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March 29, 2000
BVY 00-35

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

References:

(a) Letter, USNRC to VYNPC, "Request for Additional Information Regarding Generic Letter (GL) 96-06 at Vermont Yankee Nuclear Power Station (TAC No. M96880)," NVY 98-97, dated July 10, 1998.

(b) Letter, VYNPC to USNRC, "Response to NRC RAI Related to GL 96-06 Response," BVY 98-153, dated October 30, 1998.

(c) Letter, USNRC to VYNPC, "Request for Additional Information Regarding Generic Letter 96-06 Program at Vermont Yankee Nuclear Power Station (TAC No. M96880)," NVY 99-25, dated March 1, 1999.

(d) Letter, VYNPC to USNRC, "Response to Request for Additional Information Concerning GL 96-06," BVY 99-97, dated July 27, 1999.

(e) Letter, VYNPC to USNRC, "Response to Request for Additional Information Concerning GL 96-06," BVY 99-118, dated September 16, 1999.

(f) Letter, VYNPC to USNRC, "Update of Vermont Yankee's Plans to Address GL 96-06," BVY 99-136, dated October 29, 1999.

Subject: **Vermont Yankee Nuclear Power Station**
License No. DPR-28 (Docket No. 50-271)
Response to Request for Additional Information Concerning GL 96-06

Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996, included a request for licensees to evaluate cooling water systems that serve containment air coolers to assure that they are not vulnerable to waterhammer and two-phase flow conditions. By letters dated October 30, 1998, July 27, 1999, September 16, 1999 and October 29, 1999, Vermont Yankee (VY) provided responses and status to the Commission's July 10, 1998 request for additional information (RAI) on this issue.

In Reference (f), it was stated that VY's approach for resolving GL 96-06 had changed to an analytical solution and that a revised response, containing the additional information requested in Reference (a), would be provided by March 31, 2000. Attachment 1 to this letter provides our revised response to the Reference (a) request for additional information.

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

Sincerely,

VERMONT YANKEE NUCLEAR POWER CORPORATION

Don M. Leach
Vice President, Engineering

Attachment

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

SUMMARY OF VERMONT YANKEE COMMITMENTS

BVY NO.: 00-35

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

Attachment 1

Response to Request for Additional Information (RAI) Regarding Generic Letter 96-06

References:

1. Altran Technical Report 99251-TR-001, Rev. 0, "Drywell Cooler Response to a Simultaneous LOCA & LOOP Event."
2. Altran Technical Report 99251-TR-002, Rev. 0, "Analysis of the RBCCW Piping for LOCA/SLB and LOOP Conditions."
3. NUREG/CR-5220, "Diagnosis of Condensation Induced Waterhammer," 1988.
4. NUREG/CR-6519, "Screening Reactor Steam/Water Piping Systems for Water Hammer," 1997.
5. EPRI-NP-6766, Volume 5, Part 1, "Water Hammer Prevention, Mitigation, and Accommodation," July 1992.
6. Letter, USNRC to VYNPC, "Request for Additional Information Regarding Generic Letter (GL) 96-06, at Vermont Yankee Nuclear Power Station, NVY 98-97, dated 7/10/98.
7. Letter, VYNPC to USNRC, "Update of Vermont Yankee's Plans to Address GL 96-06," BVY 99-136, dated 10/29/99.
8. Wylie, E. B., "Fluid Transients in Systems," Prentice Hall, 1993.
9. EPRI Interim Report TR-113594, Vol. 1&2, "Resolution of Generic Letter 96-06 Waterhammer Issues."
10. Incropera and DeWitt, Introduction to Heat Transfer, Second Edition, John Wiley and Sons, 1990.
11. Crane Technical Paper No. 410, "Flow of Fluids Through Valves, Fittings, and Pipe," 25th Printing.

Item No. 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. For the LOCA scenario, identify the maximum amount of steam that could be generated, and explain why this amount of steam does not constitute a waterhammer concern. Also, while heat transfer considerations may not be of concern for the two-phase-flow issue, structural and system integrity considerations must still be addressed (this aspect of the two-phase flow issue was not addressed in the licensee's submittals). For example, the following two-phase flow effects are relevant:

- the consequences of steam formation, transport, and accumulation;
- cavitation, resonance, and fatigue effects; and
- erosion considerations.

Licensees may find NUREG/CR-6031, "Cavitation Guide for Control Valves," helpful in addressing some aspects of the two-phase flow analyses. To the extent that the possibility for waterhammer and two-phase flow to occur are eliminated, describe the minimum margin to boiling that will exist.

VY Response

The evaluation for waterhammer is documented in Altran Technical Report 99251-TR-001 (Reference 1). The evaluation of the piping system due to the waterhammer loading is documented in Altran Technical Report 99251-TR-002 (Reference 2).

The Reference 1 evaluation to determine the effects of the LOOP/LOCA or LOOP/SLB on the Reactor Building Closed Cooling Water (RBCCW) system considers multiple conditions that result in steam void formation in the RBCCW piping and potential waterhammer. Each of these conditions was considered, in a conservative manner, to determine its contribution to the waterhammer loading of the RBCCW system. The "worst case" scenarios were determined by conservatively evaluating each condition, and a summary of the important condition evaluations from the Reference 1 analysis is provided below.

1. Accident type: In order to address the limiting containment accident conditions, both Loss of Coolant Accident (LOCA) and Steam Line Break (SLB) accidents were considered concurrent with a Loss of Off-site Power (LOOP) event. The LOCA event was determined to not result in steam void formation and was therefore bound by the SLB events. Multiple SLB were considered and conservative, bounding curves for both temperature and pressure were used as the source of heat to induce voiding in the RBCCW system. The bounding Drywell temperature profile consisted of a ramp to 325°F in 2 seconds, followed by a constant 325°F for the duration of the transient.

2. Waterhammer Analysis: Both condensation induced waterhammer (CIWH) and column closure waterhammer (CCWH) were evaluated as part of the analysis. Condensation induced waterhammers can occur during periods of the event when the steam void enters long horizontal piping. This is predicted to occur during the steam void formation period and the refill period of the event. Column closure waterhammer can occur when the refilling water column closes the voids. It was determined that the column closure waterhammers would bound the condensation induced waterhammer events. The bounding column closure waterhammer pressure of 267 psig was used to analyze piping system structural capacity.

3. System Alignment: The RBCCW system was modeled to determine its hydraulic response during the LOOP/SLB event. The system was modeled in normal operating and accident conditions. In normal operating condition, one pump was assumed to be running, and this model was correlated to system test conditions. To simulate the limiting accident conditions, in which both pumps would receive a signal to restart, the system refill following restoration of power was modeled using two pumps restarting. This produced higher refill velocities, maximizing CCWH upon void closure, and conservatively bounded the single pump start. Only partial credit was taken for system resistances in voided sections of piping, maximizing the refill velocity and CCWH magnitude. Other items that could vary during the event, such as the surge tank water level, were conservatively modeled at low level for the voiding phase, to induce voiding, and at high level during refill, to increase closure velocity and CCWH magnitude.

4. Equipment/Pump Operation: The pumps were assumed to immediately stop upon loss of power instead of coasting down. This produced a conservatively small time to stop forward flow and therefore increased the void formation in the Drywell Coolers (RRUs). Two pump restart scenarios were evaluated. The first case considered the automatic restart of the RBCCW pumps at 73 seconds per system design. Both pumps were conservatively assumed to start to produce the bounding CCWH conditions. The second case that was evaluated considered no pump restart. Since system pressure and potential CIWH magnitudes would increase with time, the extended time period of 30 minutes, based on the upper bound time when Drywell spray would be initiated, was evaluated to determine conservative CIWH conditions. No other active equipment is expected to influence the response of the RBCCW system.

   The fans for the RRUs were assumed to lose power and slow exponentially with the LOOP. Sensitivity analysis showed that the fan rate did not affect the results, since the dominant heat transfer mechanism is condensation and not convection. The fans do not restart during the event.

5. Heat Transfer: The initial water temperature was assumed to be at the maximum limit of 100°F. The fouling factor for the heat exchangers was assumed to be zero. Both of these assumptions conservatively increase the steam void formation in the RBCCW piping. Additionally, at least one RRU heat exchanger tube was assumed to continue boiling throughout the transient to conservatively account for any small amount of water that could be left in the heat exchanger beyond dry-out predictions.

6. Two Phase Flow: Two phase flow was not evaluated for this effort for three reasons. First, the RRUs are not needed for post-accident heat removal. Therefore, any reduction in flow due to two-phase flow concerns does not impact the safety function of this system. Second, no control valves or orifices exist within the safety-related portion of this system. Therefore, the issues of erosion, cavitation, and fatigue/vibration cannot degrade the safety-related portion of the system. Third, erosion, cavitation, and fatigue are long term degradation issues that will have insignificant impact on the system during the short duration of the combined LOOP/SLB event.

7. Load Combination: The piping structural analysis was performed considering both the LOOP/SLB event and other occasional loads due to SSE seismic and seismic anchor displacement as required to meet the plant design basis. Seismic and waterhammer loads were considered a faulted event, and were combined by square root sum of squares (SRSS) method per the VY FSAR, Appendix C, sections C.2.2 and C.2.6. Piping was qualified to the requirements of the VY piping design criteria, which references the B31.1 – 1977 code. Piping supports were qualified to requirements of the VY

support design criteria. Piping and supports that did not meet these design criteria were addressed as described in Item 11.

Item No. 2

If a methodology other than that discussed in NUREG/CR-5220, "Diagnosis of Condensation-Induced Waterhammer," or in EPRI NP-6766, "Waterhammer Prevention, Mitigation, and Accommodations," 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).

VY Response

NUREG/CR-5220 provides specific methodologies for evaluating only condensation induced waterhammer and states that the "actual loads are usually lower by a factor from 2 to 10." These reductions are due to gas cushioning, structural compliance, oblique slug impact, friction, and slug length reduction. Credit was taken for the cushioning effects of non-condensable gas to limit waterhammer magnitude as demonstrated through an EPRI testing program to assess waterhammers resulting from the conditions defined in GL 96-06 (Reference 9).

The Reference (9) test program evaluated condensation induced waterhammer in horizontal draining pipes. The dissolved gas content, pressures, temperatures, and other conditions in the test program were similar or conservative relative to the conditions predicted to occur at VY. The conclusion of the test program was that, for low pressure systems such as the RBCCW, the effects of column closure waterhammer would bound that of condensation induced events.

Column closure waterhammer was also evaluated. Guidance from NUREG/CR-6519 (Reference 4) and from EPRI NP-6766 (Reference 5) was used for pump restart column closure waterhammer predictions. Cushioning for column closure waterhammer was also credited as discussed in the response to Item 4.

Item No. 3

Identify any computer codes that were used in the waterhammer and two-phase flow analyses and describe the methods used to bench mark the codes for the specific loading conditions involved (see Standard Review Plan Section 3.9.1).

VY Response

The formation of voids in the RBCCW system was determined using hand calculation methods based on first principles (References 10, 11). Repetitive calculations were facilitated using MathCad software.

Waterhammer magnitudes were determined using a method of characteristics (MOC) program transcribed from the work of Dr. E. B. Wylie. This program was benchmarked against the example problems in Reference 8. The MOC code was also benchmarked against test data for waterhammers resulting from the closure of steam voids between water columns.

Waterhammer loads acting on the piping system were determined using simplified methods based on the differential pressure acting across each pipe segment. A Visual Basic program was written to perform this repeated calculation for each pipe segment, and this program was verified in accordance with Altran corporation's QA program.

The structural qualification of the RBCCW piping was performed using ADLPIPE. PD-STRUDL is the structural analysis software that was used to analyze piping supports for the waterhammer loading. ALTRALUG is a software tool that was used to analyze integral welded lug attachments to the piping. All software used in this evaluation is approved for use in accordance with Altran Corporation's QA program.

Item No. 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 analysis (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.

VY Response

In addition to the parameters identified in the response to Item #1, the following conservative assumptions were used in modeling the RBCCW system response to LOOP/SLB:

1. Fluid Structural Interaction (FSI): FSI will remove energy from a waterhammer pressure pulse as the pulse travels through a piping system. FSI was conservatively not credited as a method for reducing waterhammer pulse magnitude as it travels through the RBCCW system. In specific laboratory test conditions, FSI also has the potential to amplify a pressure pulse magnitude. It was determined that these conditions do not exist in the RBCCW system and that FSI will not amplify the pressure pulse.

2. Cushioning: Dissolved non-condensable gases will be released from the RBCCW fluid when the water is boiled and steam voids are formed. These gases will reduce the impact velocity or cushion the magnitude of a waterhammer event. Credit was taken for cushioning in the determination of the waterhammer magnitude.

3. Gas Release: In order to determine the amount of cushioning, the release of non-condensables had to be determined. A very conservative model was used to estimate non-condensable gas release. First, no credit was taken for oxygen in the system, since the oxygen would be scavenged by corrosion inhibitors and the pipe wall. Therefore, only the remaining nitrogen was assumed to be liberated. Second, the amount of nitrogen assumed to be concentrated in the void corresponded to the amount of gas in the steam that could be condensed during the event, leaving behind the non-condensable gas. This model is therefore independent of the steam creation process, and this model conservatively does not credit nitrogen liberated by heating the water.

4. Sonic Velocity: The sonic velocity was conservatively assumed to be 4500 feet per second. The actual sonic velocity is likely to be lower due to two-phase flow and released non-condensables, and this would reduce waterhammer magnitude.

5. Mesh Size: The piping modeled using the MOC code was broken into 600 reaches (elements) for 886 feet of piping (approximately 1.5 feet/element). The time step for the main processor was 0.0001 seconds. These meshes and time steps are sufficiently small to capture the waterhammer behavior.

6. Flow Induced Vibration, Erosion: In many plants, two phase flow can produce the conditions that result in flow induced vibration or erosion. As described in the response to Item 1, two-phase flow is not a concern at VY and was not evaluated in response to GL96-06.

Item No. 5

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

VY Response

Application of "engineering judgement" that was of significance to the evaluation was identified as assumptions and discussed in response to Items 1 and 4 above.

Item No. 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 (e.g. surge tank level, pressures, temperatures), 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.

VY Response

No specific operating parameters, beyond the actions specified to be performed under accident conditions, are required in the analysis. The RBCCW pumps are analyzed for an automatic restart time of 73 seconds for the reasons discussed under Item 1. The condition of two pumps starting was determined to produce the bounding CCWH event. A separate case was analyzed without any pump restart, and this case was analyzed until Drywell spray is initiated, at the upper bound time of 30 minutes. This case provided bounding CIWH conditions. By analyzing both cases, no specific action is required by the RBCCW pumps.

Non-safety related portions of the RBCCW system are included in the hydraulic model. No active functions are required of the non-safety piping. Additional analysis cases were evaluated assuming breaks in the non-safety piping. Therefore, no specific operating parameters are required of the non-safety portion of the system.

Item No. 7

Implementing measures to assure that waterhammer will not occur, such as managing post-accident operation of the CACs or establishing and maintaining system overpressure requirements, is an acceptable approach for addressing the waterhammer concern. However, all scenarios must be considered to assure that the vulnerability to waterhammer has been eliminated. Confirm that all scenarios have been considered, including those where the affected containment penetrations are not isolated (if this is a possibility), such that the measures that have been established (or will be established) are adequate to prevent the occurrence of waterhammer during (and following) all applicable accident scenarios.

VY Response

No additional measures of the nature identified in the request have been implemented to manage or limit waterhammer. The analysis inputs are consistent with the current plant configuration and operating procedures, and no new assumptions were credited as part of this effort that change the current licensing basis.

Item No. 8

Confirm that the waterhammer and two-phase flow analysis 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.

VY Response

A complete failure modes and effects analysis was not performed due to the limited number of active components during the event. The only active components during the transient are the RBCCW pumps, and these were analyzed both to start and to fail to start. The plant response is consistent with the current design/configuration and operator actions are consistent with existing procedures.

No other active equipment is expected to influence the response of the RBCCW system.

Item No. 9

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.

VY Response

The primary uncertainties in the analysis exist with respect to void size, void closure location, and air release. In all cases, conservative bounding conditions were used to address these uncertainties as described below.

1. Steam void size: Conservative inputs were used to create a large steam void, capable of reaching the header pipe on the return side of the RRUs. Waterhammer occurring in this larger pipe produces the greatest structural loads on the pipe and support system. Smaller voids would close in the smaller piping leading from the RRU to the header and would significantly attenuate upon reaching the larger pipe.

2. Closure location: Uncertainties in the exact location of the column closure within the header were addressed by assuming that the closure could occur equally at any of the RRU piping connections to the header. No attenuation of the waterhammer pressure pulse between the coolers was credited.

3. Air release: As described in the response to Item 4, a conservative model was used to determine the non-condensable gas in the steam void. This model credited only the nitrogen released as steam condensed, and therefore bounded uncertainty about air released during the heating of the RBCCW water.

4. Load Combinations: The waterhammer loads were combined with seismic acceleration and seismic anchor movement loads in the analysis of the piping system in accordance with the VY FSAR, as described in the response to Item 1. This combination conservatively bounds uncertainty on the timing of this event relative to concurrent seismic events.

Item No. 10

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

VY Response

Refer to the figure included as Attachment 2 to our previous letter, BVY 98-153, dated 10/30/98.

Item No. 11

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.

VY Response

Plant modifications that have been made to address the waterhammer loading on the system consisted of changes to three pipe supports. These supports were modified to address these loads during the 1999 refueling outage.