UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ECCS OPERABILITY WITHOUT ROOM COOLER HEAT REMOVAL CAPABILITY

(AITS 91-0523, TAC NOS. M81264, M81265, M82692, and M82693)

COMMONWEALTH EDISON COMPANY

AND

IOWA-ILLINOIS GAS AND ELECTRIC COMPANY

DRESDEN NUCLEAR POWER STATION, UNITS 2 AND 3

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-237, 50-249, 50-254, AND 50-265

1.0 INTRODUCTION

By letter dated October 18, 1991, Region III requested that the Office of Nuclear Reactor Regulation assess the operability of emergency core cooling system (ECCS) equipment without room cooler heat removal capability at the Dresden and Quad Cities Stations. Commonwealth Edison Company (CECo or the licensee) isolated flow of the diesel generator cooling water (DGCW) system to the ECCS pump room coolers at Dresden Station following on-site review of a study providing technical justification for this action. This study found that the heat removal capacity through conduction and natural circulation, and the heat storage capacity of the pump room structures are adequate to maintain ECCS pump room temperatures below those temperatures assumed for equipment qualification for the period of time the equipment is required to be operable. The purpose of the action taken at Dresden Station was to prevent marginal DGCW flow conditions through the diesel generators by isolating the parallel flow path through the ECCS pump room coolers. This action was implemented based on the conclusions of evaluations conducted in accordance with the requirements of 10 CFR 50.59.

A similar study and on-site review concluded that certain ECCS pump room coolers were no longer required as attendant equipment at the Quad Cities Station. The purpose of the evaluation at Quad Cities Station was to provide the basis for improving ECCS availability. Past failures of the ECCS pump room coolers had contributed to ECCS unavailability. However, the NRR staff understands that Quad Cities Station has not issued the necessary documents and procedures to implement the conclusions of the study.

The NRR staff reviewed RSA-D-90-01, "ECCS Pump Room Transient Response to Loss of Room Cooler for Dresden Units 2 and 3," Rev. 0, and the associated on-site review report 90-23, Rev. 1. Based on this review, the NRR staff raised questions regarding the assumptions and methodology used in the analysis during a meeting at the licensee's corporate office on February 21, 1992. By letter dated March 4, 1992, the NRR staff requested that the licensee provide additional information regarding the analysis. In its response dated May 8, 1992, the licensee partially addressed the concerns identified during the February 21, 1992, meeting, and in the March 4, 1992, letter. This submittal included, as enclosures, RSA-Q-86-01, "Study of Thermodynamic Characteristics of the Quad Cities ECCS Pump Rooms," Rev. 0, and CQD-049455, "Evaluation of the Impact of Loss of Room Cooler Combined with a LOCA on the Qualified Life of Equipment Located in ECCS Pump Rooms," Rev. 1.

The staff reviewed the May 8, 1992, submittal and determined that it did not adequately address the staff's concerns. During teleconferences on May 21, 1992, and May 29, 1992; and technical meetings on September 15, 1992, and September 23, 1992, the staff requested further information in order to assess the technical adequacy of the licensee's analyses. The licensee provided submittals responding to the staff's concerns with regard to the Dresden Nuclear Power Station dated August 6, 1992, December 21, 1992, and April 30, 1993. The December 21, 1992 submittal included, as enclosures, RSA-D-92-06, "HPCI Room Thermal Response With Loss of HPCI Room Cooler at Dresden Station," Rev. 0, and RSA-D-92-07, "LPCI Room Thermal Response Due to Loss of Room Cooler at Dresden Station," Rev. 0. These documents superseded previous evaluations of ECCS operability without room cooler heat removal capability for Dresden Station.

The licensee indicated that similar engineering evaluations for Quad Cities Station would be performed. Since the submittals received to date applicable to Quad Cities Station have not adequately addressed the staff's concerns, the staff will focus its review on later submittals which are applicable to Dresden Station only. Due to the physical similarities of the ECCS pump rooms at Dresden and Quad Cities Stations, the staff considers analytical methods found to be acceptable for use at Dresden to also be acceptable for use in analyses for Quad Cities.

2.0 TRANSIENT TEMPERATURE ANALYSES

The licensee is applying the transient room temperature analyses to certain reactor building corner rooms housing the low pressure coolant injection (LPCI) and low pressure core spray (LPCS) system components and the high pressure coolant injection (HPCI) system pump rooms at Dresden Station. Two corner rooms per unit at Dresden Station house components associated with the LPCI and LPCS systems, including LPCI pumps, LPCS pumps, containment cooling heat exchangers, motor operated valves, and associated instrumentation. Two LPCI pumps and one LPCS pump are located in each corner room. These corner rooms are triangular in shape and enclose a large volume. The corner rooms are constructed such that openings to the torus area and the upper levels of the reactor building are present. The HPCI pump rooms are constructed external to the reactor building below grade level. The HPCI rooms are large, rectangular in shape, and have no significant external openings which would allow natural circulation air flow.

2.1 Computer Code

The licensee selected RELAP4/MOD6 to model the transient temperature response of the corner rooms and the HPCI pump rooms to ECCS pump operation. This computer code previously was normally used to analyze transient heat transfer and flow conditions within piping networks, and the code was approved by the NRC for this purpose. The RELAP4/MOD6 code employs a lumped parameter model, effectively treating each volume as homogeneous with regard to thermodynamic properties such as temperature and density.

The licensee stated that RELAP4/MOD6 was specifically selected for the transient temperature analyses over compartment analysis codes, such as CONTEMPT or COMPARE, based on its ability to characterize buoyancy driven flows between volumes where natural circulation flow paths exist. The code was previously employed by CECo to evaluate steam tunnel temperature response following a high-energy line break at Byron and Braidwood Stations, and this evaluation was reviewed and accepted by the staff. The licensee stated that the code was installed on the CECo computer system in accordance with approved company procedures and requirements for design application computer codes.

The licensee performed calculations RSA-D-92-05, "Validation of Loss of HPCI Room Cooler Analysis at Dresden Station," Rev. 0, and "An Evaluation of Natural Circulation Flows Predicted by RELAP 4 Mod 6 in ECCS Corner Room Analyses" (no document number) to verify by analytical methods that the code accurately models transient thermal conduction and natural circulation air flow rates, respectively. These documents were provided in the April 30, 1993, submittal. The ability of RELAP4/MOD6 to model transient heat transfer into a concrete wall was verified in RSA-D-92-05 by an exact analytical method. The evaluation of natural circulation flow used an incompressible fluid flow model to verify predicted natural circulation flow rates. The incompressible model introduces some error due to the density change as pressure and temperature change. However, this effect is small.

The study RSA-Q-86-01 documented the approach used to determine an appropriate heat transfer coefficient to account for convective and radiative heat transfer between the air within the corner room and the walls of the corner room based on a correlation of test data and the associated RELAP4/MOD6 solution. Heat transfer coefficients used in the RELAP4/MOD6 code are limited to a minimum value of 5.0 Btu/hr-ft^2-°F. The licensee corrected for this limitation by scaling the heat transfer area used in the code downward by the ratio of the actual to minimum allowed heat transfer coefficients. The heat transfer rate is computed as the product of the heat transfer coefficient, the heat transfer area, and a representative temperature difference.

2.2 HPCI Pump Room

The HPCI pump room cooler is normally supplied cooling water from the unqualified normal service water (NSW) system. The supply from the DGCW system is isolated. In the event of a loss of NSW due to a loss of offsite power or other cause coincident with HPCI system operation, the HPCI room would experience an increasing temperature moderated only by heat transfer to the room structure. If the heat load is sufficiently large, the room temperature increase will continue until the room temperature reaches the HPCI steam line isolation setpoint, at which point the function of the HPCI system would be lost.

The licensee's current analysis of HPCI pump room transient temperature response is documented in RSA-D-92-06, Rev. 0. The model for this analysis consists of one heat source representing the HPCI turbine and other heat producing equipment, and six heat structures representing the four walls, ceiling and floor of the HPCI pump room. Heat transfer coefficients are specified for each side of the heat structures, allowing through wall heat transfer (i.e., heat transfer from the HPCI pump room through the concrete wall to the soil or an adjacent compartment) to be modeled.

The transient temperature analysis model for the HPCI room is based on the following assumptions:

1. The room cooler fan is operable with an air flow rate of 4750 cfm. This air flow is sufficient to thoroughly mix the air in the HPCI pump room, thereby justifying the use of a lumped parameter model. The HPCI room cooler fan starts automatically at a room temperature of 130°F.

2. A calculated HPCI room temperature of less than 175°F will not cause isolation of the HPCI steam lines. The nominal HPCI room high temperature isolation setpoint is 180°F with an uncertainty of 5°F.

3. The heat load within the HPCI pump room is no greater than 200,000 Btu/hr. This value equals the design room cooler heat removal rate and exceeds the calculated heat load for the HPCI room during normal system operation. An additional heat load representing postulated steam leakage at a rate of 216 lb/hr was used in certain cases.

4. An initial steady state temperature distribution exists within the concrete walls of the HPCI room. This initial temperature distribution is calculated based on the initial temperatures of adjacent volumes and the assumed heat transfer coefficients at the surfaces of the walls.

5. Coefficients for HPCI room air to wall heat transfer are calculated based on the combined effects of convective heat transfer and radiative heat transfer. These values were 0.5 Btu/ft^2-°F for the floor, 0.91 Btu/ft^2-°F for the walls, and 1.0 Btu/ft^2-°F for the ceiling. Where condensation was considered an important heat transfer mechanism due to steam leakage from the gland seal condenser, a correlation was used to calculate a heat transfer coefficient which credits this mechanism.

6. The initial temperature of the HPCI pump room is maintained at or below 120°F during normal operation. An analysis using an initial room temperature of 130°F was also performed to demonstrate that operability is assured during and following performance of HPCI surveillance

testing, which may potentially raise the initial room temperature above 120°F.

7. The cooling water supply to the room cooler is isolated. The analysis does not credit the room cooler for heat removal.

8. The temperature of adjacent rooms is at the Equipment Qualification zone map temperature of 104°F or lower.

9. The soil temperature is no greater than 65°F. Heat transfer from the concrete to soil is represented by an effective heat transfer coefficient based on a calculated thermal diffusion length.

10. The thermal capacity of steel structures within the HPCI pump room are neglected. The concrete structures were modeled to their actual thickness.

The licensee documented analyses for four cases. The effect of varying the initial room temperature was determined by analyzing two cases assuming no steam leakage. The first and second cases were evaluated using initial HPCI room temperatures of 120°F and 130°F, respectively. The remaining two cases were analyzed to determine the effect of steam leakage on the HPCI room temperature response. The third and fourth cases were evaluated assuming an initial HPCI room temperature of 120°F and condensation heat transfer coefficients of 2.0 Btu/hr-ft^2-°F and 5.0 Btu/hr-ft^2-°F, respectively.

Steam leakage was postulated due to the potential for failure of the HPCI turbine gland exhaust fan which draws gases from the gland exhaust condenser. The gland exhaust fan is not qualified for operation in the expected HPCI pump room environment following turbine operation. In the event of gland exhaust fan failure, the removal of air from the gland exhaust condenser and condensation of the steam within the condenser would be impaired. Should the pressure in the gland exhaust condenser exceed atmospheric due to the impaired condensation, the gland seals along the turbine shaft will begin to release steam to the HPCI pump room. Section 6.2.5.3.3.5 of the Dresden Updated Final Safety Analysis Report (UFSAR) estimated the maximum steam leakage from the seals to be 2160 lb/hr for a fully pressurized turbine casing with a locked turbine rotor. In this case, failure of the gland exhaust condenser is due to a loss of condenser cooling water from the HPCI pump discharge. Using the locked rotor steam release as a bounding value, the licensee selected 10% of the locked rotor steam release (i.e., 216 lb/hr) as the steam leakage rate for gland exhaust fan failure in case three and case four.

The licensee determined the HPCI room temperature as a function of time for the four evaluated cases. The first case was found to be the least limiting with approximately 19 hours of HPCI system operation elapsing prior to HPCI room temperature reaching the system isolation setpoint. The third case was the most limiting, with only about 8 hours of HPCI system operation elapsing prior to HPCI room temperature reaching the system isolation setpoint. The following table presents the input conditions and the results of the HPCI room temperature transient analyses:

CASE NO.	INITIAL ROOM TEMP	HEAT TRANSFER COEFFICIENT	STEAM LEAKAGE RATE	TIME TO HPCI ISOLATION
1	120°F	0.5-1.0 Btu/ft^2-°F	0	19 hrs
2	130°F	0.5-1.0 Btu/ft^2-°F	0	9 hrs
3	120°F	2.0 Btu/ft^2-°F	216 lb/hr	8 hrs
4	120°F	5.0 Btu/ft^2-°F	216 lb/hr	16 hrs

2.3 Reactor Building Corner Rooms

The reactor building corner room coolers are also normally supplied cooling water from the unqualified NSW system, and the cooling water supply from the DGCW system is isolated. In the event of a loss of NSW due to a loss of offsite power or other cause coincident with operation of the LPCS or LPCI pumps, the corner room would experience an increasing temperature. The temperature increase will be moderated in the short term by heat transfer to the corner room structures. Long term heat removal may be established by natural circulation convection currents which transport the heat generated within the corner rooms to regions of the reactor building where the heat is transferred to the environment by conduction. If the rate of heat removal is insufficient, the room temperature may increase to a value where failure of the LPCS and LPCI pump motors is likely. Elevated temperatures may also degrade electrical equipment necessary to monitor and control the LPCS and LPCI systems. Failure or degradation of these components may impair the ability to provide long term decay heat removal from the primary containment and the reactor vessel.

The licensee's current analysis of reactor building corner room transient temperature response is documented in RSA-D-92-07, Rev. 0. The model used for this analysis consists of: three volume nodes within the reactor building representing the corner room, the reactor building above elevation 517 ft, and the torus area; one volume node to model the post-LOCA torus water temperature; one heat source representing the LPCS and LPCI pump motors and other heat producing equipment; 14 heat structures necessary to model heat transfer through the walls, ceiling, and floor of the reactor building; and five constant temperature heat sink volume nodes representing the outdoor air, the soil adjacent to the building walls, the soil underneath the building floor, the turbine building, and the sister unit reactor building. Heat transfer coefficients are specified for each side of the heat structures, allowing through wall heat transfer (i.e., heat transfer from the reactor building corner room through the concrete wall to the soil or an adjacent compartment) to be modeled. Because the two corner rooms share the heat sinks in the upper levels of the reactor building and the torus area, the model includes only a single corner room with one half of the total heat sink surface area and volume calculated for the upper levels of the reactor building and the torus area.

The transient temperature analysis model for the reactor building corner room is based on the following assumptions:

1. Natural circulation air flow is modeled by a circular flow path between the three modeled volume nodes within the reactor building. Heated air rising from the corner room into the upper levels of the reactor building draws air from the torus area into the corner room through openings in the common wall between the torus and the corner room. Cooler air in the upper levels of the reactor building flows down through openings in the 517 ft elevation floor to the torus area to replace the volume of air drawn into the corner room.

2. Natural circulation air flow is the dominant heat removal mechanism. Therefore, an analysis of the corner room with the smallest air flow areas, LPCI pump room 2A, bounds other corner rooms with regard to peak temperature. The flow areas used in the analysis between the corner room and the upper levels of the reactor building, between the upper levels of the reactor building and the torus area, and between the torus area and the corner room are 44 ft^2, 44 ft^2, and 16 ft^2, respectively.

3. The corner room air temperature is uniform with no significant stratification as a result of air flow provided by cooling fans integral to the LPCI and LPCS pump motors. This is necessary to justify use of a lumped parameter model in solving for the circulating air flow rate and corner room peak temperature.

4. The heat load within the reactor building corner room is represented by a value of 512,500 Btu/hr for room temperatures below 170°F, and a value of 431,500 Btu/hr at room temperatures at or above 170°F. The heat load for room temperatures below 170°F includes the potential heat gain from piping and heat exchangers containing post-LOCA suppression pool water; the heat load for room temperatures at or above 170°F represents only the heat load from electrical sources, such as lighting, pump motors, and fan motors.

5. The air in the torus area is heated by the water within the torus following a LOCA. The torus water temperature history is taken from the Quad Cities LOCA analysis based on operation of a single RHR cooling loop, which resulted in higher torus water temperatures relative to operation of two RHR cooling loops.

6. The mechanism of heat transfer between the air and the heat sinks within the corner rooms is a combination of natural convective, forced convective, and radiative heat transfer. Based on test data collected in the Quad Cities RHR 2B room in 1986, the combined heat transfer coefficient was selected to be 5.0 Btu/hr-ft^2-°F. Coefficients for other areas within the reactor building were calculated based on the combined effects of convective heat transfer and radiative heat transfer.

7. The initial environmental conditions for the reactor building corner room, torus area, and upper levels of the reactor building are represented by a pressure of 14.7 psia, a temperature of 104°F, and a relative humidity of 95%.

8. The normal reactor building ventilation system and the room cooler are unavailable. The analysis does not credit the ventilation system or the room cooler for mixing of room air or heat removal.

9. The temperature of the adjacent turbine building and reactor building of the sister unit is a constant 104°F.

10. The soil temperatures are represented by temperatures of 55°F and 65°F for areas under the reactor building floor and adjacent to walls, respectively. Heat transfer from the concrete to soil is represented by an effective heat transfer coefficient based on the thermal conductivity of the soil and a calculated thermal diffusion length.

11. The thermal capacity of steel structures within the reactor building is neglected. The concrete structures are modeled to their actual thickness.

The RELAP4/MOD6 code calculated the transient temperature response for the corner rooms for the first 11.7 days ($1x10^6$ seconds) of the transient. This period of time corresponds to the transient time limitation of the code. The calculated corner room temperature at the end of the period is 178°F. The licensee fit a quadratic function for room temperature to the last 34 hours of transient temperature data and used the function to calculate the peak temperature. Using this method, the peak temperature was calculated to be 178.6°F at a time of 15.5 days into the transient.

The transient analysis indicates that the room heats up quickly. The heat generated within the room is initially stored as sensible heat in the room air and the outer surfaces of the concrete walls, ceiling, and floor. As the temperature of the outer surfaces of the walls, ceiling, and floor nears the air temperature due to the relatively high heat transfer coefficient between the air and the room walls, heat transfer to the concrete structures becomes limiting due to the low thermal conductivity of the concrete. However, the increasing air temperature in the corner room establishes the necessary density difference between the corner room and upper levels of the reactor building to initiate natural circulation cooling.

2.4 Equipment Qualification

The licensee reviewed the qualification of safety-related electrical equipment within the reactor building corner rooms containing the LPCI and LPCS pumps, the upper levels of the reactor building, and the HPCI pump rooms. In its submittal dated April 30, 1993, the licensee stated that the equipment located within these affected areas within the scope of 10 CFR 50.49 is qualified in accordance with the requirements of 10 CFR 50.49 for the higher operating temperatures expected following a LOCA without room cooling. In addition, CECo evaluated all other safety-related equipment and verified that the equipment will perform the required safety functions at the elevated temperatures.

3.0 EVALUATION

3.1 Computer Code

The licensee selected the RELAP4/MOD6 computer code which was approved by the NRC for use in thermal-hydraulic applications. The code was installed on the CECo computer system in accordance with approved company procedures and requirements for design application computer codes. The staff previously reviewed and accepted analyses of compartment response to a high energy line break using RELAP4/MOD6. The licensee also demonstrated through the use of simplified calculational methods that the computer code accurately models transient heat conduction through slabs and the development of natural convection currents between well-mixed volumes. Based on the above, the staff concludes that RELAP4/MOD6 is acceptable for use in modeling the transient temperature response of the ECCS pump rooms to pump operation at Dresden and Quad Cities Stations.

3.2 HPCI Pump Room

During the review of RSA-D-90-01, the staff identified the following deficiencies in the licensee's analysis of the HPCI pump room transient temperature response:

1. The use of a lumped parameter model in the analysis was not justified.

2. The potential for an uneven temperature distribution within the HPCI pump room causing isolation of the HPCI turbine steam supply prior to the completion of the system's safety function was not evaluated.

3. The use of a heat transfer coefficient derived from test results measured in a dissimilar room with different air flow patterns was not justified.

4. The analysis did not consider potential failures of HPCI system support components due to the increased temperature during system operation which may further increase the room heat load.

5. The assumed post-LOCA HPCI room heat load was based on design room cooler capacity rather than a calculated heat load.

In RSA-D-92-06, the licensee justified use of a lumped parameter model and addressed concerns with regard to a potential uneven temperature distribution by assuming that the HPCI room cooler fan is operable. The fan produces a total air flow of 4750 cfm within the HPCI room, which encloses a volume of about 30,000 ft^3. The licensee determined conservative values for HPCI room heat transfer coefficients based on published correlations for convective heat transfer, radiative heat transfer, and condensation heat transfer. Two of the four cases evaluated in the current study assume failure of the gland exhaust fan, which results in an increased heat load due to steam leakage. The licensee performed heat load calculations which confirmed that the heat load assumed in the analysis bounded the calculated post-LOCA heat load. Based on these actions, the staff concluded that the licensee adequately addressed deficiencies with regard to the earlier analysis in RSA-D-92-06.

Since failure of the gland exhaust fan is potentially a direct result of the high temperatures caused by operation of the HPCI turbine without room cooling, the effects of the gland exhaust fan failure must be included in the licensee's evaluation. Following a postulated failure of the gland exhaust fan, approximately one-half of the total room heat load is assumed to result from condensation of the subsequent steam leakage. Although condensation of steam is an effective heat transfer mechanism, the assumed leakage rate is not particularly high. Also, some condensation will occur on structures that will transfer the latent heat released during condensation back to the air rather than out of the room. Heat transfer directly from the air to the wall by convection is much less effective than condensation heat transfer. Therefore, the staff considers the third case, which assumes steam leakage due to failure of the gland exhaust fan and a relatively low condensation heat transfer coefficient, to be the design basis case for the HPCI pump room transient temperature response.

The staff reviewed the remaining assumptions relating to the HPCI pump room transient temperature analysis. An uncertainty of 5°F with regard to the HPCI room temperature isolation setpoint provides an acceptable margin to account for setpoint inaccuracies, setpoint drift, and calculational uncertainties. The assumed HPCI pump room heat load value of 200,000 Btu/hr for equipment, lighting, and piping heat loads is reasonable based on staff experience. The assumed initial temperatures of the HPCI pump room, surrounding rooms, and the surrounding soil are consistent with the expected maximum normal temperatures for these volumes. The assumed steady state temperature distribution through the concrete walls of the HPCI pump rooms is acceptable. This temperature distribution is based on the highest expected long term temperatures in adjacent compartments. Surveillance testing or short term operation of the HPCI system will not significantly change this temperature distribution due to the slow thermal response of the concrete walls. Therefore, the assumed temperature distribution is conservative because the available thermal storage capacity of the concrete walls is minimized. Neglecting the thermal capacity of steel structures within the pump room is also a conservative assumption in that the assumed thermal storage capacity of the HPCI pump room is diminished. For a given heat load, the rate of room temperature increase is greatest when the thermal storage capacity of structures in the room is smallest.

As described above, the transient temperature response analysis for the HPCI pump room incorporated conservative assumptions. The results of the third case, which included steam leakage due to a failed gland exhaust fan and a low value for the condensation heat transfer coefficient, indicate that a minimum period of eight hours of continuous HPCI pump operation is available prior to system isolation on high room temperature. The analysis includes additional conservatism in that the HPCI system is anticipated to operate cyclically rather than continuously, and degradation of condensation within the gland seal condenser due to failure of the gland exhaust fan is expected to occur some period of time after system startup rather than immediately. An eight hour period of continuous HPCI system operation bounds the expected period of system operation for accident and transient mitigation. Therefore, the staff concludes that operation of the HPCI system without room cooling does not compromise the ability of the system to perform its safety function, and the conclusion that the HPCI system is operable without room cooling is acceptable.

4.3 Reactor Building Corner Room

During the review of RSA-D-90-01, the staff noted the following deficiencies in the licensee's analysis of the LPCI/LPCS corner room transient temperature response:

1. The upper levels of the reactor building were treated in the original analysis as a constant temperature heat sink.
2. The torus area was treated as a constant temperature volume.
3. The assumed post-LOCA LPCI/LPCS corner room heat load was based on design room cooler capacity rather than a calculated heat load.

The licensee addressed these concerns by extending the boundaries of the model used in the analysis and employing a calculated heat load in the analysis. In RSA-D-92-07, the constant temperature heat sinks consist of the soil and air around the reactor building, and adjacent buildings which are outside the natural circulation air flow path. The torus area temperature was allowed to vary based on heat gain from water within the torus following the LOCA blowdown. The torus water temperature versus time profile was based on the post-LOCA torus water temperature profile for Quad Cities Station. The model also evaluates heat transfer to and from the torus area and the upper levels of the reactor building due to air circulation within the reactor building. The staff concludes that these actions adequately address the concerns identified above.

The staff reviewed assumptions related to the LPCI/LPCS corner room transient temperature analysis. The assumed natural circulation flow is based on the head developed by density differences in the air created by temperature changes in adjacent volumes. The model includes all reasonable heat transfer mechanisms to accurately compute the temperature changes of the various volumes, and the model considers the effects of flow resistance on the air flow between volumes. Therefore, the natural circulation flow portion of the model is acceptable.

Conductive heat transfer through the walls of the corner rooms at the equipment qualification temperature is limited to a fraction of the total room heat load by the low thermal conductivity of concrete. The licensee's evaluation indicates that heat removal by conduction decreases to less than 20% of the total heat load within the first twelve days of the transient, while the rate of room temperature increase is near zero, leaving natural circulation air flow as the dominant heat removal mechanism. The computation of natural circulation air flow is based on physical principles and is considered accurate. Therefore, the analysis performed for the corner room with the most restricted flow area, LPCI pump room 2A, is bounding with regard to determination of peak temperature.

The temperature distribution within the RHR 2B pump room at Quad Cities with both RHR pumps operating is documented in RSA-Q-86-01. A review of this data indicates that the air within the room is well-mixed. However, the air temperatures measured in the areas immediately around and above the pump motors are consistently slightly warmer than the surrounding air temperature. Due to the similar arrangement of components and the similar size of the corner rooms, the temperature distribution measured within the Quad Cities RHR 2B pump room during operation of the RHR pump motors is considered to also be applicable to Dresden Station. Since sufficient margin exists between the peak temperature assumed for equipment qualification purposes and the calculated peak average temperature to accommodate these small temperature variations, the equipment qualification determination is acceptable. The well-mixed environment within these rooms justifies use of the lumped parameter model.

Based on our review, the staff found the assumed heat loads used in the calculation to conservatively represent the actual heat loads within the corner rooms. The modeling of the torus area temperature based on heat input from the Quad Cities torus water temperature profile was also judged to be acceptable. The value of the combined heat transfer coefficient used for the corner rooms based on data contained in the report RSA-A-86-01 is consistent with the published range of values for turbulent heat transfer coefficients in air. The mixing developed by the integral pump motor fans and buoyancy driven air movement along the long vertical surfaces of the corner rooms provide assurance that turbulent conditions exist in the room. The methodology used to develop heat transfer coefficients for other surfaces was adequately justified. The staff noted that the effective heat transfer coefficient used to calculate the heat transfer from the outer surface of the concrete wall to the soil would tend to over-estimate heat transfer very late (i.e. greater than 15 days) into the transient. However, the error in the calculated peak room temperature introduced by calculating the heat removal using this methodology is insignificant, and, conversely, the methodology is conservative earlier in the transient. Also, since it is unlikely that all three pumps located in one corner room would be required for core and containment cooling late in the transient, the assumed heat load late in the transient, which is based on operation of all three pumps, is very conservative. Therefore, the values of the combined heat transfer coefficients used in RSA-D-92-07 are acceptable.

The analysis assumed conservative initial environmental conditions for the reactor building. Operation of the normal reactor building ventilation system and the corner room coolers were also conservatively not credited. The temperatures selected for volumes adjacent to the reactor building were adequately justified. Neglecting the thermal capacity of steel structures within the corner room is also a conservative assumption in that the assumed thermal storage capacity of the corner room is diminished.

The staff extended the temperature profile for the corner rooms beyond the first 11.7 days of the transient using a more conservative linear function, rather than the quadratic function used by the licensee. Use of the linear function to extend the RELAP4/MOD6 results to 30 days post-LOCA indicated that corner room temperature reaches a maximum of 183.5°F at 30 days, which is below the temperature used for equipment qualification purposes. Based on this calculated maximum temperature, the staff concludes that the 185°F temperature is acceptable for determination of equipment qualification.

3.4 Equipment Qualification

The licensee's determination that equipment within the scope of 10 CFR 50.49 located in areas affected by elevated temperatures satisfies the requirements of 10 CFR 50.49 and that safety-related equipment will continue to be capable of performing the required safety functions at the elevated temperatures is acceptable.

4.0 CONCLUSION

The NRR staff reviewed the licensee's evaluation of HPCI pump room and reactor building corner room transient temperature response to a LOCA without room cooling, documented in RSA-D-90-01, which formed the basis of the licensee's original determination that isolation of DGCW from the ECCS pump room coolers is acceptable. In this analysis, the staff identified numerous deficiencies such as: inadequate justification of the lumped parameter model used in the analysis, failure to evaluate the impact of an uneven temperature distribution on the conclusion of the analysis, inadequate justification of heat transfer parameters used in the analysis, incomplete evaluation of the effects of the failure of unqualified support equipment, and incomplete evaluation of the effects of heat transfer from the ECCS pump rooms to adjacent compartments. The licensee did not demonstrate that the analysis documented in RSA-D-90-01 is acceptable.

Instead, CECo submitted additional analyses to address the staff's concerns, including RSA-D-92-06 and RSA-D-92-07, which were submitted on December 21, 1992, as the analyses of record for the transient temperature response to a LOCA without room cooling at Dresden Station for the HPCI pump rooms and LPCI/LPCS corner rooms, respectively. The staff reviewed these submittals and concluded that the additional analyses adequately addressed the staff's concerns, and that acceptable assumptions and methodologies were employed in the analyses. The licensee performed an evaluation of the equipment located within the affected areas to ensure that equipment which is within the scope of 10 CFR 50.49 is qualified in accordance with the requirements of 10 CFR 50.49 for the higher operating temperatures expected following a LOCA without room cooling, and that all other safety-related equipment will perform the required safety functions at the elevated temperatures. Therefore, the staff concludes that equipment important to safety located in the ECCS pump rooms is capable of performing its design function post-LOCA without room cooling.

Principal contributor: S. Jones, NRR/SPLB

Date: July 30, 1993