Boston Edison

Pilgrim Nuclear Power Station
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10 CFR 50.73

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October 18, 1996
BECo Ltr. #96- 088

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Docket No. 50-293
License No. DPR-35

The enclosed Licensee Event Report (LER) 96-008-00, "Reactor Building Closed Cooling Water System Heat Exchanger Leak - Technical Specification Required Shutdown," is submitted in accordance with 10 CFR Part 50.73.

The following commitment is advanced in this LER:

> "Modifications and/or replacements to address long term fatigue will be performed in RFO#11 so that the channel/partition plate will be suitable for the life of the plant."

Please do not hesitate to contact me if there are any questions regarding this report.

E T Boulette

E. T. Boulette, PhD

RAH/dmc/9600800

cc: Mr. Hubert J. Miller
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Standard BECo LER Distribution

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LICENSEE EVENT REPORT (LER)

(See reverse for number of digits/characters for each block)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE(3)
PILGRIM NUCLEAR POWER STATION	05000-293	1 of 8

TITLE (4) REACTOR BUILDING CLOSED COOLING WATER SYSTEM HEAT EXCHANGER LEAK - TECHNICAL SPECIFICATION REQUIRED SHUTDOWN

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
									N/A	05000
09	18	96	96	008	00	10	18	96	FACILITY NAME N/A	DOCKET NUMBER 05000

OPERATING MODE (9)	N	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (Check one or more) (11)							
POWER LEVEL (10)	100		20.402(b)		20.45(c)		50.73(a)(2)(iv)		73.71(b)
			20.405(a)(1)(i)		50.36(c)(1)		40.73(a)(2)(v)(D)		73.71(c)
			20.405(a)(1)(ii)		50.36(c)(2)		50.73(a)(2)(vii)		OTHER
			20.405(a)(1)(iii)	x	50.73(a)(2)(i)(A)		50.73(a)(2)(viii)(A)		(specify in Abstract below and in Text, NRC Form 366A)
			20.405(a)(1)(iv)		50.73(a)(2)(ii)		50.73(a)(2)(viii)(B)		
			20.405(a)(1)(v)		50.73(a)(2)(iii)		50.73(a)(2)(x)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Robert A. Haladyna - Senior Regulatory Affairs Engineer	(508) 830-7904

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

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
B	CC	HX	E270	Y					
B	IG	MON	G080	Y					

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 September 18, 1996, at approximately 2000 hours, a Technical Specification required shutdown was completed. A shutdown was initiated on September 17, 1996, because the 'B' Reactor Building Closed Cooling Water (RBCCW) heat exchanger was declared inoperable as a result of a through-wall leak on the seawater side of the heat exchanger. The leak was identified during a routine plant tour. The reactor mode switch was in the RUN position and the reactor was at 100% power when the leak was identified. There were no other inoperable structures, systems, or components that contributed to the event.

The leak was located in the inlet channel of the 'B' RBCCW heat exchanger. The leak was due to a through-wall longitudinal crack in the channel cylinder near the bottom on the lower partition plate. The crack resulted from fatigue. The differential pressure loads across the partition plate resulted in a bending moment at the fillet welds attached to the channel wall which initiated a crack at a location of high stress concentration. In 1991, the heat exchanger partition plate buckled at the plate center line and along the shell to plate junction. A number of repairs and modifications were undertaken to stiffen and reinforce the plate and stiffen the attachment at the channel wall. The stiffening of the partition plate with additional support plates increased the magnitude of the bending stresses in the channel wall.

Corrective actions taken included repair and increased surveillance of the heat exchanger. A through-wall leak was not a repeat occurrence, but this heat exchanger has a history of failure and repair. Long term corrective action includes a planned design modification of the heat exchanger.

The event posed no threat to the public health and safety.

EVENT DESCRIPTION

On September 18, 1996, at 2000 hours, a plant shutdown as required by Technical Specification section 3.5.B was completed when the reactor water temperature was reduced to 212 degrees Fahrenheit with the reactor mode selector switch in the shutdown position. This action was taken in accordance with procedure 2.1.5, "Controlled Shutdown from Power". All control rods were fully inserted during the shutdown.

The shutdown was required because of a leak in the 'B' RBCCW heat exchanger. Technical Specification 3.5.B.1 requires both containment cooling loops to be operable whenever irradiated fuel is in the reactor vessel and reactor coolant temperature is greater than 212 degrees Fahrenheit. Technical Specification 3.5.B.2 allows continued operation for 72 hours from and after the date that one containment cooling system loop is made or found to be inoperable. Technical Specification 3.5.B.3 requires an orderly shutdown if the preceding requirements cannot be met. The plant was shutdown on September 18, 1996, in accordance with the requirements of Technical Specification 3.5.B.3.

BACKGROUND

The RBCCW heat exchanger was back-washed at approximately 0900 hours on the morning of September 17, 1996. The leak was identified at approximately 1653 hours on September 17, 1996, when an operator on tour noted a small puddle of water underneath the heat exchanger. This was promptly reported to the Nuclear Watch Engineer who had the lagging removed on the heat exchanger, thus revealing the leak. No evidence of leakage was noted during the previous shift tour nor during the backwash; therefore, it is believed the leak developed after the backwash. The reactor was at 100% power, 1035 psig, and the mode switch was in the RUN position when the leak was identified.

The RBCCW Loop 'B' system was declared inoperable at 1723 hours, and a Limiting Condition of Operation (LCO A96-239) was entered. The Operations Department Manager was notified at 1730 hours. After visual inspection of the leak and consultations with Engineering and Maintenance, it was determined that an on line repair was unlikely and the possibility existed that the leak could degrade. Based upon this and following crew briefs, plant shutdown per procedure 2.1.5 was commenced at 2100 hours, and the NRC resident was notified. Notification was also made through the NRC Emergency Notification System in accordance with the requirements of 10CFR50.72.

The following is a chronological summary of the shutdown.

The caution zone of the power/flow map was entered at 2139 hours. Two operators and a senior reactor operator monitored the shutdown at reactor control panel 905. The caution zone of the power flow map was exited at 2146 hours.

State and local agencies were notified of the initiation of the shutdown.

Intermediate Range Monitors (IRMs) were inserted at 2310 hours. IRM 'D' did not insert on the first attempt.

Commenced de-inerting per procedure 2.2.70 at 2358 hours.

Placed 'E' IRM in bypass (spiking Hi) at 0116 hours. Entered tracking LCO T96-147.

The auxiliary power distribution system 4160v electrical buses A1- A6 were transferred to the startup transformer from the unit auxiliary transformer at 0141 hours. The generator was taken off line at 0150 hours.

IRM 'D' spiked while down-ranging from range 7 to 6; received a 1/2 scram (channel 'B') at 0415 hours. Entered LCO A96-241 for the IRM trip system 'B' inoperable at 0450 hours due to spiking on IRM channel 'D' and channel 'F'. Wrote problem report 96.9474 in response to the IRM spiking.

All control rods were fully inserted by 0955 hours and a normal plant cooldown to cold shutdown was commenced. The reactor mode selector switch was placed in the SHUTDOWN position at 1030 hours. The reactor protection system was reset per procedure 2.1.6.

High pressure coolant injection system isolated at 100 psig as expected. Reactor core isolation cooling system isolated at 75 psig as expected. The residual heat removal (RHR) system was put into service in the shutdown cooling mode at 1725 hours. The reactor vessel temperature reached 212 degrees at approximately 2000 hours. The reactor head vent valves were opened at 2110 hours on September 18, 1996, and LCO A96-239 for Technical Specification 3.5.B was cleared at 2214 hours.

Problem report 96.9473 was written to document the heat exchanger leak.

CAUSE

1. RBCCW Heat Exchanger Leak

The through-wall longitudinal crack in the heat exchanger channel cylinder was due to fatigue caused by cyclic loading of the attached lower partition plate. The cyclic loading is caused by flow impingement and fluctuating differential pressure across the lower partition plate and is transmitted to the channel shell in the form of bending at the partition plate junction. Fouling, which accumulates more heavily at the first pass tube sheet of the four pass heat exchanger tubesheet, also contributed to higher differential pressure across the lower partition plate.

The partition plate is welded to the channel shell, and the bending loads, which are a consequence of the differential pressure, are transmitted into the channel shell at this juncture. The lower partition plate is located approximately 15 inches away from the inlet nozzle which is oriented at 90° to the partition plate. Inlet flow impinges on the lower partition plate with a velocity of approximately 7 ft/sec at design flow. The combination of impingement loads, pressure loads and turbulent flow caused the partition plate to vibrate and is the primary source of fatigue failure. Loading on the lower plate is higher than loading on the upper plate because there is no direct impingement loading on the upper plate, and differential pressure on the upper plate is lower for conditions when there is some level of fouling. Back-washing also contributed to fatigue failure. When the heat

exchanger is back-washed, the applied differential pressure is reversed and a stress reversal develops in the channel shell. Back-washing is performed weekly and, over time, could eventually cause progressive fatigue damage. The combination of the two factors led to the development of a through-wall crack in the heat exchanger channel shell. Fatigue failure is due to cyclic tensile loading applied in a direction transverse to the crack orientation. The heat exchanger shell crack developed parallel to the lower side of the partition plate and is oriented in the axial tensile portion of a bending load developed from flow impingement on the partition plate. This bending moment is consistent with a load applied in a direction transverse to the crack orientation. In 1991, the heat exchanger partition plate cracked at the plate centerline and along the shell-to-plate junction. The cracks penetrated the thickness of the partition plate but did not penetrate the shell. The cracks were oriented in the axial direction relative to the shell centerline. The partition plate had separated from the channel head and tubesheet grooves which provided vertical support. Partition plate yielding was obvious from the permanent set. The evaluation of the "as-found" condition and structural analysis of the heat exchanger channel shell and partition plate showed that the plate required reinforcement to adequately withstand the applied differential pressure loads. Considering the limitation of the original design, a number of repairs and modifications were implemented to stiffen the plate and reinforce the attachment at the channel wall. This stiffening of the partition plate with additional support plates increased the magnitude of the bending stress in the channel shell.

The heat exchanger through-wall crack initiated at a fillet weld that attached a partition plate stiffener to the shell wall. The crack developed at the toe of the lower stiffening plate weld and progressed outward from the inside shell diameter. Fillet welds typically have a high stress concentration effect and it is reasonable to conclude that the crack initiated at the fillet weld. Prolonged cyclic loading propagated the crack into and through the channel wall.

Channel wall cracking identified during the repair process indicates the reinforced channel/partition plate configuration has limited fatigue life, and the repair of the channel shell also has a limited fatigue life.

CORRECTIVE ACTION TAKEN

Following the shutdown, an issue manager was assigned to evaluate the RBCCW heat exchanger leak and to implement corrective actions.

The cracks in the channel cylinder wall have been repaired by complete excavation and welding per the requirements of ASME Section XI and ASME Section VIII Div. 1 which is the construction code for the vessel. The repair was done under the BECo QA Program, and welding was done per the requirements of ASME IX.

Section XI IWA-4130 requires verification of suitability of the repair. The channel cracks are the result of fatigue caused by bending of the partition plates. Bending of the partition plates is caused by differential pressure resulting from flow impingement, back-washing, pump starts and flow through the four pass heat exchanger. This bending stress due to flow is also a cyclic stress since there is turbulent flow through the channel. After the channel was removed, additional examination of the interior showed cracking in the bottom reinforcement plate to channel welds for both lower and upper partition plates. It appears that tensile stresses resulting from partition plate bending caused cracks to initiate from the reinforcement plate to channel weld which is a location of high stress concentration. There are a total of eight channel to partition reinforcement plates with a reinforcement plate located at the top and bottom of each partition plate to channel attachment location. All four lower reinforcement plates were removed to provide access for examination. Examination showed the extent of cracking was much more severe at the lower partition plate/channel location. This is attributed to inlet impingement that only occurs on the lower partition plate. After weld repair of cracks, the reinforcement plates were reinstalled by welding. A stress reversal also occurs when the heat exchangers are back-washed, but this transient is only occasional and does not appear to be as severe since cracking was found only at the bottom reinforcement plate to channel weld locations. No cracking was found at the top reinforcement plate welds. Any cracking in the top reinforcement plate welds would have been attributable to back-washing.

Original design of the partition plates provided little design margin, and a number of repairs and modifications have previously been made to stiffen the partition plates and reinforce the attachment at the channel wall. Failure of the channel wall indicates the existing channel/partition plate configuration has a limited fatigue life, and the repair of the channel shell also has a limited fatigue life. An analysis has determined restoration of the crack areas will restore the channel to Code requirements. Modifications and/or replacements to address long term fatigue will be performed in RFO#11 so that the channel/partition plate will be suitable for the life of the plant.

The repairs were made under MR 19602034.

Examinations/Inspections

The 'B' RBCCW heat exchanger (E209B) had previously been opened, cleaned, visually examined and the tubes were eddy current tested in mid-cycle outage MCO#10 (October 1994). No cracks were found in the channel wall or the attachment welds. There were no new cracks on the partition plate, and the cracks that had been identified and dispositioned in 1991 were unchanged. The most recent examination of the 'A' RBCCW heat exchanger (E209A) was in RFO#10 (April 1995) when the heat exchanger was opened, cleaned, visually examined, and the tubes were eddy current tested. No cracks or other indications were found in the channel wall or the attachment welds. After restoration repairs, daily visual surveillance of the heat exchangers will confirm pressure boundary integrity until the design is upgraded in RFO#11.

ACTIONS TO PRECLUDE RECURRENCE

A design modification and/or replacement of the heat exchanger components is required to preclude recurrence.

2. SHUTDOWN ANOMALIES - Intermediate Range Monitors (IRM) Spiking

During the plant shutdown on September 18, 1996, a 12 hour active LCO was entered on the reactor protection system channel 'B' due to intermediate range monitor (IRM) channels 'D' and 'F' being determined to be inoperable. IRM 'D' spiked while down-ranging from range 7 to 6, and IRM 'F' began spiking in ranges 3 and 2. Problem report 96.9474 was written in response to IRM spiking. Following the shutdown, an issue manager was appointed to perform an analysis of IRMs and SRMs (source range monitor) and develop corrective actions prior to start-up. The results of the root cause are summarized below:

IRM 'A' tracked accurately with no spiking recorded. The initial diagnostic testing using a current versus voltage (I-V) curve was found to be acceptable. Five days following the shutdown, spiking began on IRM 'A'. Further diagnostic (I-V) testing identified degrading insulation resistance that was caused by a heavy carbon track found on the back side of the detector connector. The connector was replaced, and a design change was implemented to offer greater protection to moisture intrusion by installing an o-ring between the detector retainer and the cable guard. The replacement of the detector connector improved the insulation resistance, and no further spiking was recorded.

IRM 'B' spiking problems were identified in March 1995. The cable and detector connector were replaced in RFO#10, but the channel failed to respond during startup from RFO#10. This channel has been in the bypass position since RFO#10. Diagnostic testing following the shutdown on September 18, 1996, indicated the detector had failed and high vibration was detected in the detector drive assembly. The detector was replaced, and work was performed on the detector drive assembly to eliminate the source of high vibration.

IRM 'C' tracked accurately with no spiking during the shutdown. The initial diagnostic testing using a current versus voltage (I-V) curve was found to be acceptable. Five days following the shutdown, intermittent spiking began on IRM 'C'. Further investigations determined the spiking was due to moisture on the detector connector internal insulator. The connector was replaced, and a design change was implemented to offer greater protection to moisture intrusion by installing an o-ring between the detector retainer and the cable guard. The replacement of the detector connector improved the insulation resistance, and no further spiking was recorded.

IRM 'D' did not initially drive during shutdown; however, repeated actuation of the select push-button initiated movement to the full in position. The detector not driving when selected could not be recreated. Operations also reported a spike occurred on IRM 'D' during range changing. This event could not be recreated during testing. The diagnostic testing using current versus voltage (I-V) curves for IRM 'D' was found to be acceptable.

IRM 'E' also spiked during the shutdown. However, this problem could not be recreated. The diagnostic testing using current versus voltage (I-V) curves for IRM 'E' was found to be acceptable.

IRM 'F' experienced spiking during the shutdown. Trouble shooting revealed that the detector connector was wet due to moisture intrusion. The connector was dried out, and subsequent testing of the signal cable proved it to have an acceptable insulation resistance. The I-V curve indicated low resistance. Based on the diagnostic testing, a decision was made to replace the detector. After detector replacement, the instrument channel was tested satisfactorily.

IRM 'G' tracked accurately with no spiking during the plant shutdown. However, the initial diagnostic testing performed following shutdown indicated marginally acceptable insulation resistance. Further investigations revealed that the detector insulator was the cause of a marginal insulation resistance. An engineering analysis concluded the continued use of IRM 'G' during start-up was acceptable based on the previous performance of this channel. It was decided to replace the detector during RFO#11. The o-ring design change was implemented on IRM 'G' in order to prevent moisture intrusion.

IRM 'H' tracked accurately during the shutdown with no spiking. Diagnostic testing found the quality of the signal cable/connector and the detector to be excellent.

Diagnostic testing was also performed on the SRMs. During plant shutdown, SRM 'A' tracked accurately, but some signal noise/spiking was occurring. Diagnostic testing found acceptable detector, cable and connector performance. Procedure 3.M.2-5.1.4 was performed to optimize the setting of the pulse height discriminator. SRMs 'B' and 'C' tracked accurately during shutdown. Diagnostic testing found acceptable detector, cable and connector performance. No field work was necessary. Small indications of spiking and slightly lower counts compared to redundant channels were recorded for SRM 'D'. Diagnostic testing found intermittent connections occurred while driving the detector. Replacement of the cable connector corrected the intermittent problem. The pulse height discriminator and high voltage were also tested and adjusted.

ACTIONS TO PRECLUDE RECURRENCE

The corrective actions were effective. There were no IRM or SRM anomalies during startup. In addition, replacement of IRM 'G' during RFO#11 is being considered in order to improve the signal quality. Similarly, consideration is being given to the replacement of "HN" connectors with the environmentally qualified "Lemo" connectors to reduce the susceptibility to high humidity and moisture accumulation inside the cable connectors.

SAFETY CONSEQUENCES

This LER is submitted pursuant to the requirements of 50.73(a)(2)(i)(A) because a technical specification required shutdown was completed.

(1) The safety objective of the RBCCW system is to provide a heat sink for the residual heat removal system and the core standby cooling systems. The system consists of two independent closed loops with sufficient redundancy so that no single component failure can prevent the system from achieving its safety objective. The leak posed no threat to public health and safety because it was identified quickly, the unit was shutdown, and the heat exchanger was repaired. The 'A' RBCCW heat exchanger was operable prior to and through the event.

LICENSEE EVENT REPORT (LER)

TEXT CONTINUATION

FACILITY NAME (1)	DOCKET NUMBER (2)	LER NUMBER (6)			PAGE (3)
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TEXT (If more space is required, use additional copies of NRC Form 366A) (17)

(2) The intermediate range monitor system monitors neutron flux from the upper portion of the source range monitors to the lower portion of the power range monitors. The IRM system has eight IRM channels each of which includes one detector that can be physically positioned in the core by remote control. The system is designed to generate a trip signal that can prevent fuel damage from abnormal operational transients that occur while operating in the intermediate power range. The IRM spiking posed no threat to public health and safety because it was a potential failure in a conservative direction which was corrected. There were no IRM or SRM anomalies during startup from the shutdown on September 18, 1996.

The shutdown was executed in a safe and controlled manner.

SIMILARITY TO PREVIOUS EVENTS

(1) The 'B' RBCCW heat exchanger experienced a partition plate failure in 1981. The failure was reported in LER 81-049/01T-1, and it was attributed to a deficiency in the original design. Repairs to the heat exchanger consisted of removing as much of the existing cold welding compound as necessary to ensure effective adhesion of the repair material, new metal set applied and baffle grooves machined. The upper and lower partition plates of the 'A' and 'B' RBCCW heat exchangers were replaced via PDC 81-55.

The lower partition plate in the 'B' RBCCW heat exchanger was replaced in October 1989.

In 1991, the 'B' heat exchanger partition plate buckled at the plate centerline and along the shell-to-plate junction.

The partition plates in both the 'A' and 'B' RBCCW heat exchangers were modified. The partition plates were straightened and stiffener plates were added.

(2) Entering a Technical Specification action because of inoperable IRM channels was not a recurrent problem. Multiple IRM anomalies (spiking) during shutdown was not a recurrent condition; however, plans were in place to replace the IRM and SRM connectors to reduce and/or eliminate individual cases of spiking.

ENERGY INDUSTRY IDENTIFICATION (EIIS) CODES

Components	Codes
Heat Exchanger (E-209B)	HX
Intermediate Range Monitors	MON

Systems	
Reactor Building Component Cooling Water	CC
Incore Monitoring	IG