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BVY 02-75

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

Subject: **Vermont Yankee Nuclear Power Station**
License No. DPR-28 (Docket No. 50-271)
Additional Information Regarding Generic Letter 96-06

Per discussion with your staff we are providing additional information that was requested to assist in your review of Generic Letter 96-06 issues for the Vermont Yankee station.

If you have any questions concerning this submittal or desire additional information, please contact Mr. Jeffrey Meyer at (802) 258-4105.

Sincerely,

Gautam Sen

Gautam Sen
Manager, Licensing

Attachment

cc: USNRC Region 1 Administrator
USNRC Project Manager – VYNPS
USNRC Resident Inspector – VYNPS
Vermont Department of Public Service

A072

Attachment 1

Additional Information Supporting
Vermont Yankee Submittal for Generic Letter 96-06

References:

1. Altran Technical Report 99251-TR-001, Rev. 2, "RBCCW Response to a Simultaneous LOCA/SLB & LOOP Event."

2. Altran Technical Report 99251-TR-002, Rev. 0, "Analysis of the RBCCW Piping for LOCA/SLB and LOOP Conditions."

3. USNRC Generic Letter 96-06. "Assurance of Equipment Operability and Containment Integrity during Design-Basis Accident Conditions," September 30, 1996.

4. E. B. Wylie, V. L. Streeter, "Fluid Transients in Systems," Prentice Hall, 1993.

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," 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).

Numbers in [] refer to the references above.

Summary:

The Vermont Yankee Nuclear Power Station (VY) was analyzed for the issues from Generic Letter (GL) 96-06 [3] in References 1 and 2. This analysis has been compared to the methods endorsed by the NRC in a Safety Evaluation Report [7] that accepted methods of evaluation developed by EPRI [5 and 6]. This letter report certifies that the methodology used in the VY analysis was equivalent or conservative relative to the methods endorsed by the Safety Evaluation Report.

Background:

References 1 and 2 are technical reports that address the effects on the Reactor Building Closed Cooling Water (RBCCW) system from a Loss of Offsite Power (LOOP) concurrent with a LOCA or Steam Line Break (SLB) event. Reference 1 provides an analysis of the RBCCW system thermodynamic response and evaluation of predicted waterhammer loads. Reference 2 provides a qualification of the piping system and supports under these loading conditions.

The RBCCW system at VY is a closed loop system supplied by two non-safety related RBCCW pumps. A head tank maintains pump suction head. Inside the Drywell, the system consists of a header feeding four Drywell coolers also referred to as the reactor re-circulation units (RRUs), two re-circulation pump cooling systems, and a sump cooler. The safety related function of the RBCCW system in the Drywell is to maintain containment integrity.

The analyses documented in Reference 1 determined that the GL96-06 conditions would produce a transient consisting of two periods. First, a boiling period occurs in which RBCCW pumps are stopped, heat is added from the hot containment environment through the RRUs, and steam voids form in the RBCCW piping. Second, a refill period in which pumps are restarted and the steam voids are reclosed.

Under these transient conditions, two types of waterhammer can potentially affect the RBCCW system. The first is a condensation induced waterhammer (CIWH), which may occur under a combined LOOP/SLB when the Drywell heats the RBCCW water through the RRUs and introduces hot steam voids. If these voids progress into the 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, 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 primarily driven by the velocity of the refilling water from the RBCCW pumps.

Questions have been asked about the conformity of the methods used in the VY analysis with the methods developed by EPRI [5 and 6] and accepted by the NRC [7]. Specific questions were raised relative to 1) the heat transfer coefficient used in the VY analysis, 2) the amount of non-condensable gas that would be released, and 3) the specific VY risk associated with the LOOP/LOCA event. This report will address these issues as well as other issues related to the similarities between the VY methods of analysis and the EPRI reports. Specifically, the information requested in Section 3.3 of the SER will be provided.

VY Methodology:

The VY waterhammer pressure pulses were determined with a method of characteristics (MOC) computer code. The MOC methodology is widely used in the determination of waterhammer pressure problems. Although the MOC code featured the ability to determine cushioning caused by non-condensable gases and steam contained in the void [4], a negligible value for gas was used, and therefore essentially no credit was taken for non-condensable gas cushioning. The amount of non-condensable gas that was included in the plant-specific VY calculation [1] was 3 milligrams, and this is much lower than that which would have been released during the transient.

Non-Condensable Gas Release:

Non-condensable gas is predicted to be released from the RRUs during a LOCA event. Although not used for cushioning the closure velocity, the amount of non-condensable gas available in the steam void permits the use of specific heat transfer coefficients in the MOC model.

Even though the surge tank is open to the atmosphere, it is assumed in the calculation that the oxygen will be consumed in the closed loop cooling system. Only dissolved N_2 was considered in the calculation of released non-condensable gas. Since the RBCCW system is a closed loop system, lower elevation piping will operate at pressures greater than atmospheric. Therefore, it is capable of containing greater amounts of dissolved gases than water at atmospheric pressure because more gas can remain in solution at higher pressures.

The total volume of water contained in the horizontal tubes of the RRUs is calculated in Reference 1 to be in excess of 128 gallons. Considering only N_2 release (as discussed above), and using the methods outlined in section 5.2.3 of Reference 5, more than 2,400 milligrams of non-condensable gas was calculated to be released. This calculation conservatively considers only the RRU water in the horizontal tubes and not the water in the RRU headers and still produces far more than the 3 milligrams of non-condensable gas used in the analysis.

As a condition to the calculation of the non-condensable release, the User's Manual [5] page 5-6 and the SER contained therein require that the RRU tubes be at a temperature that is at least 10°F greater than the saturation temperature of the water in the RRU. This ensures release of the non-condensables.

Detailed time dependent heat transfer analyses presented in appendices B and C of Reference 1 demonstrate that the tube wall temperature is at least 10°F greater than the saturation temperature of the RRU water.

Heat Transfer Coefficient:

The User's Manual provided conditions that were required for the use of a specific heat transfer coefficient (Table 5-2 of Reference 5) are met.

The analysis presented in Reference 1 used an MOC code to determine characterization of the CCWH pressure pulse. An input to the MOC code is the heat transfer coefficient between the steam void and closing water column. Per review of Reference 5, the conditions at VY satisfied the same conditions as those demonstrated to be acceptable for a heat transfer coefficient of 72,000 BTU/(hr-ft^2-°F). In the VY analysis, a heat transfer coefficient of 73,000 BTU/(hr-ft^2-°F) was used. This is conservative since the higher coefficient increases the void steam condensation rate and therefore increases closure velocity and waterhammer magnitude. The specific thermo-hydraulic conditions contained in the Reference 5 analysis, Table 5-2, are described below. Note that void and water column length apply only to the Rigid Body Model (RBM) and do not apply to the VY MOC analysis.

a) The velocity range in Reference 5 is from 5 to 30 ft/sec. The impact velocities used in Reference 1 are within this range.

b) The non-condensable gas content limit in Reference 5 is 60mg $(ID/2)^2$. This would require a minimum of 955 mg for the VY conditions described in Reference 1. Calculations show that the dissolved gas content of the RRUs is greater than 2,400 mg. Therefore, this criterion is satisfied.

c) The void temperature should be greater than 200°F in order to consider steam cushioning. In all the cases considered in Reference 1 Appendices B and C, the void temperature exceeded 200°F. Therefore, this condition is satisfied.

Other SER Conditions:

1. Fluid structural interaction (FSI) that would result in attenuation of the CCWH pressure wave as it passed through the pipe was not considered in References 1 or 2.

2. Section 3.3 of the SER [7] requires an additional assessment of the pipe failure probability if the uncushioned velocity is more than 40% greater than the cushioned velocity.

   The MOC calculations of the CCWH in Reference 1 show that there is very little difference between the maximum steady state water column velocity and the velocity at impact [1, appendix E].. Therefore, the 40% criterion is not exceeded.

3. Condensation induced waterhammer (CIWH) was calculated in Appendix I of [1]. It was shown that the CIWH impulsive load was bounded by the CCWH loading predicted in the same report. Section 4.2 of Reference 5 states that CIWH in low pressure service water systems is bounded by CCWH as long as the following limitations are met.

   a) The system pressure at the time of the postulated CIWH is less than 20 psig.

   b) The piping system has been shown by test or analysis to be capable of withstanding a CCWH following LOOP, LOOP/LOCA, or LOOP/MSLB.

   At the times that horizontal runs are uncovered and the potential for CIWH exists, these conditions are met. This conclusion in the Reference 1 report, that the CIWH is bounded by the CCWH, is consistent with the recommendation of Reference 5 section 4.2.

Risk Consideration:

The User's Manual and the Technical Basis Report considered the risk of an unacceptable event occurring as a result of a LOOP/LOCA event. The conclusion was that the risk of an unacceptable event from the combination of the LOOP and LOCA was small and that the methods in the User's Manual were suitable to demonstrate plant acceptability. The NRC concurred with this conclusion [7]. Assurance that the VY specific risk considerations are consistent with the NRC accepted risk perspective is provided below.

The EPRI report described the "progression" of events that could lead to an unacceptable condition. Since the RBCCW system's safety function is to provide containment boundary, the "unacceptable condition" following a LOOP/LOCA event is defined as a breach of the pressure boundary. The events defined were as follows with a comparison to the VY conditions:

1. **Occurrence of a LOCA or MSLB** – NUREG/CR-5750 states that for a BWR the mean frequency of occurrence of a large LOCA is $3*10^{-5}$/year and a medium LOCA is $4*10^{-5}$/year. The MSLB is not applicable within containment in a BWR. These generic values are considered appropriate for use in this evaluation with respect to the VY plant.

2. **Occurrence of a LOOP following a LOCA or MSLB** – Studies provided in NUREG/CR-6538 indicate that the dependent probability of a Loss of Offsite Power event following a LOCA event in a BWR is $6*10^{-2}$/demand. This value is considered applicable to the VY plant.

3. **Occurrence of a Simultaneous LOCA/LOOP Event** – The frequency of the combined event depends upon the probability of the LOCA and the dependent probability of the LOOP given that the LOCA has occurred. Using the values defined in each of the NUREGs referenced above, the probability of the combined event on the order of $4.2*10^{-6}$/year. The probability of the combined event referenced in the EPRI reports, applicable primarily to PWRs, was $1.5*10^{-5}$/year. Based on the same assumptions used in the EPRI report, the event combination is less likely in a BWR. This is consistent with NUREG/CR-6538 that stated, "The CDF impact of a LOCA/LOOP accident for most BWR plants is about an order of magnitude lower than PWR plants, and thus, most BWRs are less vulnerable to a LOCA/LOOP accident."

4. **Void Formation** – The EPRI report concluded that, in a closed loop plant, void formation will depend on the specific plant characteristics and a void may or may not form. If a void does not form, a waterhammer will not occur. At VY, it is accepted that if a void forms, a waterhammer will occur.

5. **Pump Restart** – The EPRI report stated that the pumps will restart with certainty and the velocity of the fluid in the pipe, immediately prior to closing the void, will be defined by the pressure in the void, the piping geometry, and the pump characteristics. This uncushioned closure velocity can be reliably calculated. This velocity will not be higher than the rate at which the pumps, once restarted, can pump water. The calculation of the water velocity prior to closure is a plant specific analysis that can be conservatively performed. This is consistent with the situation at VY.

6. **Column Closure** - The water columns will refill the void and the velocity at closure cannot be larger than the largest calculated differential velocity for the upstream and downstream water columns. This is consistent with the situation at VY.

7. **Maximum Waterhammer Pressure** – The situation at VY is the same as that described in the EPRI report. Specifically, an upper bound on the waterhammer pressure can be calculated by the Joukowski relationship with the uncushioned closure velocity that corresponds to the pipe in which the closure will occur. The waterhammer pressure cannot be larger.

8. **Cushioned Waterhammer** - Given the conservatism of the methods used at VY in comparison to the EPRI reports, the cushioned velocity will result in a waterhammer pressure that is essentially the same as the Joukowski pressure. Using the VY waterhammer pressure, the piping stress code limits are not exceeded in the VY piping. Since essentially no cushioning is credited in the VY analysis, the probability of failure of the pipe is lower than calculated in the EPRI report. The probability of pipe rupture that was used in the EPRI reports, 10^{-2} per event, is considered to be a very conservative estimate of the probability of pipe rupture for VY.

9. **Likelihood of an Unacceptable Event** - Given the low probability ($4*10^{-6}$/year) of the initiating events at VY and the low, but conservative, probability (10^{-2}) of piping failure, the use of the methodology in the User's Manual and the Technical Basis Report will lead to a likelihood of an unacceptable event that is on the order of $4*10^{-8}$. This probability is below the threshold for significant risk to the plant.

The specific risk of the events at VY is smaller than the risk provided in the EPRI reports. Hence, from the risk-informed perspective, the methods proposed in the EPRI TBR and UM are considered appropriate for use in this evaluation with respect to the VY plant.

SUMMARY OF VERMONT YANKEE COMMITMENTS

BVY NO.: 02-75

The following table identifies commitments made in this document by Vermont Yankee. Any other actions discussed in the submittal represent intended or planned actions by Vermont Yankee. They are described to the NRC for the NRC's information and are not regulatory commitments. Please notify the Licensing Manager of any questions regarding this document or any associated commitments.

COMMITMENT	COMMITTED DATE OR "OUTAGE"
NONE	N/A