INITIAL CONSIDERATION OF THE POTENTIAL FOR WATER HAMMER IN THE STEAM CONDENSING MODE OF RHR SYSTEM OPERATION FOR BWR NUCLEAR PLANTS

by the

Office for Analysis and Evaluation

of Operational Data

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NOTE: This report documents results of studies completed to date by the Office for Analysis and Evaluation of Operational Data with regard to a particular operating event. The findings and recommendations contained in this report are provided in support of other ongoing NRC activities concerning this event. Since the studies are ongoing, the report is not necessarily final, and the findings and recommendations do not represent the position or requirements of the responsible program office of the Nuclear Regulatory Commission.

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1. INTRODUCTION

A recent review of Licensee Event Reports (LERs) has revealed that a relatively large number of water hammer events have occurred during the steam condensing mode of RHR system operation for BWR nuclear plants. Based on the review of LERs, it is not clear that the causes of these water hammer events and their relationship to the plant operating conditions have been fully analyzed by the affected licensees.

Since water hammer is an event of concern and could adversely affect the operation of safety-related systems, the Office for Analysis and Evaluation of Operational Data (AEOD) has initiated case studies regarding certain of these events. The purpose of such studies is to identify the causes of the water hammer events and to assess certain scenarios or operational sequences from which other conditions or situations conducive to water hammer could result.

In order to conduct a meaningful study of the potential for water hammer in the steam condensing mode of RHR system operation, an effort has been made to acquire information such as the RHR system design, physical arrangement and associated operating procedures. The information needed for doing the review has not been received yet and, therefore, a detailed study cannot be performed at this time. Consequently, only a brief discussion of the problem and operating experiences is provided below for anyone who may wish to enter the subject investigation.

2. OPERATING EXPERIENCES

2.1 Brunswick 1 (Docket No. 50-325)

- March 15, 1977 (LER 77-24)

  With the reactor at power in the run mode, an auxiliary operator found a damage snubber on the steam condensing line to 1A RHR heat exchanger. This snubber was damaged again on March 31, 1977 when RHR pump 1A was started for torus cooling. These damages were apparently caused by water hammer.

- November 9, 1977 (LER 77-98)

  With the reactor at power in the run mode, a snubber on the steam condensing line was found inoperative by an auxiliary operator. The broken snubber was apparently caused by water hammer.

- December 20, 1977 (LER 77-118)

  During a routine plant inspection by an operator, a snubber on the RHR steam condensing line was found broken. It was determined that water hammer resulting in excessive loading on the shock suppressor had caused the failure.

2.2 Brunswick - 2 (Docket No. 50-324)

- December 29, 1976 (LER 76-164)

  With the reactor at power in the run mode, a RHR shock suppressor was found with a broken shaft. The broken suppressor was caused by water hammer in the 2A heat exchanger due to a steam bubble in the heat exchanger during RHR pump start.

- February 8, 1977 (LER 77-6)

  With the reactor at power in the run mode, an auxiliary operator found a snubber on the B RHR steam condensing line vibrating loose from its anchor.

- April 13,1977 (LER 77-29)

  With the reactor at power in the run mode, an auxiliary operator discovered the structural attachment for a hydraulic snubber was sheared in half. It was believed that a water hammer occurred when RHR loop B was placed in torus cooling, stressing the structural attachment.

2.3 Duane Arnold (Docket No. 50-331)

- September 27, 1977 (LER 77-78)

  During an unrelated inspection, damage was noted on HPCI to RHR piping insulation. This event apparently resulted from hydraulic shock in HPCI steam supply piping which occurred on June 11, 1977. The RHR heat exhanger steam condensing supply line is tied to the HPCI steam supply line.

2.4 FitzPatrick - 1 (Docket No. 50-333)

- July 20, 1975 (LER 75-63)

  A pipe restraint on RHR steam supply to "A" heat exchanger pulled from the building wall. It was determined that water hammer had occurred while warming up the HPCI steam supply line to the HPCI turbine. The RHR heat exchanger steam supply taps off the HPCI steam piping.

- September 7, 1975 (LER 75-73)

  Several pipe restraints located on the HPCI steam line to the RHR heat exchanger were found damaged. It was determined that water hammer during warm up of the HPCI steam line caused the restraint damage.

3. DESCRIPTION OF THE STEAM CONDENSING MODE OF OPERATION

During reactor isolation, the main steam system may be relieved to the suppression pool (via relief valves) where the steam is condensed and subcooled. However, there is a limit to the amount of decay heat which can be dumped to the pool. The suppression pool temperature must at all times remain within an acceptable range such that the temperature rise due to any subsequent loss-of-coolant accident blowdown would not cause the pool temperature to exceed 170°F.

The steam condensing mode of RHR system operation (Figure 1) must be manually started as soon as possible after isolation of the primary system from the main condenser. In the steam condensing mode, steam from the reactor is admitted into the RHR heat exchanger shell side where it is condensed by the RHR service water system. The condensate from the heat exchangers returns to the torus by gravity or to the suction of the RCIC pump where it can be returned to the reactor.

When operating the RHR heat exchangers in the steam condensing mode, steam at reactor pressure and temperature is taken from the reactor vessel via a connection from the steam supply line to the HPCI turbine and reduced to 200 psig through a throttling valve before it is admitted to the RHR heat exchanger shell side.

Before the steam condensing mode of operation can be initiated, a controlled warm up on the RHR heat exchangers and other components involved in the operation is performed. The steam condensing mode is limited to use only when the HPCI steam line is not isolated. Any HPCI steam line isolation signal renders the steam condensing mode inoperable.

4. PROBLEM DISCUSSION

From the review of operating experiences, we have found that water hammers have occurred in the steam condensing mode of RHR system operation. Although a detailed study of these events could not be performed at this time, a review of the RHR system design indicates that conditions conducive to water hammer could occur if the RHR system is used in its steam condensing mode. These conditions are briefly discussed below:

- During the initiation of the steam condensing operation, a controlled warmup on the affected RHR system is required. Conditions conducive to water hammer could result if large steam flow is inadvertently admitted into the RHR heat exchanges before the controlled warm up is accomplished.

- If a small leak develops through the valve from the steam supply line to the RHR heat exchangers, a local heating of RHR system water will occur. A steam bubble may form in the RHR system thereby causing water hammer when the RHR system pump starts.

- After completing the steam condensing mode of RHR system operation, a large portion of the RHR system will be steam filled. Inadequate refilling and venting procedures could result in large voids in the RHR system thus causing water hammer when the RHR pump starts.

- There is also a possibility that the water hammer will occur automatically in the event of a loss-of-coolant accident (LOCA) while the RHR system is operating in the steam condensing mode. In the event of LOCA, initiation of the LPCI system requires automatic initiation of the RHR pumps. If the RHR system is already operating in its condensing mode, a large section of the RHR system is voided and automatic startup of the RHR pump can cause severe water hammer in the entire RHR system.

- There are two normally closed valves located on the steam condensing line separating the RHR system from the main steam system. During normal power operations, steam at reactor pressure and temperature is on one side of these valves; while on the other side is RHR water at much lower pressure and temperature. Inadvertent opening of these two valves could cause severe pressure transients or damaging water hammer in the RHR system. On the other hand, during plant startups while warming the HPCI system at low pressure, cold RHR water could flow back into the HPCI steam supply line due to leakage or inadvertent opening of the condensing line valves. It is known from operating experiences that cold water entrainment into a steam line could cause water hammer.

5. CONCLUSION

From this brief review of the water hammer events and the RHR system design, it is apparent that the function of steam condensing by the RHR heat exchangers can create precursor situations causing water hammer during operation of the RHR systems. It could potentially affect the intended safety function of the LPCI system in the event of LOCA. Therefore, continued investigation of this problem should be pursued to find means of reducing the likelihood of water hammer in the overall operation of the RHR systems.

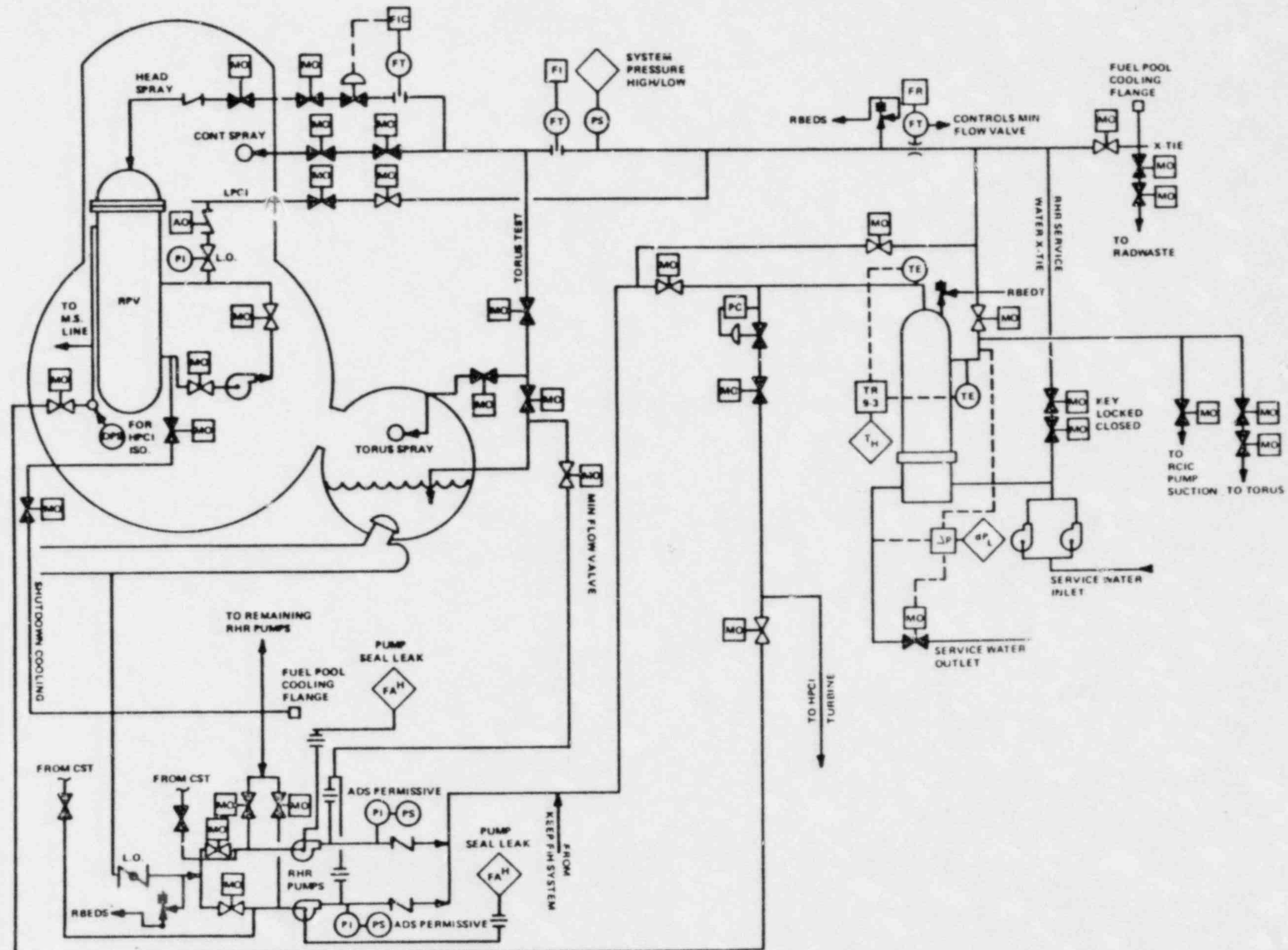

Figure 1 RHR Functional Drawing With Steam Condensing Mode