WOLF CREEK
NUCLEAR OPERATING CORPORATION

Otto L. Maynard
President and Chief Executive Officer

SEP 28 1998

WM 98-0100

U. S. Nuclear Regulatory Commission
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Washington, D. C. 20555

Reference:
1) NRC Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996
2) WCNOC Letter ET 97-0004, dated January 29, 1997, from R. Muench, WCNOC, to NRC
3) NRC Request for Additional Information Related To GL 96-06, dated July 21, 1998

Subject: Docket No. 50-482: Response to Request For Additional Information Related to Generic Letter 96-06 (TAC NO. M96887)

Gentlemen:

In Reference 1, the Nuclear Regulatory Commission (NRC) describes concerns with equipment operability and containment integrity during design-basis accident conditions. Reference 1 requested Licensees to provide a response within 120 days of the date of the reference. Reference 2 provided the requested 120-day response for Wolf Creek Nuclear Operating Corporation (WCNOC).

In Reference 3, the NRC staff requested additional information to complete their review of Reference 2. The additional information requested concerns the assessment of the waterhammer and two-phase flow issues for the Wolf Creek Generating Station. The requested information is provided in Attachment I to this letter. Attachment II identifies those actions committed to by Wolf Creek Nuclear Operating Corporation (WCNOC) in this document.

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Drawing in Files

If you have any questions regarding this response, please contact me at (316) 364-8831, extension 4000, or Mr. Michael J. Angus, at extension 4077.

Very truly yours,

Otto L. Maynard

OLM/rlr

Attachments

Enclosures:
1) ALTRAN Corporation Technical Report No. 96227-TR-01, Revision 3, March, 1998, "Containment Fan Cooler Response to a Simultaneous LOCA & LOOP Event"
2) ALTRAN Corporation Technical Report No. 96227-TR-03, Revision 0, February, 1998, "Structural Dynamic Analysis of Containment Cooling System Reactor Building Train "A" and Train "B" Supply and Return Piping"
3) Drawing G.L. 96-06-RAI-1, "Simplified Schematic of ESW System," (3 sheets)

cc: W. D. Johnson (NRC), w/a, w/e
E. W. Merschoff (NRC), w/a, w/e
B. A. Smalldridge (NRC), w/a, w/e
K. M. Thomas (NRC), w/a, w/e

STATE OF KANSAS)
) SS
COUNTY OF COFFEY)

Otto L. Maynard, of lawful age, being first duly sworn upon oath says that he is President and Chief Executive Officer of Wolf Creek Nuclear Operating Corporation; that he has read the foregoing document and knows the content thereof; that he has executed that same for and on behalf of said Corporation with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By [signature]
Otto L. Maynard
President and
Chief Executive Officer

SUBSCRIBED and sworn to before me this 28th day of September, 1998.

LINDA DELONG-OHMIE
Notary Public - State of Kansas
My Appt. Expires August 31, 2002

[signature: Linda DeLong-Ohmie]
Notary Public

Expiration Date August 31, 2002

Response to GL 96-06
Request for Additional Information

The NRC's Request for Additional Information lists ten items. The ten items are reprinted below, along with Wolf Creek Nuclear Operating Corporation's (WCNOC's) response to each item. Additional details for WCNOC's responses are provided in the enclosed hydraulic analysis (96227-TR-01, rev. 3) and the structural analysis (96227-TR-03, rev. 0) performed for the waterhammer and two phase flow issues identified in Generic Letter 96-06. The appendices/attachments for the analyses are not included due to their bulk, but are available at the plant site for review.

General Information:

The cooling water system for the Containment Coolers at Wolf Creek ha experienced water column closure waterhammer during integrated testing. I 1996, the system was modified to withstand the effects of the waterhammer. This is discussed in reference 4. In addition, the pressure pulse of the waterhammer was monitored during testing to validate the calculation of the pressure pulse.

Column closure waterhammer pressure pulse magnitude is driven by the velocity of the two advancing water columns. The velocity of the water columns is driven by the pump design, the geometry of the piping system and the void size. When the void size is large enough that the pump design and the piping geometry limits the velocity (e.g., the pump achieves maximum flow before the columns close), larger void sizes no longer affect the pulse magnitude. At Wolf Creek, the calculated void size is large enough that it no longer controls the velocity of the advancing water columns.

Condensation induced waterhammer has been determined to be possible at Wolf Creek during the drain-down phase of a LOCA and LOOP event. The condensation induced waterhammer pressure pulse magnitude is driven by the pressure of the steam. A rapid drain down of the piping system during the phase when the pumps are stopped creates a lower pressure in the coolers. This is because pressure buildup due to the heat input to the coolers is overcome by the rapidly expanding steam void. A slow drain down of the piping system creates a higher steam pressure, and therefore, a higher potential waterhammer pressure pulse.

During the analysis of the most limiting condensation induced waterhammer event, it was determined that a LOCA produces more severe waterhammer events in the cooling water system than a MSLB. A discussion of this determination is in section 4.2 of the attached hydraulic analysis report. In summary, the LOCA is more severe due to several heat transfer considerations, including the immediate condensation of the saturated steam on the tubes during a LOCA versus the cooling of the superheated steam during a MSLB. Also considered was the higher partial pressure of the steam in the Containment during a LOCA versus a MSLB.

During normal design operation, the cooling water system at Wolf Creek has a margin to boiling of at least 10PSIA at all locations. It has been calculated that the system will be at design conditions within 65.2 seconds following a LOCA plus LOOP event. The safety analyses at Wolf Creek do not take credit for containment coolers removing heat from the containment until 70 seconds following an event. Therefore, two phase flow is not a concern at Wolf Creek. (See the attached hydraulic analysis report, section 5.7, for details.).

RAI Item 1: 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. With regard to the two-phase flow analysis, describe the minimum margin to boiling that will exist throughout the ESWS for the applicable accident scenarios. Confirm that all applicable scenarios have been considered such that the measures that have been taken are adequate to address the waterhammer and two-phase flow concerns.

Note: In addition to heat transfer effects, two-phase flow conditions involve structural and system integrity effects that need to be considered. The following effects, for example, must be addressed for two-phase flow conditions:

- 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 conditions.

WCNOC Response

A. Condensation induced and column closure waterhammers were both evaluated as part of this analysis. These two waterhammer phenomena will occur at different times during the transient. Condensation induced waterhammers will occur during system drain down as partially filled horizontal pipes are exposed to steam. Column closure waterhammers will occur after pumps restart and system voids are closed. Condensation induced waterhammers will not occur during system refill since the refill velocities are sufficient to keep the horizontal pipe runs full of water. The loads resulting from condensation induced waterhammer and column closure waterhammer events were used to evaluate the structural adequacy of the containment air cooler (CAC) piping system. This included evaluation of the CAC piping, nozzles, internals, and supports. (See the attached Structural Analysis for details)

B. In order to evaluate the worst case scenario, various system lineups and component failures were evaluated against the limiting parameters for waterhammers and two-phase flow conditions. The occurrence of a Loss of Offsite Power (LOOP) only, with no Loss of Cooling Accident (LOCA), was determined by analysis to result in a more significant column closure waterhammer than a LOOP with LOCA waterhammer. In this scenario, the following factors were conservatively not considered, but would contribute to make the LOCA with LOOP waterhammer even less severe:

- Air cushioning, due to air coming out of solution.
- A bubbly, foamy water front (causing cushioning) upon closure of the column, which could be created by the heat of the LOCA.

The most conservative column closure waterhammer magnitude corresponds to a large void size. The following assumptions were made for the column closure waterhammer calculation. These assumptions assured that the void size was large enough to not be the controlling factor.

- The check valve from the Service Water supply was assumed to fail open during the draining transient to maximize the void size. The valve was assumed closed during the refill to maximize velocity.

- The Circulating Water/Service Water return path was assumed to be fully open during the draining transient to maximize the void size. The path was assumed isolated during refill to maximize velocity.

C. A LOCA with a concurrent LOOP was determined to potentially result in condensation induced waterhammers in long horizontal lines that are draining during the transient. The pressure in the containment air coolers (CAC) is a driving factor in determining the magnitude of the condensation induced waterhammer. CAC pressure was conservatively assumed to follow the saturation pressure corresponding to the containment temperature during the draining of the CAC. This produced the highest possible pressures and conservatively larger waterhammers.

The most conservative condensation induced waterhammer magnitude corresponds to a slow drainage rate. The following assumptions were made for the condensation induced waterhammer calculation:

- No reverse flow was considered through the normal Service Water supply path.

- Although several valves should be stroking closed during the transient, the Circulating Water/Service Water flow path was assumed to be isolated.

D. Erosion, cavitation, and fatigue/vibration issues during the event are not a concern since two-phase flow conditions will not occur upstream or downstream of the containment air coolers following pump restart. Once the system is refilled, the fluid at the limiting orifice locations will remain below saturation temperature and will not flash to steam. System refill is calculated to occur at 65.2 seconds following the event. The safety analyses allow 70 seconds to refill before taking credit for heat removal. Since two phase flow will not occur at Wolf Creek, there are no effects of void fraction on the system flow balance nor on the heat transfer rates.

RAI Item 2: If a methodology other than that discussed in NUREG/CR-5220, "Diagnosis of Condensation-Induced Waterhammer," was used in evaluating the effects of waterhammer, describe this alternate methodology in detail. Also, explain why this methodology is applicable and gives conservative results (typically accomplished through rigorous plant-specific modeling, testing, and analysis).

WCNOC Response

The methodology used to predict the type and magnitude of waterhammer pressure pulses was consistent with NUREG/CR-5220, using the assumptions and input parameters described in the response to Item 4 below. Plant specific modeling was performed to determine fan cooler behavior, void sizes, driving pressures, and impact velocities. Supplemental guidance from EPRI NP-6766 (Reference 3) was used for pump restart column closure waterhammer predictions and from NUREG/CR-6519 (Reference 2).

Although NUREG/CR-5220 does not specifically address the process that would initiate the draining type condensation induced waterhammer considered during the loss of power, the evaluation methodologies of NUREG/CR-5220 were applied to conservatively predict condensation induced waterhammer magnitudes prior to restart of the pumps.

RAI Item 3: Identify any computer codes that were used in the waterhammer and two-phase flow analyses and describe the methods used to validate and benchmark the codes for the specific application and loading conditions involved.

WCNOC Response

For the waterhammer portion of the analysis, hand calculations and spreadsheets were used to evaluate the piping drain down following the loss of pump pressure and the potential for waterhammer and two-phase flow occurrences.

Several commercial software packages were used to analyze stresses in the affected components. ADLPIPE, a piping software package, was used to analyze piping stress. PD STRUDL, a structural analysis software package, was used to analyze piping supports for the waterhammer loading. ALTRALUG is a vendor-developed software tool that was used to analyze integral welded lug attachments to the piping. All waterhammer loads were evaluated against the design criteria contained in the Wolf Creek Updated Safety Analysis Report (USAR). All software used in this evaluation is approved for use in accordance with the vendor's QA program.

RAI Item 4: Describe and justify all assumptions and input parameters (including those used in any computer codes) that were used in the waterhammer and two-phase flow analyses, and provide justification for omitting any effects that may be relevant to the analyses (e.g., fluid structure interaction, flow induced vibration, erosion). Confirm that these assumptions and input parameters are consistent with the existing design and licensing basis of the plant. Any exceptions should be explained and justified.

WCNOC Response

Assumptions used for the waterhammer analysis included the following:

A. During the period when power is lost, steam is formed at the fan coolers due to boiling in the tubes. This steam pressure was used as the driving pressure for condensation induced waterhammers during the draining transient, and assumptions to increase steam pressure will conservatively increase waterhammer magnitude. The steam pressure in the fan coolers was assumed to be equal to the theoretical maximum of the saturation pressure corresponding to the containment temperature during the draining of the fan cooler. This assumption is conservative because it includes negligible resistance to heat transfer across the fan cooler, producing saturation conditions in the fan cooler which follow the containment temperature during the LOCA event until the fan cooler is drained. The steam pressure was only allowed to decrease isentropically as the volume increased. The steam pressure would be reduced if condensation on the piping and water interfaces were credited during drain-down of the system. Condensation was not credited. Based on the conservative heat transfer and condensation assumptions, the magnitude of the calculated pressure pulse is conservative.

B. Fluid structural interaction was conservatively not credited as a method for reducing either column closure or condensation induced waterhammer pulse magnitude as it travels through the system. Additionally, the fluid structural interaction phenomenon was reviewed relative to the possibility of amplifying piping loads. It was determined that experimental fluid structural interaction results which showed potential amplification of long duration pressure pulses in minimally restrained piping (Ref. 5) were not applicable to the piping at Wolf Creek. Waterhammer pressure pulses are short duration and the containment cooler piping system at Wolf Creek is restrained to withstand significant seismic events.

C. Cushioning, as a result of air in the collapsing steam environment, was conservatively not credited in calculating the magnitude of the waterhammer pressure pulse.

D. A fluid sonic velocity of 2300 feet per second was used to calculate the condensation induced waterhammer pressures during the draining stage of the transient and the column closure waterhammer. This sonic velocity is approximately half the sonic velocity calculated for water with no bubbles or entrained non-condensables. This assumption is based on NUREG/CR-5220, Reference 1, which describes appropriate reductions to the classical equations for determining waterhammer loads by stating, "While an upper bound to the resulting loads is easily estimated by the methods described above, actual loads are usually lower by a factor from 2 to 10." Several reasons are provided for this load reduction including non-condensable gas, compliance of piping and hangers, and others. A sonic velocity adjustment was used to account for this reduction. NUREG/CR-6519, Reference 2, also recommends using half the sonic velocity value typically determined for water with no air or non-condensables when calculating the magnitude of the waterhammer pressure pulse.

This assumption is justified considering the fluid. The water in the open loop system at Wolf Creek is drawn from a man-made lake and, like most untreated water, has a high air (non-condensable) content. Some of these non-condensables are released during the boiling process in the fan coolers and will be in the steam void during waterhammer.

E. A steam to water volume ratio of 0.35 in the horizontal pipes during the draining was used in the condensation induced waterhammer calculations. This ratio is conservative because condensation on the water/steam interface and the resultant pressure moderation was not modeled. As the steam enters the horizontal pipes, it is expected to quickly reach a point where its condensation rate can exceed the generation rate. At this point, the steam pressure will be moderated (i.e. remain relatively constant). There are a number of horizontal piping segments where this will occur prior to restart of the pumps. This will significantly reduce the pressure below the maximum used in the calculation and will reduce the probability of reaching a volume ratio of 0.35 in the last horizontal header. The maximum steam pressure that occurs during drainage of any horizontal pipe that is susceptible to condensation induced waterhammer was conservatively used.

Additionally, the 0.35 volume ratio is justified due to the limited potential to develop waves and trap steam bubbles above a volume ratio of 0.35. The horizontal pipes of concern are draining from the top down and will develop a warm water layer at the water/steam interface. Approximately 40°F subcooling is required in order to initiate a condensation-induced waterhammer (Reference 2). As the water surface heats, the amount of subcooling will decrease substantially. As the void grows, the steam velocity is reduced because its flow area is increased. The condensing rate is reduced as the water temperature increases. The net effect is to reduce the potential for waves due to lower steam velocities, and the voids being trapped and collapsing at volume ratios above 0.35.

F. During LOCA sequencing and other testing at Wolf Creek, column closure waterhammers have occurred. Pressures that occurred during these tests were measured, post-test inspections were performed, and the piping with the modified supports was analytically evaluated and shown to be acceptable. This test experience provides less uncertainty when evaluating LOOP with LOCA waterhammer consequences than performing time history load calculations or fluid/structure interaction calculations alone. NUREG/CR-5220, Reference 1, provides guidance for use of inspection results when evaluating waterhammers. The magnitude and location of the tested waterhammers corroborates the analyzed conditions.

Assumptions for the Two Phase Flow Evaluation included:

A. The temperature of the fluid drained from the containment air coolers (CACs) into the CAC piping was conservatively increased to account for any uncertainty in fluid mixing.

B. On the CAC supply side piping, the calculated temperature of the mixed fluid was increased by 10°F.

C. On the discharge side piping, the temperature in the piping was assumed to be the exit temperature from the CAC, and no credit was taken for mixing.

These conservative estimates for temperature decrease the calculated margin to boiling/flashing. A flashing condition was still calculated to not occur in the ESW system at normal design conditions as a result of a combined LOOP/LOCA event.

RAI Item 5: Explain and justify all uses of "engineering judgement" that were credited in the waterhammer and two-phase flow analyses.

WCNOC Response

Application of "engineering judgement" that was of significance to the evaluation was identified as assumptions and discussed in response to Item 4 above.

RAI Item 6: Discuss specific system operating parameters and other operating restrictions that must be maintained to assure that the waterhammer and two-phase flow analyses remain valid, and explain why it would not be appropriate to establish Technical Specification requirements to acknowledge the importance of these parameters and operating restrictions. Also, describe and justify use of any non-safety related instrumentation and controls for maintaining these parameters.

WCNOC Response

Wolf Creek first recognized the possibility of waterhammer occurring in the containment air cooler cooling water system in 1994, when, during a test of the LOCA sequencer, a waterhammer occurred in this system. Analyses were performed and the system was modified under our plant modification process to enhance the capability of the piping supports to withstand the effects of the waterhammer. This modification was installed under our plant modification number 05818.

As a result of the concerns described in Generic Letter 96-06, a second analysis was performed on the system to verify the initial analysis and to expand the analysis to include the consideration of LOCA simultaneous with a LOOP. The results of the new analysis show that the stresses in the piping will remain below the ASME Boiler and Pressure Vessel Code stress allowables for faulted conditions. It also shows that the cooler coils, cooler supports and piping supports can withstand the effects of the postulated waterhammer events.

As stated in our response to Items 1 and 4 above, WCGS design precludes the initiation of two phase flow in the containment air cooler cooling water system.

Since the WCGS containment air cooler cooling water system can withstand the effects of all the postulated waterhammer events, and two phase flow does not occur during refill nor at steady state conditions, there are no specific system parameters or restrictions that must be maintained to assure the analyses remain valid.

RAI Item 7: Confirm that the waterhammer and two-phase flow 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.

WCNOC Response

Although a formal FMEA was not performed, a review of components that would be active during the course of the combined LOOP/LOCA event was performed in order to develop the "worst case" scenario. Of all the components, the potentially active equipment include the following:

- Pumps
- Fans
- Valves

Each ESW pump is individually powered by a single diesel generator, and the cooler trains are independent of each other. Failure or delayed operation of either pump or generator could increase the duration of the transient and therefore the steam void size. However, the increased void size will not affect column closure waterhammer magnitudes since the void size calculated is large enough to no longer be controlling. Column closure waterhammers are limited by the pump performance and piping geometry. Condensation induced waterhammers for either train are conservatively calculated and increasing void size is bound by the margin within the existing calculation.

The analysis is unaffected by the fans forcing air over the cooling coils. The heat transfer is conservatively maximized to allow for the cooler internal pressure to follow the containment pressure at the containment temperature.

Several valves change position during the event. The effects of the failure of these valves to change position are addressed below. Conservative assumptions were made for valve position during the transient for check valves and isolating valves (see also Item 1). For valves corresponding to the valve numbers, refer to the simplified drawing supplied as a response to Item 9 of this RAI.

1. Valves 49 and 50 are throttled valves. They are throttled by an electrical stop for the emergency condition. Operations has the capability to throttle them further during normal operations, but on a safety injection signal (SIS), they will go to the emergency throttle position. There is a chance that the electrical stop could fail and the valves go to the full open position. This would increase the void size. However, the column closure waterhammer magnitude will be unaffected since the velocity of void closure is not limited by void size.

2. Valves 51 and 52 could be throttled during normal operations, but normally are not since a change was made to the analysis of temperatures. These valves go full open on a SIS and could fail to do so. However, the method of determining system resistance and velocities were sufficiently conservative to bound the minor change in resistance, relative to the overall system resistance, due to the throttling of these valves.

3. Valves 59 and 60 are normally open but could be throttled during normal operations. However, they normally are not due to the same analysis of temperatures which was performed for valves 51 and 52. These valves go full closed on a SIS. If they fail to close completely, the result could be a robbing of flow from the inlet of the containment fan coolers, and an increase of back pressure on the discharge of the coolers. This could reduce containment heat removal but will not affect waterhammer magnitudes. The minor effect of reduced containment heat removal is bound by the single failure of one ESW pump to start.

4. Valves 37 and 38 are normally throttled and go full open on an SIS. If they fail to go full open, there will be increased backpressure on the discharge from the containment fan coolers. This will reduce drain down rates by approximately 2% and increase waterhammer magnitudes by a negligible amount, which is covered by the margin within the calculation.

No other failure modes and effects were considered important to the event.

RAI Item 8 Describe the uncertainties that exist in the waterhammer and two-phase flow analyses, including uncertainties and shortcomings associated with the use of any computer codes, and explain how these uncertainties were accounted for in the analyses to assure conservative results.

WCNOC Response

Uncertainty in the waterhammer and two-phase flow analyses were addressed by using conservative assumptions in the analyses. Column closure waterhammer data from previous SI/LOOP testing corroborates the analysis and provides assurance that the system is sufficiently robust to appropriately function under the waterhammer conditions analyzed.

RAI Item 9: Provide a simplified diagram of the system, showing major components, active components, relative elevations, lengths of piping runs, and the location of any orifices and flow restrictions.

WCNOC Response

A simplified diagram of the cooling water system for the containment coolers, comprised of three sheets, is enclosed.

RAI Item 10: Describe in detail any plant modifications or procedure changes that have been made or are planned to be made to resolve the waterhammer and two-phase flow issues, including completion schedules.

WCNOC Response

There are no plant modifications which have been made or are planned to be made to resolve the waterhammer and two-phase flow issues at Wolf Creek as a result of the information described in Generic Letter 96-06.

References

1. NUREG/CR-5220, "Diagnosis of Condensation Induced Waterhammer", 1988.

2. NUREG/CR-6519, "Screening Reactor Steam/Water Piping Systems for Water Hammer", 1997.

3. EPRI-NP-6766, Volume 5, Part 1, "Water Hammer Prevention, Mitigation, and Accommodation", July 1992.

4. WCNOC Letter ET 97-0004, dated January 29, 1997, from R. Muench, WCNOC, to NRC, Docket No. 50-482: Final Response to Generic Letter 96-06, "Assurance of Equipment Operability and Containment integrity During Design-Basis Accident Conditions"

LIST OF COMMITMENTS

The following table identifies those actions committed to by Wolf Creek Nuclear Operating Corporation (WCNOC) in this document. Any other statements in this submittal are provided for information purposes and are not considered to be commitments. Please direct questions regarding these commitments to Mr. Michael J. Angus, Manager Licensing and Corrective Action at Wolf Creek Generating Station, (316) 364-8831, extension 4077.

COMMITMENT	Due Date/Event
None	