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EDWIN I. HATCH NUCLEAR PLANT
Generic Letter 96-06
Response to Request for Additional Information

Ladies and Gentlemen:

By an electronic message dated September 19, 2002, the staff issued draft request for additional information (RAI) questions concerning the Edwin I. Hatch Nuclear Plant GL 96-06 submittal of August 6, 2002. In a subsequent telephone conversation on September 26, 2002 between the Hatch NRC Project Manager (PM) and the Southern Nuclear Operating Company (SNC) Hatch Licensing Manager, the draft RAI questions were briefly discussed and a subsequent telephone conference call was set for October 3, 2002 to discuss the RAI questions in detail. In the October 3, 2002 call, SNC agreed to provide a comparison of the calculation methodology used for Plant Hatch with the Electric Power Research Institute (EPRI) methodology for waterhammer analysis, in lieu of responding to the individual RAI questions.

The enclosure to this letter provides a detailed, point-by-point discussion of the methodology specified in Section 7.3 of EPRI Report 1006456 (Generic Letter 96-06 Water Hammer Issues Resolution – User's Manual) in relation to the Hydraulic System Transient Analysis (HSTA) program used for the Plant Hatch analysis, to document that Plant Hatch complies with the requirements of the EPRI Report.

Should you have any questions in this regard, please contact this office.

Sincerely,

Lewis Sumner

H. L. Sumner, Jr.

HLS/IFL/il

Enclosure: Edwin I. Hatch Nuclear Plant Generic Letter 96-06 Waterhammer Analysis Methodology as Compared to the EPRI Methodology

cc: (See next page)

A072

cc: Southern Nuclear Operating Company
Mr. P. H. Wells, Nuclear Plant General Manager
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Mr. Joseph Colaccino, Project Manager – Hatch

U. S. Nuclear Regulatory Commission, Region II
Mr. L. A. Reyes, Regional Administrator
Mr. J. T. Munday, Senior Resident Inspector – Hatch

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Introduction

NRC issued draft RAIs in response to the August 6, 2002, submittal by Edwin I. Hatch Nuclear Plant on the subject of GL 96-06 waterhammer. Discussions with NRC on these draft RAIs resulted in NRC requesting that Hatch explain their calculational methodology with reference to the EPRI methodology (Reference 1), specifically as outlined in Section 7.3 of this reference. This document provides Bechtel's input to Hatch to assist in responding to the NRC. The issue is the column closure waterhammer analysis as performed by Bechtel using their Method Of Characteristics based computer program Hydraulic System Transient Analysis (HSTA).

Discussion

Before discussing the detailed methodology in Section 7.3 of Reference 1, the following paragraph is quoted from Reference 1, Executive Summary Section, Page xvii, Sub-Section "Column Closure Waterhammer":

> "The column closure waterhammer (CCWH) occurs after the pumps are restarted and the final closure occurs. An accepted method of evaluation for CCWH is the method of characteristics (MOC). The method of characteristics includes closure velocity reduction due to potential pressurization of non-condensables and steam in the void and wave propagation effects in the fluid."

The Method of Characteristics is a method of solving the non-linear time dependent mass and momentum balance equations for waterhammer analysis. When this method is applied to a generalized piping flow network, flow devices such as valves, flow restriction orifices, branches, and reservoirs, etc. are generally treated as boundary conditions internal or external to the network. The presence of non-condensables (air or steam that does not condense and thus behave as a gas) can also be treated as internal moving boundaries. However, they are not necessarily an integral part of MOC. Therefore, the basic MOC without the use of non-condensables should also be an accepted (though conservative) method of evaluation for CCWH.

For the HATCH analysis, Bechtel chose not to use the presence of air in their MOC model, thereby, producing results that are conservative as compared to the results that would be obtained had the EPRI methodology been used in its entirety. The pressure in the vapor pocket was assumed to be a constant (equal to the vapor pressure as computed from the heat transfer analysis). This in effect means that the steam condensation rate is always equal to its volume reduction rate. Under this assumption, the steam pressure never increases, and therefore, steam provides no cushioning to the column collapse.

Section 2.2 of the EPRI User's Manual (Reference 1) suggests in general terms the method for waterhammer analysis as broken down by various tasks (see Reference 1 for details).

Section 7.3 of Reference 1 gives a method description for the evaluation of GL 96-06 waterhammer, as it applies to plant systems. The following are the suggested analysis steps (Reference 1 section numbers are retained for easy reference):

7.3.1. Initial Velocity

This section gives the methodology for the calculation of the initial closure velocity. The third bullet in the section states:

> "Solving the set of simultaneous equations for re-closure flow rate (this step may be performed by using commercially available steady state software for hydraulic modeling of a system. If a hydraulic model of the system is already available, then it may be performed by creating another run for the voided configuration)."

The HSTA code solves the set of simultaneous equations for re-closure flow velocity for a transient flow situation. It has also been shown to correctly predict steady state flows in a complex flow network. Therefore, it calculates the closure or initial velocity as per the methodology described above. By keeping the void pressure constant for HATCH analysis, the calculational methodology is the same as one employed in the sample calculation in section 7.4.1.of Reference 1. HSTA provides the added advantage that the void collapse location need not be assumed (as in the EPRI methodology) for a complex system with moving valves.

7.3.2. Accelerating Columns and Void Lengths

This section gives the methodology for the calculation of the lengths of the accelerating water columns and gas volume.

Since air and/or steam cushioning is not credited in the HSTA analysis for HATCH, there is no need for the calculation of the accelerating column lengths and gas volumes.

7.3.3. Mass of Gas

This section gives the methodology for the calculation of the mass of gas that gets concentrated in the void as a result of boiling/two-phase flow before the pumps are restarted.

Since air and/or steam cushioning is not credited in the HSTA analysis for HATCH, there is no need for the calculation of the mass of gas released.

7.3.4. Cushioned Velocity

Given the initial velocity, pipe size, void and water column lengths, this section gives the methodology for the calculation of the cushioned velocity using the charts given in Appendix A of Reference 1.

Since air and/or steam cushioning is not credited in the waterhammer analysis for HATCH, the final column closure velocity is conservatively the same as the un-cushioned velocity calculated by HSTA.

7.3.5. Sonic Velocity

This section gives the methodology for the calculation of the sonic velocity using Equation 5-1 and Equation 5-2 from Section 5.2 of Reference 1.

The sonic velocity in the HATCH analysis is calculated from Equations 5-1 and 5-2 from Section 5.2 of Reference 1. It is an input to the HSTA code and remains constant through out the duration of the transient analyzed.

7.3.6. Peak Pulse with No Clipping

This section gives the methodology for the calculation of the peak waterhammer pressure pulse without any clipping using the cushioned velocity, sonic speed, and Joukowski equation.

HSTA calculates the peak pressure when the column collapses. The HSTA program is based on the MOC solution of the basic mass and momentum equations. There are no correlations used. Since the Joukowski equation is derived from the unsteady mass and momentum conservation equations (Reference 2), the calculated peak pressure from HSTA is exactly the same as that given by the Joukowski equation.

7.3.7. Rise Time

This section gives the methodology for the calculation of the rise time (using Equation 5- 4 of Reference 1) knowing the cushioned velocity.

Since air and/or steam cushioning is not credited in the HSTA analysis for HATCH, the rise time is not calculated and a zero rise time is conservatively used. The pressure rise due to column closure in the absence of air and steam cushioning is instantaneous. This is conservative since the rise time can reduce the peak pressure and unbalanced forces significantly.

7.3.8. Transmission Coefficients

This section gives the methodology for the calculation of the pressure wave transmission coefficients using the methods presented in Section 5.3 of Reference 1.

A transmission coefficient (τ) is defined as the ratio of the transmitted pulse to the incident pulse at branches, area changes, and flow throttle devices. The ratio of the reflected to incident pulse or the reflection coefficient is then ($1-\tau$). HSTA calculates the transmitted and reflected pulse from first principles usage of the mass and momentum equations. The transmitted and reflected pulses as calculated by HSTA have been shown to agree exactly with those given in Section 5.3 of Reference 1. When it is necessary to calculate these coefficients outside the HSTA run (due to lumping of the piping to reduce model size), the equations in Section 5.3 are used.

7.3.9. Duration

This section gives guidance for the calculation of the pressure pulse duration using the method provided in Section 5.3 of Reference 1.

Since air/steam cushioning is not credited in the HATCH analysis, the rise time is zero and the pulse duration is essentially calculated by the HSTA code based on the wave travel times and reflections from area changes, etc.

7.3.10. Peak Pressure Clipping

This section gives guidance for the calculation of the peak pressure pulse considering duration using the method provided in Section 5.3 of Reference 1.

Peak pressure clipping is a result of the reflection of the pressure pulse before the peak pressure is developed due to a column collapse. Air/steam cushioning results in a slow rise in pressure. When air/steam cushioning is not credited, as in the HATCH analysis, the peak pressure is reached instantaneously and there is no peak pressure clipping. As pressure clipping reduces the peak pressure, ignoring this phenomenon leads to conservative results for HATCH.

7.3.11. Pressure Pulse Shape

The pressure pulse shape is the graphical representation of the pressure versus time. The pressure rises from its steady state value to it peak value during the "rise time," stays at the peak value until a reflection comes back when it decreases to its steady value over the time equal to the rise time.

In the HATCH analysis, the rise time is zero as described in 7.3.7 above. Therefore, the pulse shape is calculated by HSTA as an instantaneous pressure increase to the peak value and remaining at that peak value until the wave reflection when it reduces to a lower value.

7.3.12. Flow Area Attenuation

Using the transmission coefficients determined in Section 5.3 of Reference 1, this section gives a methodology to calculate the attenuation of the pulse as it travels through the system. In this methodology, the pressure pulse shape is assumed to remain unchanged as it travels in the system.

As described in 7.3.8 above, HSTA calculates the transmission coefficients internally. Therefore, the attenuation of the pressure pulse, as it travels in the system and as it encounters flow area changes, is automatically computed during the HSTA computations. As such, assumptions are not required as to the shape of the pulse as it travels in the system.

Conclusions

From the above discussion, the following conclusions can be drawn with regard to the waterhammer analysis methodology used for HATCH as compared to the EPRI analysis methodology in Reference 1:

1. The use of the Method of Characteristics is an acceptable method for the evaluation of CCWH, as per Reference 1. This method can be applied to the extent of calculating the un-cushioned initial velocity, as was done for the HATCH, in which credit was not taken for the air/steam cushioning of the column collapse velocity.
2. The peak surge pressure, resulting from a collision of two columns at an initial velocity equal to their relative velocity just before impact, is calculated internally by HSTA. Since the Joukowski equation (recommended in Section 7.3.6 Reference 1) is derived from the transient flow equations, the calculated peak pressure from HSTA is exactly the same as that given by the Joukowski equation. Therefore, the peak pressure calculation is consistent with the EPRI methodology.
3. The sonic velocity input in the HSTA model is calculated as per EPRI recommended equations in Section 5.2 of Reference 1.

4. Peak pressure clipping is not credited in the HATCH waterhammer analysis.
5. No credit is taken for "rise time" of the pressure pulse. This introduces a very significant level of conservatism in the calculation of the unbalanced fluid forces that are used for the structural integrity evaluation of the system.
6. Pressure wave transmission and reflection coefficients at flow area changes are calculated by HSTA from the first principle equations used for the computer program. These have been proven to give the same results as the methods presented in Section 5.3 of Reference 1. Therefore, the EPRI methodology is effectively used in this respect. This conclusion also applies to flow area attenuation calculations.
7. The pressure pulse shape and duration are calculated by HSTA. These depend on the system model lengths and sonic velocity. Since the sonic velocity is calculated as per EPRI recommended equations, the pressure pulse shape as calculated by HSTA is consistent with the EPRI methodology.

References

1. "Generic Letter 96-06 Waterhammer Issues Resolution. User's Manual - Proprietary", EPRI, Palo Alto, CA: 2002. 1006456.
2. E. B.Wylie and V. L. Streeter, FLUID TRANSIENTS IN SYSTEMS, Published by Prentice Hall, Upper Saddle River, NJ 07458, 1993.