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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING GENERIC LETTER 96-06, "ASSURANCE OF EQUIPMENT OPERABILITY AND CONTAINMENT INTEGRITY DURING DESIGN-BASIS ACCIDENT CONDITIONS"

Ladies and Gentlemen:

By letter dated April 26, 2002, the NRC provided a copy of the evaluation titled, "Evaluation of the Electric Power Research Institute Report TR-113594, 'Resolution of Generic Letter 96-06 Waterhammer Issues,' Volumes 1 and 2 dated December 2000." The NRC letter also requested H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, to complete actions to address Generic Letter (GL) 96-06 and to submit the information referred to in Section 3.3 of the enclosed evaluation.

The actions to address GL 96-06 have been completed. Attachment I provides an Affirmation for this submittal. The response to the request for additional information is provided in Attachment II. The response to the previous request for additional information regarding two-phase flow is provided in Attachment III.

If you have any questions concerning this matter, please contact Mr. C. T. Baucom.

Sincerely,

B. L. Fletcher III
Manager - Regulatory Affairs

Attachments:
I. Affirmation
II. Response to Request for Additional Information
III. Response to the Previous Request for Additional Information Regarding Two-Phase Flow

c: Mr. L. A. Reyes, NRC, Region II
Mr. R. Subbaratnam
NRC Resident Inspector, HBRSEP

Robinson Nuclear Plant
3581 West Entrance Road
Hartsville SC 29550

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AFFIRMATION

The information contained in letter RNP-RA/02-0128 is true and correct to the best of my information, knowledge and belief; and the sources of my information are officers, employees, contractors, and agents of Carolina Power and Light Company. I declare under penalty of perjury that the foregoing is true and correct.

Executed on: AUG 27 2002

J. W. Moyer
Vice President, HBRSEP, Unit No. 2

H. B. ROBINSON STEAM ELECTRIC PLANT UNIT NO. 2

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

NRC Request for Information:

Certify that the EPRI methodology, including clarifications, was properly applied, and that plant-specific risk considerations are consistent with the risk perspective that was provided in the EPRI letter dated February 1, 2002. If uncushioned velocity and pressure are more than 40 percent greater than the cushioned values, also certify that the pipe failure probability assumption remains bounding.

Response:

The recommended waterhammer evaluation methodology is contained in the EPRI report TR-113594, and consists of the following analysis steps, summarized from Volume 2, Section 2.2:

1) Evaluate System:
   a) Gather Data
   b) Develop an Event Time Line
2) Model System Hydraulics:
   a) Determine Fan Cooler Unit Performance
   b) Determine System Voiding
   c) Determine System Refill
3) Determine Condensation Induced Waterhammer (CIWH) Magnitude
4) Determine Potential Closure Locations
5) Determine Column Closure Waterhammer (CCWH) Magnitude and Pulse Characteristics:
   a) Determine Column Closure Velocity Limited by Inertia
   b) Determine Released Non-Condensables
   c) Determine Refilling Velocity Limited by Cushioning
   d) Determine CCWH Magnitude and Pulse Shape
6) Determine Pressure Pulse Propagation and Pipe Loading:
   a) Determine Loading Functions (Force-Time Histories)
   b) Determine Pulse Amplification and/or Attenuation
7) Determine Pipe Stress and Support System Loads

Analysis Step 1 (Evaluate System), Step 2 (Model System Hydraulics), Step 4 (Determine Potential Closure Locations), and Step 5 (Determine CCWH Magnitude and Characteristics), including subtasks, were performed in a manner consistent with or more conservative than the EPRI TR-113594 methodology. Although the analysis was performed before the final approval of the EPRI methodology, the inputs used in the analysis were subsequently evaluated and found to produce conservative results. The analysis did not credit cushioning of the closure velocity (subtasks b, c).

HBRSEP, Unit No. 2, meets the EPRI TR-113594 criteria that permit CIWH to not be explicitly analyzed. The criteria, as stated in EPRI TR-113594, are that the system steam pressure at the time of the postulated CIWH is less than 20 psig, and the piping has been shown by test or analysis to be capable of withstanding a CCWH following a Loss of Offsite Power (LOOP).

An additional plant specific task described in the EPRI TR-113594, Volume 2, Analysis Step 2, requires a review of the piping configuration for outliers to the normal refilling analysis, including voided vertical risers, dead legs, orifices in the voided region, and refilling Froude number. These outliers were specifically reviewed for HBRSEP, Unit No. 2. No outliers were found that impact the analysis.

Analysis steps 6 and 7 were satisfied using previous test data and stress analysis to show system acceptability. That is, tested (LOOP-only) waterhammers did not result in observed piping or support damage and the developed pipe stress and support loads were found to meet plant design requirements. The system is qualified for loss of coolant accident with loss of offsite power (LOCA/LOOP) because the LOOP-only waterhammer magnitudes, as previously measured by tests, bound the waterhammers predicted for LOCA/LOOP.

Plant specific risk of GL 96-06 induced pipe failure is much lower than the EPRI risk perspective provided in an EPRI letter dated February 1, 2002, as described in the NRC Safety Evaluation Report (SER) for EPRI TR-113594. Specifically, the plant risk of a combined LOCA/LOOP is 4.23×10^{-6}. The NRC SER value for the likelihood of subsequent pipe failure is less than 1×10^{-4}, based on analyzed pipe stress levels meeting the design code. These values produce a combined risk of 4.23×10^{-10}, which is significantly less than the threshold of significant risk to the plant of 1×10^{-7}.

NRC Request for Information:

Provide additional information that was requested in RAIs that were issued by the NRC staff with respect to the GL 96-06 two-phase flow issue (as applicable).

Response:

A request for additional information pertaining to the evaluation of GL 96-06 for HBRSEP, Unit No. 2, was provided in NRC letter dated April 24, 1998. The request for additional information (RAI) items from the April 24, 1998, letter that pertain to two-phase flow are addressed in Attachment III.

NRC Request for Information:

Provide a brief summary of the results and conclusions that were reached with respect to the waterhammer and two-phase flow issues, including problems that were identified and actions that were taken. If corrective actions are planned but have not been completed, confirm that the affected systems remain operable and provide a schedule for completing and remaining corrective actions.

Response:

The analyses performed for HBRSEP, Unit No. 2, provided conservative evaluations of waterhammer and two-phase flow conditions in the service water (SW) system, during the draining, refill, and post-refill periods of the transient.

During the initial, draining portion of the transient, heat transferred from the LOCA environment will boil water in the containment fan-cooler (CFC) tubes and steam voids will form in the discharge side piping. CIWHs are expected to occur; however, the system conditions meet the EPRI criteria, which shows that the bounding system loads will be due to CCWH. Therefore, CIWH do not require specific evaluation.

Upon pump restart and steam void re-closure, CCWH is expected to occur, producing a conservatively predicted waterhammer pressure of 397 psi. This predicted waterhammer magnitude for LOCA/LOOP is less than test data showing waterhammers due to LOOP alone to be as high as 554 psi. The pipe stress and support loads produced by LOOP waterhammers meet plant design requirements. Steps were taken to prevent the LOOP waterhammers from occurring in the future, including modification of operation and maintenance procedures to keep the system from draining and, if drained, by refilling the system in a controlled manner. Since LOOP-only waterhammer pressure magnitudes, as previously measured by test, bound the waterhammers predicted for LOCA/LOOP, the system is qualified for LOCA/LOOP.

After void re-closure, water heated in the fan cooler will travel to the outlet control valves (V-34 A, B, C, and D) and a brief period of flashing will occur. The flashing duration will last approximately 10 seconds and will be completed for all CFC trains within 80 seconds from the start of the transient. The flashing will degrade heat removal by a minor amount (approximately 15%) during this 10-second period. Required heat removal will be available after 80 seconds. In all cases the CFCs are expected to meet their design basis heat removal requirements of 13112 BTU/sec, as stated in the HBRSEP, Unit No. 2, UFSAR. The two-phase mixture generated at the valves will condense in the 24-inch header downstream of the valves. Therefore, the effects of the two-phase flow do not significantly affect operation of the system.

H. B. ROBINSON STEAM ELECTRIC PLANT UNIT NO. 2

RESPONSE TO THE PREVIOUS REQUEST FOR ADDITIONAL INFORMATION REGARDING TWO-PHASE FLOW

NRC Request for Information:

For both waterhammer and two-phase flow analyses, provide the following information:

a. Identify any computer codes that were used in the waterhammer and two-phase flow analyses and describe the methods used to benchmark the codes for the specific loading conditions involved (see Standard Review Plan Section 3.9.1).

b. Describe and justify all assumptions and input parameters (including those used in any computer codes) such as amplifications due to fluid structure interaction, cushioning, speed of sound, force reductions, and mesh sizes, and explain why the values selected give conservative results. Also, provide justification for omitting any effects that may be relevant to the analysis (e.g. fluid structure interaction, flow induced vibration, erosion).

c. Provide a detailed description of the "worst case" scenarios for waterhammer and two-phase flow, taking into consideration the complete range of event possibilities, system configurations, and parameters. For example, all waterhammer types and water slug scenarios should be considered, as well as temperatures, pressures, flow rates, load combinations, and potential component failures. Additional examples include:

- the effects of void fraction on flow balance and heat transfer;
- the consequences of steam formation, transport, and accumulation;
- cavitation, resonance, and fatigue effects; and
- erosion considerations.

Licenses may find NUREG/CR-6031, "Cavitation Guide for Control Valves," helpful in addressing some aspects of the two-phase flow analyses. (Note: while the four items listed above are important considerations for evaluating two-phase flow conditions, the last three were not addressed in the licensee's response).

d. Confirm that the analyses included a complete failure modes and effects analysis (FMEA) for all components (including electrical and pneumatic failures) that could impact performance of the cooling water system and confirm that the FMEA is documented and available for review, or explain why a complete and fully documented FMEA was not performed.

e. Explain and justify all uses of engineering judgment.

Response:

a. Computer codes were not used in the development of the two-phase flow analysis.

b. The input parameters that affect the two-phase flow analysis are: The LOCA environment, Containment Fan Cooler (CFC) flow rate, heat transfer coefficients, tube fouling and plugging factors, and inlet and outlet temperatures. These input parameters are discussed individually below. The input parameters of fluid structural interaction, cushioning, speed of sound, force reductions, and mesh size, pertain to waterhammer calculations and are not applicable to the two-phase flow issue.

- **LOCA Environment:** The limiting event was the large break LOCA described in the HBRSEP, Unit No. 2, UFSAR. The heat transfer for this event was greater than for the main steam line break (MSLB), due to the higher condensation heat transfer rate. The containment response to the LOCA event does not credit heat removal by the CFCs until 46 seconds after LOCA initiation, which provides higher containment temperature than expected. Therefore, the heat input from this event is conservative.

- **CFC flow rate and heat transfer coefficients:** The design flow rates and heat removal rates were used to determine the fan cooler heat transfer coefficients.

- **Fouling factor:** Both the fouled and clean conditions were evaluated to account for two competing objectives: 1) maximizing heat transfer to produce the most two-phase flow, and 2) minimizing heat transfer to determine if the CFC could meet the design basis heat transfer requirements. It was shown that in both cases, the CFCs would meet the design heat transfer requirements, regardless of minor flow reductions due to a temporary flashing condition. The limiting condition was determined to be the fouled case, in which less heat could be removed.

- **Tube Plugging:** Since the limiting condition for the two-phase flow analysis was the fouled case, a bounding 3% tube plugging would conservatively provide additional reduction to the heat transfer capabilities and was added as a conservative assumption.

- **CFC inlet water temperatures:** The highest design inlet temperature of 100°F was used to determined heat transfer. This is conservative because 97°F is the Technical Specification ultimate heat sink temperature limit. Cooler inlet water would provide greater heat removal.

- **CFC outlet water temperatures:** During the transient, water moving along each CFC tube was predicted to heat as it traversed the tube length. To provide a conservative assessment of the potential two-phase flow as hot water reached the outlet control valves, the entire volume remaining in the CFCs (about 1/6 of the total volume) was assumed to be at outlet temperature.

c. The goals of the two-phase flow analysis were to determine if flashing could occur at the outlet control valves and to determine if design heat removal can still be achieved. Given these two goals, maximizing CFC heat transfer and minimizing water flow and system pressure would maximize the chance for flashing to occur. However, minimizing CFC heat transfer and water flow would decrease the CFC ability to meet design basis heat removal. The analysis for the configuration at HBRSEP, Unit No. 2, determined that flashing could occur in either condition, but the flow limitation due to flashing is small. Therefore, while the lower heat transfer model is closer to the limit, design basis heat removal will be maintained for both the minimal or maximal heat transfer conditions.

In order to evaluate the worst-case scenario for two-phase flow issues, various system lineups and component failures were considered in the choice of inputs in the analysis. A sensitivity study to these inputs is included in the analysis, and bounding, "worst case" conditions were used to evaluate the system.

Steam voids created in the discharge piping during the transient were evaluated to determine the effect on flow balance in the system. Steam voids were determined to not significantly affect the system because the voids created during the transient close within 10 seconds of pump restart.

The "feedback" from hot water flashing at the control valves, limiting flow through the CFCs, and thereby increasing the CFC outlet temperature to potentially cause more flashing was evaluated in the analysis. Flashing at the outlet control valves has the potential to reduce flows up to 15% for a period of approximately 10 seconds. It has been determined that the vapor created at the 6-inch outlet control valves would be condensed in the 24-inch outlet piping immediately downstream of the valves, and there is no potential for these voids to remain in the system. The heated water created by the CFCs during the transient is flushed from the system within approximately 80 seconds of the start of the transient.

After 80 seconds from the start of the transient, no other flow restrictions would inhibit normal system operation. Given the brief period of these events, the damaging potential of cavitation erosion or vibration, producing resonance or fatigue, are negligible. Additionally, HBRSEP, Unit No. 2, has replaced the piping in this region with AL-6XN® "super-austenitic" stainless steel material, which is extremely resistant to corrosion and erosion damage.

d. Although a formal FMEA was not performed, the system alignments and components that would be active during the course of the combined LOOP/LOCA event were considered in the choice of inputs in the analysis.

For two-phase flow, the system starting alignment included flow paths to the turbine building, providing lower system pressures and lower flow rates through the CFCs. The lower flow rates to the CFC paths increase the potential for flashing and lower system heat removal, thus providing a worst-case for heat removal and two-phase flow.

The equipment potentially affecting the response to a LOOP/LOCA transient include the following:

- Service Water (SW) Pumps (4) and SW Booster (2) Pumps
- CFC Fans
- Valves

HBRSEP, Unit No. 2, has four SW pumps and two SW booster pumps. For single failure concerns, it is appropriate to consider all pumps running for the waterhammer analysis and the failure of a train for the two-phase flow issue. The loss of a train would prevent two SW pumps and a SW booster pump from restarting, lowering system flows, and reducing heat removal capabilities.

The failure of the CFC fans does not affect the waterhammer analysis because the fans are assumed to lose power at the start of the transient and not regain power until after pump restart. The loss of a fan after this point will have far less effect on heat transfer than the loss of a train of safeguards equipment (i.e., two SW pumps and one SW booster pump).

The potential failure of SW system valves does not affect the analysis because no active valves, other than check valves, are required to operate during the transient.

No other failure modes and effects are of consequence to the event.

e. Unsupported engineering judgment without reference or justification was not used.

NRC Request for Information:

Determine the uncertainty in the waterhammer and two-phase flow analyses, explain how the uncertainty was determined, and how it was accounted for in the analyses to assure conservative results for the H. B. Robinson plant.

Response:

Uncertainty in the waterhammer and two-phase flow analyses was addressed by using bounding values for all parameters that could vary over a range of conditions. In this manner, the uncertainty was bounded by the conservative results provided in the analyses. The uncertainty in the analysis method is conservatively bounded by the use of higher test data in the qualification of the system. Column closure test data from previous LOOP testing corroborates the analysis and provides assurance that the system is within design basis.

In the two-phase flow analysis, uncertainty in the CFC heat transfer model was assessed by benchmarking the heat transfer results against those obtained in an independent model. The CFC heat transfer model benchmarking shows that the results are within 1% of the independent model. Additionally, model sensitivity to boiling heat transfer, SW coastdown, fouling factor were tested and the outlet water temperature varied between 213°F and 222°F (±2%). For conservatism, the high outlet temperature conditions were used.

NRC Request for Information:

Confirm that the waterhammer and two-phase flow loading conditions do not exceed any design specifications or recommended service conditions for the piping system and components, including those stated by vendors; and confirm that the system will continue to perform its design-basis functions as assumed in the safety analysis report for the facility.

Response:

A primary goal of the two-phase flow analysis was to determine if the design basis heat removal capability of the CFCs was achieved, regardless of the possibility of flashing at the outlet control valves. This capability is demonstrated in the analysis performed for HBRSEP, Unit No. 2. The system will continue to perform its design-basis function as assumed in the safety analysis report for HRSEP, Unit No. 2, because the piping integrity is also shown through the waterhammer analysis.