Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion

JUN 10 2003

Docket No. 50-336
B18893

RE: GL 96-06

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Millstone Power Station, Unit No. 2
Response to a Request for Additional Information
Regarding Resolution of Issues Related to Generic Letter 96-06

This letter provides Dominion Nuclear Connecticut, Inc. (DNC) response to a request for additional information regarding the resolution of issues related to Generic Letter (GL) 96-06[1] for Millstone Unit No. 2. GL 96-06 included a request for Licensees to evaluate cooling water systems that service containment air coolers to assure that they are not vulnerable to waterhammer and two-phase flow conditions. Responses to the requested actions of GL 96-06 were provided for Millstone Unit No. 2. by letters dated October 30, 1996,[2] January 28, 1997,[3] January 12, 1999,[4] and July 11, 2001.[5] As discussed in our submittals, the RELAP5 computer code had been used to evaluate waterhammer in the Reactor Building Closed Cooling Water (RBCCW) System for Millstone Unit No. 2.

---

(1) T. T. Martin letter to Licensees, Generic Letter 96-06, "Assurance of Equipment Operability and Containment Integrity During Design - Basis Accident Conditions," September 30, 1996.

(2) T. C. Feigenbaum letter to U.S. Nuclear Regulatory Commission (NRC), "Millstone Nuclear Power Station, Unit Nos. 1, 2 and 3, Haddam Neck Plant, Seabrook Station, Response to Generic Letter 96-06," October 30, 1996.

(3) M. L. Bowling letter to NRC, "Millstone Nuclear Power Station, Unit No. 2, Response to Requested Actions of Generic Letter 96-06," January 28, 1997.

(4) M. L. Bowling letter to NRC, "Millstone Nuclear Power Station, Unit No. 2, Response to the Request for Additional Information Regarding Resolution of Issue Related to Generic Letter 96-06 (TAC No. M96833)," January 12, 1999.

(5) J. A. Price Letter to NRC, "Millstone Nuclear Power Station, Unit Nos. 2 and 3, Response to a Request for Additional Information Regarding Resolution of Issues Related to Generic Letter 96-06," July 11, 2001, (Accession No. ML012000319).

A072

The NRC requested additional information in a facsimile dated July 11, 2002.[6] In a letter dated, September 6, 2002,[7] DNC committed to provide supplemental information addressing the GL 96-06 waterhammer issue by June 15, 2003. Accordingly, DNC is providing a response to each of the questions contained in the July 11, 2002, facsimile as Attachment 1 to this letter.

There are no regulatory commitments contained within this letter.

If you should have any questions regarding this submittal, please contact Mr. David W. Dodson at (860) 447-1791, extension 2346.

Very truly yours,

DOMINION NUCLEAR CONNECTICUT, INC.

J. Alan Price
Site Vice President - Millstone

Sworn to and subscribed before me

this 10 day of June, 2003

Diane M. Phillipo
Notary Public

My Commission expires 12/31/2005

DIANE M. PHILLIPO
NOTARY PUBLIC
MY COMMISSION EXPIRES 12/31/2005

Attachment (1)

cc: H. J. Miller, Region I Administrator
R. B. Ennis, NRC Senior Project Manager, Millstone Unit No. 2
Millstone Senior Resident Inspector

---

[6] R. Ennis (NRC) Facsimile to R. Joshi, "Request for Additional Information Regarding Resolution of Generic Letter 96-06," July 11, 2002, (Accession No. ML021960551).

[7] J. A. Price letter to NRC, "Millstone Power Station, Unit No. 2, Response to a Request for Additional Information, Regarding Resolution of Issues Related to Generic Letter 96-06," September 6, 2002, (Accession No. ML022600373).

Docket No. 50-336
B18893

Attachment 1

Millstone Power Station, Unit No. 2
Response to a Request for Additional Information
Regarding Resolution of Issues Related to Generic Letter 96-06

Millstone Power Station, Unit No. 2
Response to a Request for Additional Information
Regarding Resolution of Issues Related to Generic Letter 96-06

BACKGROUND:

The Reactor Building Closed Cooling Water (RBCCW) system is a closed loop system supplied by two safety related RBCCW pumps that deliver water to two trains, "A" and "B." An elevated surge tank that is vented to the auxiliary building provides pump suction head to these pumps. Inside containment, each train of the RBCCW system delivers cooling water to two Containment Air Recirculation (CAR) coolers. The safety related function of the RBCCW system is to transfer heat from safety related structures, components and equipment to the ultimate heat sink during an accident.

Dominion Nuclear Connecticut, Inc. (DNC) has evaluated the effects on the RBCCW system from a Loss of Offsite Power (LOOP) concurrent with a Loss of Coolant Accident (LOCA) or Main Steam Line Break (MSLB) event. The analyses show that the postulated conditions in Generic Letter (GL) 96-06 would produce a transient consisting of two periods. First, a boiling period occurs when the RBCCW pumps are stopped. Heat is added from the hot containment environment through the CAR coolers, and steam voids form in the RBCCW piping. Second, a refill period occurs when the pumps are restarted and the steam voids are closed.

Under these transient conditions, two types of waterhammer could potentially affect the RBCCW system. The first is a Condensation Induced Waterhammer (CIWH), which may occur under a combined LOOP/LOCA or a LOOP/MSLB when the containment heats the RBCCW water through the CAR coolers and introduces hot steam voids. If these voids progress into sub-cooled water in the header pipe, rapid condensation can lead to CIWH events. The CIWH may occur during the voiding phase of the event and/or during the refill phase before all the voids are closed. A second waterhammer is caused by the final closure of the steam voids when the system refills. This event is referred to as Column Closure Waterhammer (CCWH). The CCWH is driven by the velocity of the refilling water from the RBCCW pumps as the water columns close.

The original analysis in response to GL 96-06 was performed using the RELAP5 computer code. The analysis predicted pressure pulses of 250 psi above the static pressure of approximately 45 psig due to CCWH. The transient pressure time histories were used to calculate resulting force time histories for the RBCCW pipe segments. Dynamic structural analysis produced pipe stresses and pipe loads. The structural analysis resulted in modifying four (4) pipe supports and adding another.

Subsequent to the original waterhammer analysis, DNC concluded that the severity of the CCWH in the RBCCW system could be significantly reduced with the addition of restriction orifices in the pump supply lines from the surge tank. These flow restriction orifices greatly reduced the pressure pulsations during pump starts. This CCWH

analysis was performed using guidelines in the Electric Power Research Institute (EPRI) Technical Basis Report(1) and User's Manual(2) for the modified piping configuration. The analysis predicted pressure pulses of approximately 100 psi above the static pressure of approximately 45 psig due to CCWH. Recently DNC has evaluated CIWH in the RBCCW piping and concluded that a detailed CIWH analysis is not required for horizontal sections of piping in the RBCCW system inside containment.

REQUEST FOR ADDITIONAL INFORMATION:

During a July 9, 2002, conference call with DNC, the NRC requested additional information for addressing the GL 96-06 waterhammer issue. Questions from the conference call were transmitted to DNC via facsimile on July 11, 2002.(3) In a letter dated September 6, 2002,(4) DNC committed to provide the supplemental information for addressing the GL 96-06 waterhammer issue with the EPRI method by June 15, 2003. Accordingly, we are providing our response to each of the questions in the balance of this Attachment.

QUESTION 1:

As discussed in a letter from the NRC to the Electric Power Research Institute (EPRI) Waterhammer Project Utility Advisory Group dated April 3, 2002 (reference ADAMS Accession No. ML020940132), the NRC staff has approved EPRI Report TR-113594 as an acceptable method for performing evaluations to address the GL 96-06 waterhammer concerns. NUREG/CR-5220 also provides an acceptable method for evaluating waterhammer events. As discussed in your submittals dated January 12, 1999, and July 11, 2001, the RELAP5 computer code was used to evaluate waterhammer in the Reactor Building Closed Cooling Water (RBCCW) system for MP2 [Millstone Unit No. 2]. The NRC staff does not believe that the RELAP5 computer code is an appropriate method for evaluating waterhammer. This is because the code uses a nodal solution that is incapable of tracking individual water slugs in horizontal pipes. The collision of these water slugs produced by the rapid condensation of steam is the process that can cause waterhammer to occur. In reaching this decision concerning RELAP5, the NRC staff had discussions with the RELAP5 developers and performed sample RELAP5 waterhammer calculations comparing the results with other methodologies. In a letter dated October 23, 2001 (ADAMS Accession No. ML013020519), the Advisory Committee for Reactor Safeguards (ACRS) stated that a code such as RELAP5 may have trouble modeling waterhammer events because it

(1) EPRI Report 1003097, "Resolution of Generic Letter 96-06 Waterhammer Issues, Technical Basis Report – Non Proprietary," dated April 2002.

(2) EPRI Report TR-1006459, "Resolution of Generic Letter 96-06 Waterhammer Issues, User's Manual – Non Proprietary," April 2002.

(3) R. Ennis (NRC) Facsimile to R. Joshi, "Request for Additional Information Regarding Resolution of Generic Letter 96-06," dated July 11, 2002, (Accession No. ML021960551).

(4) J. A. Price letter to NRC, "Millstone Power Station, Unit No. 2, Response to a Request for Additional Information, Regarding Resolution of Issues Related to Generic Letter 96-06," dated September 6, 2002, (Accession No. ML022600373).

does not have a good representation of direct contact condensation, the mixing and stratification processes in the main pipes, nor the phase separation that may occur in the coolers (reference page 7 of the enclosure to the letter).

Since the MP2 RBCCW system evaluations for GL 96-06 were done with a methodology that the staff does not believe is appropriate for waterhammer analysis (i.e., RELAP5), please provide the results of waterhammer calculations using appropriate methodology. If you choose to use a methodology that has not been previously approved, please provide documentation including all equations. Provide justification by comparison to experimental waterhammer data that is applicable to the conditions in the Millstone 2 RBCCW system.

RESPONSE TO QUESTION 1:

The original analysis in response to GL 96-06 had been performed using the RELAP5 computer code. The analysis had predicted pressure pulses of 250 psi above the static pressure of approximately 45 psig due to CCWH. Subsequent to the original waterhammer analysis, DNC concluded that the severity of the CCWH could be significantly reduced with the addition of restriction orifices in the pump supply lines from the surge tank.

The modified RBCCW system (with orifices installed) was reanalyzed for pump starts for scenarios under normal operation as well as accident conditions. In this reanalysis, the waterhammer magnitude calculations for the RBCCW system used methods that were consistent with EPRI methodology.[5][6] These methods are the same as those accepted by the NRC in the Safety Evaluation Report[7] that documented NRC acceptance of the EPRI Report TR-113594. Analysis of the RBCCW system shows that the restriction orifices greatly reduce the rate of void closure and therefore the calculated peak pressures following a LOOP/LOCA or a LOOP/MSLB transient. This analysis shows that with the addition of the orifices, the calculated waterhammer pressure pulse is approximately 100 psi above the static pressure of approximately 45 psig.

In summary, the reanalysis using the NRC approved EPRI methodology of the RBCCW system with modified piping and restriction orifices shows the system to be adequately designed for these waterhammer concerns. Additional details on CCWH as well as results on CIWH are provided in response to questions that follow.

---

(5) EPRI Report TR-1006459, "Resolution of Generic Letter 96-06 Waterhammer Issues, User's Manual – Non Proprietary," April 2002.

(6) EPRI Report 1003097, "Resolution of Generic Letter 96-06 Waterhammer Issues, Technical Basis Report – Non Proprietary," dated April 2002.

(7) Safety Evaluation Report, NRC Acceptance of the EPRI Report TR-113594, "Resolution of Generic Letter 96-06 Waterhammer Issues," Volumes 1 and 2, John Hannon to Vaughn Wagoner, April 3, 2002. (Note that the number of the EPRI reports changed after issue of this SER) (Accession No. ML020940132).

QUESTION 2:

"Your response dated July 11, 2001, indicates that following a loss of offsite power and either a loss-of-coolant accident (LOCA) or a main steam line break (MSLB) inside the containment, if the RBCCW pumps are not automatically restarted within 26 seconds, emergency procedures instruct operators to wait until the containment pressure has decreased to 20 psig [sic.] *before restarting the RBCCW pumps. Please provide the results of analysis for the automatic pump restart and the delayed restart for the peak waterhammer pulse. Provide the results of the structural analysis for the RBCCW piping, supports, valves and penetrations. Based on a telephone conversation on July 9, 2002, we understand that flow orifices have recently been provided in the RBCCW system. What would the loads on the flow orifices be as a result of waterhammer from restarting the RBCCW pumps? For the most severe case of waterhammer, please provide the margin to failure for each component.*

RESPONSE TO QUESTION 2:

Items a through d, below, address the separate parts to Question 2:

a. *Please provide the results of analysis for the automatic pump restart and the delayed restart for the peak waterhammer pulse.*

   DNC evaluated the automatic pump restart (within 26 seconds). The CCWH analysis using the EPRI methodology shows the calculated waterhammer pressure pulse to be approximately 100 psi above the static pressure of approximately 45 psig.

   The analysis shows that in the event the pump fails to restart in 26 seconds, the void inside the RBCCW system continues to grow, reaching a maximum void size in approximately one minute. The maximum size of the void is approximately 80 cubic feet and extends into the 10 inch supply and return lines. The analysis shows that the steam temperature inside the CAR units closely follows the containment temperature during the cooldown period. The volume of the void shrinks as the containment temperature drops and the void reaches a volume well below that predicted at 26 seconds once the containment pressure reaches below 20 psig. A delayed restart of a RBCCW pump with a smaller void volume will result in CCWH pressure transients significantly less severe than predicted at the 26 second automatic restart. Emergency procedures have been established to assure that delayed restart will not occur unless containment pressure is below 20 psig. Therefore a separate reanalysis for delayed pump restart for the peak waterhammer pulse was not performed.

b. *Provide the results of the structural analysis for the RBCCW piping, supports, valves and penetrations.*

The CCWH analysis using EPRI methodology shows the calculated waterhammer pressure pulse to be approximately 100 psi above the static pressure of approximately 45 psig. A bounding structural analysis had been previously performed on the RBCCW system for a pressure pulse of 250 psi above the static pressure. This pressure pulse was predicted in the original (i.e., RELAP5) analysis. This bounding structural evaluation resulted in modifying four supports and adding one new support. With these modifications, the piping stresses were all acceptable. All components, nozzles, and welded attachments were also evaluated for these loads and found to be acceptable, in accordance with Licensing Basis criteria. The peak transient pressures used in the structural analysis were approximately two and one-half times more severe than those expected from waterhammer analysis using the EPRI method with the new flow restriction orifices installed. Thus, these RBCCW piping stress analyses, support evaluations and component qualifications, are conservative for the potential LOOP/LOCA transients with the current system configuration. Therefore, there was no necessity for reanalysis of pipe stresses, supports, or components for the lower pressure transients calculated using the EPRI method after flow restriction orifices were installed.

c. *What would the loads on the flow orifices be as a result of waterhammer from restarting the RBCCW pumps?*

The orifice plates are outside of containment, located between the surge tank and its connection to the RBCCW pump suction. This location is remote from the origin of the waterhammer, so that transient pressure wave loading is not significant when it is attenuated by the many branch connections and area changes. Furthermore, this is a piping configuration with a 3 inch orifice in an 8 inch pipe full of water, and a transient wave will pass quickly in this type of piping configuration without developing a significant pressure difference across the orifice plate. Thus, the loads on the flow orifices are governed by the pump flow and not the CCWH. The maximum hydraulic pressure differential across the orifice plates during pump restart was determined to be 40.9 psi. The orifice plate is acceptable for this small differential pressure.

d. *For the most severe case of waterhammer, please provide the margin to failure for each component.*

There is no reduction in the margin to failure for components from the most severe case of waterhammer postulated in the analysis because components have been evaluated and determined to be within allowable values for structural design.

The piping stresses in the RBCCW system must be within the yield strength of the material for Faulted loads such as for the postulated LOOP/LOCA transient to satisfy the Final Safety Analysis Report (FSAR) limits. Since all components were designed to satisfy the FSAR limits for a Faulted load, they have the same margin for failure as other equipment in the plant.

Integral welded attachments to the piping and penetrations must satisfy the requirements of the piping, and would have also satisfied the FSAR limits and would have the same margin for failure as other equipment in the plant. Valves are evaluated by virtue of the pipe acceptability because the valves have a larger section modulus than the attached piping components.

Pipe supports were designed to meet the American Institute of Steel Construction (AISC) Code. The allowable stress for Faulted loads in supports is no more than 90 percent of the yield strength to satisfy the FSAR limits. Since all pipe supports were designed to satisfy the FSAR limits for a Faulted load, they have the same margin for failure as other equipment in the plant.

QUESTION 3:

Provide the following information as a function of time for the most severe condition of waterhammer following the restart of the RBCCW pumps into a partially voided system:

a. *pressure in the gas phase between the water columns;*
b. *liquid velocity in the water columns;*
c. *liquid temperature at the closing face of the water column; and*
d. *saturation temperature in the water column.*

RESPONSE TO QUESTION 3:

From the recent analysis using the EPRI methodology with the orifice installed:

a. Pressure in the gas phase between the water columns:

   The pressure in the gas phase between the water columns is assumed to be constant at 45 psia (the saturation pressure of the maximum containment temperature of 275 degrees F).

b. Liquid velocity in the water columns:

   The liquid velocity in the water columns is at rest when the RBCCW pumps restart following a LOOP/LOCA transient. The velocity increases to 11.1 ft/s approaching the CAR units and 7.6 ft/s in the piping exiting these units. The velocity differential of 3.5 ft/s is controlled by the rate of refill from the elevated surge tank that must flow through the restriction orifice in the pump suction line.

c. Liquid temperature at the closing face of the water column:

The steam void was presumed to be at the containment saturation temperature of 275 degrees F in the EPRI methodology model. The liquid temperature was assumed to be the same. These temperatures, though, did not affect the results of the analysis, as the EPRI methodology utilized did not take credit for steam cushioning. Therefore, the liquid temperature at the steam/water interface was not a factor in the analysis.

d. Saturation temperature in the water column:

The saturation temperature in the water column was assumed to be at the containment saturation temperature of 275 degrees F. This temperature, though, did not affect the results of the analysis, as the EPRI methodology utilized did not take credit for steam cushioning. Therefore, the saturation temperature in the water column was not a factor in the analysis.

QUESTION 4:

"GL 96-06 suggested that licensees may find the information contained in Volumes 1 and 2 of NUREG/CR-5220, "Diagnosis of Condensation-Induced Waterhammer," to be informative and useful in evaluating potential waterhammer conditions. Condensation-induced waterhammer (CIWH) might occur as containment cooling systems are drained during a loss of offsite power (LOOP) condition, or during initiation of cooling water flow. CIWH typically occurs in horizontal pipe segments partially filled with cold water overlaid by steam that is supplied by a steam source. Condensation of steam on the surface of the water can cause tongues of water to be whipped up in a wave-like manner. If steam condensation is vigorous enough, a water tongue can extend to the top of the pipe forming a plug. The steam bubble trapped between two plugs of cold water would experience a drop in pressure from continued condensation. The pressure difference then causes the two plugs to be driven together. CIWH occurs when the trapped steam bubble condenses and the plugs of water converge. Please provide evaluations of CIWH for MP2 in the RBCCW piping."

RESPONSE TO QUESTION 4:

CIWH may occur during the time between LOOP/LOCA (or LOOP/MSLB) occurrences and pump restart. During this time, the heat from the LOCA or MSLB inside containment will boil the water in the CAR coolers. This will force steam out of the CAR cooler coils into the CAR supply and discharge lines. When the steam enters horizontal runs of pipe, CIWH may occur.

The EPRI study has shown that CIWH is not a concern if the steam pressure at the point of potential CIWH is less than 20 psig and if the system has been shown to withstand a CCWH event. The RBCCW piping and supports had been evaluated for a

potential CCWH with the transient pressure peak 250 psi above the system static pressure. The CCWH analysis had predicted significant loading on the RBCCW piping system that resulted in several pipe support modifications.

The pressure that would accompany a potential CIWH in a horizontal line is controlled by the head of water between that horizontal line and the surge tank. The horizontal pipe that will have the highest pressure is in the return line of the CAR cooler unit X-35B at elevation 29.4 ft. At this point, the system pressure is 21.9 psig.

The 21.9 psig pressure for the worst location of potential CIWH represents approximately a 5 percent increase above the EPRI 20 psig limit. As described in the EPRI reports, though, it is not the pressure as much as the impulse that determines the ability of a transient pressure to damage a system. The impulse is controlled by the square root of the pressure, and as such, the higher pressure at the worst CIWH location will cause an increase of 2.7 percent in the CIWH impulse. This increase in the pressure and the impulse have been judged to be acceptable, especially given that the pressure pulse magnitude of the CCWH evaluated was conservatively high (up to 250 psi) and that a detailed structural analysis was performed at that higher value.

QUESTION 5:

"In lieu of detailed waterhammer analyses, an alternative approach that may be acceptable is to manage how the RBCCW pumps are restarted so as to prevent system failure due to waterhammer. If this option is pursued, describe specifically how pump restart will be managed and what procedural changes will be made to assure that system failure will not occur. Note that this approach would not be appropriate if immediate response by the RBCCW system is required for accident mitigation."

RESPONSE TO QUESTION 5:

Detailed waterhammer analyses have been performed for the RBCCW system, consistent with an approved EPRI methodology. Results of these analyses are adequately evaluated by structural analysis performed that establishes the structural integrity of the system for these postulated waterhammer conditions.

Evaluation of the delayed restart shows that restarting a pump greater than 26 seconds after the event could cause a significant pressure transient in the system. Refer to the response to Question 2, item a., which describes the procedural guidance to avoid this transient.