NMC
Committed to Nuclear Excellence

Palisades Nuclear Plant
Operated by Nuclear Management Company, LLC

February 28, 2003

U S Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

PALISADES NUCLEAR PLANT
DOCKET 50-255
LICENSE No. DPR-20
RESOLUTION OF GENERIC LETTER 96-06 WATERHAMMER ISSUES
(TAC NO.M96844)

By letter dated April 24, 2002, the Nuclear Regulatory Commission (NRC) forwarded to the Nuclear Management Company, LLC (NMC) their acceptance of Electric Power Research Institute (EPRI) report TR-113594, "Resolution of Generic Letter [GL] 96-06 Waterhammer Issues," Volumes 1 and 2. The letter contained a request for NMC to complete actions to address GL 96-06 for the Palisades Plant and submit the information referred to in Section 3.3 of the attached NRC safety evaluation by July 30, 2002.

By letter dated July 24, 2002, NMC requested an extension to February 28, 2003, to provide the requested information. The requested information addresses waterhammer and two-phase flow issues. Attachment 1 to this letter contains the response to the waterhammer issue. NMC has reassessed post-accident containment air cooler performance due to potential two-phase flow conditions and determined that reasonable assurance exists that current safety analysis results remain bounding. Additional documentation to address all outstanding two-phase flow questions is necessary. As a result, NMC requests an extension to July 30, 2003, to complete this additional documentation.

A072

SUMMARY OF COMMITMENTS

NMC makes the following new commitment:

> All outstanding questions related to two-phase flow, as described in NRC letter dated April 24, 2002, will be addressed by July 30, 2003.

In addition to providing the requested information contained in the NRC Staff's letter of April 24, 2002, addressing waterhammer issues, NMC had also made the following commitment. No changes are made. The commitment is restated for completeness:

> Compliance with FSAR piping design criteria for the containment air cooler discharge piping, when subjected to realistically predicted waterhammers, will be verified prior to the completion of the refueling outage after the first full operating cycle following the NRC disposition of the industry initiative final report.

for

Douglas E. Cooper
Site Vice-President, Palisades

CC Regional Administrator, USNRC, Region III
Project Manager, USNRC, NRR
NRC Resident Inspector – Palisades

Attachment

ATTACHMENT 1

NUCLEAR MANAGEMENT COMPANY
PALISADES NUCLEAR PLANT
DOCKET 50-255

RESOLUTION OF GENERIC LETTER 96-06 WATERHAMMER ISSUES

7 Pages Follow

RESOLUTION OF GENERIC LETTER (GL) 96-06 WATERHAMMER ISSUES

REQUESTED ACTIONS TO ADDRESS GL 96-06

PALISADES NUCLEAR PLANT

DOCKET NUMBER 50-255

Requested Item

Licensees who choose to use the methodology in TR-113594, ["Resolution of Generic Letter 96-06 Waterhammer Issues,"] Volumes 1 and 2, for addressing the GL 96-06 waterhammer issue, may do so by supplementing their response to include:

- *Certification that the [Electric Power Research Institute] 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 the uncushioned velocity and pressure are more than 40 percent greater than the cushioned values, also certify that the pipe failure probability assumption remains bounding. Any questions that were asked previously by the staff with respect to the GL 96-06 waterhammer issue should be disregarded.*

Response

Nuclear Management Company, LLC (NMC) has implemented the EPRI methodology of TR-113594 as characterized in EPRI reports TR-1003098, "Technical Basis Document," and TR-1006456, "Users Manual," and the Palisades plant-specific risk considerations, as reviewed by the site safety analysis personnel, are consistent with the EPRI letter dated February 1, 2002 and Section 3.0 of TR-1003098. The methodology applied for the waterhammer development is discussed below.

The cushioned pressure and uncushioned pressure of the waterhammer pulse are equal, as discussed below, due to the size of the calculated void in the waterhammer pulse development. The uncushioned pressure is used in the piping analysis. The impact velocity and the normal service water (SW) velocities are the same. Therefore, the 40 percent criterion is met. Therefore, for Palisades, the failure probability used in the EPRI risk perspective remains bounding.

WATERHAMMER

Hydraulic Considerations

NMC has investigated the potential impact of waterhammers as described in Generic Letter 96-06 employing the methodology of EPRI Report TR-113594 for the Palisades Plant. More specifically, the guidance of EPRI Reports TR-1003098 and TR-1006456 has been used. Engineering analyses have been performed to characterize a bounding waterhammer event, by magnitude and service water system (SWS) location, and to use the waterhammer pulse as input to piping system models in order to determine the effect on the structural integrity of the system components.

The approach to the waterhammer load development addresses the determination of applicable site events, appropriate single failures and the bounding SWS lineups. Palisades SWS has an open loop design with relatively little elevation change between the high point, at the containment penetrations (612 feet), and the discharge to the makeup basin in the intake structure (approximately 583 feet). This elevation differential is less than the manometric water column of 33.9 feet and indicates small pumping head losses from the pumps to the containment air coolers (CACs). This lack of elevation differential also implies that water column separation due to draining of the SW return piping is not expected to occur under a Loss Of Offsite Power (LOOP) event only.

The EPRI research shows that the condensate-induced water hammer will be a less limiting event than the column closure waterhammer (CCWH) under certain circumstances relating to flow rates, pressures and aeration. These circumstances exist in the SWS at Palisades. The system steam pressure was concluded to be less than 20 psig during the time that a condensate-induced waterhammer (CIWH) could be initiated, since the system has not been degassed and a Froude Number calculation arrived at flow velocity that yielded a value above 1.0. Therefore, the analytical approach directed to characterizing a waterhammer focused on two initial operating assumptions. These assumptions address maximizing the refill rate after the initiating event of a LOOP coincident with a Loss Of Coolant Accident (LOCA). This maximization ensures that the CCWH effect will be bounded. The first assumption is that all three SW pumps are operating for refill. The second assumption is that, despite the LOOP, instrument air is available to preclude flow diversion away from the CACs, which is the area where the waterhammer could occur.

The initiating event for the purposes of this waterhammer evaluation is a combined LOOP and LOCA, or a Main Steam Line Break (MSLB) with offsite power available and its associated single failure. For a LOOP and LOCA event, which is limiting, a short-term flow loss, elevated containment temperature and a small (approximately 7 psia) backpressure on a CAC could occur. A temperature of less than 176 degrees F would generate flashing in the CACs and void formation under these conditions. This would form the initiating conditions for a water hammer event.

An investigation of potential single active failures was pursued to define a minimum number of configurations to subject to detailed analysis. The primary criterion for evaluating the failures was to provide a system lineup that maximizes SW flow rate. The three check valves in the SW pump discharge lines to the CACs were considered in order to determine if they could be expected to fail and drain back through the SW supply piping. Operations and testing experience has not indicated failures with these valves. There are other smaller drainage paths that exist on the supply to the CACs such as the diesel generator coolers, control room heating ventilation and air conditioning (HVAC), air compressors engineered safeguards room coolers etc. Control Valve CV-1359 that, when open, diverts SW supply from the CACs to the non-critical SWS is assumed closed to maximize flow to the CACs as it would be expected to be based upon a safety injection signal. Varying failures of the eight CAC inlet and discharge control valves were considered with their differing effects on flow distribution. Various scenarios involving the outlet valves of the component cooling water heat exchangers were considered for their impact on the CAC flows. Little effect existed with any of these failures. Therefore, supply side waterhammer is not postulated from the perspective of maximizing refill flow.

Another reason why the waterhammer is taken to occur on the return side considers the potential event scenario and the configuration of the supply and return piping. The supply piping drain path provides significantly more flow resistance than the return side given the length of pipe, in-line piping components (check valves, reducers etc.) and heat exchangers. This resistance, along with the generally higher piping elevation and initial flow inertia, indicates a preferential flow of water to the return side after the pump stops. The SWS piping is insulated, while the CACs are not. Therefore, any steaming that might occur after the pump stops would likely start in the CACs. The steam bubble would grow from the CACs to the supply and return side piping preferentially in inverse proportion to their respective flow resistances. It is possible to have steam in the CACs and both the supply and return piping shortly after the pump stops.

Upon SW pump startup, the SW flow will push a steam/water interface toward the CACs and the steam in the CACs toward the return side. As flow progresses, the supply piping will tend to cool and make the CACs tend to a water-solid condition. Heat removal from the containment would become efficient and keep the temperature in the supply piping and CACs relatively high, thus precluding steam bubble collapse in the supply piping and CACs. The steam in the supply piping and CACs would be pushed into the discharge piping where it could be discharged or where it could be compressed, condensed and a waterhammer could occur at a water-water interface.

Given the focus on the CCWH, the waterhammer location site determination considered the outlet of the CACs. During the LOOP/LOCA or MSLB, the outlet side of the CACs would lose pressure, voids will develop and column separation would occur in the 16-inch risers on either side of the containment penetration on the discharge of the CACs.

Five specific SWS configurations, reflective of single failures, were selected for detailed evaluation. These configurations addressed different arrangements of CAC isolation. Two system lineups were then selected for detailed analysis. The system lineups reflect the configuration of the SW inlet valve (either open or closed) on the non-safety CAC, VHX-4. The system boundary conditions were as follows:

1. Three service water pumps in service.
2. CV-1359 to the non-critical service water closed.
3. CAC VHX-1, 2 and 3 outlet and temperature control valves open.
4. CAC VHX-4 outlet valve open and temperature control valve closed.
5. CAC VHX-4 inlet valve open or closed –variable.
6. All service water isolation valves open.
7. Diesel generator flow paths open.
8. Control room HVAC paths open.
9. Engineered safeguards room cooler flow paths open.
10. Water-cooled instrument air compressor flow paths open.
11. Component cooling water heat exchangers high capacity valves closed.
12. Component cooling water heat exchanger temperature control valves open with low (500 gpm) flow controls in place.
13. Service water basin level set to 583-foot elevation – a relatively high level.
14. Makeup basin water level set to a high level of 586.7 feet.
15. Pressure at the proposed water hammer location at a vacuum.

The SW flows from these operating alignments were reviewed and the maximum flow of 9140 gpm was used. This corresponds to the system lineup where all CAC inlet valves are open.

The refill column and void lengths were calculated with the assistance of EPRI Report TR-1006456 to determine pressure pulse duration for incorporation into the hydraulic analysis. The water slug impact mass was calculated with transmission coefficients developed from system geometry. The void length was determined to be 132 feet with a water column length of 55 feet. These lengths resulted in neglecting the "cushioning" effect where void compression could absorb water slug impact energy and reduce the pressure loads on the piping and piping components. The bounding flow was determined, from EPRI TR-1006456 charts, to be the steady state flow as determined from pump characteristics and system configuration. Therefore, the uncushioned velocity and pressure do not exceed 40% more than the cushioned velocity and pressure.

The result of the evaluation was a waterhammer pressure pulse in the 16-inch SW piping with a 435 psi magnitude, a rise time of 14 milliseconds and a duration of 107 milliseconds. That pulse output was employed as input into six piping model configurations for the SWS.

Piping System Analysis

Six piping models that were developed for existing Final Safety Analysis Report (FSAR) design load combinations were investigated for the impact of water hammer loads. Five of these models were for inside CAC return piping. The sixth model was for the outside containment piping including the component cooling water heat exchanger and engineered safeguards room cooler connections. As suggested in EPRI Report TR-1006456, the trapezoid-shaped pulse was employed at the speed of sound (4021 feet/second). The pulse was placed at locations of momentum changes using the appropriate pipe lengths, areas and transmission factors associated with the 435 psi waterhammer pressure.

The load combination employed in the analysis was the faulted load combination with the faulted seismic load case replaced by the water hammer load case. Pipe stress results in three of the models indicated that stresses met the FSAR allowables for faulted loads. In three other models the resulting stresses exceeded FSAR allowables. The latter models contained stub-ins with stress intensification factors of as high as 9.0. Such stresses occurred at a small number of pipe joints, typically stub-in branch connections.

The support calculations and equipment nozzle loads for all these models were reviewed for the new load combination. As could be expected, quantitative allowables for operability of equipment nozzles were not available as they are for typical pipe supports.

The support loads associated with the waterhammer load combination were generally higher than the same support loads for the current design. The vast majority of the fabricated supports could accommodate the larger loads via the margin in the original design. However, a small number of supports were loaded beyond design allowables to the extent that they might be postulated to fail. The loads on equipment nozzles were dispositioned by engineering judgment based upon experience with vendor criteria (as further discussed below). Some of the nozzle load components on the CAC increased beyond current design. Typically, some of the six loads on a given CAC containment air cooler nozzle increased while the others decreased. The outlet connections of the component cooling water heat exchangers were loaded beyond their current design loads for all nozzle load components.

In EPRI Reports TR-1006227,"Investigation of Stress Intensification Factors and Directionality of Loading for Branch Connections," TR-110996 ,"Stress Intensification Factors and Flexibility Factors for Unreinforced Branch Connections," and TR-110755 "Stress Intensification Factors and Flexibility Factors for Pad Reinforced Branch

Connections," Wais and Rodabaugh provide insight on the magnitudes and directionality of the stress intensification factors for unreinforced branch connections. The in-plane stresses associated with the water hammer loads are considered to be significantly overstated by the fatigue-based, out-of-plane stress intensification factors that ANSI/ASME B 31.1 employs. There is little experience that indicates that a pipe tear or rupture would occur based upon the pipe movements that have been calculated or the pipe stresses implied by the analysis that has been completed. Noticeable pipe distortion would be expected and significant amounts of energy would be absorbed in plastic deformation. However, no loss of structural integrity of the piping itself would occur. The piping itself is therefore considered operable.

The loads on the CAC nozzles have not been calculated to increase beyond the vendor design allowables to the extent that operability would be questioned. The loads on the component cooling water heat exchangers have significantly increased. However, the robust design of the component cooling water cooler heat exchanger enables those nozzles to be considered to be operable. The containment penetration loads from the water hammer are acceptable. Some of the supports in the affected piping configurations may be expected to fail. Nonetheless, the number of such supports is few enough and their energy absorbing capacity large enough that the pipe stress results that have been determined would continue to reflect the elastically calculated response. Therefore, the piping system as a whole is considered operable.

TWO-PHASE FLOW – WATER HAMMER CONSIDERATION

NMC has not conducted a detailed two-phase flow evaluation of the CACs for the water hammer evaluation. The fact that the CACs are not insulated and that the SW system pressure is reduced after a load loss indicates that little heat transfer is required to result in some boiling in the CACs. This would occur only for the very short period of time before pump flow would be established. Effects such as erosion, fatigue or vibration would not be experienced. The primary effect of such boiling would be to increase local pressure and to push water out the CAC outlet and create an environment of voids that would make the system vulnerable to the CCWH that has been evaluated. EPRI technical reports indicate that a system where significant CCWH loads can be developed reflects a system where CIWH loads will not be bounding. This condition is applicable to the Palisades SWS.

The logic for the CIWH scenario applies to the two-phase flow concern also. There is no low-flow environment that appears that would enhance the impact of either two-phase flow or the CIWH. The two-phase flow is not amenable to definitive load calculation. However, any results that would be obtained would yield loads that are bounded by the CCWH. Many component failures would have to occur which could make the two-phase flow scenario effective in loading the SW return system. As indicated in the development of the CCWH, the most limiting scenario approximates the situation where system equipment operates as designed – a much more likely scenario for generating bounding loads with a higher probability of occurrence.

Requested Item

- *A brief summary of the results and conclusions that were reached with respect to the waterhammer 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.*

Response

The result of the waterhammer piping system analysis shows a small number of local stresses greater than the design limits for the waterhammer load combination. The piping support loads have been screened with respect to existing analyses. A number of the supports do not meet their design limits for the waterhammer load combination.

The conclusion is that the piping system remains operable. However, pipe support additions are anticipated to ensure that the system meets its FSAR design requirements.

Requested Item

- *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).*

Response

NMC has reassessed post-accident containment air cooler performance due to potential two-phase flow conditions and determined that reasonable assurance exists that current safety analysis results remain bounding. Additional documentation to address all outstanding two-phase flow questions is necessary. As a result, NMC will complete this additional documentation and provide this response by July 30, 2003.