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

June 12, 2001

NRC INFORMATION NOTICE 2001-09: MAIN FEEDWATER SYSTEM DEGRADATION IN SAFETY-RELATED ASME CODE CLASS 2 PIPING INSIDE THE CONTAINMENT OF A PRESSURIZED WATER REACTOR

Trojan 16 Years

Addressees

All holders of operating licenses for pressurized water nuclear power reactors except those who have 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 (IN) to alert addressees to the discovery of main feedwater (MFW) system wall thinning to below allowable limits in turbine building components and in risk-important, safety-related portions of American Society of Mechanical Engineers (ASME) Code Class 2 piping inside the reactor containment building (containment) at the Callaway Plant.

It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. However, suggestions contained in this IN are not NRC requirements; therefore, no specific actions or written response is required.

Description of Circumstances

During a refueling outage that began on April 7, 2001, the Callaway Plant licensee conducted scheduled inspections to assess the effects of erosion/corrosion on steel piping exposed to flowing water (single-phase fluids) and water-steam mixtures (two-phase fluids). These effects are commonly referred to as flow-accelerated corrosion (FAC). Inspections identified several instances of localized MFW system piping wall thinning to below the minimum thickness required by ASME Boiler and Pressure Vessel Code, Section III, for safety-related piping, and to below the minimum thickness specified by American National Standards Institute (ANSI) B31.1, "Power Piping," for non-safety-related portions of the MFW system. The wall thicknesses in the degraded areas had not been previously measured.

The licensee had expanded and upgraded its FAC program following an August 11, 1999, event in which an 8-inch moisture separator reheater drain line experienced a double-ended guillotine break causing operators to manually trip the reactor. The upgraded and expanded FAC program, utilizing CHECWORKS™ Rev. F software, predicted wall thinning in the MFW system. However, without wall thickness trending data, the software was not able to accurately predict the extent of degradation. After performing an inspection during the current outage, the licensee found the MFW degradation to be more extensive than anticipated.

significance of pipe wall thinning.

MFW systems, like other power conversion systems, are important to the safe operation of nuclear power plants. Past failures of feedwater and other high-energy system components have resulted in complex challenges to operating staff when the released high-energy steam and water interacted with other systems, such as electrical distribution, fire protection, and security systems. Personnel injuries and fatalities have also occurred. The failure to maintain high energy piping and components within allowable thickness values can (1) increase the initiating event frequency for transients with loss of the power conversion system, main steam line breaks, and other initiating events due to system interactions with high-energy steam and water; (2) adversely affect the operability, availability, reliability, or function of systems required for safe shutdown and accident mitigation; and/or (3) impact the integrity of fission product barriers.

This IN 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.

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Attachments:

1. Table 1: Summary of Related Previous Generic Communications
2. Table 2: Summary of Previously Identified Pipe Wall Thinning Issues and Events
3. List of Recently Issued NRC Information Notices

(ADAMS Accession Number ML011490408)

ATTACHMENT 1

IN 2001-09

Table 1: Summary of Related Previous Generic Communications

The titles of generic communications referenced in the text of this IN or considered particularly relevant are underlined.

1. IN 82-22, "Failures in Turbine Exhaust Lines," July 9, 1982, addressed the rupture of a 24-inch-diameter long-radius elbow in a feedwater heat extraction line at Oconee Unit 2 and four similar failures identified by the Institute of Nuclear Power Operations (INPO).
2. IN 86-106, "Feedwater Line Break," December 16, 1986, addressed a potentially generic problem with feedwater pipe thinning and other problems related to the catastrophic failure of an 18-inch-diameter MFW pump suction line at Surry Unit 2.
3. IN 86-106, Supplement 1, "Feedwater Line Break," February 13, 1987, discussed the licensee's failure analysis, the parameters that could have potentially contributed to pipe break, the predictive measures used to detect erosion/corrosion, and the inservice inspection requirements of ASME Code for Code Class 1 and 2 piping systems and of ANSI B31.1 for other piping systems.
4. IN 86-106, Supplement 2, "Feedwater Line Break," October 21, 1988, addressed the discovery that an

Based on the licensee's initial findings and on additional industry information, FAC inspections were expanded to include portions of the condensate system, auxiliary feedwater (AFW) system, feedwater heaters, and other areas. Additional degradation was found in piping for the feedwater heaters.

Several instances of MFW system wall thinning were identified in risk-important sections of 14-inch ASME Code Class 2 safety-related piping components inside the containment. The licensee identified six 90-degree elbows, two 45-degree elbows, one 14-to-16-inch expander, and a 6-foot section of piping that had degraded to less than the ASME minimum design allowable wall thickness (below allowance) or that the licensee projected would degrade below allowance during the following cycle. The as-found wall thicknesses for components degraded below allowance ranged from 75 to 96 percent of the minimum allowable thickness required by the code. These components were identified in common MFW/auxiliary feedwater (AFW) flow paths to three of the unit's four steam generators (SGs). All safety-related components in the containment that were below allowance (or that the licensee predicted would degrade below allowance during the following cycle) were replaced. Some degraded non-safety-related components outside the containment were repaired rather than replaced.

Background

Since 1982, the NRC has issued numerous generic communications addressing various issues and events related to pipe wall thinning. Several of those communications are particularly relevant to the recently identified MFW wall-thinning at Callaway Plant. They are summarized below and annotated in Table 1, "Summary of Related Previous Generic Communications." Table 2 is a brief chronology of previously identified pipe wall thinning issues and events.

IN 87-36, "Significant Unexpected Erosion of Feedwater Lines," August 4, 1987, addressed the 1987 discovery of MFW degradation at the Trojan Nuclear Plant similar to that observed at Callaway Plant. The thinning was discovered when Trojan's steam piping inspection program was expanded to include single-phase piping. It was attributed to high fluid flow velocities and other operating factors.

IN 88-17, "Summary of Responses to NRC Bulletin 87-01, 'Thinning of Pipe Walls in Nuclear Power Plants'," April 22, 1988, summarized licensee responses to and NRC observations on the thinning of nuclear power plant pipe walls. The IN noted that all licensees reported having established programs for inspecting pipe wall thinning for two-phase, high-energy carbon steel piping systems. Inspection locations were generally reported to have been selected in accordance the 1985 guidelines in Electric Power Research Institute (EPRI) Document NP-3944, "Erosion/Corrosion in Nuclear Plant Steam Piping: Causes and Inspection Program Guidelines." However, because implementation of these guidelines was not required, the scope of the programs varied significantly from plant to plant.

Generic Letter 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," May 2, 1989, requested licensees to implement long-term erosion/corrosion monitoring programs to provide assurance that procedures or administrative controls were in place to maintain the structural integrity of all carbon steel systems carrying high-energy fluids. EPRI released the pipe wall thinning predictive computer code CHEC™ in June 1987, CHECMATE™ in April 1989, and CHECWORKS™ in August 1994, to assist licensees in selecting for testing those areas of the piping systems with the highest probabilities of wall thinning. The Massachusetts Institute of Technology method described in NUREG/CR-5007, "Prediction and Mitigation of Erosion-Corrosive Wear in Secondary Piping Systems of Nuclear Power Plants," September 1987, also ranked systems and components according to their erosion/corrosion susceptibility.

IN 93-21, "Summary of NRC Staff Observations Compiled During Engineering Audits or Inspections of Licensee Erosion/Corrosion Programs," March 25, 1993, addressed NRC observations on the industry's design and implementation of erosion/corrosion programs in response to Generic Letter 89-08. Among other observations, the IN identified instances of erosion/corrosion in safety-related portions of MFW and main steam systems and described the problems licensees were having in implementing effective FAC programs. In November 1993, EPRI released document NSALC-202L, "Recommendations for an Effective Flow-Accelerated Corrosion Program." Rev. 2 of the document was released in April 1999.

Discussion

Although the MFW degradation was identified and addressed by the licensee before catastrophic failure, the extent of the degradation at the time of discovery is of concern to the NRC, given the maturity of the industry's FAC programs. Of particular concern is the degradation in risk-important non-isolable sections of single-phase ASME Code Class 2 piping inside the containment. These factors can impact the safety elbow installed on the suction side of a MFW pump during a 1987 Surry Unit 2 refueling outage had thinned more rapidly than expected, giving up 20 percent of its 0.500-inch wall thickness in 1.2 years. Wall thinning was also observed in safety-related MFW piping and in other non-safety-related condensate piping.

5. IN 86-106, Supplement 3, "Feedwater Line Break," November 10, 1988, further addressed the faster-than-expected wall thinning at Surry Unit 2, noting the disparity between the previously estimated 20-30 mils/year thinning rate and maximum observed rate of 90 mils/year. The IN also noted that accelerated wall thinning may have coincided with a reduction in feedwater dissolved-oxygen concentration.

6. NRC Bulletin 87-01, "Thinning of Pipe Walls in Nuclear Power Plants," July 9, 1987, requested licensees to inform the NRC about their programs for monitoring the thickness of pipe walls of carbon steel piping in both safety-related and non-safety-related high-energy fluid (single-phase and two-phase) systems.

7. IN 87-36, "Significant Unexpected Erosion of Feedwater Lines," August 4, 1987, addressed potentially generic unexpected erosion which resulted in pipe wall thinning in both safety-related and non-safety-related portions of feedwater lines (both inside and outside the containment) at Trojan Nuclear Plant. The thinning was discovered when Trojan's steam piping inspection program was expanded to include single-phase piping and was attributed to high fluid flow velocities and other operating factors.

8. IN 88-17, "Summary of Responses to NRC Bulletin 87-01, 'Thinning of Pipe Walls in Nuclear Power Plants,'" April 22, 1988, reported the results of responses to NRC Bulletin 87-01 and described a recent event at LaSalle County Station Unit 1.

9. IN 89-01, "Valve Body Erosion," January 4, 1989, addressed a potential generic problem with erosion in carbon steel valve bodies in safety-related systems.

10. Generic Letter 89-08, "Erosion/Corrosion-Induced Pipe Wall Thinning," May 2, 1989, requested licensees to implement long-term erosion/corrosion monitoring programs to obtain assurance that procedures or administrative controls were in place to maintain the structural integrity of all carbon steel systems carrying high-energy fluids.

11. IN 89-53, "Rupture of Extraction Steam Line on High Pressure Turbine," June 13, 1989, addressed a potential generic problem with erosion in carbon steel piping in secondary plant systems.

12. IN 91-18, "High Energy Pipe Failures Caused by Wall Thinning," March 12, 1991, addressed continuing erosion/corrosion of high-energy piping systems and apparently inadequate monitoring programs.

13. IN 92-35, "Higher Than Predicted Erosion/Corrosion in Unisolable Reactor Coolant Pressure Boundary Piping Inside Containment at a Boiling Water Reactor," May 6, 1992, addressed an unexpectedly high rate of erosion/corrosion in certain main feedwater piping inside the containment at the Susquehanna Unit 1 boiling water reactor (BWR). The condition was noted to be of particular concern since it was in a section of piping that could not be isolated from the reactor vessel.

14. IN 93-21, "Summary of NRC Staff Observations Compiled During Engineering Audits or Inspections of Licensee Erosion/Corrosion Programs," March 25, 1993, addressed NRC observations on the industry's design and implementation of erosion/corrosion programs in response to Generic Letter 89-08.

15. IN 95-11, "Failure of Condensate Piping Because of Erosion/Corrosion at a Flow-Straightening Device," February 24, 1995, addressed possible piping failures caused by flow disturbances that were not accounted for in erosion/corrosion programs.

16. IN 97-84, "Rupture in Extraction Steam Piping as a Result of Flow-Accelerated Corrosion," December 11, 1997, addressed potential generic problems related to the occurrence and prediction of flow-accelerated corrosion (FAC) in extraction steam lines.

17. IN 99-19, "Rupture of the Shell Side of a Feedwater Heater at the Point Beach Nuclear Plant," June 23, 1999, addressed the rupture of the shell side of a feedwater heater at the Point Beach Nuclear Plant Unit 1.

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Table 2: Summary of Previously Identified Pipe Wall Thinning Issues and Events

Date	Site	Details	Ref.
1976	Oconee 3	Pinhole leak in an extraction steam line. A surveillance program utilizing ultrasonic examination of extraction steam lines was initiated and, in 1980, identified two degraded elbows identical to the Unit 2 elbow that subsequently failed in 1982. The elbows were replaced.	IN 82-22
1981	Millstone 2	Use of engineering personnel unfamiliar with plant operating conditions, plant as-built designs, or erosion/corrosion hazards.	IN 82-22
January 1982	Vermont Yankee	Licensee shut down the plant after identifying steam blowing from a leak in the 12-inch-diameter drain line between a moisture separator and heater drain tank.	IN 82-22
January 1982	Trojan	Steam line failure resulting in plant shutdown.	IN 82-22
February 1982	Zion 1	Steam leak in 150 psig high-pressure exhaust steam line originating from an 8-inch crack on a weld joining 24-inch piping with the 37.5-inch high-pressure steam exhaust piping leading to the moisture separator reheater. The event resulted in plant shutdown.	IN 82-22
June 1982	Oconee 2	While operating at 95-percent power, a 4-square-foot rupture occurred in a 24-inch-diameter long-radius elbow in a feedwater heat extraction line. The reactor was manually tripped; a steam jet destroyed a non-safety-related load center and certain non-safety-related instrumentation. Personnel were hospitalized overnight with steam burns. An ultrasonic inspection had identified substantial erosion of the elbow In March 1982, but the erosion failed to meet the licensee's criteria for rejection.	IN 82-22
June 1982	Browns Ferry 1	Steam line failure resulting in plant shutdown.	IN 82-22
March 1983	Dresden 3	Steam leak from the shell side of the 3C3 low-pressure feedwater heater near the extraction steam inlet nozzle. The leak was attributed to erosion by deflected extraction steam. The feedwater heaters had not been included in a periodic inspection program.	IN 99-19
March 1985	Haddam Neck	Pipe rupture, approximately ½-by-2-1/4-inch, downstream of a normal level control valve for a feedwater heater.	GL 89-08
December 1986	Surry 2	Catastrophic failure of 18-inch MFW pump suction line elbow when a main steam isolation valve failed closed on one of the steam generators. A 2-by-4-foot section of the elbow was blown out and came to rest on an overhead cable tray. The reactive force completely severed the suction line. The free end whipped and came to rest against the discharge line for another pump. The failure of the piping, which was carrying single-phase fluid, was caused by erosion/corrosion of the carbon steel pipe wall. The unit had been operating at full power. An automatic plant trip occurred and four workers suffered fatal injuries. Released steam caused the fire suppression system to actuate, releasing halon and carbon dioxide into emergency switchgear. The NRC dispatched an augmented inspection team to the site.	IN 86-106 Bulletin 87-01 IN 88-17 GL 89-08

June 1987	Trojan	MFW degradation was discovered by the licensee in at least two areas of the straight sections of ASME Class 2 safety-related MFW piping inside containment. The thinning was discovered when the Trojan steam piping inspection program was expanded to include single-phase piping. The thinning was attributed to high fluid flow velocities and other operating factors.	IN 87-36 IN 88-17 GL 89-08
December 1987	LaSalle 1	Through-wall pinhole leaks due to erosion were discovered in a 45-degree elbow down stream of a turbine-driven reactor feedwater pump minimum-flow control valve. Subsequent inspections identified additional areas of wall thinning.	IN 88-17
September 1988	Surry 2	The pipe wall of an elbow installed on the suction side of a MFW pump during a 1987 refueling outage was discovered to have thinned more rapidly than expected, losing 20 percent of its 0.500-inch wall thickness in 1.2 years. Wall thinning was also observed in safety-related MFW piping and in other non-safety-related condensate piping.	GL 89-08
December 1988	Brunswick 1	Inspection indicated areas of significant but localized erosion on the internal surfaces of several carbon steel valve bodies. The affected safety-related valves were the 24-inch residual heat removal/low pressure core injection (RHR/LPCI) system injection and 16-inch suppression pool isolation valves.	IN 89-01
April 1989	Arkansas Nuclear One Unit 2	Steam escaping from a ruptured 14-inch high-pressure steam extraction line caused a spurious turbine/reactor trip from 100-percent power. This straight run of piping terminates at an elbow that was replaced during the previous outage because of erosion-induced wall thinning. The pipe and those of similar geometries had not been included in the licensee's surveillance samples, and the degraded condition was not detected during the elbow replacement.	IN 89-53
March 1990	Surry 1	Rupture of a straight section of piping downstream of a level control valve in the low-pressure heater drain (LPHD) system. The LPHD system was included in the licensee's FAC program at the time, but the program did not provide an inspection for the affected section of piping.	IN 91-18
May 1990	Loviisa 1 (foreign)	A flow-measuring orifice flange in the main feedwater system ruptured after one of five main feedwater pumps tripped, causing a check valve in the line to slam shut, creating a pressure spike. Subsequent inspections determined that 9 of 10 flanges had thinned to below minimum wall requirements.	IN 91-18
July 1990	San Onofre 2	The licensee was forced to shut down the unit after discovering a steam leak in one of the feedwater regulating valve bypass lines.	IN 91-18
December 1990	Millstone 3	Two 6-inch pipes in the moisture separator drain (MSD) system ruptured when a MSD pump was stopped to facilitate component isolation for repairs. Stopping the pump caused a pressure transient. The high-energy water flashed to steam and actuated portions of the turbine building fire protection deluge system. Two 480-volt motor control centers and one non-vital 120-volt inverter were rendered inoperable by the flooding, resulting in the loss of the plant process computer and the isolation of the instrument air to the containment building.	IN 91-18
November 1991	Millstone 2	Rupture at an 8-inch elbow of a moisture separator reheater. High-energy water flashed to steam, actuating portions of the turbine fire protection deluge system. The license had not selected the ruptured elbow for ultrasonic testing in its erosion/corrosion	IN 91-18

		monitoring program. See LER 50-336/91-12.	
1992	Millstone 3	See LER 50-309/92-07.	IN 93-21
1992	Maine Yankee	See LER 92-007.	IN 93-21
1992	Salem 1	Improper determination of code minimum wall thickness acceptance criteria resulted in improper disposition of degraded components. See Inspection Report 50-272/92-08.	IN 93-21
1992	Hope Creek	Lack of baseline thickness measurements (history) of originally designed piping was identified. See Inspection Report 50-354/92-11.	IN 93-21
1992	Millstone 1	Lack of baseline thickness measurements of replacement piping before the replacement piping was put into service. See Inspection Report 50-245/92-80.	IN 93-21
1992	Hope Creek	Use of engineering personnel who are unfamiliar with plant operating conditions, plant as-built designs, or erosion/corrosion history.	----- -----
1993	Diablo Canyon 1	Erosion/corrosion wear was discovered behind a thermal sleeve in the interior of the feedwater nozzle and on the feedwater nozzle itself.	IN 93-21
November 1994	Sequoyah 1	Licensee identified a 180-degree circumferential crack in a reduced section of 14-inch condensate piping used for flow-metering. The section of piping had been modeled incorrectly in CHECMATE™ without any diameter or thickness changes and had not been visually inspected.	IN 95-11
April 1997	Fort Calhoun	Manual scram and emergency boration following a 6-square-foot rupture of a 12-inch diameter sweep elbow in the fourth-stage extraction steam piping. A non-safety-related electrical load center, several cable trays and pipe hangers were damaged. In addition, asbestos-containing insulation was blown throughout the turbine building and portions of the fire protection system were actuated.	IN 97-84
May 1999	Point Beach 1	Manual trip from 100-percent power and manual safety injection actuation when the shell side of the feedwater heater ruptured. The fish-mouth rupture was approximately 27-inches long and 0.75-inch at its widest point. Feedwater heater leaks were also identified at Pilgrim Station and the Susquehanna units. None of the feedwater heaters had been included in a periodic inspection program.	IN 99-19
August 1999	Callaway	Operators manually tripped the reactor on indication of a steam leak in the turbine building. An 8-inch line from the first stage reheater drain tank to the high-pressure heater experienced a double-ended guillotine break.	Event Notification 36015