AEOD TECHNICAL REVIEW REPORT

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EVAUATOR/CONTACT: C. Hsu

SUBJECT: FOLLOW-UP ON STEAM BINDING OF AFW PUMPS

EVENT DATE:

SUMMARY

This is a retrospective study of operating experience that shows that licensee actions to decrease steam binding of AFW pumps have been effective.

AEOD issued case study report "Steam Binding of AFW Pumps" in July 1984. This study identified a number of events involving the inoperability of auxiliary feedwater (AFW) pumps as a result of steam binding. The steam binding was due to backleakage of main feedwater past the isolation check valves in the AFW system. Because of the piping configuration, most AFW systems are potentially vulnerable to common-mode failure of the redundant AFW pumps as a result of steam binding. Steam binding of these pumps and subsequent loss of its safety function could contribute significantly to risk of core melt in PWRs. The case study had recommend several measures to ensure that backleakage is minimized and detected before a pump becomes steam bound.

Since the AEOD study was issued, a series of events involving backflow of hot water into the AFW systems occurred at several operating plants. To deal with the concern of check valve backleakage and potential resulting steam binding of the AFW pumps, NRC Bulletin 85-01 was issued in October 1985 with the requirements for immediate corrective action to monitor the AFW pump discharge lines for indication of the presence of steam and hot water (leakage in check valve), and maintain procedures for venting and refilling the AFW pump discharge lines should steam or hot water be present. Generic Issue (GI) 93 was subsequently created to determine if additional actions beyond those indicated in the bulletin were necessary. GI-93 has recently been resolved with the issuance of Generic Letter 88-03 in February 1988. This generic letter concludes that actions taken by licensees in response to Bulletin 85-01 are sufficient and such actions should be continued to provide protection that backleakage will not cause steam binding of the AFW pumps and a consequent loss of the AFW system.

A search of the LER data base indicates that the number of backleakage events reported subsequent to the issuance of the IE Bulletin are very low and decreasing. The backleakage that occurred in these events was detected before a pump became steam bound. Therefore, we believe that the licensees have effectively implemented mitigative actions. Certainly, fixing the problem of check valve leakage is the ultimate solution of the steam binding due to backleakage. However, since check valve leakages cannot be ruled out, especially as the plant ages, it is especially important to have appropriate system monitoring capability and recovery procedures for assuring prevention of pump steam binding. The probability of unexpected check valve leakage problem

can be expected to be reduced when the current proposed industry program on improvement in check valve reliability is implemented. Therefore, additional action regarding the AFW system steam binding problem is not necessary at present.

DISCUSSION

In July 1984, AEOD issued case study report "Steam Binding of Auxiliary Feedwater Pumps" (Ref. 1). This study identified a number of events involving the inoperability of auxiliary feedwater (AFW) pumps as a result of steam binding. The steam binding was due to the backleakage of main feedwater past the interfacing isolation check valve between the AFW and MFW systems. In the low pressure AFW system, the leaking subcooled water flashes into steam, and a backflow mixture of steam and hot water may develop that forces itself upstream past other leaking check valves to one or more of the AFW pumps. The continued buildup of the steam void content can lead to pump cavitation and consequent failure when the pumps are subsequently started up. The 22 events identified in this study had occurred at six operating PWRs since 1981; 13 of these occurring in 1983. These events involved the misoperation or failure of about 60 check valves and five motor-operated valves installed to prevent reverse leakage. Other plants were known to have experienced backleakage, but the events were not considered as reportable occurrences. The analysis of the causes for check valve leakage did not identify any pattern or single cause of the failures of the check valves. The causes differed between plants and involved different valve designs.

The safety implication of these events was that backleakage represent a potential common cause failure for the AFW system that can cause the loss of its safety function. The potential for failure of the AFW system is present whenever one pump is steam bound because the other redundant pumps are connected by common piping (discharge header, suction header and/or reciculation piping) with only a single check valve to prevent backleakage of hot water to a second or third pump. Also, there was no regulatory requirements or uniform plant practices to reduce the likelihood of steam binding of the AFW pumps and common-mode failure of the AFW system.

To minimize and detect backleakage before a pump becomes steam bound, and to reduce the likelihood for the common-cause failure of the AFW system, the AEOD case study recommended that: (1) NRR require the regular monitoring of the AFW system to detect leakage and ensure that the fluid condition are well below saturation condition, and (2) confirm that such a practice is already being implemented.

After the AEOD study was issued, a series of events involving backflow of hot water into the AFW system occurred at McGuire 2 over a period of 7 days in August 1984, before effective corrective action was taken. One of these events involved overpressurization of the suction line and damage to instruments. In November 1984, Catawba 1 experienced backflow of hot water into AFW resulting in fumes from the pipe insulation and blistering of paint. In October 1984, the NRC's Office of Nuclear Reactor Regulation (NRR) determined that steam binding of AFW was a generic issue and assigned it a high priority (Generic Issue 93, "Steam Binding of Auxiliary Feedwater").

To determine the extent of the safety issue and the need for short-term action related to the problem of steam binding, IE requested that the regional offices (temporary instruction 2515/67-03) conduct a survey in April and May of 1985. The survey reviewed the licensee responses to previous NRC and industry recommendations regarding: (1) the monitoring of pipe temperature at least once per shift and (2) the availability of procedures for detecting and correcting a steam binding conditon. Of the 58 units surveyed, approximately half had both procedures and related training in place, while the other lacked either certain procedures or training or both.

Although some action had been taken at some units, many had not incorporatred these actions into procedures to detect or correct steam binding. Without these provisions, there were little assurance that effective actions would continue. Based on this reason, IE Bulletin 85-01 (Ref. 2) was issued (dated October 29, 1985) to require those licensees who had not already done so in response to previous NRC and industry recommendations to develop and implement procedures for monitoring AFW piping temperature on a recommended once per shift basis, for recognizing steam binding, and for restoring the AFW system to operable status should steam binding occur. The Bulletin also required that procedural controls were to remain in effect pending the adoption of an appropriate hardware fix substantially reducing the likelihood of steam binding, or until superseded by action implemented as a result of resolution of Generic Issue 93.

A search of LER and other operational experience data bases was conducted for AFW system events involving check valves, cavitation, loss of suction and steam binding as a means of ascertaining if AFW steam binding events were continuing to occur. Although the search, which covered the period from 1980 to the present, identifiified a number of events involving backleakage in the AFW systems that occurred after the issuance of Bulletin 85-01, none of these backleakage events have resulted in the steam binding of AFW pumps. The data search included SCSS and NPRDS.

Of the backleakage events identified, only one event was reportable in the LER system and was retrieved from the SCSS data base. This event occurred at Crystal River 3 in 1988. The others occurred at four other plants and were reported to the NPRDS on a voluntary basis. The event which occurred at Crystal River 3 was reported in LER 88-014. While the plant was operating at the rated power, elevated temperatures exceeding the design temperature were present in parts of the AFW system. This also caused a mechanical containment penetration to exceed its design temperature. System walkdowns following the event revealed that the expansion anchors of one pipe restraint were partially pulled loose from their structural attachment. The event resulted in a condition that was outside the design basis of the system and became reportable in the LER system.

The backleakages in the events reported to the NPRDS were identified by the increased temperatures on the discharge pipings upstream of the isolation check valves. The elevated temperatures, which were higher than ambient but still far below the design, were noted either during walkdowns or by alarms from the temperature monitors. These events involved only check valve defects which did not constitute a reportable condition defined in the LER system -- the January 1984 LER rule does not require reporting of individual component failures.

FINDINGS

The utility responses to Bulletin 85-01 indicated that various methods are being used to monitor piping temperatures. In most cases, the method involves simple touching of the pump casing or pipe, such that if it is "hot" to the touch, the operator or shift supervisor is notified, and recovery procedures are initiated (e.g., venting of pump casing, operating the pump and flushing out the affected discharge lines). At a number of plants, temperature readings are obtained using contact pyrometers, temperature sensitive color tape, or other permanently attached temperature instruments with local readout. The monitoring frequency is generally once per shift, although some plants, depending on their previous backleakage experience, may conduct surveillances every 4 hours. Still other plants have installed a continuous, instrumented monitoring system, with a control room alarm to alert the operator when the pipe temperature has risen above a given setpoint.

Generic Issue 93 was declared resolved in 1987. The result of the regulatory analysis (Ref. 3) indicated that the recommendations in Bulletin 85-01 would ensure that the contribution of AFW pump steam binding to core-melt frequency and public risk was sufficiently low and that there was no need for new recommendations beyond those in Bulletin 85-01. In resolving this Generic Issue RES surveyed the backleakage experience in operating plants following the implementation of monitoring procedures. Although the number of backleakage events varied from an average of less than one per-reactor year at a large majority of plants to more than 100 per reactor-year at others, none of the backleakage events that occurred during the review period appeared to have resulted in the steam binding of an AFW Pump. This indicates that the various monitoring methods employed can be highly effective in preventing steam binding if backleakage occurs. For the plants with a high backleakage event rate, the installation of continuous monitoring systems with control room alarms was instrumental in providing early warning to the operator and timely corrective action.

Although RES concluded that the currently assessed risk associated with this issue is reasonably low, it is still concerned about the generally unsatisfactorily reliability of check valves in operating plants. Plant operators should continue to be alert to the possible development of malfunctioning check valves, especially as the plant ages. They should be prepared to increase the monitoring frequency as needed and to implement appropriate recovery procedures to ensure that steam binding failure of the AFW pumps does not occur. NRR concluded that the recommended monitoring action of Bulletin 85-01 should be continued. In February 1988, Generic Letter 88-03 (Ref. 4) was issued to reinforce this conclusion.

To ensure licensee adherence to the requirement of Bulletin 85-01, NRR has revised NRC Inspection Procedure 71707-03C (Ref. 5) to include the matter of monitoring the AFW Pumps for steam binding as a example of a recurring operational event that should be periodically checked by the NRC inspectors.

The search of SCSS and NPRDS data bases in this review indicated that the number of backleakage events subsequent to the issuance of Bulletin 85-01 are very small and decreasing. None of these events have resulted in the steam binding of an AFW pump. This indicates that the licensees' monitoring procedures have been effective in catching these backleakages early enough to prevent any subsequent steam binding of the AFW pumps.

CONCLUSION

Fixing the problem of AFWS check valve leakage is certainly vital in reducing the frequency of backleakage challenges to the AFW system. However, the actions taken by the licensees to monitor and correct backleakage that could lead to steam binding of the AFW pumps appear to be adequate. Our review of operating experience as described in the preceeding discussion also support this conclusion. Moreover, the probability of unexpected check valve leakage problem can be expected to be reduced when the current proposed industry program on improvement in check valve reliability is implemented. Therefore, we believe that the recommendations to prevent the steam binding that were raised in the AEOD case study are being implemented effectively by the licensees, and no further action regarding the AFW pump steam binding problem is needed at present.

REFERENCES

1. AEOD/C404, "Steam Binding of Auxiliary Feedwater Pumps," Office for Analysis and Evaluation of Operational Data, U.S. Nuclear Regulatory Commission, July 1984.

2. IE Bulletin No. 85-01, "Steam Binding of Auxiliary Feedwater Pumps," U.S. Nuclear Regulatory Commission, October 29, 1985.

3. Regulatory Analysis of Generic Safety Issue 93, "Steam Binding of Auxiliary Feedwater Pumps," Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, February 1987.

4. NRC Letter to All licensees, Applicants for Operating Licenses, and Holders of Construction Permits for Pressurized Water Reactors, "Resolution of Generic Safety Issue 93, 'Steam Binding of Auxiliary Feedwater Pumps' (Generic Letter 88-03)," February 17, 1988.

5. Memorandum for E. Beckjord from T. Murley, "Resolution of Generic Safety Issue 93, 'Steam Binding of Auxiliary Feedwater Pumps,'" August 14, 1987.