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U S Nuclear Regulatory Commission
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PRAIRIE ISLAND NUCLEAR GENERATING PLANT
Docket Nos. 50-282 License Nos. DPR-42
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RESOLUTION OF GENERIC LETTER 96-06

By letter, dated April 24, 2002, the NRC requested that Prairie Island complete actions necessary to address Generic Letter (GL) 96-06 and submit the information referred to in Section 3.3 of the safety evaluation (SE). The following discussion specifically addresses the items in Section 3.3 of the SE attached to the April 24, 2002, letter.

Waterhammer

Provide certification 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.

Following receipt of the NRC letter and attached SER, the methods in EPRI TR-113594, Volumes 1 and 2, were applied to determine the potential waterhammer loads in the Cooling Water (CL) Piping associated with the containment fan coil units (FCUs). This evaluation was performed in a systematic manner consistent with the EPRI User's Manual (UM). This review/evaluation was performed as follows:

- The first step was to determine the limiting system configurations - paying particular attention to system alignments, single failures and component operation that could maximize the severity of the postulated waterhammer. Using Section 3 of the UM, the event time line, system or component allowable operating configurations and possible single active failures were evaluated. The time line was evaluated for the limiting scenarios to define system

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configuration(s) at the time of the postulated waterhammer event. Each of the components that could impact the severity of the event was identified with their corresponding operating times (after event initiation) initially assuming the component was operating normally. Then, allowable plant operating configurations were reviewed to determine the affect these configurations could have on the severity of the waterhammer. Furthermore, combined with any possible single active failures, the limiting system alignments were defined for determining the magnitude of the waterhammer event.

As an example, an allowed operating configuration is to be able to maintain the supply valve to a FCU closed during normal operation without entering a Technical Specification action statement (although, this would not be a normal alignment). This valve would then open automatically in response to a Safety Injection (SI) signal to restore CL flow to the FCU for accident mitigation. If the valve failed to open (single active failure), a column closure event could occur at the closed valve; which would essentially result in a pressure pulse twice that of a column closure event against a stagnant water column.

- Following identification of the limiting system alignments, the next step was to identify the location of the waterhammer event. This was performed through review of the piping configuration for each FCU using plant drawings and determining system response during the accident before flow is restored; i.e., due to system draining and steam formation. Based on this part of the evaluation, it was determined that the potential existed for a column closure event to be experienced in some of the FCU supply lines and that three of these supply lines were identified as being more limiting. Note that a waterhammer event in the supply line would be more limiting than in a return line due to higher refill velocity in the supply line due to the lower resistances.

- The next step was to determine the closure velocity for each of the limiting configurations. This was performed following the methodology in the sample problem in Section 7.4 of the UM. The hydraulic characteristics of the CL system are known from the steady state single-phase hydraulic model. To maximize the refill velocity, the maximum pump curve is used (maximum is defined by upper operability limit from the In-Service Testing pump curves). Based on system hydraulics and using the maximum pump curve, the refill velocity is determined at the point of predicted void closure.

- Based on the calculated closure velocity, the magnitude, the rise time and time duration of the waterhammer pressure pulse is determined. Due to different system configurations (based on time line, operating configurations and postulated single active failures), a total of seven different cases with a total of fourteen different sub-cases were considered for the three lines.

- These fourteen different sub-cases were then evaluated for the affect on the piping and pipe supports. Based on an initial evaluation, it was determined that the fourteen sub-cases could be reduced to nine sub-cases because some sub-cases bound (based on magnitude and rise time) other sub-cases. These nine cases were then modeled in the piping stress analysis model to determine the system response. The pulse was characterized as a trapezoid. The piping analyses have been preliminarily completed by a consultant and need to be reviewed by site personnel. The results indicate that all of the piping meets the acceptance criteria. Additional work is ongoing to reconcile a few pipe supports to demonstrate they also meet the criteria. This portion of the work (part of an earlier commitment) is expected to be complete by December 31, 2002.

Site probabilistic risk assessment (PRA) personnel reviewed the risk perspective that was provided in the EPRI letter dated February 1, 2002, and concluded that the plant specific risk considerations are consistent with this perspective. That is, the probability of a loss of coolant accident concurrent with a loss of offsite power (LOCA/LOOP) or main steam line break concurrent with a loss of offsite power (MSLB/LOOP) is consistent with the numbers in the subject EPRI letter. Furthermore, for the analyses discussed above, the uncushioned velocity and pressure are not more than 40 percent greater than the cushioned values. Therefore, for Prairie Island, the pipe failure probability used in the EPRI perspective remains bounding.

Two Phase Flow

Provide the 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).

As discussed in previous correspondence related to GL 96-06, there is the potential for two-phase flow downstream of the FCUs following a postulated large break LOCA. This is primarily due to the heat addition and the low pressure condition at the FCUs as a result of system hydraulics and the elevation of selected FCUs inside of containment.

In order to evaluate the effects of two phase flow conditions, a transient thermal hydraulic model (TREMELO) was developed that is capable of modeling the increased resistance due to the two phase flow condition. The TREMELO model was described in a Northern States Power (NSP) letter to the NRC, dated September 15, 1997. This was also discussed between NSP personnel and NRC Staff during a telephone conversation held on April 29, 1998; documented in NSP letter to the NRC, dated May 15, 1998. During this conversation, relative to the two phase flow analyses, the only NRC comment was that consideration needed to be given to the CL pump operating at the 93% pump curve. NRC Staff acknowledged that there was no other comments on the two phase flow calculation or methods.

Using the TREMELO model, the following inputs were used to evaluate the two phase flow conditions:

- A large break LOCA was assumed to occur. Several sensitivity analyses were performed with varying containment atmospheric temperatures of 270, 240 and 210°F. 270°F is used as this represents the peak containment temperature during the LOCA. The other temperature conditions were used to determine the transition from two phase to single phase in the return piping from the FCUs.

- A coincident LOOP was assumed to occur. This minimized the number of CL pumps that were operating. With the supply ring header split by the safeguards signal and the assumed single failure (loss of one train of safeguards equipment), only one pump operates on one header to provide the necessary cooling.

- The operating CL pump is assumed to be operating at minimum in-service testing pump curve; which in this case is the 93% curve. The hydraulic analysis indicates that with the pump operating at the 93% pump curve the header pressure would be sufficiently low to isolate the non-essential loads; which then increases the pressure and flow to the FCUs. Thus, the limiting case actually occurs if the header pressure is assumed to be just at the low-pressure setpoint. Therefore, the hydraulics are analyzed with the non-essential loads not isolated. To provide a bounding case, this is the configuration that is used to determine the flow and pressure to the FCUs.

- Sensitivity studies were performed to determine the limiting FCU fouling factor. Cases were run with assumed fouling factors of 0.000 (minimum fouling) and 0.002 (maximum fouling). With minimum fouling the heat transfer is maximized; which increases the potential for two phase flow conditions downstream of the FCUs. With a fouling factor of 0.002, the two phase flow analysis indicates that the flow is single phase downstream of the FCUs. With a fouling factor of 0.000 and peak containment temperature conditions, the two phase flow analysis indicates that two phase flow would exist downstream of the FCUs and the heat removal capability of the affected FCUs would be reduced.

- The Instrument Air System is assumed not to be available. This results in air operated valves in the CL system failing open, which, in turn, maximizes the flow demand on the system. This minimizes the flow and pressure available to the FCUs; which increases the potential for two-phase flow. The Instrument Air

Compressors are non-safety related; however, the air compressors are automatically loaded on the Emergency Diesel Generators (EDGs) and would be available during a LOOP. However, as the compressors are not safety related, credit is not taken for their operation during this scenario.

Containment integrity analyses were performed for both LOCA and MSLB using the CONTEMPT computer code. Using this model, the limiting containment temperature and pressure conditions were determined. These limiting conditions were based on maximizing the heat input into containment from the accident and minimizing the heat removal by assuming the limiting active single failure and minimum operation of the safeguards components. In this case, the limiting active single failure is the loss of one train of safeguards equipment; that is, one spray pump and two FCUs are not available. The heat removal assumed in this analysis for the operable train of FCUs was limited to be equivalent to that of a single FCU at design conditions.

Using these two computer models, the heat removal capability of the FCUs and the time that the two phase flow conditions could exist are determined. The results from these analyses demonstrate that the heat removal capability of the FCUs operating in a two phase flow condition would be greater than the minimum value used in the containment integrity analyses or a LOCA or a MSLB. The LOCA has the more severe containment temperature environment with respect to duration of elevated temperature; thus, the remaining discussion will focus on the LOCA. At the peak containment temperature conditions (approximately 270°F), the two phase flow could exist from the exit of the FCUs to the CL return header. This would only occur for a very brief period of time; for example, containment temperature is reduced to less than 250°F within the initial 1000 seconds. At the lower containment temperatures, the two-phase flow conditions are predicted to occur only in limited areas of the return piping. At a containment temperature of 210°F, all of the flow is predicted to be single phase. The containment integrity analysis for the LOCA predicts that containment temperature is reduced to less than 210°F within three hours. Thus, the period of time that two-phase flow could exist is less than three hours.

With regards to other effects due to two phase flow (e.g., erosion, cavitation effects, resonance), these are longer term effects and, due to the short duration of the two phase flow (under the bounding analysis), are not significant concerns. As discussed above, the two-phase flow condition would exist for less than three hours. These other affects are discussed in more detail below.

EPRI NP-3944, "Erosion/Corrosion in Nuclear Plant Steam Piping: Causes and Inspection Program Guidelines," and EPRI TR-106611, "Flow Accelerated Corrosion in Power Plants," provide methodologies to estimate the amount of accelerated pipe wall erosion due to two phase flow. One of these methods is Keller's Model. This model was developed based on studies of damage attributed to two phase flow conditions. This model only provides an approximate measure of the susceptibility to two phase flow induced erosion. Despite its limitations this model is a useful guideline for assessing the vulnerability to two phase flow induced erosion. To that end, this model is useful in determining if more sophisticated analysis is needed to evaluate the susceptibility to erosion in this specific instance.

Using Keller's Model with very conservative inputs (bounding values for temperature, steam wetness, and geometry) the results indicate that less than 0.0002 inches of wall thickness would be eroded in the three hour time period in the eight-inch return piping. The erosion would be less in the ten inch piping due to the lower velocity. The nominal wall thickness of the eight-inch piping is 0.322 inches and the minimum wall thickness of 0.053 inches. Therefore, this indicates that the pipe wall erosion during this three hour time period is not significant.

In addition, these piping sections are monitored as part of the pipe wall thinning inspection program at Prairie Island. This program provides assurance that adequate wall thickness exists in these systems during normal operation.

Potential pipe wall loss or resonance affects due to cavitation would also be minimal. This is primarily due to the short duration of the two phase flow condition and the cavitation mechanism, which could possibly be occurring. As discussed in NUREG/CR-6031, "Cavitation Guide for Control Valves," there are primarily two different mechanisms that can result in cavitation. These two mechanisms are cavitation due to pressure recovery or cavitation due to condensation back into the liquid stage primarily by cooling. During cavitation due to pressure recovery, the collapse of the vapor phase occurs violently and damage generally occurs in the collapse region. During cavitation due to condensation back into the liquid stage primarily by cooling, there is no violent collapse and generally no classical cavitation damage occurs. In this specific case, the cavitation mechanism is primarily condensation back into the liquid phase by cooling in lieu of pressure recovery, and cavitation damage would not be expected. Any transient waterhammer loads would bound consequences of steam formation, transport and accumulation in the steady state two-phase flow.

Consistent with the conclusions from the EPRI program, the limiting waterhammer in these lines would be due to column closure; which is discussed previously. The limiting waterhammer could occur in the supply lines resulting in higher magnitude pressure pulse with a shorter rise time than in the return lines. Thus, as described above, these are the waterhammer events that are specifically analyzed.

Summary

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 along with corrective actions that were taken. If corrective actions are planned but have not been completed, confirm that the affected systems remain operable and provide the schedule for completing any remaining corrective actions.

Waterhammer

Thus far, the results from the waterhammer analyses indicate that the piping and pipe supports would satisfy their acceptance criteria. As discussed above, there is still some work in progress to complete site review of stress analyses and to evaluate a few of the pipe supports. However, the results from these analyses are expected to also satisfy the acceptance criteria. It is expected that this work will be completed by December 31, 2002.

Two Phase Flow

The results and conclusions from the two-phase flow analyses are discussed above. During the past several years, a number of modifications have been made to the CL system to enhance the system response during an accident. These modifications were primarily aimed at reducing or eliminating potential flow diversion paths, thus, increasing the flow and pressure to the FCUs. These actions improve the performance capabilities of the FCUs in response to an accident. Some of these changes were proactively initiated prior to GL 96-06. The modifications include:

- Providing a back-up air source to the CL strainer back wash valves to prevent these valves from failing open on a loss of Instrument Air.
- Providing an automatic signal (SI with low header pressure) to the Motor Operated Valve to isolate the non-essential loads in the Turbine Building during accident mitigation.
- Provide a position stop on the CL System Temperature Control Valve for each Component Cooling Heat Exchanger to limit the valve open travel on a loss of Instrument Air.

All of these modifications are complete. No other corrective actions are planned to preclude the possibility for two phase flow occurring in the FCUs.

In this letter we have made no new Nuclear Regulatory Commission commitments. Please contact Jeff Kivi (651-388-1121) if you have any questions related to this letter.

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