UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

October 30, 1997

NRC INFORMATION NOTICE 97-76: DEGRADED THROTTLE VALVES IN EMERGENCY CORE COOLING SYSTEM RESULTING FROM CAVITATION-INDUCED EROSION DURING A LOSS-OF-COOLANT ACCIDENT

Addressees

All holders of operating licenses for pressurized-water reactors except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to potential problems caused by degradation of emergency core cooling system (ECCS) throttle valves in the intermediate-head safety injection pump hot-leg and cold-leg flow paths and in the charging pump (high-head safety injection) cold-leg flow paths during certain loss-of-coolant-accident (LOCA) scenarios. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On January 11, 1996, Westinghouse issued Nuclear Safety Advisory Letter (NSAL) 96-001, "Erosion of Globe Valves in ECCS Throttling Applications," which alerted Westinghouse plant owners to the potential cavitation and erosion of throttling valves used in high- and intermediate-head ECCS. The valve erosion occurs as a result of high differential pressure and flow that may occur during a LOCA. As a result of the valve erosion, the high- and intermediate-head safety injection pumps may exceed their run out limits, thus forcing the operator to secure the pumps before the time established in the licensing basis for pump operability. This issue was originally identified at Sequoyah Nuclear Plant through the corrective action program generic review of a problem at the Watts Bar Nuclear plant in 1993.

Using plant-specific calculations, the Tennessee Valley Authority (TVA) evaluated the service conditions for the ECCS throttle valves during post-LOCA long-term recirculation (more than 100 days) at Sequoyah and Watts Bar. The licensee concluded that the valves might be operating under conditions that could result in erosion-induced damage and eventual failure. A Westinghouse evaluation of the ECCS throttle valves confirmed TVA's analysis and recommended that (1) the throttle valves be replaced with valves better able to operate for extended periods under the analyzed conditions, (2) orifice plates be installed in series with the throttle valves to reduce the pressure drop across the valves, or (3) testing be performed to better define the wear rate and determine appropriate corrective actions. At both Sequoyah and Watts Bar, orifice plates will be installed.

The Westinghouse evaluation identified two operational effects caused by degradation of the ECCS throttle valves during a LOCA. The first effect is reduced throttling capability of the valves. This occurs through erosion of the valves as a consequence of cavitation engendered by high differential pressure and flow across the valves. As a result of the erosion, in approximately 12 days the valves would be unable to adequately throttle ECCS flow. The second effect is increased pump flow in that valve erosion could increase the valves' throttling area and result in increased pump flow. In this increased flow condition, the ECCS pumps could reach run out conditions, resulting in pump damage.

Discussion

The subject throttle valves are located in ECCS flow paths for both the high-head and intermediate-head safety injection pumps and are designed to balance injection flows between loops while maintaining total injection flow within normal parameters.

NRC requirements and guidance for the ECCS are provided in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," and 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," Criteria 33, 34, and 35. Section 50.46 requires, in part, that "after any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core."

To meet this requirement during a LOCA, the high-pressure ECCS injects water into the reactor coolant system (RCS) cold legs to provide cooling flow to the reactor core. Following the initial injection phase, the ECCS pumps may be aligned for cooling in the recirculation phase.

During a LOCA, the ECCS may experience a large pressure drop across the throttling valves, thereby causing cavitation and valve erosion. As the valves erode, their throttling capability is reduced. This reduction, in turn, increases ECCS pump flow. If the ECCS pumps reach run out conditions as a result of the continued valve erosion, the pumps may have to be stopped before the plant can utilize the residual heat removal (RHR) system for core cooling.

At Sequoyah and Watts Bar, the valves that could experience this type of erosion are stainless steel, plug guided globe valves with stellite plugs and seats. Valves for this application are often supplied by the utility and/or the architect engineer. Thus, there may be other valve designs used in this application.

Westinghouse analyzed long-term operability of throttle valves during both a small-break LOCA (SBLOCA) and a large-break LOCA (LBLOCA). During an SBLOCA, the pressure drop across the valves, and the resulting valve erosion, is smaller than that experienced during an LBLOCA. Relatively little valve erosion would occur before the plant's emergency operating procedures (EOPs) direct the operator to secure the pumps. As a result, if the pumps are secured in accordance with the plant EOPs following an SBLOCA, minimal valve erosion will occur. This will allow the valves to perform their throttling function and will prevent pump run out and subsequent pump damage during the SBLOCA.

However, for LBLOCAs, the rate and amount of valve erosion are greater because of the greater differential pressure across the valves. As a result, the valves may erode to the point at which high- and intermediate-head pump flows could reach run out conditions, thus necessitating the premature shutoff of the pumps.

Another problem associated with erosion of this type of valve concerns preventing boron precipitation in the RCS. Without adequate flow through the core, boron will concentrate in the reactor vessel. When the boron concentration reaches the solubility limit, boron could plate out in the core and inhibit flow. If boron plate out occurs, the safety injection pumps and the RHR pumps can be realigned to inject into the RCS hot legs to provide hot-leg recirculation and prevent boron accumulation. However, because the valves in the recirculation lines for the safety injection pumps can also experience the same valve erosion that occurs in the cold-leg injection line, the RHR pumps may have to be used to provide hot-leg recirculation. Depending on the system design, in this mode of operation a single failure could occur which could interrupt hot-leg recirculation flow, leading to possible boron precipitation in the core. This could occur if the single motor-operated crossover valve fails.

Westinghouse, as part of TVA's Justification for Continued Operation (JCO), analyzed four scenarios related to the effect of an LBLOCA on core cooling and boron precipitation. These scenarios constituted the worst-case challenges to establishing and maintaining core cooling and hot-leg recirculation. Each scenario is discussed below.

(1) Large Cold-Leg Break With No Failure of the RHR Hot-Leg Motor-Operated Crossover Valve

In this scenario, RHR flow would be realigned to the RCS hot legs approximately 12 hours after the LBLOCA (in accordance with the EOPs). With the break in the cold leg and the RHR realigned to the hot leg, a flow path through the core is established and maintained while preventing boron buildup in the core. In this scenario, flow from one RHR pump would be sufficient to maintain core cooling and prevent boron precipitation.

(2) Large Cold-Leg Break With Failure of the RHR Hot-Leg Motor-Operated Crossover Valve

In this scenario, an attempt would be made to realign RHR flow to the RCS hot legs approximately 12 hours after the LBLOCA (in accordance with the EOPs). However, realignment would be unsuccessful due to the postulated failure of the motor-operated crossover valve. RHR flow would then need to be realigned to the cold legs, resulting in cooling water bypassing the core and flowing out the break. Boron concentration would increase, ultimately causing boron precipitation in the core.

(3) **Large Hot-Leg Break With No Failure of the RHR Hot-Leg Motor-Operated Crossover Valve**

In this scenario, RHR flow would be realigned to the RCS hot legs approximately 12 hours after the LBLOCA (in accordance with the EOPs). Because the break is in the hot leg, injection flow would transit above the core and out the break without substantial mixing in the core. For this scenario, adequate flow through the core is available if the hot-leg injection flow exceeds 3.3 times the boil off. This requirement is met with one RHR pump.

(4) **Large Hot-Leg Break With Failure of the RHR Hot-Leg Motor-Operated Crossover Valve**

In this scenario, an attempt would be made to realign RHR flow to the RCS hot legs approximately 12 hours after the LBLOCA (in accordance with EOPs). However, realignment would be unsuccessful because of the postulated failure of the motor-operated crossover valve. In this case, RHR flow would be realigned to the cold legs, thus allowing one RHR pump to provide adequate flow through the core and preventing boron buildup in the core.

Westinghouse evaluated these scenarios and determined that in each case, with the exception of scenario 2, the flow from the RHR pumps was sufficient to mitigate the accident. In scenario 2, as there is only a single flow path for hot-leg injection using an RHR pump, a failure of the motor-operated crossover valve in this flow path could cause a loss of hot-leg injection during the long-term recirculation cooling mode. This scenario could result in blockage of the reactor coolant flow path to the core because of boron precipitation once the boron solubility limit was reached. It should be noted that in scenario 2, the review took credit for recirculation flow through the hot-leg nozzle gaps in a forward flush path through the core in accordance with a methodology described in Westinghouse NSAL-94-016, "Recriticality During LOCA Hot-Leg Recirculation," dated July 25, 1994. This methodology has not been reviewed or approved by the NRC. Therefore, depending on plant-specific components and design, the conclusions may or may not be valid.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

Jack W. Roe

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97-75	Enforcement Sanctions Issued as a Result of Deliberate Violations of NRC Requirements	09/24/97	All U.S. Nuclear Regulatory Commission licensees
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original signed by

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