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January 06, 2014
TMI-14-001

10 CFR 50.73

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1)
RENEWED FACILITY OPERATING LICENSE NO. DPR-50
DOCKET NO. 50-289

SUBJECT: LICENSEE EVENT REPORT (LER) NO. 2013-001-00
"Reactor Coolant "B" Cold Leg Drain Line Flaw"

This report is submitted in accordance with 10 CFR 50.73 (a)(2)(ii)(A). For additional information regarding this LER contact Mike Fitzwater, Sr. Regulatory Engineer, TMI Unit 1 Regulatory Assurance at (717) 948-8228.

There are no regulatory commitments contained in this LER.

Sincerely,

Mark Newcomer
Plant Manager, Three Mile Island Unit 1
Exelon Generation Co., LLC

MN/mdf

cc: TMI Senior Resident Inspector
Administrator, Region I
TMI-1 Senior Project Manager

IE22
NRR

NRC FORM 366 (10-2010) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

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

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
Three Mile Island, Unit 1	05000289	1 OF 6

4. TITLE: Reactor Coolant "B" Cold Leg Drain Line Flaw

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	05000
11	07	2013	2013	- 001 -	00	01	06	2014	N/A	05000

9. OPERATING MODE: N

10. POWER LEVEL: 0

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

☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)
☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☒ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☐ OTHER
☐ 20.2203(a)(2)(vi)	☐ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER (Include Area Code)
Michael Fitzwater, TMI Unit 1 Regulatory Assurance Engineer	(717) 948-8228

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

14. SUPPLEMENTAL REPORT EXPECTED		15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☒ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)*	☐ NO		02	14	14

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

On November 7, 2013 TMI-1 was in a refueling shutdown mode for the planned T1R20 refueling and maintenance outage. During a planned ISI volumetric examination of the reactor coolant "B" cold leg drain line a flaw in the pipe weld was discovered. The flaw is located in a 2 inch drain line elbow to pipe weld. The flaw was determined to not meet acceptance standards under ASME Section XI, IWB-3600, "Analytical Evaluation of Flaws", and the RCS strength boundary was considered degraded. This condition required reporting under 10 CFR 50.72(b)(3)(ii)(A) as a non-emergency degraded condition. The eight hour report was made at 13:02 on November 07, 2013 documented under EN# 49512. An extent of condition and ISI scope expansion was performed. Similar pipe configurations were examined and their structural integrity to meet ASME code requirements was confirmed. The flawed section of "B" cold leg drain line was cut out and replaced. This LER is to be supplemented after receipt of destructive laboratory test results of the flawed section. There was no actual breach of the RCS that resulted in leakage. There were no adverse safety consequences or safety implications that resulted from this event and this event did not affect the health and safety of the public.

The submittal of this LER constitutes reporting to the NRC in accordance with 10 CFR 50.73 (a)(2)(ii)(A).

A. EVENT DESCRIPTION

Plant Conditions before the event:

Babcock & Wilcox – Pressurized Water Reactor – 2568 MWth Core Power
Date/Time: November 07, 2013 / 13:02 hours
Power Level: 0%
Mode: Refueling Shutdown

There were no structures, systems, or components out of service that contributed to this event.

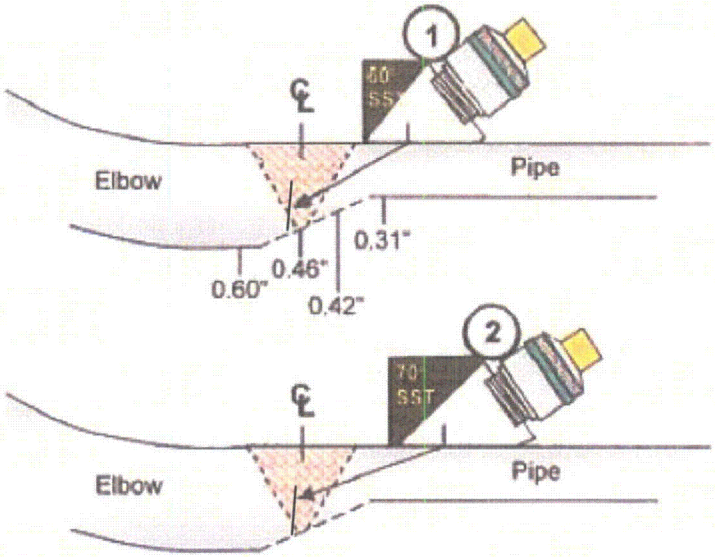
Event:
On November 07, 2013, TMI-1 was in a refueling shutdown status for the T1R20 planned refueling and maintenance outage. During a planned Inservice Inspection (ISI) volumetric examination of the reactor coolant "B" cold leg drain line a flaw in the pipe weld was discovered. The flaw is located in a 2 inch drain line elbow to pipe weld.

The flaw was determined to not meet acceptance standards under ASME Section XI, IWB-3600, "Analytical Evaluation of Flaws", with the RCS strength boundary considered degraded requiring report under 10 CFR 50.72(b)(3)(ii)(A) as a non-emergency degraded condition. The eight hour report was made at 13:02 on November 07, 2013 documented under EN# 49512.

System/Component Description:
The TMI-1 RCS has two Once Through Steam Generators (OTSG) [AB/HX]* with four Reactor Coolant Pumps (RCP - two in OTSG Loop "A" and two in OTSG Loop "B"), and includes piping and instrumentation. Each RCP [AB/P]* cold leg suction line (28 inch diameter) has a 2 inch drain. Each drain line contains two manual valves in series. The drain lines are routed to a header connected to the suction of the Reactor Drain Pump [WD/P]*.

The 2 inch drain lines for the "A," "B," and "D" RCP suction lines are connected to 1.5 inch nozzles (with inconel safe ends) by 1.5 inch by 2 inch reducing 90 degree elbows. The "C" RCP suction leg drain is through the 2.5 inch diameter RCS letdown line which taps off of the bottom of the "C" RCP suction leg.

During T1R20 the "B" RCP cold leg suction drain elbow was examined using ultrasonic technology. At the weld designated as weld RC-289, an indication was found within the weld that initiated at the inside diameter (ID) and progressed approximately 66% through wall, toward the outside diameter (OD). The defect was verified using phased array technology and confirmed. The wall thickness at the defect was 0.460" and the defect was 0.280" in length leaving a remaining ligament of 0.180" (180 mils).



Weld RC-289 - NDE report diagram from 2013 discovery. The crack location, black line, is at the tip of the arrow.

ASME Section XI 2004, subsection IWB, paragraph IWB-3514-2 requires the acceptable flaw depth to be less than 12 ½% of measured wall thickness. The maximum wall loss that would have been allowable at this location was 57.5 mils. Based on 280 mils of wall loss measured, the crack was greater than the code allowable limit and the flaw was required to be removed. The fitting was shipped to B&W for destructive analysis to determine the failure mechanism. A new and similar fitting was welded in place. The weld that replaced RC-289 was performed under shop conditions and was radiographed. No indications were noted from the installation Non-Destructive Examination (NDE).

B. CAUSE OF EVENT

The apparent root cause that RCS weld RC-289 was found cracked in T1R20 was that a resultant stress, composed of multiple smaller stresses focused by weld geometry, initiated a crack in RC-289. This crack was driven through the weld by stresses from plant heatup, cooldown, and thermal fatigue.

Schedule 160 Type 316 Stainless steel should perform over the full life of the plant. This has occurred, up to date, in the "A" and "D" cold leg drains despite two failures in the "B" cold leg drain. Some unique circumstance related to the "B" cold leg or a higher total force resulting in greater weld stress has cracked at this location and was found in 1995 and again in 2013. Actions taken in 1995 have not proven successful in preventing the crack from re-occurring.

The flaw found in 2013 was at the same location of a previously identified geometric indication (during T1R18 in 2009). The geometric indication was not thoroughly described and characterized in the NDE report. Additionally no Exelon review of the data report was conducted. As there was no geometric indication at this location noted during the pre-service examination (1995) nor during a follow-up exam (2001) it is believed the indication in 2009 may have been a flaw of a smaller size.

Both the 1995 and 2013 defects are believed to have failed due to a concentration of stresses that were maximized at the upper side of the weld on the ID. The initiation stress may be different from the propagation stress. A thorough evaluation of an exhaustive list of the stresses involved was completed. The exhaustive list of stresses is as follows:

1.) Weld internal stresses (can be relieved by post weld heat treatment)
2.) RCS cold leg growth in the downward and horizontal directions pushing the pipe against a hard stop
3.) Thermal stresses from heat up and cool down of the piping
4.) Thermal stresses from swirl introduction of rapid heat up and cool down cycles, called Thermal Fatigue
5.) Stresses from internal pressure, called Hoop Stress.
6.) Stresses from the pull of gravity on pipe and fittings between the supports, called Bending Moment.
7.) Stresses that come from vibrations of a reactor coolant pump start and steady state running conditions
8.) Stresses that come from transient loading, such as standing on the pipe or placing lead shielding on the pipe.

Stresses that come from an unknown acceleration, such as an earthquake or a sudden shift in coolant density due to a reactor trip.

The cracked fitting was removed during T1R20 and sent to B&W Labs for destructive analysis. The result of this analysis is due back in January of 2014. Because the subsequent laboratory information has not been completed within the 60 days of discovery, this LER will be supplemented by 02/14/14.

C. ANALYSIS / SAFETY SIGNIFICANCE

If the crack propagated to through wall condition, as in 1995, a very small coolant leak in the area of 30 drops per second would develop. This leak would be detectable through reactor building instrumentation and the reactor coolant leak rate calculation. The material properties of the stainless steel used are elastic enough to provide a leak before break presentation, which was the presentation demonstrated in 1995.

A shear failure of the "B" RCS cold leg drain line is bounded by the TMI-1 accident analysis for a small break loss of coolant accident (SBLOCA) described in the TMI-1 Updated FSAR section 14.2.2.4. The cold leg drain line break size is applicable to the small SBLOCA category for which all the cases analyzed concluded: "For the small SBLOCA cases analyzed, the RCS pressure did not depressurize sufficiently to allow LPI flow to enter the reactor vessel. In each case, at the time the analysis was ended, the core was completely recovered, the downcomer level was increasing, and the HPI flow was sufficient to absorb the decay heat and wall metal heat contributions. These conditions confirmed that the (High Pressure Injection) HPI flow, while inadequate to prevent partial core uncovering, was adequate to ensure long-term cooling." Procedures and operator training (including plant replica simulator training) are routinely conducted to provide confidence that such an event would be handled without endangering the health and safety of the public.

There was no actual breach of the RCS that resulted in leakage for this event. There were no actual adverse safety consequences or safety implications that resulted from this event and this event did not affect the health and safety of the public.

D. CORRECTIVE ACTIONS

Determine the source of the stress that is initiating the crack through the application of the following testing: Strain gauges, thermography, temperature measurement, and laser scanning.

If the crack source can be found and stopped, actions will be created to eliminate the source of the cracking.

If the crack source cannot be determined, actions will be created to determine if proactive replacement is warranted.

Additional actions from the root cause analysis:

- Take measurements on the safe end on the "B" Cold Leg drain and determine if a future elbow can be replaced without work on the safe end
- Revise procedure to require 100% review of all NDE examinations that meet the following criteria:
  a. Component can't be isolated
  b. High safety significance
  c. Geometry not previously reported
- Revise the Root Cause Analysis to include the B&W destructive test lab report
- Change the frequency of examination of the RCS cold leg drains from every 4 years to every 2 years beginning in 2017

E. PREVIOUS OCCURENCES

Previous Events	Previous Event Review
TMI-1 LER 1995-003-00 Reactor Coolant Leak Due To A Cracked Weld In A Cold Leg Drain Line	**Summary:** On September 9, 1995 a through wall leak was discovered at TMI on a reactor coolant cold leg drain line while the plant was in the process of cooling down for a refueling outage. The leak was estimated at 20 drops per second while the Reactor Coolant System (RCS) was at 2,000 psig and 535 °F. The failure was concluded to be cause by fatigue during metallurgical analysis. The crack initiated in the ID from an initial flaw and grew over through wall from thermal stratification and cycling caused by turbulent penetration of the RCS into the stagnant drain line. The flaw was located at top dead center (TDC) of the pipe weld. The failure occurred on the "B" drain line in the weld between the 2" schedule 160 horizontal piping and the 1.5" x 2" Schedule 160 reducing elbow. The piping and the elbow were both 316 stainless steel. The top of the ID of the horizontal piping run (flaw location) is 14.3 inches (10.7 diameters) below the RCS piping ID. The horizontal line extends for 7 feet with a horizontal bend before the first isolation valve. The line was not insulated at the time of the leakage. A rigid vertical support was located a few feet from the elbow. Subsequent examination

determined the flaw was 0.55" on the OD (7 to 33 degrees from the top of the pipe) and 2" on the ID (-13 to 122 degrees from the top of the pipe). The crack initiated in the ID from the heat affected zone in the pipe wall and grew through wall through the weld. It was noted during analysis that there was a notch present at the flaw initiation site. The flaw started in a section of metal undergoing intergranular attack (3 mils deep) and propagated in a transgranular manner.

There were 41 beach marks believed to be associated with plant heat up/cool down cycles, of which there were 42 since plant startup in 1974. Additionally striations were observed with a spacing of 0.2 µm (8 µin), corresponding to 44,000 striations through wall. Additionally damage was noted on the vertical rigid supports due to thermal growth of the RCS downward. The stress at the weld was determined to be 38 ksi without consideration of the thermal stratification stresses. It was determined that the "B" drain line had a positive slope from the elbow during operation allowing hot water penetrating from the RCS into the horizontal piping to move upward in the horizontal section towards the valve and colder water to flow to the weld. This condition did not exist in the other drain lines.

The drain line was replaced with the same components as the original construction with the exception of the addition of insulation to prevent heat loss and modification of supports to reduce stresses from thermal growth and remove the positive slope of the drain line.

Applicability:
The cracked weld found during the 2013 outage is the replacement weld from the 1995 through wall crack. The 2013 crack is in the same location as the 1995 crack was with the exception that the 2013 crack was not through wall and smaller on the ID, indicating that the flaw was found earlier in its growth cycle.

The main differences between the two flaws is that in the case of the 2013 flaw, the line was insulated and vertical supports had been removed to reduce stresses due to thermal growth and to remove a positive slope from the elbow through the horizontal piping segment. The original 1995 construction weld was made in the shop with a consumable insert; the 2013 weld was made in the shop with an open butt weld. Though the stresses due to thermal growth were reduced by removal of vertical supports, an increase in weld stresses and stress concentration is believed to be present due to the unusual geometry in the location of the weld.

It is believed a high stress state is created in the weld due to thermal movement of the RCS coupled with the increased stress concentration in the open butt weld. The drain line slopes upwards to the first isolation valve as it did in 1995 (the slope is believed to be less prominent in the current state), and thermal fatigue is the mechanism that grew the weld through wall.

* Energy Industry Identification System (EIIS), System Identification (SI) and Component Function Identification (CFI) Codes are included in brackets, [SI/CFI] where applicable, as required by 10 CFR 50.73 (b)(2)(ii)(F).