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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

Subject: Davis-Besse Nuclear Power Station
Response to NRC Request for Additional Information Concerning Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions" (TAC No. M96803)

Ladies and Gentlemen:

Generic Letter (GL) 96-06, issued by the NRC on September 30, 1996, requested, in part, that licensees evaluate their cooling water systems that serve containment air coolers to assure that they are not vulnerable to waterhammer and two-phase flow. In response, FirstEnergy Nuclear Operating Company (FENOC) provided an assessment of the GL 96-06 issues for the Davis-Besse Nuclear Power Station (DBNPS) in letters dated January 28, 1997, February 28, 1997, July 28, 1997, and September 30, 1997. FENOC's responses identified a large break Loss of Coolant Accident (LOCA) with a simultaneous Loss of Offsite Power (LOOP) as the bounding event for consideration.

While the DBNPS GL 96-06 response was being reviewed by the NRC, the DBNPS experienced a LOOP while shut down in Mode 5 on August 14, 2003. This event triggered a waterhammer in the Service Water (SW) system that appeared to result in pressure spikes and piping loads greater than those previously predicted in the analyses performed in response to GL 96-06. FENOC responded to the waterhammer by implementing several modifications to the Containment Air Cooler (CAC) SW piping.

By letter dated November 20, 2003, the NRC staff requested that FirstEnergy Nuclear Operating Company (FENOC) respond to three observations regarding the DBNPS responses to GL 96-06. In addition, because FENOC modified the DBNPS cooling water piping to the containment air coolers, the NRC staff requested that FENOC review the DBNPS responses to GL 96-06 and supplement them where appropriate. Also, although the NRC staff concluded that the DBNPS response to the two-phase flow issue was acceptable, due to recent piping modifications, the NRC staff requested that FENOC either affirm that the DBNPS responses are still valid in this area or supplement the

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responses for two-phase flow. Since it was anticipated that the modifications would not be completed until the end of the 14th refueling outage, by letter dated December 30, 2003, FENOC committed to provide the requested information within 90 days following completion of that refueling outage. The planned modifications were completed during Spring 2006, and accordingly Attachment 1 provides the requested information.

Attachment 2, Commitment List, identifies that there are no commitments contained in this letter. If there are any questions or if additional information is required, please contact Mr. Gregory A. Dunn, Manager – FENOC Fleet Licensing, at (330) 315-7243.

The statements contained in this submittal, including its associated enclosures are true and correct to the best of my knowledge and belief. I am authorized by the FirstEnergy Nuclear Operating Company to make this submittal. I declare under penalty of perjury that the foregoing is true and correct.

Executed on: July 25, 2006

By: [signature]
Mark B. Bezilla, Vice President-Nuclear

MSH

Attachments

cc: Regional Administrator, NRC Region III
DB-1 NRC/NRR Project Manager
DB-1 NRC Senior Resident Inspector
Utility Radiological Safety Board

Davis-Besse Nuclear Power Station Updated Response to Generic Letter (GL) 96-06

1. Updated GL 96-06 Responses Based on CAC SW Modifications

While the Davis-Besse Nuclear Power Station (DBNPS) GL 96-06 response was being reviewed by the NRC, the DBNPS experienced a Loss of Offsite Power (LOOP) while shut down in Mode 5 on August 14, 2003. This event triggered a waterhammer in the Service Water (SW) system that appeared to result in pressure spikes and piping loads greater than those previously predicted in the analyses performed in response to GL 96-06. FENOC responded to the waterhammer by implementing several modifications to the Containment Air Cooler (CAC) SW piping.

In view of the modifications that had been made to the CAC SW piping, by letter dated November 20, 2003, the NRC requested that the FirstEnergy Nuclear Operating Company (FENOC) **review the previous Davis-Besse responses to GL 96-06 and supplement them where appropriate.** Although the NRC staff concluded the FirstEnergy Nuclear Operating Company (FENOC) response to the two-phase flow issue was acceptable, the NRC also requested FENOC to **either affirm the responses for the two-phase flow issue are still valid in this area or to supplement the response for two-phase flow.**

FENOC has reviewed the previous GL 96-06 responses and has determined that a supplemental response is required. Considering the waterhammer in the CAC SW piping following the LOOP event in August 2003, the bases for the previous GL 96-06 responses for the waterhammer and two-phase issues were questioned. Previous analysis assumptions for minimum void fraction were not conservative for predicting the waterhammer loads, especially for the LOOP only event. Several modifications were developed and implemented to address this issue, focusing on eliminating the potential for waterhammer. In particular;

- The CAC SW inlet and outlet valve control logic was changed to prevent rapid collapse of voids by throttling the CAC SW inlet valves for a slow flow rate that ensures any voids in the CACs are filled slowly.
- CAC inlet check valves and outlet vacuum breakers were installed to eliminate the potential for voiding in the CAC SW piping during LOOP and minimize void formation to acceptable sizes within the CACs during a LOOP concurrent with a Loss of Coolant Accident (LOOP/LOCA).
- Piping supports were modified following the LOOP event and during 14RFO to provide additional design margin in the event of a waterhammer.

New waterhammer analyses for the LOOP/LOCA scenario were performed using methods and assumptions that are consistent with Electric Power Research Institute (EPRI) TR-1006456, "Generic Letter 96-06 Waterhammer Issues Resolution," April 2002. These analyses incorporate conservative assumptions that, combined with the modifications, demonstrate the CAC SW piping remains operable for all design basis events.

A brief description of the recent modifications and analyses is provided below followed by updated responses for the GL 96-06 waterhammer and two-phase flow issues respectively. Since the thermal overpressurization issue is closed and not impacted by the recent changes, no updated response is necessary for that issue.

1.1 Summary of Recent Modifications to CAC SW Piping

1.1.1 CAC SW Valve Logic Modifications

After the August 2003 LOOP event, the CAC SW inlet and outlet valves control logic was changed for a LOOP or LOOP/LOCA event to throttle the CAC SW flow established upon restart of the SW pumps to slowly fill the CAC lines and therefore prevent rapid pressure transients (from either CIW or CCW) from occurring in the CAC SW piping.

1.1.2 CAC SW Check Valve/Vacuum Breaker Modifications

To account for a postulated single failure of the new CAC SW inlet valve controls, FENOC installed check valves on each of the SW CAC inlet lines to maintain the CAC inlet piping filled with water, and redundant vacuum breaker assemblies on each of the CAC outlet lines and 30 inch discharge header to prevent vapor voiding of the piping inside containment on loss of pumping power in the SW system. In particular, assuming failure of any CAC SW inlet valves to function with the logic modification, the modifications prevent vapor voiding in the CAC piping during a LOOP event, and minimize steam voiding during a LOOP/LOCA event. The analyses show that the loads generated on subsequent restart of the SW pump for these conditions are acceptable.

1.1.3 CAC SW Piping and Support Modifications

Although the modifications described in above are designed to prevent waterhammer, several piping supports inside containment and around the CACs have been modified to increase structural margins in the unlikely event of a waterhammer.

1.2 Updated GL 96-06 Responses Based on CAC SW Modifications

The following sections provide updated responses for each area requested by the NRC based on the above modifications and the corresponding analyses performed for those modifications.

As discussed in FENOC's letter dated August 28, 1998 (Serial Number 2554), procedure changes and modifications for the applicable containment penetrations resolved the issue of post-LOCA thermal over-pressurization. The CAC SW lines are not susceptible to thermal over-pressurization, so the analysis results were not affected by the recent modifications. However, FENOC wishes to correct an error on page 3 of FENOC's August 28, 1998 letter. The maximum calculated fluid pressure identified for penetration P56 was stated as 5235 psig. FENOC's calculation for this penetration actually identified this value as 4250 psia. Since the valves bounding penetration P56 were hydrostatically tested at 5400 psig, this error had no impact on the analysis conclusions.

1.2.1 Updated Response Regarding Potential for Waterhammer Loads

Modifications have been implemented to further address the GL 96-06 concerns by preventing or minimizing the effects of waterhammer in the CAC SW piping. As discussed below, the waterhammer analysis is consistent with the methods described in EPRI TR-1006456.

- For a LOOP event, analyses show that the modifications will prevent vapor voiding of the piping on loss of pumping power in the SW system. More specifically, the analyses show that the vacuum breakers are appropriately sized to mitigate the depressurization in the SW CAC piping high points following the loss of SW pump flow to a CAC during a LOOP. In addition, the confirmatory testing validated the design approach and shows that the check valves and vacuum breakers will prevent column separation or vapor voiding at the high points of the CAC piping. The maximum pressure increase on the SW piping upon a pump restart following a LOOP will be only thirty-three pounds per square inch over five seconds; therefore, there will be no significant dynamic loads on the SW piping.

- For a LOOP/LOCA, the elevated containment temperature may cause some steam voiding. However, analyses demonstrate the steam voiding is restricted to within the CAC tubing during the time frame prior to diesel start and subsequent SW pump restart. The key difference from previous analyses is the fact that the modifications maintain pressure in the high points of the CAC SW piping near or slightly above atmospheric pressure, whereas previous analyses included subatmospheric conditions in these

locations due to effects of CAC SW piping draindown. The higher pressure in the recent analysis results in a delay to the onset of boiling and limits steam formation.

Transient thermal hydraulic analysis was performed to model the heat up and boiling in the CAC SW system following a LOOP/LOCA. The thermal hydraulic model included the upstream CAC piping, the CAC water boxes, the three levels of CAC tubing, and the CAC downstream piping. When boiling occurs in the CAC, the pressure in the CAC tubes will increase to about thirty pounds per square inch (absolute) due to the steam formation. This pressure will tend to drive the steam into the discharge piping on the downstream side of the CACs. However, the analysis results show that at 25.5 seconds following the LOOP/LOCA, the steam will just fill the CAC waterboxes and will not have propagated into the six-inch discharge piping. Also, the analyses demonstrate the heat that is transferred into the CAC following a LOOP/LOCA from the time the pump trips to the time the pump restarts is insufficient to heat the water in the discharge piping between the CAC and the high point to saturation conditions.

- For a LOOP/LOCA, the CAC SW inlet valve control logic modifications prevent waterhammer by limiting the SW flow to the CACs. Even if the CAC SW inlet valve fails full open (as the limiting assumed single failure), the modifications will limit the steam void formation so that resulting dynamic loads from the steam void collapse after pump restart are shown to be bounded by transient loads evaluated in dynamic evaluations of the SW system piping.

With regard to the potential for waterhammer for a LOOP/LOCA, the accelerating column of water will collapse the steam void formed in the CAC. However, the approach used in the analyses did not determine if the final void collapse occurs inside the CAC tubes or if some of the steam void is pushed into the downstream piping before it collapses. Nevertheless, the analyses assumed that both conditions are possible and determined the resulting pressure pulse characteristics for each case.

The calculated pressure pulse was applied to a separate computer model of the SW piping to calculate the transient force time histories. These transient hydraulic analyses were based on the simple, conservative approach recommended in EPRI TR-1006456. This approach assumed that the pressure at the steam void would be equal to the saturation pressure and the columns of water upstream and downstream of the CAC will be accelerated into the void as rigid bodies in motion by the pressure differences generated by the pump and the elevation head. The differential velocity developed between the two columns of water at the time the void collapses was used to calculate the magnitude of the pressure surge that will be generated at the void collapse location. The resulting pressure wave characteristics were determined and were used to calculate dynamic loads on the piping. This evaluation included the following conservative assumptions.

- The air released during boiling will have a significant effect on the condensation rate and the speed of sound in the fluid. Since the pressure pulse magnitude will be directly proportional to the speed of sound, the pulse peak pressure will be lower than predicted in this calculation as no credit was taken for the air.

- Full pump flow was assumed at the time of final void collapse. However, since two-phase flow provides a significant hydraulic resistance due to the increased pressure drop that is created by increased steam velocities, the hydraulic resistance in the CAC will reduce the flow that can be generated by the pump prior to steam void collapse. It is likely that the flow from the pump will not have attained its full flow capacity at the time the final void collapses. Since the pressure wave magnitude will be proportional to the differential velocity, the calculated loads would be over-estimated.

- Although the condensation heat transfer coefficient in the CAC at the steam-water interface may be low, some condensation of the steam void in the CAC is bound to occur due to the temperature difference between the steam and the water being pumped. As a result the size of the steam void that may reach the discharge piping will be smaller than the initial void size. The condensation of the smaller void will be completed near the CAC and the resulting pressure wave will be clipped due to reflection from the waterbox. The analysis assumed that the size of the steam void that collects in the discharge piping is the same as the initial void size in the CAC at 25.5 seconds. Therefore, the void collapse in the analysis will be delayed and will occur farther from the waterbox. The effect of clipping due to reflection from the waterbox will be reduced and the calculated pressure wave magnitude will be over-predicted.

1.2.2 Updated Response Regarding Two-Phase Flow

As indicated above, the previous response indicated that there is no effect of long-term transient two-phase flow on the heat removal capability of the CACs since single phase flow would be restored at approximately the time the CACs are credited in the containment analysis. This statement was supported by the Fauske analyses which concluded that the system would return to equilibrium conditions around 60 seconds following a LOOP/LOCA. The NRC previously concluded the Davis-Besse response for two-phase flow was acceptable.

Following modification, drain down of the CAC SW piping will no longer result in low pressures and voiding at the high points of the CAC SW piping inside containment. Also, the pressure maintained with the CAC SW piping was shown by analysis to limit steam void formation to inside the CACs coils. In particular, these changes improved the margin from that described in the original response.

Modifications included throttling the CAC SW inlet valves to limit SW flow to 600-1350 gallons per minute to the CACs for almost 300 seconds following the initiating LOOP/LOCA. The 600 gallons per minute minimum value was designed to provide sufficient flow to prevent steam/vapor (i.e., to prevent the two-phase flow) and to prevent Condensation Induced Waterhammer. In any event, based on the changes, the Containment Vessel Analysis was revised to account for the 300 second delay. Also, even if the inlet valve fails to fully open in one train following the 300 second delay, the second train would still be available to satisfy the design basis requirements. Consequently, the previous response is still valid for the modified conditions.

The previous response is also valid when considering limiting failures that could potentially result in flows less than 600 gallons per minute. For example, in the scenario where the Turbine Plant Cooling Water (TPCW) isolation valve fails to close, the SW system will operate in its "normal" configuration of 540 gallons per minute; however, the Component Cooling Water heat exchanger temperature control valves will have also opened on the Safety Features Actuation System (SFAS) signal. Since the Component Cooling Water system provides a very large flowpath, it is likely that the SW flow will drop below 540 gallons per minute. However, if this scenario occurs, it is expected that alarms will occur in the control room on low SW system pressure (due to large available flowpaths) as well as high Component Cooling Water outlet temperature. Therefore, the operator will mitigate these scenarios quickly. In addition, the Emergency Operating Procedures require that the operators verify that all SFAS valves (including the TPCW isolation valve) move to their safe position. Therefore, there are several methods to detect this scenario.

Even for low flow conditions of less than 600 gallons per minute with the SW inlet valves throttled, there is no potential for waterhammer greater than already evaluated because; a) the differential approach velocities are significantly lower than with the 1600 gallons per minute flows already evaluated, b) the pressure and flows in the CACs will increase to a quasi-steady state condition, and c) further opening of the throttled inlet valve is slow (valve has a 19 to 20 second full stroke time). The slow inlet valve opening generates a pressure increase ramp rate that is significantly lower than that assumed in the analyses based on a pump start with the valve full open (i.e., the slow valve opening results in more gradual pressure increase). Case 1 of the 2003 Fauske analysis covered a previous analysis of the system performance when the valve logic behaves as designed for a LOOP/LOCA with the inlet valve throttled. This analysis concluded that since the refill rates are quite slow, boiling in the fan cooler and its downstream piping is not collapsed as a waterhammer, rather it is pushed out of the end of the pipe at approximately 129.9 seconds. Consequently, the axial pressure profile along the piping at this time is in essence a quasi-steady state profile under the heat removal conditions associated with the LOCA event and therefore, there are no significant waterhammers associated with this condition. Also, the modifications make the previous results more conservative since the vacuum breakers

introduce air into the downstream piping which would potentially mix with the steam and dampen any localized void collapses during the quasi-steady state conditions.

2. *Information Systems Laboratories Observations*

The NRC also requested resolution of three observations made by Information Systems Laboratories (ISL). As discussed above, FirstEnergy Nuclear Operating Company (FENOC) has implemented several design modifications to address this issue and has performed new analyses using methods recommended by the Electric Power Research Institute (EPRI). As a result, ISL's observations are for the most part no longer applicable to the revised analyses for the modified systems. Details of the impact of the new analyses on the ISL observations is as follows:

- **The condensation-induced waterhammer (CIW) evaluation for the drain down phase was based on qualitative discussions and some small scale experiments, and the evaluation incorrectly assumes that fully developed flow during the drain down phase will prevent occurrence of CIW.**

  RESPONSE: For the Loss Of Offsite Power (LOOP) only conditions, modifications eliminate any need to consider CIW for drain down. For the LOOP/LOCA case, the modifications allow drain down while preventing voiding in the high points of the Containment Air Cooler (CAC) Service Water (SW) piping. As discussed in EPRI TR-1006456, "Generic Letter 96-06 Waterhammer Issues Resolution," April 2002, CIW events are limited in magnitude and duration in low pressure service water systems and do not create a limiting transient, particularly in systems that experience Column Closure Waterhammer (CCW). Consequently, analysis of the CCW events bounds the CIW events. Further, CCW events can be evaluated using the method of characteristics or rigid body model methods considering steam and non-condensables pressurization in the void. The evaluations address CCW and use conservative rigid body methods consistent with the EPRI methodology.

- **The column closure waterhammer (CCW) evaluation relies on several user specified empirically derived model parameters. No scaling rationale for the as-built piping configuration or for the actual accident time sequence was provided to address biases that might exist due to scale distortion.**

  RESPONSE: Certain parameters and scaling effects were defined in the original waterhammer analyses based on comparison of the Davis-Besse configuration and the testing setup used by Fauske & Associates, Inc. (Fauske) for confirmation of the analyses methods. The recent analysis for the modified configuration does not rely on the Fauske testing and analysis methods. Instead, the recent analysis uses the methodologies developed by EPRI and documented in EPRI TR-1006456.

- **Scaling and piping configuration effects on the minimum void fraction that was selected for calculating the two phase sonic velocity were not addressed.**

  RESPONSE: The original analysis model assumed certain quantities of air exit solution during the initial void formation and also remain out of solution (a minimum void fraction is used) after the void has collapsed. The use of air, and the corresponding reduction in wave velocity, in the analysis was a critical parameter for determining the severity of the water hammer loads. The recent analyses for the modified configurations conservatively neglect air exiting solution during initial void formation.

COMMITMENT LIST

The following list identifies those actions committed to by the Davis-Besse Nuclear Power Station, Unit Number 1, (DBNPS) in this document. Any other actions discussed in the submittal represent intended or planned actions by the DBNPS. They are described only for information and are not regulatory commitments. If there are any questions or if additional information is required, please contact Mr. Gregory A. Dunn, Manager – FENOC Fleet Licensing, at (330) 315-7243.

COMMITMENTS	DUE DATE
None	Not applicable.