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Subject: Arkansas Nuclear One - Unit - 2
Docket No. 50-368
License No. NPF-6
Licensee Event Report 50-368/2000-001-00

Gentlemen:

In accordance with 10CFR50.73(a)(2)(ii), enclosed is the subject report concerning Pressurizer heater sleeves and a Reactor Coolant System resistance temperature detector nozzle.

Very truly yours,

Jimmy D. Vandergrift
Director, Nuclear Safety

JDV/tfs

enclosure

IE22

cc: Mr. Ellis W. Merschoff
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NRC FORM 366
(5-92)

U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Arkansas Nuclear One - Unit 2	05000368	1 of 6

TITLE (4) Pressurizer Heater Sleeves And A Reactor Coolant System Hot Leg Resistance Temperature Detector Nozzle Were Leaking Due To Primary Water Stress Corrosion Cracking

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
07	30	2000	2000	001	00	08	29	2000	FACILITY NAME	DOCKET NUMBER

OPERATING MODE (9)	5
POWER LEVEL (10)	000

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (Check one or more) (11)

	20.402(b)		20.405(c)		50.73(a)(2)(iv)		73.71(b)
	20.405(a)(1)(i)		50.36(c)(1)		50.73(a)(2)(v)		73.71(c)
	20.405(a)(1)(ii)		50.36(c)(2)		50.73(a)(2)(vii)		OTHER
	20.405(a)(1)(iii)		50.73(a)(2)(i)		50.73(a)(2)(viii)(A)		Specify in
	20.405(a)(1)(iv)	X	50.73(a)(2)(ii)		50.73(a)(2)(viii)(B)		Abstract Below
	20.405(a)(1)(v)		50.73(a)(2)(iii)		50.73(a)(2)(x)		and in Text

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Thomas F. Scott, Nuclear Safety and Licensing Specialist	501-858-4623

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX

SUPPLEMENTAL REPORT EXPECTED (14)			EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE)	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On July 30, 2000, with the plant in cold shutdown conditions for a Steam Generator tube inspection outage, twelve Pressurizer heater sleeves and one Reactor Coolant System (RCS) hot leg resistance temperature detector nozzle were found to have been leaking. Leakage was indicated by boric acid accumulation. The root cause evaluation concluded that the failure mechanism was primary water stress corrosion cracking of Alloy 600 material. Inspections were performed at other RCS and Pressurizer locations containing potentially susceptible material. No other leakage was found. Inspections of base material in the area of the leakage revealed no degradation. The leaks were repaired with an ASME Code-qualified process. The repairs were qualified for a limited service life until at least the refueling outage scheduled to begin in September 2000.

A. Plant Status

At the time this condition was discovered, Arkansas Nuclear One Unit 2 (ANO-2) was in cold shutdown, Mode 5, with a Steam Generator (SG) [AB] tube inspection outage in progress. The Reactor Coolant System (RCS) [AB} was in reduced inventory with water level approximately 24 inches above the bottom of the hot legs.

B. Event Description

Twelve Pressurizer [AB] heater sleeves and one RCS hot leg resistance temperature detector (RTD) nozzle were found to have been leaking.

During a routine inspection on July 30, 2000, a licensed operator noticed boric acid crystals on the floor below the Pressurizer. Subsequent inspection indicated boric acid accumulation on electrical cables of two of the Pressurizer heaters. When insulation was removed and all heater sleeves inspected, ten additional heater sleeves exhibited evidence of past leakage. Pressurizer pressure and level tap nozzles and a thermowell were inspected with no leakage indications found. Insulation was removed from Alloy 600 RCS hot leg nozzles, and one RTD nozzle was found with evidence of past leakage. (Following the start of plant heatup from the outage, it was discovered that one Alloy 600 hot leg sample nozzle located near the leaking RTD nozzle did not have an inspection with insulation removed; however, due to the inspection and repair activity in that area, it was concluded that any significant amount of boron would have been detected if it were present at that location.) RCS cold leg nozzle locations were visually inspected. Insulation was left in place since it did not significantly impair the examination. No leakage was found.

After the heaters were removed, an eddy current examination was performed on three of the heater sleeves. The eddy current testing (ECT) report documents that there were deposits in the sleeves that interfered with the eddy current testing so that none of the sleeves could be examined full length. To get the probe to start moving in the sleeve, the first inch of the sleeve bottom was not examined. Additionally, some length at the sleeve top, where the weld is located, could not be examined due to the debris interference with the probe. Approximately one inch of the sleeve top was not examined on two sleeves and a longer distance in the third. The ECT results from two sleeves indicated that there was a single, through-wall, axial crack in both sleeves below the J-groove weld that joins the sleeve to the cladding on the inside surface of the Pressurizer. These cracks were close to the heat affected zone of the J-groove welds, although this exact distance could not be determined. These cracks originated on the inside surface of the sleeves. The estimated crack length in one was 0.43 inch, and the estimated crack length in the second was 0.28 inch. The NDE technicians were unable to obtain measurement from the third sleeve near the weld area.

Ultrasonic testing (UT) was performed on the Pressurizer head shell material adjacent to two heater sleeves after the ECT testing was completed. One of the areas was selected for UT examination because it had the largest leak indication of the sleeves and was considered the bounding location for possible base metal degradation or cracking. Test results for both UT examinations showed that there were no cracks or other degradation in the shell base metal in these areas.

UT testing of the RCS hot leg base metal adjacent to the RTD nozzle was also conducted. Test results for the examination showed that there were no cracks or other degradation in the hot leg pipe around the RTD nozzle that had indications of prior leakage.

C. Root Cause

The root cause evaluation considered several potential failure mechanisms. Mechanisms that were rejected include intergranular stress corrosion cracking from contaminants, nozzle denting, and thermal fatigue. The evaluation concluded that primary water stress corrosion cracking (PWSCC) was the mechanism that produced the twelve heater sleeve failures. This conclusion is based on the results of the ECT on two sleeves, UT examinations on two other sleeves, the failure analysis performed on a previous failed heater sleeve (same heat of Alloy 600), and the numerous Alloy 600 nozzle failures in Pressurized Water Reactor (PWR) plants. The following evidence supports this conclusion.

- The ECT results indicate a single axial crack exists near the J-groove weld in two sleeves. This is virtually identical to inspection results for cracking observed in a sleeve from the same material heat that was extracted from the ANO-2 Pressurizer in 1987. The failure analysis for that sleeve conclusively identified the cracking to be intergranular (two non-connected cracks). It also documented that the microstructure, processing, high yield strength, and environmental conditions were ideal to produce PWSCC.

- The axial nature of the ANO 2 Pressurizer heater sleeve cracks is identical to the type of PWSCC cracking of Alloy 600 nozzles that has been found in other plants.

- The ECT tests showed these cracks originated near the J-groove weld, which is an area of high residual stress. This conclusion is consistent with the extensive database of PWSCC cracking that has occurred in small bore Pressurizer and hot leg nozzles throughout the industry. Cracking has been axial in almost every occurrence of PWSCC in small-bore nozzles. A few axial cracks have also been identified in large bore Control Element Drive Mechanism/Control Rod Drive Mechanism (CEDM/CRDM) [AA] reactor vessel nozzles at another facility. PWSCC cracks are intergranular and occur in or near the weld heat affected zone of

partial penetration welds. Crack initiation occurs on the inside diameter. Rarely are circumferentially oriented microcracks observed. Generally, the tubular products are given a low temperature anneal which is insufficient to re-dissolve carbon. The material exhibits a small grain size and a relatively high yield strength. The resulting microstructure generally contains intragranular carbides, making the material susceptible to PWSCC.

- When heaters were removed from the twelve leaking sleeves at ANO-2, there was no indication of growth or swelling of heater elements. The heat of material used to fabricate all the heater sleeves is susceptible to PWSCC. Considering the nature of failures in other small bore nozzles and the proximity of the cracks to the weld detected by ECT, it was concluded that the residual weld stresses were sufficient to cause PWSCC. Additional stresses from either swelling of the heater insulation in failed heaters or a denting type phenomena were not required to produce the observed cracking.

- The reaming process that was used for the ANO 2 heater sleeves most likely increased their susceptibility to PWSCC. Most Combustion Engineering (CE) Pressurizers, including ANO 2, were lightly reamed to remove local high spots resulting from weld shrinkage and distortion. Sleeves in these plants are in a condition that should not be conducive to circumferential PWSCC. However, these sleeves can still be susceptible to axial PWSCC if they have high yield strength and an unfavorable microstructure.

- The normal operating temperature for the Pressurizer (approximately 653 degrees F) greatly increases the susceptibility of the Alloy 600 heater sleeves to PWSCC, particularly if other material conditions (reaming, poor microstructure, high yield strength) are present. These other conditions existed for all twelve failed heater sleeves, as well as for the remaining original heater sleeves of the same material heat.

- The filler metal that was used to weld the heater sleeves to the Pressurizer cladding was Alloy 82. This weld metal has not cracked from PWSCC in plant conditions because of the high chromium content of this material. This means it is not expected that the heater sleeve welds experienced PWSCC cracking even though there were no NDE examinations of them.

PWSCC was also the failure mechanism for the RTD nozzle. This conclusion is based on the following information.

- The material yield strength, hardness, and carbon content of the RTD nozzle material heat all indicate that this material may be susceptible to PWSCC.

- While the temperature of the Pressurizer heater sleeves is significantly higher than the RTD nozzles, hot leg temperatures are high enough for PWSCC to occur.

- The RTD nozzles in both RCS hot legs were mechanically reamed to enlarge the bore. This process imposed additional internal diameter surface stresses making them potentially more susceptible to PWSCC.

D. Corrective Actions

Inspections were conducted at other RCS and Pressurizer locations containing Alloy 600 nozzles. Insulation was removed before some inspections but was left in place for others. No additional leakage indications were found. ANO-2 reactor vessel head CEDM penetrations were not inspected based on previous evaluations that concluded that their susceptibility to PWSCC is low and plans to inspect that area during a refueling outage scheduled to begin in September 2000.

The Pressurizer heater sleeves and RCS RTD nozzle that had been leaking were repaired with an ASME Code-qualified process. The repairs were qualified for a limited service life until at least the next scheduled refueling outage. Before startup from the refueling outage currently scheduled to begin in September 2000, repair qualifications for both the Pressurizer sleeves and RCS RTD nozzle will be extended for at least the next operating cycle or additional repairs will be performed.

E. Safety Significance

At a meeting with the NRC on March 25, 1992, the CE Owners Group (CEOG) presented an update of the status of the CEOG Alloy 600 program. This program consisted of evaluations of PWSCC in Pressurizer heater sleeves, Pressurizer instrument nozzles, and other primary pressure boundary nozzles. The scope of the meeting did not include CEDM reactor head penetrations, as those nozzles had not yet been shown to be a concern. In a letter dated May 5 1992, the NRC provided a summary of the meeting of March 25. This summary states that "the Staff continues to believe that the cracking on Inconel 600 (Alloy 600) penetrations in domestic PWRs will not impose a major safety concern because all the reported Inconel 600 cracking in French reactors and domestic PWRs are short and axially oriented. Short axial cracking does not threaten the structural integrity of the affected components and, therefore, are not currently considered to be a significant safety concern." Although the NRC did not issue a safety evaluation for PWSCC of small-bore Alloy 600 nozzles, the Staff did issue a safety evaluation addressing Alloy 600 CRDM/CEDM reactor vessel head penetrations. In this letter dated November 19, 1993 to the Nuclear Management and Resources Council, the NRC stated that "there are no unreviewed safety questions associated with CRDM/CEDM penetration cracking." The letter further stated that "the staff believes that catastrophic failure of a penetration is extremely unlikely. Rather, a flaw would leak before it reached critical flaw size and would be detected during periodic surveillance

walkdowns for boric acid leakage pursuant to Generic Letter (GL) 88-05." Subsequent to this letter, the NRC issued GL 97-01 regarding PWSCC cracking of reactor vessel (RV) head penetrations. Also, several plants with a high degree of susceptibility to PWSCC of RV head penetrations either have performed non-destructive examination (NDE) inspections of these nozzles or have committed to inspect them. Plants that do not perform NDE inspections still conduct the GL 88-05 walkdowns and consider these walkdowns a sufficient means to manage this issue.

The UT examinations performed on the hot leg pipe surrounding the RTD nozzle and the Pressurizer shell indicates that there is not a concern for crack propagation into the base metal.

The measured RCS unidentified leak rate before shutdown for the outage in which this condition was discovered was at a background level of 0.149 gpm.

For these reasons, this condition is considered to have had minimal actual safety significance.

F. Basis for Reportability

Using the guidance from Section 3.2.4 of NUREG-1022, "Event Reporting Guidelines - 10CFR50.72 and 50.73," the identified leaks were considered a serious degradation of a principal safety barrier. Discovery of the first two leaking Pressurizer heater sleeves was reported to the NRC Operations Center at 1739 CDT on July 30, 2000, in accordance with 10CFR50.72(b)(2)(i). An update to this report was made at 2352 CDT on July 30, 2000, to report leakage indications from additional heater sleeves and the RCS hot leg RTD nozzle. This report is submitted in accordance with 10CFR50.73(a)(2)(ii).

G. Additional Information

ANO has reported as Licensee Event Reports (LERs) three conditions involving RCS pressure boundary leakage attributed to PWSCC of Alloy 600 material. In LER 50-368/87-003-01 (letter number 2CAN088801) dated August 12, 1988, ANO-2 reported leaking Pressurizer heater sheaths. In LER 50-313/90-021-00 (letter number 1CAN019112) dated January 21, 1991, ANO-1 reported leakage from an Alloy 600 Pressurizer level sensing nozzle. In LER 50-313/2000-003-00 (letter 1CAN030001) dated March 16, 2000, ANO-1 reported leaking welds for RCS hot leg level instrument nozzles. Corrective actions for these events were not intended to prevent recurrence of PWSCC in Alloy 600 material that is subject to this failure mechanism.

Energy Industry Identification System (EIIS) codes are identified in the text as [XX].