AEOD ENGINEERING EVALUATION REPORT*

UNIT: Edwin I. Hatch 2
DOCKET NO.: 50-366
LICENSEE: Georgia Power Company
NSSS/AE: General Electric/Bechtel

EE REPORT NO.: AEOD/E411
DATE: May 22, 1984
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SUBJECT: FAILURE OF ANTI-CAVITATION DEVICE IN RESIDUAL HEAT REMOVAL SERVICE WATER (RHRSW) HEAT EXCHANGER OUTLET VALVE

EVENT DATE: August 13, 1982 (LER 82-085/03X-1)

SUMMARY

Licensee Event Report 82-085 for Hatch 2 describes an event in which two pumps of the Residual Heat Removal Service Water (RHRSW) system failed to meet minimum flow requirements and were declared inoperable during a functional test. Since both pumps served in the same loop of the RHRSW system, only one of the two RHRSW loops became inoperable. The cause of this event was the failure of an anti-cavitation device which was installed in the flow control valve. This was a recurrent event; two previous events at Hatch 2 involved similar failure of anti-cavitation devices installed in the same system. In one of the events, one loop of the system became inoperable; in the other, both loops were declared inoperable. Two additional events at Salem 1 found during this review have had similar failure of anti-cavitation devices. The damaged anti-cavitation devices and their associated control valves used in these two units are different in size but were made by the same manufacturer.

The apparent cause of damage to the anti-cavitation devices was erosion due to sand suspended in high velocity fluid. The sand suspended in the raw water used for cooling was assumed to have settled out before the raw water was pumped into the cooling systems. Therefore, the condition of tube erosion caused by sand has not been fully specified in the design and qualification of these devices. The damage of anti-cavitation devices could be attributed to inadequate specification of operational conditions. The flow control valve of the RHRSW system has a dual function to regulate service water flow for cooling during a reactor shutdown and to maintain a positive differential pressure between the Residual Heat Removal (RHR) system and RHRSW system in the RHR heat exchangers to prevent primary to secondary side leakage. The damaged devices have caused their associated control valves to be stuck, and thus the control valves would not be able to regulate properly to perform their safety functions to regulate flow and differential pressure. As a result, the operation of RHRSW system could be restricted or be totally lost, and radioactivity may possibly be released into the environment in the event of tube leakage in the RHR heat exchanger. Since the anti-cavitation device was installed in the port of control valve, the damage or wear of the device could not be observed without disassembly of the valve flanges. This suggests that an inservice inspection and maintenance program is needed to detect damage before it could cause adverse effects on the control valve.

*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

This report suggests that NRR consider the following actions:

1. Review the compatibility of the anti-cavitation device for use in raw water application.

2. Address inservice inspection and maintenance requirement for anti-cavitation devices in plant technical specifications.

3. Clarify the condition in which an anti-cavitation device should be included in the active valve operability assurance program for its associated valve.

INTRODUCTION

This engineering evaluation reviews a report of an event at Hatch 2 described in LER 82-85, which involved the failure of Residual Heat Removal Service Water (RHRSW) pumps to meet minimum flow requirements. Failure of these pumps to operate was attributed to failure of an anti-cavitation device in the control valve. This control valve is installed in the service water outlet of a RHRSW heat exchanger. This was a recurrent event. Two similar events have previously occurred in the same system and were reported in LER 81-098 and LER 78-046. These latter two events are similar to the one reported in LER 82-85 and involved broken and bent tubes in an anti-cavitation device which resulted in flow restriction and failure of the RHRSW pump to operate.

The anti-cavitation device is installed within the control valve to prevent cavitation damage to the valve and adjacent components. Cavitation is formation and subsequent collapse of vapor bubbles in the liquid flow stream, within valve pathway, due to pressure fluctuation as a result of throttling of the valve. The collapsing bubbles generate a crackling noise and vibration, and can mechanically damage valve components and the pipe wall. This damage can lead to failure of the control valve, particularly the valve disc and seat ring. The anti-cavitation device, which was installed in the control valve of the RHRSW system at Hatch 2, consisted of a bundle of tubes attached to a flange. The tubes can prevent the flow stream from reaching its potential minimum cross sectional area as it passes through the valve, thus maintaining maximum pressure internal to the valve and reducing the likelihood of vapor bubble formation.

LER 82-85/03X-1 dated June 30, 1983, provides a description of an event involving the failure of RHRSW pumps which occurred at Hatch 2 on August 13, 1982. With the plant in steady state full power operation, the RHR service water pumps A and C were declared inoperable as a result of their failing to meet minimum flow requirements during a periodic functional test for system operability. The RHRSW system has two independent loops; each loop contains two pumps. Since pump A and pump C are both in one loop (loop A), this loop was declared inoperable. After adjusting the flow control valve, a second attempt at the pump operability also failed. Subsequent licensee investigation revealed that the cause of this event was the failure of the anti-cavitation device in a flow control valve. The device was found to have both broken and bent tubes which restricted the flow. The device was replaced with a new one and a follow-up test was satisfactory. The architect engineer indicated that the apparent cause of damage was due to normal wear and, therefore, recommended that the device should be insnected and replaced as necessary at approximately two-year intervals. The licensee subsequently incorporated this recommendation into the plant maintenance program.

A similar event occurred on October 7, 1981, in the redundant loop and was reported in LER 81-093 dated November 5, 1981. As described, during normal operation while performing the RHR service water pump operability test, pumps B and D were found to be incapable of establishing the required flow. The associated RHRSW loop was thus declared inoperable. Further review of this event revealed that restricted flow was caused by a damaged anti-cavitation device within the discharge control valve which is located in the outlet of the RHR heat exchanger B. The tubes on the upstream side were found to be broken and/or clogged with debris. When an investigation was made to determine the source of the debris which had clogged some of the tubes, one of the two parallel strainers in this loop was discovered to be ruptured. Since a replacement was not available, a temporary fix was to cut the damaged end of the tubes off. The modified device was then installed after the system was flushed to remove any additional debris. The loop was returned to service on October 10, 1981. As this loop (loop B) was identical to loop A, the flow in the loop A was checked. The results of the check was that no restriction or reduction in flow were evident. The architect engineer believed that the apparent cause of tube damage was due to normal wear. Accordingly, they recommended that the device should be inspected, and replaced as necessary, at approximately two-year intervals. In May 1983, the devices in both loops were inspected and found acceptable.

The third event occurred at Hatch 2 on September 26, 1978, and was reported in LER 78-046. The event involved flow restriction in both loops of RHRSW system. While performing start-up testing, it was discovered that the rated flow with two pumps running in one loop could not be achieved for either of the two loops. The condition constituted a degraded mode of operation. The restricted flow was caused by damaged anti-cavitation devices within the 10" control valves. These devices had one-third to one-half of their tubes broken off and/or clogged. Before new devices could be procured, a temporary design, adding an orifice at the valve, was installed. New devices were expected to be installed by November 10, 1978.

DISCUSSION

These three events suggest a common cause failure mode for the anti-cavitation device. The cited damage, which restricted the flow and caused the pumps to be inoperable, included clogged, bent and broken tubes. The apparent cause of this damage was the tubes being eroded or wearing due to high velocity river water containing sand and/or sludge. The velocity of the fluid accelerates as it flows through the restriction area in the control valve, reaching maximum velocity at the location of the tube bundle. The fluid which contained a high concentration of sand was very abrasive at the high velocity. Prolonged abrasion of the tube wall at specific localized areas could produce excessive localized thinning on the tube and result in reduction of strength of the tubes. It appears that the sand and/or other particulate suspended in the water of the Altamaha River was assumed to have settled out or to have been screened before the cooling water reached the pump suction. Therefore, the content of sand and its concentration in the cooling water had not been fully specified or considered in the operational condition for the tube bundle design. The settling of sand suspended in the river depends on the river flow conditions; as the velocity of flow is increased due to meteorology condition and especially when the velocity is high enough to generate a turbulent-flow regime, the turbulent eddies will tend to maintain the sand or particles in suspension as well as to transport them in the mainstream to the intake of pump suction. Hence, the suspended sand will flow with the cooling water and reach the control valve.

The control valves used in the RHRSW system at Hatch 2 are Fisher Vee-ball control valves. These are a ball type of throttle valve with a V-notch ball design. These valves, similar to a plug valve, are quick opening needing only a quarter turn of its V-notch ball from full open to full close. The configuration of waterway in the valve is essentially an unrestricted, straight through flow design providing greater flow than other types of valve to ensure a non-clogging operating for raw water application. With the installation of an anti-cavitation device within the valve as shown in Fig. 1, that part of the control valve became somewhat restricted, creating a dead end to stop and accumulate sludge or impurities suspended in incoming cooling water. Once the accumulation reaches the port sealing surface, it is likely that the sealing surfaces could be impaired and become restricted due to the movement of V-notch ball that could render the control valve inoperable. Furthermore, if some of the tubes become bent in the installation, the bent tubes tend to rest on the sealing surface or stick to the V-notch ball, either of which could obstruct rotation of the V-notch ball and cause the valve to be stuck. Should the valve be stuck in the closed position, the system, which utilizes the control valve, would become inoperable due to no flow in the system.

Two events involving sticking of the control valve in the closed position as a result of damaged anti-cavitation devices occurred at Salem 1 and were reported in LER 82-37 and LER 81-69. The control valves involved in those two events were also Fisher Vee-ball control valves with an anti-cavitation tube bundle similar to that used in the RHRSW system at Hatch 2. The sizes of the valves were 8" and 16". Both valves were used in the service water system which uses raw water pumped from the ocean bay. The 8" valve was a flow control valve to control the service water flow to the containment fan coil unit. The tube bundle of the anti-cavitation device in this valve was found extensively damaged by erosion and corrosion. The 16" valve was used to control flow through a component cooling water (CCW) heat exchanger. The operator noticed the valve would not open while he was trying to adjust service water flow through the CCW heat exchanger. A subsequent inspection revealed that the sealing surface was marred, restricting movement of the valve. Based on the manufacturer's evaluation, the licensee redesigned the system to eliminate the 16" control valve from the system due to material degradation of the anti-cavitation device.

The flow control valves at Hatch were installed in the outlet of RHRSW heat exchanger. The function of the valves is to control the service water flow for cooling during a reactor shutdown and also to maintain the pressure on the service water side a minimum 20 psi above that on the RHR side of the heat exchanger at all flow rates, thereby preventing reactor water leakage into the service water system. Damage of the anti-cavitation device could result in either degrading or disabling the operation of the control valve, which in turn will cause flow restriction in the system. Once the flow is restricted to lower than the minimum flow requirement, the pumps of the system will be considered inoperable. This constitutes a potential threat to the plant safe shutdown operation during normal and accident conditions. Additionally, failure of control valves to function properly will likely make the system unable to maintain sufficient pressure above that of the RHR system in the RHR heat exchanger which may result in the release of radioactivity into the environment through the discharge of service water in the event of tube leakage in the RHR heat exchanger.

NRC Regulatory Guide (Refs. 1, 2, and 3) and Standard Review Plan (Refs. 4, 5, 6, and 7) define requirements pertaining to design qualification, acceptance test, functional specification, and inservice testing for active valve assemblies in systems important to safety. These requirements are provided to ensure valve operability in various operational conditions. However, none of these requirements provide definite guidance as to identification of the relationships between separate accessories and valve operation which require the separate accessories to be considered as a part of valve assembly in meeting the operability assurance requirements for active valve. It appears that due to lack of specific requirements in the regulatory review guidance, the anti-cavitation devices such as tube bundle used at Hatch 2 and Salem 1 were treated as a separate item and not covered in the safety programs of the active valve even though the device has adverse effects on operation of the valve.

FINDINGS AND CONCLUSIONS

Based on the preceding discussion and related follow-up activities in this evaluation, the following findings and conclusions are provided:

1. Similar damage to anti-cavitation devices have occurred to control valves of different size at two units, Hatch 2 and Salem 1. The damaged devices were found to have broken, bent and/or clogged tubes.

2. The anti-cavitation devices used in these two units are identical and manufactured by Fisher Valve Company for use in its Vee-ball control valve to eliminate cavitation created from valve throttling. The device basically is a bundle of tubes.

3. The Fisher Vee-ball control valve provides a non-clogging flow path ideal for raw water application. However, with the installation of anti-cavitation tube bundles, the port of the valve seems to be a place to stop and accumulate sludge impurities suspended in passing raw water. High accumulation of sludge could damage the port sealing surface, restricting movement of the valve.

4. The anti-cavitation devices used in Hatch 2 were installed in the 10" control valve of RHRSW system using raw water from the Altamaha River for cooling, while that of Salem 1 were installed in 8" and 16" control valves in the services water system using ocean water for cooling. The 8" valve was installed in the containment fan coil unit. The 16" valve was in a component cooling water heat exchanger.

5. The tubes of these anti-cavitation devices appear susceptible to damage caused by erosion from sand suspended in high velocity fluid. The licensee evaluation concluded that the cause of tube damage at Hatch 2 was tube erosion from high velocity river water containing sand and sludge.

6. Both broken and bent tubes of the anti-cavitation devices obstructed the motion of the control valve and caused the control valves to be stuck at both units (Hatch 2 and Salem 1) which resulted in flow restriction and even complete loss of flow in the service water cooling systems.

7. Three events occurred at Hatch 2. Among those three events, two events resulted in failure of operation in one of the two trains of RHR system and one event resulted in failure of operation in both trains.

8. Two events occurred at Salem 1. The control valves were found stuck in the closed position as a result of damaged anti-cavitation devices. The licensee redesigned the system of component cooling water heat exchanger to eliminate its 16" control valve from the system.

9. The architect engineer of Hatch 2 has determined that the apparent cause of damage was due to normal wear under this particular plant operational condition. Therefore, the device should be inspected and replaced as necessary at approximately two-year intervals.

10. Whether the anti-cavitation device is unique to the Fisher Control Valve or is also being used with valves other than the Fisher is not known. In this review, a search of the LER data base file could not identify sufficient information to determine how widespread the device is being used or whether the damage to this device is also widespread. This may be due to the manner in which this item was categorized and/or coded into the computer data base systems.

It appears that erosion was the cause of anti-cavitation device damage. The tube erosion by sand suspended in high velocity cooling water presents a loading condition which had not been fully specified in the design and qualification requirements of anti-cavitation devices. This inadequate specification could contribute to the damage of devices resulting in inoperability of the system. Similar damage has occurred to the devices attached to different size of control valves at two units. The damage in one of these two units is a repetitive event. This represents a potential generic problem with this product. It is evident that the damage of the anti-cavitation device could cause the control valve to be stuck and result in either complete loss or degraded system function. The control valves described in this evaluation are used in engineering safeguard systems. Degradation or loss of operation in these systems will constitute a potential threat to the plant safe shutdown operation during normal and accident conditions. In addition, the RHRSW system of Hatch 2 is designed to operate with the service water pressure above that of the RHR system in the RHR heat exchanger to ensure an in-leakage in case of tube leaking. One of the safety functions of the control valve in the RHRSW system is to maintain a positive differential pressure. The stuck control valve would not regulate properly to maintain sufficient differential pressure. As a result, radioactivity could be released into the environment through discharge of service water in the event of tube leaks inside the RHR heat exchanger.

In view of the above, it seems appropriate to inform NRR of the specification inadequacy of anti-cavitation devices and their adverse effects on operation of control valves. Accordingly, it is suggested that NRR consider the following actions:

1. Review whether the tube type of anti-cavitation device is compatible for use with ball valves in raw water application in which the raw water occasionally contains sand and sludge in high concentrations. The review should include impact of functional effect on valve operation, damage resulting from cavitation induced by valve misuse with throttling outside the specified range, and suitability of material.

2. In any case, if the anti-cavitation device should continue to be used in raw water application, an inservice inspection and maintenance requirement should be provided in the plant technical specification to ensure the system safety function can be performed without undue risk.

3. Since the damaged device has adverse effects on the operation of the associated valve, the device should be identified in the active valve operability assurance program of the valve for review. This could be accomplished by clarifying the definition of active valve assemblies specified in RG 1.148 (Ref. 3) to include anti-cavitation device.

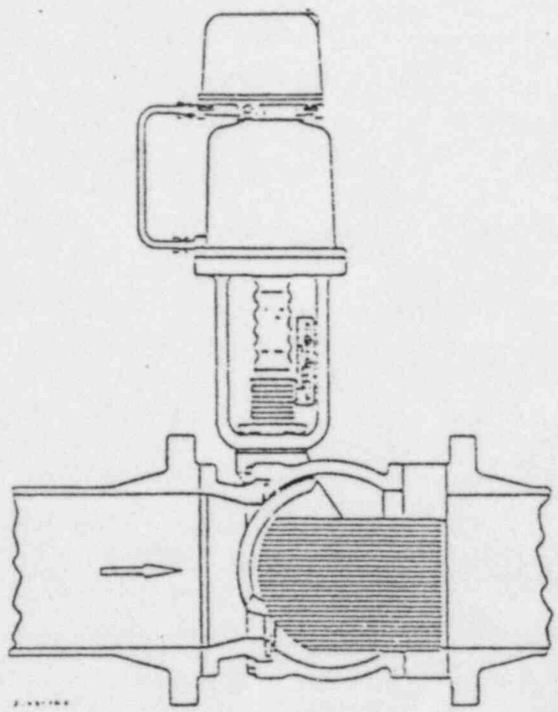

Figure 1. Typical Installation of Anti-Cavitation Device in Fisher Vee-Ball Valve

REFERENCES

1. USNRC, Regulatory Guide 1.48 - Division 1 Power Reactors, "Design L: its and Loading Combinations for Seismic Category I Fluid System Components," May 1973.

2. USNRC, Regulatory Guide 1.70 - Division 1 Power Reactors, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Section 3.9.3.2 and 3.9.6, Rev. 3, November 1978.

3. USNRC, Regulatory Guide 1.148 - Division 1 Power Reactors, "Functional Specification for Active Valve Assemblies in Systems Important to Safety in Nuclear Power Plants," March 1981.

4. USNRC, "Standard Review Plan - LWR Edition," USNRC Report NUREG-0800, Section 3.9.2, "Dynamic Testing and Analysis of Systems, Components, and Equipment," Rev. 2, July 1981.

5. USNRC, "Standard Review Plan - LWR Edition," USNRC Report NUREG-0800, Section 3.9.3, "ASME Code Class 1, 2, and 3 Component Supports, and Core Support Structures," Rev. 1, July 1981.

6. USNRC, "Standard Review Plan - LWR Edition," USNRC Report NUREG-0800, Section 3.9.6, "Inservice Testing of Pumps and Valves," Rev. 2, July 1981.

7. USNRC, "Standard Review Plan - LWR Edition," USNRC Report NUREG-0800, Section 3.11, "Environmental Qualification of Mechanical and Electrical Equipment," Rev. 2, July 1981.