers. The team determined that the licensee's program was not fully developed in that minimum and maximum d/p acceptance criteria were not established, and the procedures did not specify what the proper cooler inlet conditions should be while the d/p was being monitored. The licensee stated that d/p monitoring program would be reevaluated.

Also in response to Action II of GL 89-13, the licensee was attempting to balance the flows in the RHRSW and the DGCW systems. Modifications were made to the RHRSW and DGCW systems during the Unit 1 Cycle 11 refueling outage to facilitate flow balancing and differential-pressure (d/p) monitoring. Modification Test Procedures M4-1-87-026 Revision 0 were performed for both the RHRSW and the DGCW systems to establish the proper flow balance for these systems. The licensee was initially able to balance the cooling water flow rates in both the RHRSW and the DGCW systems, but the ECCS room cooler throttle valves and the throttle valves for the diesel generator jacket water coolers subsequently had to be returned to the fully open position due to silting problems. Additionally modifications were being made to the Unit 2 DGCW system during the current Unit 2 Cycle 11 refueling outage to resolve this problem using a combination of installed orifices and some valve throttling to control flow. Similar modifications were planned for the Unit 1 Cycle 12 refueling outage. The team reviewed the original modification test procedures that were completed on Unit 1 and noted several technical errors. For example,

- The licensee failed to recognize that no additional margin was added to the minimum allowable flow rates to account for instrument uncertainty, variations in intake water level, pump degradation allowed by the IST program requirements, dynamic effects that may occur when operating both the RHRSW and the DGCW systems simultaneously, and routine fouling effects that cam accumulate during plant operation;

- Throttle valve setpoints were not established based on the most limiting system configurations. System lineups such as the back-flow alignment of the diesel generator jacket water coolers and the RHR heat exchangers was not considered, and operation of the Unit 1 DGCW pump supplying flow to the Unit 1 ECCS room coolers while also supplying cooling water to the 1/2 diesel generator jacket water coolers was not considered; and

- DGCW flow the DGCW pump cubicle cooler was not addressed in the flow balancing procedures.

3.4 Periodic Maintenance and Inspection

Action III of GL 89-13 requested that licensees establish a routine inspection and maintenance program for open-cycle SWS piping and components to ensure that corrosion, erosion, protective coating failure, silting, and biofouling cannot degrade the performance of the safety-related systems supplied by service water.

The team reviewed the licensee's "Generic Letter 89-13 Implementation Program" and implementing procedures and concluded that the licensee's program for routine inspection and maintenance of piping and components did not satisfy the action requested by the generic letter. More specifically, the team identified the following weaknesses.

- A specific review of industry experience and equipment failure information was not completed to identify appropriate preventive maintenance (PM) measures that should be taken for maintaining the RHRSW and the DGCW systems operable.
- Valves and components that are periodically disassembled and inspected were not identified and included in the GL 89-13 program, as appropriate.
- Specific guidance for performing as-found inspections and evaluations during PM and corrective maintenance (CM) activities was not established and implemented to address GL 89-13 concerns.
- Evaluations were not completed to ensure that critical sections of small bore piping and tubing would not become clogged with silt and debris.
- The program did not encompass non-safety-related service water piping downstream of the safety-related heat exchangers, as mentioned earlier
- The Service Water Design Review Report (Reference 2) credited the ability to operate certain valves to satisfy or mitigate single-failure scenarios, but actions were not taken to ensure that these valves would be functional.
- Assumption 5 on page 12 of the Service Water Design Review Report stated the assumption that surveillance tests, inspections, and normal process and equipment monitoring features effectively detect all significant failure modes, so that no undetectable failures will exist in combination with a single failure. This assumption was not validated by in-depth review and evaluation and establishment of an appropriate PM program (relat ' to the first item above).
- The Phase II Report (Reference 3) that was completed by Stone and Webster to address GL 89-13 Actions I and II provided the following guidance regarding inspection of the intake structure:
  - Section 3.2.2 provided general guidance for inspecting concrete and indicated that an inspection of the primary flow areas should be completed.

- Section 3.2.2.4 identified specific areas to be included in the inspection and additional inspection guidance was provided.

- Section 3.3.2 stated specific acceptance criteria for RHRSW suction piping wall thickness.

These elements of the Phase II Report were not included in the licensee's GL 89-13 program.

• Specific qualifications and training were not required for the diver who performed the intake structure inspections.

3.5 Design Function Verification and Single Failure Analysis

In response to Action IV of GL 89-13, the licensee completed a detailed study of the DGCW and RHRSW systems to identify any single failures that may exist. The results of the study were documented by Stone and Webster in the "Service Water Design Review Report." The team reviewed the report and examined the P&IDs and performed system walkdowns to independently assess the single-failure and common-mode failure vulnerabilities of the RHRSW and DGCW systems at Quad Cities. The team identified that significant single failure vulnerability issues were not fully evaluated by the licensee. These included:

• Nonsafety-related RHRSW and DGCW system piping downstream of these safety-related heat exchangers could rupture or clog, the effects of which could render safety-related service water system equipment inoperable.

• The reliance upon nonenvironmentally-qualified RHRSW heat exchanger flow reversal valves, that allowed the operators to reverse flow through the RHR heat exchangers during accident conditions if the heat transfer capability of the RHRSW heat exchangers was degraded.

• Common mode failures that could result from maintenance and operator errors.

The report also credited the use of operator action to operate various system valves to mitigate potential single-failure problems, but the licensee did not follow up the report to ensure that 1) the actions could in fact be taken during the event, 2) the valves were being maintained and included in the inservice testing (IST) program, 3) the valves were qualified for operation in the postulated environment, and 4) that emergency procedures included appropriate instructions.

The licensee did not systematically validate the service water system functional capability against its licensing bases, as requested by Action IV of the GL; only the single failure vulnerabilities were addressed.

As a separate matter, the team identified additional service water and fire water system interfaces that are important to safety and subject to service water system degradation but that were not included within the scope of GL 89-13. These system interfaces include:

- the SWS supply to the standby coolant supply system
- fire water and SWS supply to the safe shutdown makeup system
- service water/fire water system supply to the safe shutdown makeup system room cooler
- fire water system supply to the RHR system

Although these plant-specific, unique service water ties were not addressed in the GL, the team concluded that these service water and fire water system interfaces should be considered by the licensee for inclusion in the GL 89-13 program for the Quad Cities Nuclear Power Station.

4.0 MECHANICAL DESIGN REVIEW

The safety-related part of the service water system consists of the residual heat removal service water (RHRSW) system and the diesel generator cooling water (DGCW) system. The RHRSW system provides flow to the RHRSW pump vault (cubicle) coolers, control room heating, ventilating, and air conditioning (HVAC) unit and the RHR heat exchangers. The DGCW system provides flow to the DGCW pump vault coolers, the high-pressure coolant injection (HPCI) room coolers, the RHR heat exchanger room coolers, the core spray room coolers and the diesel generator heat exchangers.

4.1 Design Documentation

Since the system functionality had not been thoroughly evaluated against its licensing bases as recommended by GL 89-13 Action IV, system design information, including system descriptions was not readily available for the RHRSW and DGCW systems. The few calculations pertaining to room cooler evaluations that were available for review were of poor quality, lacking in accuracy and detail. Additional details of these calculations are discussed in Section 4.3.

4.2 Hydraulic Models for RHRSW and DGCW Systems

S&L engineers generated hydraulic models of the RHRSW and DGCW systems that used component data on friction to calculate flows through the various parts of the systems. The licensee planned to use these models for a variety of applications including trending and assessing the effectiveness of modifications. The licensee considered these models preliminary because they had not been benchmarked against plant data.

Although the team found these models satisfactory, it identified a list of unverified assumptions incorporated into the model. For example, the RHRSW pump vault coolers flow versus loss characteristics, the RHR pump seal coolers and pump heat exchangers flow versus loss characteristics, and the valve loss coefficients were not verified for the RHRSW system hydraulic model and the DG heat exchanger flow versus loss characteristics, the DGCW pump vault coolers flow versus loss characteristics, and the valve loss coefficients were not verified for the DGCW hydraulic model. In addition, the effect of fouling has not been incorporated in these models.

The licensee acknowledged that these models could be effectively used only after verification of the assumptions through additional vendor information and benchmarking and agreed to implement appropriate corrective actions. This is Observation 92-201-01 in Appendix B.

4.3 Calculation of Heat Loads for DGCW Pump and RHRSW Pump Vaults

Sargent & Lundy (S&L) Calculation VT-15, dated January 1991, addressed the heat loads in the RHRSW and DGCW pump vaults by analyzing various loading combinations. In the case of only one DGCW pump operating with its associated room cooler, the heat load was larger than the rated cooler capacity 30,000 Btu/hr for the FSAR-specified vault air temperature of 105°F. In the case of one RHRSW pump operating with its associated room cooler, the calculation indicated that total heat load generated exceeded the rated cooler capacity of 150,000 Btu/hr for the FSAR-specified vault temperature of 105°F. In addition, the calculations failed to include the heat loads generated by a sump pump motor and the cooler fan motors also located in the vault.

In response to the team's observations, the licensee initiated a new heat load calculation designated as "V-16." This calculation verified that, under accident conditions, a vault temperature of 105°F could not be maintained. However, the licensee provided preliminary data, from a recent engineering evaluation of equipment operability at elevated temperatures, indicating that vault temperatures of 120°F would be acceptable. On the basis of the new temperature data and incorporating all applicable heat loads, calculation V-16 indicated that heat removal capacities of the coolers associated with each pump exceeded the heat generated in the vault. The calculation also considered the effect of tube plugging to assess cooler performance margins.

S&L's design calculation (performed in 1968) for sizing the ECCS pump room coolers lacked the required detail and contained many unverifiable assumptions in the determination of heat loads in the ECCS pump rooms (e.g., heat load per unit surface and total hot surface area).

On the basis of the existing calculations, the acceptability of elevated room temperatures of 120°F, and the fact that the designated flow requirement to the coolers can be met, the team concluded that reasonable assurance existed that the ECCS room coolers would perform their safety functions. At the conclusion of the inspection the licensee stated that equipment operability at 120°F temperatures would be verified, calculation V-16 would be finalized, and reliable calculations would be developed to verify the operability of the ECCS pump room coolers. This is Deficiency 92-201-02 in Appendix A.

In addition, Stone and Webster Engineering Corporation (SWEC) Calculation 004, dated November 1990, addressed coolers for motor loads. For the HPCI room, it computed a heat load that was higher than the room cooler capacity. However, this calculation was in error since it assumed that the pump was motor driven instead of turbine driven.

The team noted that in September 1991, the licensee completed a safety evaluation that indicated the RHR and HPCI pump rooms did not require the operation of safety-related room coolers during accident conditions. However, NRC Region III inspectors identified concerns regarding the licensee's safety evaluation and the licensee suspended the implementation of the safety evaluation pending the completion of an NRC staff review (see Section 7.4).

4.4 Operability Determination of the Unit 1 DGCW System

In response to Action IV of GL 89-13, the licensee completed a study of the DGCW flow distribution system establishing flow requirements to the individual ECCS pump room coolers and the emergency diesel generator heat exchanger. Subsequently, the licensee balanced flow distribution in Unit 1 by throttling valves located downstream of these components. However, problems associated with silt and fouling of these valves resulted in flow blockage. The valves were subsequently fully opened, and the system returned to an unbalanced configuration for the remainder of the current operating cycle. The team expressed a concern about the unbalanced system condition.

Two recent flow tests for Unit 1 indicated that the flow through the DGCW pump was approximately 1500 gpm with 1050 gpm going to the DG heat exchanger and the remaining 450 gpm going to the ECCS coolers. This represented a 15 percent margin above the combined ECCS pumps cooler design flow of 404 gpm. The calculated flow distribution through the coolers was 40 gpm to HPCI, 68 gpm each to A and B core spray, and 114 gpm each to A and B RHR coolers. However, during both tests, the flow distribution through the various coolers was unknown.

In response to the team's concern, the licensee measured service water flow to the individual room coolers with an ultrasonic device. Preliminary results indicated that adequate flow was provided to the various coolers with the exception of core spray pump cooler B, for which the flow was slightly below the required 68 gpm. The licensee concluded that the flow to the core spray pump room cooler was acceptable because of the existing seasonally low river water temperature. However, the licensee did not consider operability at the maximum water temperature of 95°F, as identified in the design documentation, in combination with minimum river water level. The total DGCW pump flow was 1620 gpm, which was about 8 percent higher than total flow measured during the two previous tests and 25 percent above pump design flow of 1304 gpm at 215 foot total head. The team questioned the ability of these pumps to operate continuously at the higher flow. This is Deficiency 92-201-02 in Appendix A.

4.5 Common-Mode and Single-Failure Analysis

The team had a concern regarding the potential single failure of check valve 3999-560 to close, which would allow DGCW to be directed to the non-safety-related SWS during an event and result in insufficient DGCW supply to the ECCS room coolers and possibly to the associated diesel generator jacket water heat exchangers. Although the SWEC Service Water Design Review report assumed that manual valve 3999-562 could be closed to mitigate the failure of check valve 3999-560 to close, the licensee had not taken action to ensure that plant operators could close valve 3999-562 following a plant event and that appropriate changes were made to the emergency procedures. In response to the team's concern, as a temporary measure, the licensee closed manual valve 3999-562 to isolate check valve 3999-560 and stated that permanent corrective action will be evaluated. This is part of Deficiency 92-201-03 in Appendix A.

4.6 Heat Exchanger Heat Transfer Testing Program

In response to the GL 89-13, the licensee conducted a test to verify the heat transfer coefficient of the Unit 2 RHR heat exchangers.

The first test was conducted with one RHRSW pump operating at 3500 gpm, which was the flow requirement specified during an accident condition. The test acceptance criteria, which required that the overall heat transfer coefficient measured under the test condition exceed the heat transfer coefficient calculated based on the manufacturer's limiting conditions, could not be met by the test.

The licensee repeated the test in January 1992. At this time, two RHRSW pumps were operated, producing a flow of 5800 gpm through the heat exchanger. Before the test, the heat exchanger was backflushed to reduce biofouling and silting in the unit. The test acceptance criteria was met for the 5800 gpm flow. The licensee's methodology duplicated the heat exchanger manufacturer's overall heat transfer coefficient at the limiting conditions of 105 E+06 Btu/hr at 7000 gpm. However, the methodology used for the higher flow may not be applicable for the accident mode with only one RHRSW pump operating at approximately 3500 gpm. The licensee stated that the methodology would be re-evaluated to ensure applicability and the test would be repeated at the lower flow. This is Observation 92-201-02 in Appendix B.

4.7 Conclusions

These weaknesses and deficiencies were indicative of a lack of independent review and critical assessment of contracted engineering work by the licensee and of poor follow-through in confirming the adequacy of existing programs and procedures. The licensee's engineering organization appeared to lack the staffing and experience to provide continuous and reliable technical support to site operations, as evidenced by the team's findings discussed above.

5.0 OPERATIONS

The team reviewed plant operations to assess the knowledge of the operators and the accuracy and completeness of procedures and training with regard to the service water system (SWS). The team performed detailed system walkdowns; reviewed the procedures for normal, off-normal, and emergency conditions; assessed the conduct of operations in the field and control room; and evaluated training manuals, lesson plans, and actions on a simulated loss of service water.

5.1 System Configuration Walkdowns

The team conducted detailed walkdowns of the safety-related portions of the SWS using the current revisions of the piping and instrumentation drawings (P&ID) (M-22, sheets 1, 2, and 3; M-69, sheets 2 and 3; M-39, sheet 2; and M-81, sheet 2) and the system lineup procedures QCOP 1000-4, Unit 1(2) Revision 0, "RHR Service Water System Operation and Preparation For Standby"; QOP 6600-1, Revision 10, January 1991, "Diesel Generator 1/2 Preparation For Standby Operation"; and QOP 6600-4, Revision 10, February 1990, "Diesel Generator 1(2) Preparation For Standby Operation Following Extended Maintenance." The overall system material condition reflected its age and continuous exposure to a fresh-water environment and surface condensation. Unpainted, external sections of piping systems were corroded, having some pitted surfaces. The extent of surface corrosion reflected the lack of a dedicated preservation program. However, the system was not degraded to the extent that the overall operability would be affected.

The team noted several equipment problems that had not been previously identified by the licensee. These included a handwheel with its stem sheared off (2-3999-537), missing handwheel (PI-1/2-3941-25), loose handwheel (1-1001-209C), and the seal water lines on the 1/2 DGCW pump that were leaking and were corroded at the connections. There were a significant number of work requests written on the systems for leaking seals, broken handwheels, and leaking valves. Some of these items were 2 years old, while others were written within 2 months of the team's inspection. The 1A RHRSW pump suction valve handle was disconnected. A leak in the 1A RHRSW pump would be unisolable and because it was upstream of the 1B RHRSW pump could cause the loss of service water to the A RHR loop. This was identified by the licensee and had been in this condition for over a month.

The drawings were not detailed or entirely accurate. The Unit 2 RHRSW diagrams were drawn exactly like Unit 1 when, in reality, the system was installed as a mirror image. Seal cooling water lines on all the RHRSW pumps were not shown on the diagrams and the isolation valves in those lines were not labeled. The 2½-inch lines coming off the SW header in each RHRSW pump vault were not shown on the diagrams. These items were brought to the licensee's attention. The licensee stated that walkdowns of the service water system to correct drawing and material condition deficiencies were in progress. This is Observation 92-201-03 in Appendix B.

5.2 Operations Procedures

The team reviewed various procedures associated with RHRSW and DGCW operations, including operating procedures (QCOP and QOP), abnormal procedures (QOA), operating surveillance (QOS), and emergency operating procedures (QGA). The majority of the procedures were well constructed and sufficiently detailed. However, the team identified the following concerns with valve position verifications:

- Procedure QOP 6600-1, "DG 1(2) Preparation for Standby Operation Following Extended Maintenance," did not require a position verification of discharge valve 1(2)-3999-87. If this valve was shut, DGCW would not pass through the heat exchangers and the emergency diesel would not be cooled.

- Procedure QOP 1000-4, "RHR Service Water System Operation and Preparation for Standby," did not include a valve lineup for the RHRSW pump room cooler, did not include steps to verify that the vault level alarm and the vault sump pump are operable, and did not require the opening of vents on top of the RHR heat exchanger (e.g., 2-1001-129A and 2-1001-130A) when filling the RHRSW system to eliminate the potential formation of an air bubble in the top section of the heat exchanger.

Another concern was the contradictory references for the required position of some valves in the system. For example, QOP 1000-4 gave specific throttle positions for the RHRSW pump discharge valves, but the S-lock log gave different throttle positions for some of the same pump discharge valves, (i.e., the valve checklist position of these valves was indicated as "open", not throttled). If a system was declared "out-of-service," there was no readily available reference to be used to return the valves to their proper position when the system was returned to service. The licensee agreed to evaluate the team's concerns and to take appropriate corrective actions. This is Observation 92-201-04 in Appendix B.

The precaution sections of QCOP 1000-21, Revision 1, 10/15/91, "LPCI Mode of RHR Manual Initiation," and QCOP 1000-9, Revision 1, 5/17/91, "Torus Cooling Startup and Operation," allowed the operators to operate the flow reversing valves of the RHR heat exchangers during an event to enhance heat transfer capability. Eight RHRSW heat exchanger motor-operated valves (MOVs) (1(2) 1001-186 A(B) and 1(2) 1001-187A(B)) for reviewing flow were not environmentally qualified. The team was concerned that the unqualified valves could fail in some intermediate position and render the RHRSW heat exchanger inoperable during an accident mitigating activity. The licensee stated at the exit meeting that this matter would be reviewed immediately. Subsequently, the licensee removed the permission to operate the subject valves during accident conditions from the procedures and indicated that the valves would be evaluated for inclusion into the licensee's environmental qualification program. This is Deficiency 92-201-04 in Appendix A.

5.3 Operation Walkdowns

The licensee's operators walked through, performed, or explained operations, including preparing the RHRSW system for standby and explaining how to transfer from the normal to the alternate power supply for the DGCWPs and valve in the RHRSW pump room coolers.

Several licensed reactor operators and senior reactor operators performed simulator scenarios of a loss of all service water and a loss of the normal power supply to the 1/2 DGCWP without an automatic bus transfer. The actions taken by the operators in response to the scenarios were appropriate.

The team interviewed several reactor operators and senior reactor operators in the control room and one operator walked through the procedure to add service water to the hotwell for emergency reactor water level control. The operators' level of knowledge about SWS equipment operations and procedures were strengths.

5.4 Operations Training

The operations training program was accredited by the Institute of Nuclear Power Operations. Operations training on the SWS consisted of classroom, simulator scenarios, job performance measures, and on-the-job training tasks. The licensee was developing in-plant training assignments. Separate classroom lesson plans were sufficiently detailed describing system design, components cooled by SW, power supplies, and how the systems respond to emergency conditions.

The operator training materials related to the RHRSW and DGCW systems, including system descriptions and appropriate licensed and non-licensed operator on-the-job training tasks, and simulator scenarios, were current and promptly updated. The system descriptions were thorough and accurate. Only one discrepancy was found between the licensed and non-licensed training material, which involved the question of whether the Unit DGCWP would start on a diesel automatic start signal when supplied from its alternate power supply.

Another discrepancy was identified during the observance of the simulator scenarios. The power supply for the 1/2 DGCWP did not automatically transfer upon the loss of bus 18. This failure to automatically transfer was not part of the scenario and it was determined that the simulator computer was not programmed for automatic transfer. The licensee initiated immediate corrective actions to address these items.

5.5 Conclusions

The licensee was operating the RHRSW and DGCW system in an appropriate manner. Drawing inaccuracies appeared to be numerous throughout all plant systems; however, a long-term licensee program appeared to be in place to address those deficiencies. Inadequate technical review resulted in a weakness in the verification and validation of some operating procedures. The training program for the safety-related service water system and the competency of the operators were a strength. However, the material condition of the service water system was poor.

6.0 MAINTENANCE

The team reviewed maintenance procedures, training programs, and maintenance history for selected components to determine if the RHRSW and DGCW components and piping were being adequately maintained to ensure their operability and to detect system equipment that required frequent attention. The team also reviewed recently completed maintenance work request packages and interviewed maintenance personnel.

6.1 Procedures

The maintenance procedures applicable to the RHRSW and DGCW systems and associated equipment addressed predictive, preventive, and corrective maintenance activities. The procedures were well written and sufficiently detailed to perform the task. However, QEPM 400-6, Revision 2, "AC Motor Inspection" (the procedure for inspecting oil level and condition in the RHRSW pumps), did not have acceptance criteria or specify the type oil to use if the level was low or replacement was required. This appeared to be an isolated case. The subject procedure should be corrected.

6.2 Work Activities

The following work packages appeared to be well prepared, containing sufficient information for the mechanics to perform the maintenance activity, and post-maintenance testing was adequately described in each package.

2A RHR HX Room Emergency Cooler - Inspect/Clean - Q90858
2A RHR Pump Cooling Coil - Inspect/Clean - Q90862
Unit 2 DGCW Pump Cubicle Cooler - Inspect/Clean - Q90853
2 DGCW Pump - Pump Overhaul/Bearing Replacement - Q92333

However, QAP 1500-S28, "Work Request History Form," Section C, was not properly completed to describe the as-found condition for the three heat exchanger work requests to provide useful data for analysis. On the other hand, QAP 1500-S28 was more detailed for the Unit 2 DGCW pump overhaul to replace the bearing because higher-than-normal vibration levels on the 2 DGCW pump were identified during inservice testing. The team informed the licensee of the inconsistent use of QAP 1500-S28.

6.3 Trending of Preventive and Corrective Maintenance

The maintenance department used several programs to track the maintenance history of components, including the general surveillance system master file (GSRV), maintenance history listing (TJM), and nuclear plant reliability data system (NPRDS). However, it was not clear if GSRV, TJM, NPRDS, and QAP 1500-S28 forms were all reviewed to provide a complete history on each component and to ensure adequate trending. With several groups performing the actual maintenance work, there did not appear to be a single point of contact to ensure adequate trending occurred. This is part of Observation 92-201-05 in Appendix B.

Quad Cities preventive maintenance/corrective maintenance annual assessment reports for 1990 and 1991 were general in nature to allow upper management to see the ratio of preventive to corrective maintenance and the associated costs. Reliability-centered engineering studies were performed on the RHR and DG systems, providing insights into the maintenance history of the systems and recommended actions to be taken to address identified concerns with the high failure rates of certain equipment. Followup on these recommendations did not appear to exist in all cases. For example, the recommendation to perform an analysis to determine if a better filtration system for RHRSW should be provided to prevent impeller damage from debris in the river water was not included on the nuclear tracking system (NTS). Subsequently the licensee stated that various self-assessment report items not included in the NTS have been identified and entered into the system. This is Observation 92-201-06 in Appendix B.

Leaking pump seals was a significant problem associated with the RHRSW system that had existed for over 10 years. Leakage had resulted in work requests being written for most seals on RHRSW pumps. The most significant problem was the inboard seal on the high-pressure pump of these tandem pumps. The original pump installation had a packing seal that was later replaced by a mechanical seal. The mechanical seals had experienced about a 1-year life expectancy before they started to leak. The licensee had reviewed this problem and believed it to be caused by pump vibration between the low- and high-pressure pumps due to cavitation at the discharge of the low-pressure pump. The vibration problem also appeared to be the cause of the cracking seal water lines that failed on several of the pumps.

Modification 87-002 was designed to install a larger impeller on the low-pressure pump and a smaller impeller on the high-pressure pump, which would eliminate the cavitation problem by increasing the discharge pressure of the low-pressure pump and reduce pump vibration. The modification was installed on the 1A and 2C RHRSW pumps, and although the cavitation problem was eliminated, some vibration continued to exist, and the seal leakage problem remained. The installation of the modification on the other pumps was delayed as a result of a change in component qualification requirements since the original bronze impellers were installed. This issue had not been resolved at the time of the inspection although work was ongoing and the licensee expected that resolution was forthcoming this year. To prevent cavitation on pumps without the impeller modification, the licensee throttled discharge valves.

6.4 Training

Procedure MMAMI, "Administrative and Management Information for Mechanical Maintenance Training," Revision 10, described the training program for mechanical maintenance personnel. The procedure was intended for training a new employee to become a qualified mechanic through structured classroom lectures and practical on-the-job training. The maintenance training program was INPO accredited and included such attributes as a basic plant systems course, generic maintenance training, site-specific task training, personnel qualifications, examinations, on-the-job training, monthly safety meetings, and continuing training. The program was task oriented and mechanics were trained and qualified on specific tasks. Maintenance supervisors reviewed a task matrix in order to assign qualified mechanics to a specific job.

Action V of GL 89-13 required licensees to confirm that maintenance training was adequate to ensure that safety-related equipment cooled by service water would function properly and as intended. Checklist criteria were developed by the corporate office and compared to the training program by a contractor to determine compliance. In all but one case the criteria were generic in nature (e.g., requirements for removing equipment from service, using MWRs and RWPs, and qualifying to perform a task) and not specific to concerns of service water systems. Nevertheless, the training department had revised lesson plans, such as GPE 11 for heat exchangers, to address industry service water events. In addition, these events were discussed at one of the monthly safety meetings. The licensee appeared to have appropriate maintenance training.

6.5 System Unavailability

The team calculated the unavailability of major RHRSW and DGCW components to assess the reliability of the associated safety-related equipment. The team omitted unavailability resulting from recurring maintenance or testing (e.g., a scheduled DG maintenance outage or RHR system logic testing) from the calculated unavailability because the parent system would be available. Since the DGCW and RHRSW systems were capable of performing their primary safety functions in their surveillance testing alignment, the team also omitted surveillance testing periods from the calculated system unavailability. The team reviewed records from January 1989 to December 1991 including a list of system unavailability hours compiled by the licensee and licensee-prepared deviation reports (DVRs).

The team evaluated DG unavailability for the DGCW system resulting from cooling water system problems and determined that the 1/2 DG had an unavailability of 0.4 percent while the Unit 1 and Unit 2 DGs had unavailabilities of less than 0.1 percent. The team noted that the 1/2 DG unavailability resulted primarily from heat exchanger fouling following a period of extended operation, as documented in DVR 04-01-91-087. The licensee elected to continue a maintenance program of periodic DG heat exchanger cleaning and establish a program of frequent flow reversals to reduce the likelihood of DG heat exchanger fouling.

The licensee performed extensive bearing maintenance on the Unit 2 DGCW pump in February 1992 during the eleventh refueling outage for Unit 2 and coincident with a DG maintenance outage. The team noted that vibration trending data indicated that similar maintenance may be necessary for the remaining DGCW pumps. The licensee confirmed that preventive maintenance will be performed to correct the increasing trend in DGCW pump vibration. The licensee appeared to effectively schedule elective DGCW system maintenance to coincide with DG maintenance outages. The overall unavailability of the DGCW system to support DG operation appeared very low (approximately 0.1%) and resulted primarily from corrective maintenance.

RHRSW pump unavailability was attributed to the three equipment failures and the corrective maintenance that followed. The team calculated an average RHRSW pump unavailability of 0.5 percent, which was very low, and noted that RHRSW pump unavailability resulted primarily from corrective maintenance.

6.6 Conclusions

The maintenance program related to the RHRSW and DGCW was adequate. Maintenance procedures were well written in most cases and documentation of completed work packages was available and clear, although more attention to detail was needed in documenting as-found conditions. The maintenance training program was task oriented and appeared comprehensive. However, there appeared to be no structured trending program to consider the results of different activities, such as inspections, preventive and corrective maintenance, and inservice test data.

7.0 SURVEILLANCE AND TESTING

The team reviewed preoperational test procedures, surveillance procedures, and the licensee's IST program and implementing procedures to determine if sufficient testing had been conducted to confirm system design requirements and to determine if periodic surveillance and inservice testing (IST) were adequate to maintain continued operability of the system. The team also reviewed actions that were taken to satisfy the surveillance and inspection recommendations stated in GL 89-13.

7.1 Preoperational Testing and System Flow Balancing

The licensee was able to only locate the records for the Unit 2 RHRSW system preoperational test, which was completed around December 1971 in accordance with Preoperational Test Procedure A-9. The team's review of the completed preoperational test procedure focused primarily on the test scope, methodology, and results. Quality of the procedure and documented test results were reflective of the less rigorous standards being implemented during that time period. For example, a test director's log was not maintained to document problems that were encountered during the test, the actual water level that existed in the intake structure during the test was not recorded, system pressure was not recorded for two-pump operation, and operating restrictions were not established to avoid pump runout conditions.

The licensee made several attempts to determine the flow characteristics of the DGCW pumps and to assess the adequacy of the flow to the individual safety-related ECCS pump room coolers and to the diesel generator jacket water coolers. In one instance, the licensee performed flow testing of the DGCW system in accordance with Test Number 1-52, "ECCS Room Cooler and D/G Heat Exchanger Flow Test," dated May 1981. The test data indicated that the flow of service water to the ECCS room coolers was insufficient and that the flow of service water to the diesel generator jacket water coolers was excessive. In another instance, Test Number 1-80, "Diesel Generator Cooling Water Pump Flow Test," performed in June 1985 to verify proper operation of the 1/2 DGCW pump to supply cooling water to the 1/2 DG jacket water coolers and to the ECCS room coolers, indicated that the 1/2 DGCW pump did not supply sufficient cooling water to the DG jacket water coolers while concurrently supplying flow to the ECCS room coolers. The team found no indication that the licensee initiated corrective actions to address the flow distribution of the pumps following each of these tests. This is part of Unresolved Item No. 92-201-03.

In June 1985 (following completion of Test Number 1-80) the licensee completed a pump performance evaluation for the diesel generator cooling water pumps. The Unit 1 and Unit 2 DGCW pumps were supplying approximately 30 percent more flow than the system required; however, the pumps were operating at the end of the pump curves where runout and cavitation may occur. The licensee concluded that the DGCW pumps were well suited for supplying the system flow requirements although throttling of certain valves was necessary to establish the proper DGCW flow rates through the individual heat exchangers and to eliminate the excessive burden being placed on the DGCW pumps. The licensee attempted to balance the DGCW system flow in August 1985 by performing another test (Test Number 1-80, Revision 1, "Diesel Generator Cooling Water Pump Flow Test"). However, the test procedure was abandoned because the existing valves were not well suited for throttling system flow.

7.2 Surveillance Procedures

Sections 3.5.B and 4.5.B of the Quad Cities Technical Specifications (TS) require pump and valve testing, pump flow testing, and logic system functional testing to be completed periodically on the RHRSW system. The TS do not state any specific requirements for the DGCW system, but system operability was demonstrated during the performance of monthly diesel generator surveillance testing. Also, the RHRSW and the DGCW systems were subject to the American Society of Mechanical Engineers (ASME) inservice testing requirements specified in Section XI of the Boiler and Pressure Vessel Code.

The team found the following procedures for implementing TS surveillance requirements were well written and accomplished their stated objectives.

QTS 110-1 (Revision 15)	Unit 1 Emergency Core Cooling System Simulated Automatic Actuation and Diesel Generators Auto-Start Surveillance
QTS 110-3 (Revision 13)	Unit 2 Emergency Core Cooling System Simulated Automatic Actuation and Diesel Generators Auto-Start Surveillance

QCOS 1000-2 (Temporary)	Monthly RHR Pump/RHR SW Pump Operability Test (Units 1 and 2)
QCOS 1000-5 (Revision 0)	Monthly RHR Containment Cooling Valve Operability Test (Units 1 and 2)
QCEMS 350-2 (Revision 1)	LPCI and Containment Cooling Modes of RHRS Logic Test (Units 1 and 2)

7.3 Inservice Testing of Pumps and Valves

The team reviewed Revision 3 of the Quad Cities Station Inservice Testing (IST) Program and the associated NRC staff safety evaluation issued December 2, 1991. The staff approved relief request RV-OOF pertaining to disassembly and inspection of DGCW pump discharge check valves to verify closure capability on an interim basis. The licensee stated that alternative methods of disassembly were being evaluated to verify capability of check valve closure. The procedures implementing RV-OOF appeared adequate.

QAP 350-1, "Administration of the Inservice Testing Program," clearly defined responsibilities for the IST program and established general methods for the testing of pumps and valves. The following procedures, relating to testing of the RHRSW and DGCW systems, contained clear and sufficient preparation and alignment steps, acceptance criteria, and verification steps: QOS 1000-4, "RHR Service Water Pump Flow Rate Test"; QCOS 1000-4, "Quarterly RHR Service Water Pump Operability Test"; QOS 6600-6, "Diesel Generator Cooling Water Pump Flow Rate Test"; and QOS 6600-8, "Diesel Generator Cooling Water to Unit 2 ECCS Room Coolers Check Valve Test." The licensee informed the team that the procedure to test the check valves (1(2)-3999-560 and 1(2)-3999-561) supplying the HPCI pump room included in Revision 3 of the Quad Cities IST program, was under review.

IST records showed that the licensee trended test results for each component to detect degradation; reconfirmed or established reference values for pump vibration, differential pressure, and flow following maintenance or replacement; and verified that the new reference values represented acceptable operation. When testing results indicated component performance was outside the acceptance range, the licensee took appropriate corrective action as directed by the ASME Boiler and Pressure Vessel Code, Section XI. The licensee also entered appropriate limiting conditions for operation (LCOs) when IST indicated that a component was inoperable although the component met technical specification requirements for level of performance.

The calibration records for instruments used in the licensee's IST program for the RHRSW and DGCW systems showed that the licensee calibrated these instruments on a yearly interval in accordance with QAP 350-1. The team noted instances where DGCW pump flow instrument drift from the previous calibration was substantial (calibration of FI 1-3941-26 on June 22, 1990, and FI 1/2-3941-27 on April 24, 1991). The licensee partially attributed Unit 2 DGCW pump performance outside the acceptance range to instrument drift (DVR 04-02-91-031). During heat transfer testing of an RHR heat exchanger in December 1991, the licensee noted a substantial discrepancy in measured RHRSW flow between the installed flow instrumentation and a temporary ultrasonic flow measuring device. The licensee attributed the discrepancy to erosion of the installed flow orifice and stated that a modification to replace these orifice plates was under review. The team found that the licensee took appropriate immediate corrective action for the items identified above.

The team compared Quad Cities piping and instrumentation diagrams and a design review report with a list of valves included in the Quad Cities IST program to evaluate the completeness of the program. The team identified a number of valves that were credited to mitigate the effect of a single failure or were required to change position to perform a safety function (such as admitting cooling water flow to a heat exchanger) that were not included in the IST program. The licensee stated that the valves identified by the team would be reevaluated for inclusion into the IST program. This is Deficiency 92-201-05 in Appendix A.

7.4 Heat Exchanger Routine Inspection and Maintenance

The team reviewed the details of the licensee's heat exchanger and room cooler inspection program, and reviewed the results of the Unit 1 and Unit 2 Cycle 11 inspections. Heat exchanger inspections were performed and documented in accordance with Procedure QCP 1400-29, "Heat Exchanger Inspection Program."

The initial inspections, conducted in November 1990 and January 1991, identified significant flow restrictions in both of the Unit 1 RHR heat exchanger room coolers 1A and 1B. The licensee determined that the flow restriction affected the heat removal capacity of the coolers beyond their 17-percent design margins. The licensee failed to recognize and subsequently address the plugging of the coolers as a potential operability issue. Consequently, required NRC notification of the degraded condition of the safety-related coolers was not made. Similar coolers on Unit 2, which was on line and continued to operate for the remainder of its cycle, were not inspected until March 1992. Inspection of the Unit 2 RHR heat exchanger room coolers identified that 28 percent of the first-pass tubes of the four-pass cooler were plugged in the 2A cooler and 58 percent of the first-pass tubes were plugged in the 2B cooler.

The licensee concluded from a completed study, NFS Report No. RSA-Q-90-02, Revision 2, dated August 1990, and a safety evaluation in accordance with 10 CFR 50.59 that the RHR heat exchanger room coolers were not required to mitigate the consequences of an accident. The team noted that the licensee's study assumed that natural ventilation was available in the ECCS pump rooms. However, a field verification during the inspection identified no natural ventilation pathway for the 2B RHR heat exchanger room. The team concluded that the licensee failed to take appropriate corrective action to address the degraded RHR heat exchanger room coolers that were identified during the Unit 1 Cycle 11 refueling outage in that timely action was not taken to inspect and evaluate the operability of the Unit 2 RHR heat exchanger room coolers. Therefore, the Unit 2 RHR room cooler appeared to be inoperable for at least 1 year while Unit 2 was on line, potentially affecting the operability of the RHR system during this period. This is Deficiency 92-201-06 in Appendix A.

7.5 Conclusions

The licensee's performance in satisfying TS surveillance and testing requirements was satisfactory. However, the licensee failed to address a surveillance-identified issue that could have affected the operability of the RHR pump room coolers and the operability of the RHR system for Unit 2 over a period of 1 year. This may be indicative of significant implementation failures of programs in the areas of technical support and safety review. There also appeared to be a significant failure to recognize and evaluate safety issues and poor follow-through in the review and site implementation of applicable engineering reports and evaluations.

The continued difficulties encountered by the licensee in evaluating test data and in implementing corrective actions to ensure adequate flows to safety-related equipment appeared indicative of weaknesses in technical support of plant operations.

8.0 QUALITY ASSURANCE AND CORRECTIVE ACTIONS

The team evaluated assessments and technical audits of the RHRSW and DGCW systems, reviewed the corrective action tracking system to ensure adequate treatment of RHRSW and DGCW items, and reviewed the RHRSW and DGCW operational history (as contained in nuclear plant reliability data system (NPRDS) reports and maintenance work requests) to assess the adequacy of root-cause evaluations.

8.1 Root-Cause Evaluations

QCAP 1780-10, "Root Cause Investigation Program," and QCAP 1780-11, "Root Cause Investigation Procedure," clearly define responsibility for root-cause analysis and provide a thorough methodology for performance of root-cause analyses.

A number of deviation reports (DVRs) relating to the RHRSW and DGCW systems showed that the licensee generally performed a thorough root-cause evaluation and effective corrective action for identified problems.

A list of NPRDS entries on the RHRSW and DGCW systems from 1977 to February 2, 1992 showed 23 entries of which 3 had indicated the cause as indeterminate. In those three cases, the component was replaced with like-for-like and no repetitive failures were noted. The resolution of these items appeared appropriate.

Several procedures pertaining to root-cause evaluations were reviewed by the team and determined to be of good quality. It did not appear that the component failures experienced in the RHRSW and DGCW systems were significant enough to require these procedures to be used.

8.2 Quality Assurance and Onsite Safety Review Committee Meeting Reports

The team reviewed several nuclear quality program (NQP) and onsite safety review committee reports related to the RHRSW and DGCW systems, and an internal safety system functional inspection (SSFI) on the 1/2 diesel generator system. The NQP reports consisted of 2 in-depth audits and 20 field monitoring reports. All field activities, as observed by NQP, were satisfactory.

The team reviewed one onsite safety review committee review meeting report (91-30) that concerned leaking seals on the 1A RHRSW pump. The unit was ending an outage when the problem was discovered. Although TS allowed a 30-day LCO with one RHRSW pump out of service, the committee recommended that the outage be extended to repair the leaking seal.

8.3 Corrective Action Tracking System

The Nuclear Tracking System (NTS) program, as delineated in QCAP 1780-6, "Station Commitment and Action Item Tracking," appeared to properly prioritize items on the basis of response due dates and periodic progress updates. The selected items reviewed on NTS associated with the RHRSW and DGCW systems appeared to be adequately tracked.

8.4 Conclusions

The programs implementing root-cause evaluations, quality assurance, and onsite safety review committee reports, and the corrective action tracking, with regard to the RHRSW and DGCW systems, were in place at the time of the inspection.

9.0 EXIT MEETING

On March 20, 1992, the team conducted an exit meeting at the Quad Cities Nuclear Power Station. NRC and licensee personnel attending this meeting are listed in Appendix B. The licensee did not identify as proprietary any materials given to the inspection team. During the exit meeting, the team summarized the scope and findings of the inspection.

APPENDIX A

SUMMARY OF FINDINGS

DEFICIENCY 92-201-01

Finding Title: Heat Load Calculations for RHRSW and DGCW Pump Vaults and ECCS Pumps Coolers (Section 4.3)

Description of Condition:

- RHRSW and DGCW Pump Vaults

  Sargent & Lundy (S&L) Calculation VT-15 analyzed various loading combinations. In the case of only one DGCW pump operating with its associated room cooler, the heat load was larger than the rated DGCW vault cooler capacity of 30,000 Btu/hr for an air temperature of 105°F. In addition, this calculation did not include heat loads from the sump motors and fan motors. However, the licensee used an unverified higher cooler capacity of 104,500 Btu/hr, provided by the manufacturer for a higher room air temperature (120°F versus 105°F), to defend its position that the coolers would remove the generated heat load. A new S&L calculation, VT-16, under preparation during the team inspection, verified that the loads were higher than the cooler capacity, confirming the team's concerns. However, for an air temperature of 120°F, VT-16 calculated a new cooler capacity that exceeded the heat loads.

  In the case of one RHRSW pump operating, VT-15 indicated total heat load generated was again higher than the cooler capacity. Again some heat loads, such as sump pump motors, were neglected. The new calculation, VT-16, indicated a heat load of 196,480 Btu/hr, which was substantially higher than the RHRSW pump cooler capacity of 150,000 Btu/hr, assuming an air temperature of 105°F. However, by using an air temperature of 120°F, this new calculation showed that the cooler capacity exceeded the heat load.

  Stone and Webster (SWEC) Calculation 0.4 showed the required heat load raised the RHRSW and DGCW temperature by 5°F as it passes through the coolers. This calculation contained only pump motor loads. The fact that the calculation contained only pump motor loads demonstrated, once again, that RHRSW pump vault cooler capacity, corresponding to a maximum air temperature of 105°F, was smaller than the heat load. This result was in agreement with the results of VT-15 and VT-16.

  The new calculation, VT-16, which addressed the RHRSW and DGCW pump vaults, considered the effect of tube plugging on the cooler performance and could be used to assess cooler margin. The licensee stated that the V-16 calculation would be finalized and components and equipment would be qualified for the higher temperature of 120°F.

- ECCS Room Coolers

  SWEC calculation 004, which contained only motor loads, computed a heat load for the HPCI room that was higher than the room cooler capacity. However, this calculation was in error since it assumed that the pump was motor driven instead of turbine driven.

  S&L's 1968 calculation, sizing the ECCS coolers, lacked required detail and contained many unverified assumptions of the heat loads. Therefore, it could not be used to verify the cooler capacities for all ECCS rooms were higher than the heat loads.

Requirements:

10 CFR 50, Appendix B, Criterion III, "Design Control," requires: "Measures shall be established for the identification and control of design interfaces and for coordinating among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval release, distribution, and revision of documents involving design interfaces. The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program."

10 CFR 50, Appendix B, Criterion VI, "Document Control," requires, in part, that "Measures shall be established to control the issuance of documents, such as instructions, procedures and drawings, including changes thereto, which prescribe all activities affecting quality. These measures shall ensure that documents, including changes, are reviewed for adequacy and approved for release by authorized personnel...."

References:

1. S&L Calculation No. VT-15, "Water Flow Requirements for Diesel Generator Cooling Pump Cubicle Coolers 1(2)-5749 & 1/2-5749," Revision 0, dated January 7, 1991.

2. SWEC Calculation 004, Job Order or Work Order 18864.08, "Determination of Heat Load Adequacy for Room Cooler Temperature Effectiveness Testing," Revision 0, dated November 5, 1990.

3. S&L Calculation (two pages) dated June 7, 1968.

4. S&L Calculation VT-16, "RHRSW and DGCW Pump Cooler Performance Evaluation," Revision 0, dated March 19, 1992.

DEFICIENCY 92-201-02

Finding Title: Operability of Unit 1 DGCW System (Section 4.4 and 7.1)

Description of Condition:

As part of the response to Generic Letter (GL) 89-13, the licensee installed pressure taps (Modification M4-1-87-026) for measuring pressure differential across heat exchangers. M4-1-87-026 post-modification testing demonstrated that the DGCW pump can provide the required flow to all components. Flow balancing was achieved in Unit 1 by throttling valves located downstream of these components. Problems associated with silt and fouling of these valves resulted in flow blockage. These valves were subsequently fully opened. The Unit 1 DGCW System was left in an unbalanced configuration for the current operating cycle.

Two flow tests performed over the last month for Unit 1, indicated that the flow through the DGCW pump was about 1500 gpm, with 1040 gpm going to the DG heat exchanger and the remaining 450 gpm going to the ECCS coolers. The design flow to the coolers was 404 gpm. The actual flow represented a 15 percent margin over the design flow. The design flow distribution through the coolers was 40 gpm to HPCI, 68 gpm each to A and B core spray, and 114 gpm each to A and B RHR coolers. However, during both tests, the flow distribution to the individual coolers was unknown. The flow would be a function of individual path/component hydraulic resistance, which appeared to increase substantially as a result of fouling of core spray pump cooler B, considering that core spray pump cooler A had about twice the flow of B.

For all of the above tests, the measured Unit 1 DGCW pump flows were higher than the design flow. A letter by the pump manufacturer stated that the design flow throughout the pump was 1304 gpm at 210 foot total head. The manufacturer recommended installing a larger impeller if flows up to 1600 gpm are desirable.

The licensee did not provide the team with any assessment of the effect of higher flow on the pumps, including vibration, erosion, and the adequacy of pump motor.

Alternate water supply to the Unit 1 ECCS pump room coolers was obtained from the shared 1/2 DGCW pump. Based on previous test data, the subject pump delivered approximately 1300 gpm. The licensee has not demonstrated that the 1/2 DGCW pump can meet the demands of the 1/2 emergency diesel generator heat exchanger and the Unit 1 ECCS pump coolers, as required during specific scenarios of Appendix R to 10 CFR Part 50.

Requirements:

10 CFR 50, Appendix B, Criterion III, "Design Control," requires: "The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program."

References:

1. Modification Test for Modification M4-1-87-026, Procedure QAP 1270-S13, dated April 9, 1991.

2. Test QAP 1100-T6, dated February 25, 1992.

3. Test conducted on March 18, 1992.

4. Letter from the pump manufacturer (INGERSALL-RAND) to Mr. Steve Laughlin, Quad Cities Nuclear Power Station, dated January 29, 1992.

DEFICIENCY 92-201-03

Finding Title: Single Failure Vulnerabilities (Section 4.5)

Description of Condition:

The following single failure vulnerabilities, identified by the Stone & Webster Engineering Corporation (SWEC) service water design review, have not been addressed by the licensee:

- Upon DGCW initiation, check valve (CV) 1-3999-561, which was normally closed, may fail in the closed position. This will result in the loss of DGCW flow to the HPCI coolers.
- Upon DGCW initiation, Check Valve CV 1-3999-560, which was normally open, may fail in the open position. This would result in the diversion of DGCW flow from the ECCS room coolers to the normal service water system (backflow) and potentially divert from the coolers required flow. Although the SWEC report recognized that manual valve 3999-562 could be closed to mitigate the failure of check valve 3999-560 to close, the licensee had not taken action to ensure that the 3999-562 valve could be closed by plant operators and that the appropriate changes were made to the emergency procedures. In response to the team's concerns, as a temporary measure, the licensee closed manual valve 3999-562 to isolate check valve 3999-560 and stated that permanent corrective action will be evaluated.

Requirements:

10 CFR 50, Appendix A, Criterion 35, requires a suitable redundancy of components and suitable connection so the safety function can be accomplished, assuming a single failure.

10 CFR 50, Appendix B, Criterion XVI requires that measures shall be established to ensure that conditions adverse to quality are promptly identified and corrected.

References:

1. Service Water Design Review, Quad Cities Nuclear Power Station Unit 1, Revision 0, dated January 22, 1991, Addendum 1, dated February 18, 1992.
2. Service Water Design Review, Quad Cities Nuclear Power Station Unit 2, Revision 0, dated January 22, 1991.

DEFICIENCY 92-201-04

Finding Title: RHR Heat Exchanger Valves Not Environmentally Qualified (Section 5.2)

Description of Condition:

The precaution sections of the referenced emergency procedures allowed the operators to change the position of the flow reversing valves during an event, as necessary, to enhance heat transfer capability. Eight RHR heat exchanger motor-operated valves (MOVs) for reversing flow (1(2) 1001-186 A(B) and 1(2) 1001-187A(B)) were not environmentally qualified. The team was concerned that the unqualified valves could fail in some intermediate position and render the RHR heat exchanger inoperable during an accident mitigating activity. The licensee stated at the exit meeting that this matter would be reviewed immediately. Subsequently, the licensee removed the permission to operate the subject valves during accident conditions from the procedures. The valves would be evaluated for inclusion into the licensee's environmental qualification program.

Requirements:

10 CFR 50, Part 49, "Environmental qualification of electric equipment important to safety for nuclear power plants," requires the licensee to establish a program for qualifying non-safety-related electric equipment whose failure under postulated environmental conditions could affect the capability to prevent of mitigate the consequences of accidents.

Reference:

1. QCOP 1000-21, "LPCI MODE OF RHR MANUAL INITIATION," Revision 1, October 15, 1991

2. QCOP 1000-9, "TORUS COOLING STARTUP AND OPERATION," Revision 1, May 17, 1991

DEFICIENCY 92-201-05

Finding Title: Incomplete Inservice Testing Program (Section 7.3)

Description of Condition:

The team identified the following valves, which were credited in performing various safety functions, but were not included in the licensee's inservice testing program:

- valves credited for single failure:
  - RHRSW/SWS Supply to Control Room HVAC

    1/2-5799-410
    1/2-5799-381

  - DGCW/SWS Supply to ECCS Room Coolers

    1(2)-3999-562

- valves required to admit/redirect flow:
  - RHRSW/SWS Supply to Control Room HVAC

    1/2-5741-319A (RHRSW flow admission valve)
    1/2-5741-33 (RHRSW/SWS flow control valve)
    1-5799-384/406/385 (Unit 2 RHRSW supply)
    2-5799-406/384/407/385 (Unit 2 RHRSW supply)

  - RHRSW supply to RHR heat exchanger:

    1(2)-1001-5A/5B (RHRSW flow control valve)
    1(2)-1001-4A/B, -185A/B, - 186A/B, & -187A/B (RHR heat exchanger flow reversing valves)

  - DGCW supply

    3906/3907 (DG heat exchanger flow reversing valves)
    1(1/2)-3999-89 (1/2 DGCW pump supply to ECCS room coolers)

Requirements:

IWV-1100 of the ASME Boiler and Pressure Vessel Code, Section XI, requires that certain Class 1, 2, and 3 valves required to perform a specific function in shutting down a reactor to the cold shutdown condition or in mitigating the consequences of an accident be tested to assess operational readiness.

Reference:

Quad Cities Station Inservice Testing Program, Revision 3.

DEFICIENCY 92-201-06

Finding Title: Unit 2 RHR Heat Exchanger Room Cooler Inoperable (Section 7.4)

Description of Condition:

The team reviewed the details of the licensee's heat exchanger and room cooler inspection program and the results of the Unit 1 and Unit 2 Cycle 11 inspections. Heat exchanger inspections were performed and documented in accordance with Procedure QCP 1400-29, "Heat Exchanger Inspection Program."

The initial inspections, conducted in November 1990 and January 1991, identified significant flow restrictions in both of the Unit 1 RHR heat exchanger room coolers 1A and 1B. The licensee determined that the flow restriction affected the heat removal capacity of the coolers beyond their 17-percent design margins. The licensee failed to recognize and subsequently address the plugging of the coolers as a potential operability issue. Consequently, required NRC notification of the degraded condition of the safety-related coolers was not made. Similar coolers on Unit 2, which was on line and continued to operate for the remainder of its cycle, were not inspected until March 1992. Inspection of the Unit 2 RHR heat exchanger room coolers identified that 28 percent of the first-pass tubes of the four-pass cooler were plugged in the 2A cooler and 58 percent of the first-pass tubes were plugged in the 2B cooler.

The licensee concluded from a completed study, NFS Report No. RSA-Q-90-02, Revision 2 dated August 1990, and a safety evaluation in accordance with the Code of Federal Regulations 10 CFR 50.59 that the RHR heat exchanger room coolers were not required to mitigate the consequences of an accident. The team noted that the licensee's study assumed that natural ventilation was available in the ECCS pump rooms. However, a field verification during the inspection identified no natural ventilation pathway for the 2B RHR heat exchanger room. The team concluded that the licensee failed to take appropriate corrective action to address the degraded RHR heat exchanger room coolers that were identified during the Unit 1 Cycle 11 refueling outage because timely action was not taken to inspect and evaluate the operability of the Unit 2 RHR heat exchanger room coolers. Therefore, the Unit 2 RHR room cooler appeared to be inoperable for approximately 1 year while Unit 2 was on line, which could have affected the operability of the RHR system during this period.

Requirements:

10 CFR Part 50, Appendix B, Criterion III, "Design Control," requires: "The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program."

10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," requires: "Measures shall be established to assure that conditions adverse to quality such as failures, malfunctions, deficiencies, deviations, defective material and equipment, are promptly identified and corrected."

Reference:

NFS Report No. RSA-Q-90-02, Revision 2.

APPENDIX B

LIST OF OBSERVATIONS

During the service water system operational performance inspection at the Quad Cities Nuclear Power Station, the U.S. Nuclear Regulatory Commission's inspection team made the following observations. The relevant sections of the inspection report are given in parentheses.

Observation No. 92-201-01,	Hydraulic Models for RHRSW and DGCW Systems Contained Several Key Unverified Assumptions (Section 4.2)
Observation No. 92-201-02,	RHR Heat Exchanger 2A Failed a Special Heat Transfer Test (Section 4.6)
Observation No. 92-201-03,	Inaccurate RHRSW system drawings (Section 5.1)
Observation No. 92-201-04,	Operations Procedural Weaknesses (Section 5.2)
Observation No. 92-201-05,	Inconsistent Equipment Operability Trending Program (Section 6.3)
Observation No. 92-201-06,	Recommendation Listed in the RHR Reliability Centered Engineering Study Did Not Appear to be Tracked (Section 6.3)

APPENDIX C

EXIT MEETING ATTENDEES

NRC

Andy Dunlop	Reactor Inspector, NRC, RIII
Brian Grimes	NRC, NRR
Tony Hsia	NRC, Acting Section Chief, RIII
Steven Jones	NRC, NRR
Peter Koltay	NRC, Team Leader
Hubert J. Miller	NRC, RIII, DRS
Donald Norkin	NRC, NRR
Charles J. Phillips	NRC, RIII
Paul F. Prescott	QC, Resident Inspector
Tom Taylor	NRC, Resident Inspector
Spyros Traiforos	NRC, Contractor
James Tatum	NRC, HQ

CECo Personnel

Richard Bax	Station Manager
Steve BVoline	Sargent and Lundy
Robert Bryer	Detroit Edison Quality Engineering
Davis Craddick	QCNPS Assistant Superintendent Maintenance
Steve Davis	Technical Staff
Chris Fonner	Bechtel
Len C. Fron	Detroit Edison Nuclear Engineering
Dennis Galle	Vice President BWR Operation
James J. Galligan	Quality Assurance, Nuclear Safety
Gloria Gamboa	Nuclear Chemistry Service
Frederick J. Geiger	ENC, QCNPS
Kenneth L. Graesser	General Manager BWR Operations
Daniel Kanakares	Regulatory Assurance
T. A. Kuban	Maintenance
Greg Lupia	NED NYS Group
Erryl Mendenhall	ENC, BWRSD, Site
Alex L. Misak	Quad Cities Regulatory Assurance Supervisor
Jeffery A. Neal	Onsite Nuclear Safety
Mike Neels	Quality Control Supervisor
Bob Rybak	Nuclear Engineer, Mech. & Struct. Design
John L. Schrage	Nuclear Licensing
Girija S. Shukla	Nuclear Licensing, Detroit Edison
Gary Spedl	Quad Cities Production Superintendent
Sam Stapp	Nuclear Quality Programs
Paul Thimmesch	NED, M/S
George P. Wagner	Nuclear Engineering Manager
Bob Walsh	Quad Cities Technical Staff
Charlie Sargent	BWR Operations
Gerald Tietz	Technical Superintendent, Quad Cities
Robert C. Tubbs	Operating Engineer

APPENDIX D

ABBREVIATIONS

1/2	shared between two units
CM	corrective maintenance
DG	diesel generator
DGCW	diesel generator cooling water
DVR	deviation report
ECCS	emergency core cooling system
GL	generic letter
gpm	gallons per minute
GSRV	General Surveillance System Master File
HPCI	high-pressure coolant injection
HVAC	heating, ventilating, and air conditioning
INPO	Institute of Nuclear Power Operations
IST	inservice testing
LOCA	loss-of-coolant accident
LCO	limiting condition for operation
MOV	motor-operated valve
MWR	maintenance work request
NPRDS	Nuclear Plant Reliability Data System
NQP	nuclear quality program
NSO	nuclear station operator
NTS	nuclear tracking system
P&ID	piping and instrumentation drawings
PM	preventive maintenance
QCOP and QOP	operating procedures
QGA	emergency operating procedures
QOA	abnormal procedures
QOS	operating surveillance
RCM	Reliability Centered Engineering
RHR	residual heat removal
RHRSW	residual heat removal service water
RWP	radiation work permit
SCRE	shift control room engineer
SE	shift engineer
S&L	Sargent & Lundy Engineers
SWEC	Stone and Webster Engineering Corporation
SWS	service water system

TJM	Maintenance History Listing/Total Job Maintenance
TS	technical specifications