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November 6, 2009

SVP-09-066

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

Quad Cities Nuclear Power Station, Unit 1
Renewed Facility Operating License No. DPR-29
NRC Docket No. 50-254

Subject: Licensee Event Report 254/09-004, "Pinhole Leak in Core Spray Piping Results in Loss of Containment Integrity and Plant Shutdown for Repairs"

Enclosed is Licensee Event Report (LER) 254/09-004, "Pinhole Leak in Core Spray Piping Results in Loss of Containment Integrity and Plant Shutdown for Repairs," for Quad Cities Nuclear Power Station, Unit 1.

This report is submitted in accordance with the requirements of the Code of Federal Regulations, Title 10, Part 50.73(a)(2)(i)(A), which requires the reporting of the completion of any nuclear plant shutdown required by the plant's Technical Specifications.

There are no regulatory commitments contained in this letter.

Should you have any questions concerning this report, please contact Mr. W. J. Beck at (309) 227-2800.

Respectfully,

Timothy J. Tulon
Site Vice President
Quad Cities Nuclear Power Station

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station

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NRR

NRC FORM 366 (9-2007) U.S. NUCLEAR REGULATORY COMMISSION

APPROVED BY OMB: NO. 3150-0104 EXPIRES: 08/31/2010

Estimated burden per response to comply with this mandatory collection request: 80 hours. Reported lessons learned are incorporated into the licensing process and fed back to industry. Send comments regarding burden estimate to the Records and FOIA/Privacy Service Branch (T-5 F52), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by internet e-mail to infocollects@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0104), Office of Management and Budget, Washington, DC 20503. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

LICENSEE EVENT REPORT (LER)

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

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4. TITLE

Pinhole Leak in Core Spray Piping Results in Loss of Containment Integrity and Plant Shutdown for Repairs

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO.	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
									N/A	N/A
09	08	09	2009	- 004 -	00	11	06	2009	FACILITY NAME: N/A	DOCKET NUMBER: N/A

9. OPERATING MODE

1

10. POWER LEVEL

100%

11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: *(Check all that apply)*

- ☐ 20.2201(b)
- ☐ 20.2201(d)
- ☐ 20.2203(a)(1)
- ☐ 20.2203(a)(2)(i)
- ☐ 20.2203(a)(2)(ii)
- ☐ 20.2203(a)(2)(iii)
- ☐ 20.2203(a)(2)(iv)
- ☐ 20.2203(a)(2)(v)
- ☐ 20.2203(a)(2)(vi)
- ☐ 20.2203(a)(3)(i)
- ☐ 20.2203(a)(3)(ii)
- ☐ 20.2203(a)(4)
- ☐ 50.36(c)(1)(i)(A)
- ☐ 50.36(c)(1)(ii)(A)
- ☐ 50.36(c)(2)
- ☐ 50.46(a)(3)(ii)
- ■ 50.73(a)(2)(i)(A)
- ☐ 50.73(a)(2)(i)(B)
- ☐ 50.73(a)(2)(i)(C)
- ☐ 50.73(a)(2)(ii)(A)
- ☐ 50.73(a)(2)(ii)(B)
- ☐ 50.73(a)(2)(iii)
- ☐ 50.73(a)(2)(iv)(A)
- ☐ 50.73(a)(2)(v)(A)
- ☐ 50.73(a)(2)(v)(B)
- ☐ 50.73(a)(2)(v)(C)
- ☐ 50.73(a)(2)(v)(D)
- ☐ 50.73(a)(2)(vii)
- ☐ 50.73(a)(2)(viii)(A)
- ☐ 50.73(a)(2)(viii)(B)
- ☐ 50.73(a)(2)(ix)(A)
- ☐ 50.73(a)(2)(x)
- ☐ 73.71(a)(4)
- ☐ 73.71(a)(5)
- ☐ OTHER

Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER *(Include Area Code)*
Tom Petersen – Regulatory Assurance	(309) 227-2825

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

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX
B	BM	PSP	N/A	Y					

14. SUPPLEMENTAL REPORT EXPECTED

☐ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)* ■ NO

15. EXPECTED SUBMISSION DATE

MONTH	DAY	YEAR
N/A	N/A	N/A

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

On September 8, 2009, during the performance of a quarterly 1A Core Spray (CS) system [BM] flow test, a pinhole leak was identified in the 1B CS minimum flow line just downstream of MO 1-1402-38B (1B CS minimum flow valve [V]). The leaking pipe [PSP] could not be isolated from primary containment [NH]. As a result, primary containment was declared inoperable at 1935 hrs and Technical Specification (TS) 3.6.1.1, Required Action B.1, was entered requiring a plant shutdown in 12 hours. Unit 1 was shut down on September 9, 2009 at 0638 hrs. This event is therefore reportable under 10 CFR 50.73(a)(2)(i)(A), "The completion of any nuclear plant shutdown required by the plant's Technical Specifications."

After Unit 1 was shutdown the affected CS piping (5 inches long by 1-1/2 inches in diameter) was removed and an inspection was performed. The inspection confirmed that an area of the pipe had severely thinned. The thinned area had indications consistent with cavitation erosion.

The 1B CS piping downstream of 1-1402-38B was replaced on September 10, 2009, and a section of the 1B CS piping upstream of 1-1402-38B was also replaced on September 10, 2009. Unit 1 was synchronized to the grid at 0822 hrs on September 12, 2009.

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NARRATIVE

PLANT AND SYSTEM IDENTIFICATION

General Electric - Boiling Water Reactor, 2957 Megawatts Thermal Rated Core Power

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

EVENT IDENTIFICATION

Pinhole Leak in Core Spray Piping Results in Loss of Containment Integrity and Plant Shutdown for Repairs

A. CONDITION PRIOR TO EVENT

Unit: 1 Event Date: September 8, 2009 Event Time: 0925 hours
Reactor Mode: 1 Mode Name: Power Operation Power Level: 100%

B. DESCRIPTION OF EVENT

On September 8, 2009 at 0925 hrs, while performing a scheduled visual leakage examination (VT-2) of the Unit 1 "A" CS system Class 2 piping in accordance with procedure, "Section XI Pressure Testing," the VT-2 examiner identified a pinhole leak in the 1-1/2 inch diameter piping immediately downstream of MO 1-1402-38B valve (which is located in the Unit 1 "B" CS minimum flow piping line). The 1A CS minimum flow piping is adjacent to the 1B CS minimum flow piping. The leak was located on the bottom of the 1-1/2 inch diameter pipe, approximately 1/4 inch from the socket weld at the valve outlet.

The MO 1-1402-38B valve provides the CS min flow function (open function) for the "B" loop of CS, and is also a Primary Containment Isolation Valve (PCIV) [ISV] (closed function). The MO 1-1402-38B valve is a 1-1/2 inch flow under the seat Crane model 3652-U globe valve with a Limitorque SMB-000 motor operator [84]. The valve is located in a horizontal section of the 1B CS min flow piping run and is normally closed. The valve is fully opened during each operation of the 1B CS pump to provide minimum flow protection. The valve typically is open for a short duration for quarterly system testing.

Convinced that the leak was a through wall leak in the 1-1/2 inch CS pressure boundary the condition was reported to the Unit Supervisor (US). As a result of the leak, the US terminated the ongoing 1A CS surveillance, "Quarterly Core Spray System Flow Rate Test," and the visual examination was also terminated.

With the structural integrity of the piping in question, primary containment was declared inoperable at 1935 hrs and Technical Specification (TS) 3.6.1.1, Required Action B.1, was entered requiring a plant shutdown in 12 hours. In addition, Operations concluded that the extent of degradation on the piping downstream of MO 1-1402-38B valve might also impact the structural integrity of the 1B Loop of CS, thus the 1B CS system was also declared inoperable, therefore at 2057 hrs, TS 3.5.1, Required Action B.1, was entered requiring restoration of CS to operable status within 7 days.

On September 9, 2009 at 1033 hrs, Unit 1 entered Mode 4 (cold shutdown). On September 10, 2009, at 0030 hrs, the 5 inch long run of piping between the 1-1402-38B and the downstream 8 inch diameter header was removed from the system and an initial inspection of the pipe bore was performed on site by a Senior Metallurgical Engineer from

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Exelon Generation Company, LLC, PowerLabs. The inspection confirmed a patch of severe internal thinning in the pipe section that was closest to the upstream PCIV. The thinned region exhibited a jagged, irregular contour that was consistent with cavitation erosion.

Following the identification of the pinhole leak on the 1B CS piping, an immediate assessment of other similar piping was performed. The piping that was considered included the min flow lines on residual heat removal (RHR) [BO], high pressure coolant injection (HPCI) [BJ], and reactor core isolation cooling (RCIC) [BN] as well as the test return lines that the min flow lines are aligned to discharge to. UT exams were then targeted for locations immediately upstream and downstream of valves, restricting orifices [OR], and piping tees [PSF]. As inspection results were obtained, the extent of condition locations were re-assessed. The UT results showed most locations had wall thicknesses that were within the manufacturing tolerances established for the size and schedule of pipe installed. The only locations that exhibited obvious wall loss were the recently identified locations upstream and downstream of the 1-1402-38B valve, and areas around the 1-1406-8 inch (1A and 1B CS common return header) where previous damage was recorded prior to removing a restricting orifice from the header in 1992 (but still of acceptable minimum wall thickness).

Recent inspections in March 2009 (1B CS piping loop Class 2 leak test), and Q1R20, May 2009, (1A and 1B CS piping pressurized during the integrated leak test), provided similar opportunities to identify leaks, but did not identify any leakage from this leak location. The 1B CS piping section had been previously formally successfully leak tested (per VT-2) for the presence of through wall leaks in September 2002.

The 1B CS piping downstream of 1-1402-38B was replaced on September 10, 2009. A section of the 1B CS piping upstream of 1-1402-38B was replaced on September 10, 2009. The 1-1402-38B valve was also inspected during the piping replacements, and although cavitation damage was observed, it was evaluated as acceptable. Unit 1 was restarted on September 12, 2009.

C. CAUSE OF EVENT

A Root Cause evaluation was completed on October 21, 2009. The root cause of the 1B min flow piping pinhole leak at Quad Cities Station was due to a piping design that produced high water flow velocity (approximately 26 fps) in the 1B CS Min Flow Piping. The high flow velocity exceeded typical piping design recommendations (to maintain less than 20 fps), and when combined with the globe valve (MO 1-1402-38B), resulted in a high pressure drop and cavitation downstream of the valve. The cavitation led to the erosion of the downstream pipe wall during operation of the min flow line. It is likely in this case, considering the low usage expected from the min flow line, that it was not anticipated by the designers that the high flow velocities would eventually cause damage.

Contributing to the event was the lack of any formal controls (administrative barriers) to monitor for velocity induced cavitation erosion susceptibility and to monitor for potential damage in critical piping systems. Cavitation erosion is a known degradation mechanism associated with piping systems but is not specifically monitored at Quad Cities unless it is within the scope of the Risk Informed Inservice Inspection (RI-ISI) program or the Flow Accelerated Corrosion (FAC) program. The 1B CS min flow line was exempt from both the RI-ISI and FAC programs due to either size or service conditions and was appropriately exempted from inspections under the Inservice Inspection (ISI) program, and from Local Leak Rate Testing (LLRT) under the 10CFR50, Appendix J program. This section of piping is required to be tested/inspected during the periodic Integrated Leak Rate Test (ILRT) and associated walkdowns. In reviewing the governing codes and program requirements, the exemptions that were applied were found to be valid and did not contribute to this event.

D. SAFETY ANALYSIS

System Operation

Two independent core spray divisions are provided for use under loss of coolant accident (LOCA) conditions associated with large pipe breaks and reactor vessel depressurization. Each of the two core spray divisions consists of a 4500 gpm capacity pump [P], valves, piping and an independent circular sparger ring inside the inner shroud just over the core. Each core spray system is designed to operate in conjunction with low pressure coolant injection (LPCI) [BO] and either the automatic depressurization system (ADS) or HPCI subsystems to provide adequate core cooling over the entire spectrum of liquid or steam pipe break sizes. [UFSAR 6.3.2.1]

The injection valves in both injection divisions will remain closed until the reactor pressure decays to approximately design discharge pressure of the pumps, at which time the valves will open to admit flow into the reactor vessel. The pumps are operated on the minimum flow bypasses which discharge back to the suppression pool [NH] during the period they are running with the injection valves closed. [UFSAR 6.3.2.1.3]

The MO 1-1402-38B (1B CS minimum flow valve) valve has safety functions to open and to close. This valve provides the CS min flow function (open function) for the "B" loop of CS, and is also a Primary Containment Isolation Valve (PCIV) (closed function).

The safety function of MO 1-1402-38B to open is to provide a minimum flow path for the core spray pump.

The safety function of MO 1-1402-38B to close is to isolate primary containment and to prevent diversion of core spray flow to the suppression pool during an accident. The plant is normally operated with the MO 1-1402-38B valve in the closed position.

System Impact

Based on a review of recent RHR in-service test results, the pinhole leak would not have had an adverse impact on suppression pool cooling. The suppression pool inventory loss (less than 1/2 gpm) is well within station makeup capabilities and would have had minimal impact on Emergency Core Cooling System (ECCS) performance under accident conditions. Procedures allow torus makeup from a variety of water sources including the floor drain surge tank, main condenser, and contaminated condensate storage tank (CCST). Furthermore, the pinhole leak did not represent a significant flooding concern.

Other redundant safety systems, such as 1A CS and LPCI, were available during the time the 1B Loop of CS was inoperable due the pinhole leak event, and the MO 1-1402-38B valve could have been operated to the open position if required.

The time the 1B Loop of CS was inoperable due the pinhole leak, although potentially impacting the ability to achieve CS minimum flow, did not create any actual plant or safety consequences, since Unit 1 was not in an accident condition requiring CS injection during this event.

A finite element analysis of the as-found condition determined that substantial structural integrity had existed in the CS min flow piping. This analysis supports the conclusion that the pinhole leak would not have caused the pipe to rupture under accident conditions. Since cavitation erosion damage is time dependent, it is estimated that the wall loss that occurred was the result of erosion that occurred over the intermittent operation of the CS min flow line. Assuming the worst case operation of 1B CS where the CS pump may be operating on min flow while waiting for the reactor to depressurize, it is expected that the resultant min flow run time would conservatively be a few hours. In this

worst case condition, 1B CS operation on min flow with cavitation erosion occurring would not impact the structural integrity of the 1B CS piping.

Radiological Impact

The pinhole leak would have contributed to post-accident Engineered Safety Feature (ESF) leakage, however, given the leakage was small (leakage was estimated to be less than 1/2 gpm), accident dose would not have exceeded regulatory limits. Considering available margins (with the control room operator dose being limiting), a leak of up to 60 gpm would have met the regulatory requirement for post-LOCA exposure. Therefore, the predicted control room operator dose following a LOCA would not have exceeded any regulatory requirements (Alternate Source Term).

Risk Insights

Although the 1B Loop of CS was declared inoperable due the pinhole leak, the 1B Loop of CS was not unavailable for CS injection, hence there was no impact on CDF since the pinhole leak did not affect CS availability. In addition, the guidance provided in NRC IMC 0609, Appendix H (Containment Integrity Significance Determination Process) indicates that since this event did not affect CS availability, there is no impact on CDF, and hence there is no Large Early Release Frequency (LERF) contribution since "small lines (less than 2 inches diameter) and lines connecting to closed systems would not generally contribute to LERF." The CS min flow line is a 1-1/2 inch diameter line, and is considered a closed system. Therefore, there is no impact on the Station PRA.

In conclusion, there was no impact on plant risk, and the overall safety significance of this event was minimal.

E. CORRECTIVE ACTIONS

Immediate:

- Replaced 1B CS piping downstream of 1-1402-38B.
- Other immediate actions included performing additional UTs on the 1B CS piping upstream of 1-1402-38B as well as other similar ECCS min flow lines on Unit 1 and a similar CS min flow line on Unit 2. The additional examinations identified only one other location where the wall thickness was below manufacturing tolerances. As a result, a section of the 1B CS piping upstream of 1-1402-38B was also replaced.
- The 1-1402-38B valve was also inspected during the piping replacements and although cavitation damage was observed, it was evaluated as acceptable.

Follow-up:

- Corrective actions to prevent reoccurrence will focus on periodic monitoring activities rather than redesigning the 1B CS min flow line. A PM will be created to evaluate periodic UT exams performed on the 1-1402-38B piping sections that were replaced.
- To address other susceptible ECCS piping systems, a velocity induced cavitation erosion monitoring program will be developed and implemented at the site.

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- Guidance to address velocity induced cavitation will be developed and will include methods for identifying susceptible piping segments, the timing for performing volumetric inspections on susceptible piping segments, and the manner in which the required actions will be sustainable.

F. PREVIOUS OCCURRENCES

The station events database, EPIX, NPRDS, and LERs were reviewed for similar events. This event was caused by high fluid flow velocity which led to cavitation erosion, wall thinning, and ultimately a through wall piping leak in a standby system.

- Station Event Database – Quad Cities CR Q2000-00599, RHRSW Vault Room Cooler Leak, and follow-up CR 93444, RHRSW Vault Room Cooler Leak Quad Cities (2/3/00) - A cooling water supply line for the 2A RHRSW pump cubicle cooler developed a pinhole leak due to cavitation erosion. The erosion occurred downstream of a restricting orifice and where flow velocity was over 50 fps. The initial Condition Report (CR) did not result in an investigation so a follow-up Apparent Cause Evaluation (ACE) was performed under CR 93444. The ACE resulted in actions to perform additional UTs on similar cooling water lines to other cubicle coolers and modifications to install an additional restricting orifice in the susceptible lines to reduce flow rates. This event represents a missed opportunity to have assessed other piping systems where high velocity flows may drive cavitation, however at that time station guidance provided limited extent of condition reviews, whereas current requirements concerning extent of condition as well as extent of cause would have expanded the reviews to include other piping systems. This station event is relevant to this LER because it supports the fact that high fluid flow velocity, low use piping systems are susceptible to cavitation erosion.

- EPIX/ NPRDS – No similar events identified for Quad Cities

- LER 254-012-01 – 05/29/1998, Quad Cities Station, The Unit One Reactor Bottom Head Drain Line Developed a Leak Due to Outside Diameter Initiated Stress Cracking When Surface Contaminants Were Inadvertently Introduced as a Result of an Isolated Inadequate Work Practice During Original Installation or Welding Near Affected Crack Site. The failure mechanism for this event was outside diameter initiated stress corrosion cracking and therefore, this event is not related to the core spray piping pinhole leak event of this LER.

Other than the Station Event Database issue above, no other previous events have occurred at Quad Cities where high fluid flow velocity led to cavitation erosion in standby or low usage systems.

G. COMPONENT FAILURE DATA

This event has been reported to EPIX as Failure Report No. 979.

The component that failed is 1-1/2 inch, schedule 80 piping manufactured from ASME SA-106 GR. B, Carbon Steel. The pipe has an internal diameter of 1-1/2 inches and a minimum wall thickness of 0.175 inches.