SAFETY EVALUATION REPORT

STEAM GENERATOR WATER HAMMER

CALVERT CLIFFS UNITS 1 AND 2

OCTOBER 1979

1.0 INTRODUCTION

Steam generator water hammer has occurred in certain nuclear power plants as a result of the rapid condensation of steam in a steam generator feedwater line and the consequent acceleration of a slug of water which, upon impact within the piping system, causes undue stresses in the piping and its support system. The significance of these events varies from plant to plant. Since the total loss of feedwater could affect the ability of the plant to cool down after a reactor shutdown, the NRC is concerned about these events occurring, even though an event with potentially serious consequences is unlikely to happen.

Because of the continuing occurrence of water hammer events, the NRC, in September 1977, informed all PWR licensees that water hammer events due to the rapid condensation of steam in the feedwater lines of steam generators represented a safety concern and that further actions by licensees for Westinghouse and Combustion Engineering designed nuclear steam supply systems are warranted to assure that an acceptably low risk to public safety due to such events is maintained.

Various approaches have been proposed by the Licensees to reduce the potential for steam generator water hammer in the feedwater piping. Considered among the acceptable ones are:

(1) to keep the feedwater pipes filled with water under all normal and transient conditions; and

(2) to prevent subcooled water from entering the feedwater piping while steam is present in the feedwater pipes.

We have reviewed the licensee's submittals dated March 15, 1979 and October 15, 1979, and other pertinent documents listed in Section 4.0 regarding the steam generator water hammer events at Calvert Cliffs Units 1 and 2.

The report summarizes our evaluation of these submittals and presents our conclusion with regard to their acceptability.

2.0 EVALUATION

2.1 FEEDWATER SYSTEM DESCRIPTION

The feedwater system is designed to provide an adequate supply of feedwater to the secondary side of the two steam generators during all operational conditions. The two main feedwater pumps are each one-half of the full power capacity. Each pump has a capacity of 15,000 gpm at 2350 feet total dynamic head (TDH). The

pumps are each driven by a separate variable speed steam turbine Feedwater from the main feedwater pumps is supplied to a main header via the high pressure heaters. The main header splits into two 16-inch feedwater lines to supply a feedring inside each steam generator. Feedwater is discharged inward through inverted "L" shaped tubes at the top of the feedring. The horizontal run of feedwater piping just up stream of the feedring is about 12 feet.

The auxiliary feedwater system is designed to provide feedwater for the removal of decay heat and to cool the primary system to 300°F upon loss of main feedwater flow. The system may also be used for normal system cooldown.

Auxiliary feedwater can be supplied by two non-condensing steam turbine-driven pumps. Each of the pump units has a capacity of 700 gpm at 2490 feet TDH which is sufficient for the removal of decay heat. The main water supply source for the system is the 300,000 gallon condensate storage tank. The flow is discharged from the pump to a common line which branches into two 4-inch lines to each of the two steam generators. The horizontal piping upstream of the steam generator nozzle contains only an elbow and is about 6-inches long.

Unlike all Westinghouse plants and all other CE plants, the auxiliary feedwater system at Calvert Cliffs feeds the steam generators via a separate feedring. It is located about one foot below the main feedring. There is no connection or path between the main feedwater and auxiliary feedwater piping. As a result, the cold water delivered by the auxiliary feedwater system can not enter the main feedwater piping.

The auxiliary feedwater system is initiated by remote manual control. The system is normally used for either of the following conditions:

(1) Loss of off-site power, or

(2) Complete loss of feedwater flow.

Under proposed procedural changes by the licensee in their October 15, 1979 submittal, the auxiliary feedwater system will also be used if both of the following conditions exist:

(a) the main feedring is uncovered; and

(b) the main feedwater flow is stopped, interrupted or decreased to less than 5% of rated flow.

2.2 WATER HAMMER EXPERIENCE

Four water hammer events have occurred at Calvert Cliffs plants since 1974 including preoperational tests. Two of the events were reported in some detail:

(1) At 9:04 a.m. on May 13, 1975, Unit 1 reactor tripped on loss of feedwater. Approximately 40 minutes after the trip, three water hammers were experienced in the feedwater piping as the main feedwater was being re-established to the steam generators.

(2) On May 19, 1976, a preoperational test was performed on Unit 2 to determine the effectiveness of the addition of internal standpipes to the new main feedring. With the reactor in mode 3, steam generator level was decreased to 85" via the blowdown system. Thirteen minutes after securing blowdown, feedwater was introduced into the steam generator at 5% of rated flow via the main feedring. As water reached the feedring, water hammer occurred.

A review of these water hammer events indicates that water hammer could occur when the water level is below the feedring if a cut-off of feedwater were followed by restarting of the main feedwater flow. Even with top discharge devices on the feedring, the second event at Unit 2 showed that the potential for water hammer might still exist under the conditions of stop and restart of main feedwater flow. This is because the feedring can still be drained through the thermal sleeve even though the drainage rate is much less than that from a bottom discharge feedring.

2.3 MEANS TO REDUCE THE POTENTIAL FOR WATERHAMMER

The following means are now employed to reduce the potential for damaging waterhammer:

(1) "L" tubes on the feedring, and

(2) Procedures that require that the auxiliary feedwater system be used to recover the steam generator water level following a reactor trip.

In its recent submittals dated March 15, 1979 and October 15, 1979, the licensee proposed the following modification to the procedural changes, i.e.,

> "Given the initial condition that the steam generators are being supplied with feedwater from the main feedwater system via the main feedring, we propose to continue to supply feedwater using this path provided the following conditions do not exist simultaneously:

a) The volumetric flow rate of main feedwater being supplied to a steam generator drops below 5 percent of full (100%) feedwater flow; and

b) The water level in the steam generator drops below the top of the main feedring.

If the above conditions exist simultaneously, we propose to cease feeding the steam generator from main feedwater and to commence feeding the steam generator using the auxiliary feedwater system via the separate and independent auxiliary feedring at such time as it is determined that this flow path should be initiated based on the operating conditions in effect at that time.

When the steam generator water level has once again risen above the top of the main feedring, the normal feed path using the main feedwater system will be permissable."

The intent of the L-tubes is to keep the main feedring filled with water under all normal and transient conditions so that conditions conducive to water hammer would not occur in the feedwater piping. However, should a leakage path develop in the feedring, a complete interruption or loss of feedwater can cause a partial or complete draining of the main feedrings. That could in turn result in conditions conducive to waterhammer if cold water were ever reintroduced into the steam generator via the main feedwater piping.

For Calvert Cliffs plants, a small leak path is found behind the thermal sleeve at the feedwater nozzle connection. A small drainage rate in the order of 10 to 20 gpm could occur if the steam generator water level drops below the main feedring. A feedwater flow greater than the drainage would be needed to keep the main feedring full of water.

Under the proposed operational procedure, the main feedwater system will be used but must be maintained at a rate of at least 5% of full flow when the steam generator water level drops below the feedring. The 5% flow is approximately 750 gpm and is more than sufficient to keep the main feedring full of water.

Under the same proposed procedure, the auxiliary feedwater system must be used to feed the steam generator if the main feedwater is decreased below 5% of full flow and concurrently the steam generator water level drops below the main feedring. This procedure would prevent the cold condensate water from reentering drained, steam-filled main feedrings. Consequently,

it would eliminate the potential for waterhammer in the main feedwater piping.

2.4 SUSCEPTIBILITY OF AUXILIARY FEEDWATER SYSTEM TO WATERHAMMER

Calvert Cliffs plants have the unique design of separate bottom-discharge feedrings for the auxiliary feedwater system. Because of that, the conditions conducive to waterhammer such as drained feedrings may be encountered in the operation of the auxiliary feedwater system. However, the potential for damaging waterhammer would be reduced if either or both of the following conditions exist:

(1) The feedwater is supplied at a sufficiently high flow rate such that partially filled piping and formation of a slug of water in the piping would not be likely to occur.

(2) The horizontal piping is sufficiently short so that a damaging waterhammer would not be likely to result.

Our evaluation of the Calvert Cliffs auxiliary feedwater system indicates that the system operation and piping configuration meet both of the above conditions. The auxiliary feedwater is normally supplied about 9 ft/sec which we believe is sufficient to preclude a partially filled condition in the piping. In addition, the horizontal piping is the shortest length practical and contains only an elbow attached to the steam generator. Therefore, we conclude that a damaging waterhammer would be very unlikely to occur in the auxiliary feedwater system. This conclusion has been substantiated by the plant operating experience. Since November 30, 1976, the auxiliary feedwater system has been operated several times a year but has not experienced any waterhammer.

3.0 CONCLUSION

The licensee has installed top discharge main feedwater rings (L-tubes) in all the steam generators at the Calvert Cliffs Generating Station and also committed to shift to the auxiliary feedwater system when the operating conditions require.

Based on our knowledge of waterhammer phenomena and our review of the licensee's submittals, we have concluded that the provisions for minimizing the likelihood of steam generator water hammer events in the feedwater systems are adequate and acceptable. We

therefore find that steam generator water hammer presents no undue risk to the health and safety of the public resulting from the continued operation of the Calvert Cliffs Stations.

4.0 REFERENCES

1. Letter dated July 8, 1975 from BG&E to A. Giambusso, NRC.

2. Letter dated November 13, 1978, from BG&E to H. Denton, NRC.

3. Letter dated February 9, 1979, from R. Reid to BG&E.

4. Piping Diagram 60-227-E, Condensate and Feedwater Systems.

5. Calvert Cliffs FSAR Section 10, Main Feedwater System and Auxiliary Feedwater System.

6. Piping drawing SK-M-600 (Rev. 1) Main Feedwater Piping.

7. License Condition 2.C.3 on Steam Generator Water Level Rise Rate.

8. Letter dated July 31, 1979, from BG&E to NRC.