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UNITED STATES
NUCLEAR REGULATORY COMMISSION
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MEMORANDUM TO: William D. Travers
Executive Director for Operations

FROM: Ashok C. Thadani, Director
Office of Nuclear Regulatory Research

SUBJECT: CLOSEOUT OF GENERIC SAFETY ISSUE 165, SPRING-ACTUATED SAFETY AND RELIEF VALVE RELIABILITY

The purpose of this memo is to document the resolution of the subject generic safety issue (GSI). The GSI was identified after failure of a spring-actuated safety relief valve (SRV) at Shearon Harris Plant potentially degraded the high head safety injection system (HHSI) and it went undetected for a significant period. The concerns which led to the assignment of the generic issue were that the failure was potentially serious, that there were no ASME requirements for testing the SRVs at that time, and that little attention had been focused on these SRVs, with the result that there was no confidence that the design at Shearon Harris was unique. Because of the operating conditions of the SRV at the Shearon Harris plant, cross-tying of systems and the difficulty of detecting the failures, AEOD estimated a conditional core damage probability of 6×10^{-3} attributable to this type of failure. The Shearon Harris Plant, and others like it, were modified to eliminate the design features which led to the failure of the valve and the effect of its failure on the HHSI. In prioritizing this GSI, it was estimated that 5-8% of the 55-60 of this type of valve in a plant could be significant contributors to core-melt frequency. In addition, it was estimated that 10% of the SRVs would have the capability to fail their trains. Finally, it was estimated that the failure probability could be significantly reduced by economical tests performed in the plants. The estimate of core-melt frequency calculated for this issue in the prioritization phase ranged from a best estimate of 5×10^{-3} to an upper bound of 5×10^{-2}. These factors resulted in the GSI being assigned a high priority.

The actions taken to evaluate and resolve the GSI did not confirm the assumptions made in the prioritization. Review of P&IDs for important safety-related systems failed to identify the type of system cross-tying that contributed to the seriousness of the Shearon Harris degradation. Review of related valve data only identified a single valve in one plant type that had the potential for failing its train. That SRV was analyzed as a worst-case. The analysis showed that the increase in core damage frequency (CDF) for that SRV is acceptable, (6×10^{-6}). Review of LERs did not reveal any other instances of valve spring failure besides the one at Shearon Harris, nor did review of Nuclear Plant Reliability Data System (NPRDS) narratives during data gathering for failure rate estimation reveal any. Finally, and, perhaps most significantly, the additional testing requirements for these SRVs contemplated in the

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prioritization for the resolution of this GSI were included in the 1986 Edition of the ASME Code. That edition was endorsed in the 1992 update of 10 CFR 50.55a, and the additional testing is already being performed in most plants.

The ACRS reviewed the proposed resolution of GSI 165 and agreed with the staff that no additional requirements were necessary based upon the increased surveillance requirements that were incorporated into the ASME Code and implemented by nuclear power plant licensees. This reflects continued utilization of consensus standards as discussed in the NRC's Strategic Plan and Public Law 104-113, "National Technology Transfer and Advancement Act of 1995."

The attachments consist of a short paper presenting the scope of the activities undertaken to resolve the GSI, contractor reports detailing the identification of systems to be studied and the analysis of the worst-case valve and the ACRS letter agreeing with the resolution of the GSI without additional licensee action.

Attachments: As stated

Summary of Resolution for Generic Safety Issue 165, "Spring-Actuated Safety and Relief Valve Reliability"

Introduction

This Generic Safety Issue (GSI) was identified when, on a number of occasions, licensees reported that spring-actuated safety and relief valves (SRV) failed to meet set point criteria within the desired tolerance. Other incidents more seriously degrading performance were reported. These events were documented in AEOD/S92-021556 in which the staff concluded that most pressurizer safety valves (PSVs), main steam safety valves (MSSVs), and BWR safety/relief valves did not meet the 1% set point drift tolerance and many were above 3%. These results suggested that other systems with safety and relief valves could be adversely affected by set point drift. The staff discussed some of these systems in Information Notices 90-05 and 92-64 and in NUREG/CR-6001. Although Generic Safety Issue (GSI) B-55 addressed the reliability of Target Rock two-stage pilot-operated SRVs and GSI-70 addressed the reliability of power-operated relief valves (PORVs) and block valves, there was no generic issue for spring-actuated SRVs. More importantly, at Shearon Harris, a cracked spring on a SRV used for pressure regulation in the Alternate Minimum Flow system (AMF) reduced effective set point, and cross-tying with the High Head Safety Injection system (HHSI) caused a situation where inadequate emergency core coolant injection would be available if a small-or intermediate-break loss of coolant accident (LOCA) had occurred. This event was discussed in detail in LER 91-008-01 and Information Notice 92-61.

Spring-actuated SRVs provide over pressure protection for numerous systems in both PWRs and BWRs. It was postulated that failure of these valves in safety-related support systems could cause a significant diversion of flow from these systems and thus prevent the systems from performing their design function. Because of the size of these valves (<4 inches), it was believed that most of them could be tested at the plant site (many of them in situ), thus reducing the time and cost for testing. Because significant NRC and industry resources had been spent on both evaluating the risk of improving the reliability of PSVs, PORVs, MSSVs, and BWR SRVs, the focus of this issue was limited to small spring-actuated SRVs in safety-related support systems and the effects of their unreliability on plant operation.

Consideration was given to failures of SRVs that could possibly lead to a core-melt from loss of core cooling and inventory makeup. Possible sources of loss include failure of a valve to close after opening, and premature opening of a valve below set point resulting in a loss or diversion of fluids. Failure of a valve to open when challenged, resulting in coolant boundary failure, is covered in LOCA analysis.

Probabilistic Screening Analysis

The first step in evaluating the impact of failure of these valves was to select 5 plants that represented a diverse cross-section of plant designs. Core damage frequencies (CDFs) were calculated for the safety systems in these plants with the assumption that the system (both trains) was failed. This identified the systems with the greatest influences on CDF. The system piping and instrumentation diagrams (P&IDs) were then examined to determine whether they contained SRVs. Systems without SRVs were eliminated from further consideration, as were systems with a contribution to CDF of less than 10^{-4} / reactor year assuming a total loss of the system. This value was low enough to ensure that no significant systems were excluded from consideration.

CDFs were then recalculated for selected systems with the condition that only one train containing a SRV failed. Trains with a calculated CDF above 3.5×10^{-4} in this step were selected for further evaluation. The next step of the screening process relied on analysis of the impact of the failure of the valve on the system. A conservative failure rate for these valves was estimated using data from the Nuclear Plant Reliability Data System (NPRDS) to be 8.6%. Using this failure rate and assuming that the failure of the valve would fail the system, the calculated increase in CDF was found to be 3.6 E-5 (6×10^{-6} above the base case value).

Deterministic Screening Analyses

Deterministic analyses were conducted to broaden the scope of the evaluation and to obtain a better understanding of the potential for SRVs to result in system failure. These analyses included an examination of other SRVs identified in the probabilistic screening analysis and SRV types identified in a review of Licensee Event Reports (LERs).

Examination of Other Valves

P&IDs and information requested from the licensees were used to examine the potential for other SRVs to fail the trains in which they were installed. No valves with the potential to fail their systems were found. The plant systems examined were:

Babcock and Wilcox (B&W)
HPSI, low pressure safety injection (LPSI), emergency feedwater, high pressure service water, condenser circulating water, and the primary pressure control path.

General Electric (GE)
High pressure core spray (HPCS); reactor core isolation cooling (RCIC), and emergency diesel generator (EDG) air start tanks.

Westinghouse three loop (W3L)
HPSI, auxiliary feedwater (AFW), low pressure recirculation (LPR), and EDG air start tanks.

Westinghouse four loop (W4L)
HPSI, LPSI, and the EDG air sub-system

Combustion Engineering (CE)
HPSI, LPSI, safety injection tanks, chemical and volume control system, EDG air start tanks, AFW, and saltwater cooling and component cooling water.

The LER database was searched for the period 1990 through 1997 for events involving small SRVs. Forty-nine such LERs were identified, with seven relevant to GSI 165. Only the alternate minimum flow system failure at Shearon Harris, which precipitated this GSI, was found to constitute a potentially significant degradation. The SRVs that failed were replaced with an orifice at Shearon Harris, and similar plants instituted enhanced maintenance and inspection programs following NRC Information Notice 92-61. No instances were identified of a failure of one of these additional SRVs to open that would lead to the potential for failing the system or creating at LOCA.

Depletion of Fluids

SRV failures also have the potential to deplete fluids accumulated for safety-related use. Three such situations were studied; depletion of a supply of reactor coolant makeup, depletion of diesel starting air, and depletion of nitrogen pressure in safety injection tanks.

The FSAR for the plant with the worst case SRV reports a flow of 160 gpm at 2735 psi. Assuming a failure of the valve spring similar to that which occurred at Shearon Harris might allow the set pressure to be reduced to the range of the HPSI pump shutoff head of, and assuming that the discharge flow would be the same as the flow from an unfailed SRV at 2735 psi, the 490,000 gal nominal inventory of the Refueling Water Storage Tanks would be sufficient to provide flow for over 50 hours. Even if an unprecedented fracture of the spring, or loss of disk and trim should occur such that the entire output of the pump would be lost, coolant would be available for nearly 20 hours. While SRV discharge is lost to floor drains and directed to the radioactive waste system, it could be recovered for recirculation.

EDG starting air tanks have small spring-operated SRVs that normally are exposed to operating pressure. These tanks, which are sized for multiple EDG starts, are also instrumented and alarmed. These factors led to the conclusion that the SRVs on the air start systems would not make a significant contribution to the failure rate of the overall EDG system.

The safety injection tanks on a CE plant hold over 13,000 gal of borated water. The system is instrumented, alarmed, and connected to a large supply of nitrogen. The SRVs in this system are normally exposed to system pressure. These factors led to the conclusion that the potential for failure of the SRVs in this system would not make a significant contribution to system unreliability.

Other Considerations

Section XI of the 1986 ASME Code contains inservice testing (IST) requirements for SRVs within the scope of GSI-165. This version of the Code was adopted by rulemaking in 1992. Presently, all but seven plants have updated their IST programs to these testing requirements as required by 10 CFR 50.55a. All plants are expected to update their IST programs with such SRV testing by the end of 2002. At that time, all SRVs in safety-related systems will be subject to periodic testing.

The studies of this issue indicate that common cause failures of these SRVs are not a concern. In all cases considered, either the failure of the SRV could be tolerated without a loss of functionality or there would be enough warning for a reasonable expectation of operator action.

Conclusion

No spring-actuated SRVs studied within the scope of GSI-165 were found to have a significant impact on safety, and industry actions have either already been implemented or are under way that will further reduce the potential risk from these valves. As a result, GSI-165 will be considered resolved without recommending any safety enhancements or other regulatory action.

References

1. INEEL-96/0222, Effect on Core Damage Frequency of Safety-Related Spring-Actuated Relief Valve Performance
2. P. H. McCabe, Deterministic Analysis of Safety Relief Valve Failure Consequences, INEEL