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An Exelon/British Energy Company

December 5, 2001
5928-01-20328

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

Dear Sir or Madam:

SUBJECT: THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1)
OPERATING LICENSE NO. DPR-50
DOCKET NO. 50-289
LICENSEE EVENT REPORT (LER) NO. 2001-002-00
"REACTOR COOLANT SYSTEM PRESSURE BOUNDARY LEAKAGE DUE TO STRESS CORROSION CRACKS FOUND IN SEVERAL SMALL BORE REACTOR VESSEL HEAD NOZZLE PENETRATIONS"

This letter transmits LER No. 2001-002-00, regarding the discovery of reactor pressure vessel head leakage due to stress corrosion cracks found in several reactor vessel head nozzle penetrations. For a complete description of the evaluated condition, refer to the text of the report provided on Forms 366 and 366A.

This report is being submitted in accordance with 10 CFR 50.73 (a)(2)(I)(B) and (a)(2)(ii)(A). For this event, the overall safety significance was minimal and there was no actual impact on the health and safety of the public. For additional information regarding this LER contact Mr. Adam Miller of TMI Unit 1 Regulatory Assurance at (717) 948-8128.

Sincerely,

George H. Gellrich
Plant Manager

GHG/awm

ATTACHMENT: List of Regulatory Commitments

cc: TMI Senior Resident Inspector
Administrator, Region I
TMI-1 Senior Project Manager
File No. 01080

IE22

SUMMARY OF AMERGEN ENERGY CO. L.L.C. COMMITMENTS

The following table identifies commitments made in this document by AmerGen Energy Co. L.L.C. (AmerGen). Any other actions discussed in the submittal represent intended or planned actions by AmerGen. They are described to the NRC for the NRC's information and are not regulatory commitments.

COMMITMENT	COMMITED DATE OR "OUTAGE"
There are no NRC Commitments contained in this LER	N/A

NRC FORM 366 U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

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

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Three Mile Island, Unit 1	05000289	1 OF 12

TITLE (4)

Reactor Coolant System Pressure Boundary Leakage Due to Stress Corrosion Cracks Found in Several Small Bore Reactor Vessel Head Nozzle Penetrations

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
10	12	2001	2001	- 002 -	00	12	05	2001	FACILITY NAME	DOCKET NUMBER

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

OPERATING MODE (9)	N							
POWER LEVEL (10)	0							
	20.2201(b)		20.2203(a)(2)(v)	X	50.73(a)(2)(i)(B)		50.73(a)(2)(viii)
	20.2203(a)(1)		20.2203(a)(3)(i)	X	50.73(a)(2)(ii)(A)		50.73(a)(2)(x)
	20.2203(a)(2)(i)		20.2203(a)(3)(ii)		50.73(a)(2)(iii)		73.71
	20.2203(a)(2)(ii)		20.2203(a)(4)		50.73(a)(2)(iv)		OTHER
	20.2203(a)(2)(iii)		50.36(c)(1)		50.73(a)(2)(v)		Specify in Abstract below or in NRC Form 366A
	20.2203(a)(2)(iv)		50.36(c)(2)		50.73(a)(2)(vii)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Adam W.Miller of TMI-1 Regulatory Assurance	(717) 948-8128

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
B	AB	NZL	B015	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 October 11 and 12, 2001, following shutdown for a scheduled refueling outage, Three Mile Island Unit 1 (TMI-1) performed a visual inspection of the Reactor Pressure Vessel (RPV) Head Nozzle Penetrations per NRC Bulletin 2001-01. The inspection revealed evidence of boric acid buildup around all eight (8) Thermocouple (T/C) nozzles and boric acid buildup around twelve (12) Control Rod Drive Mechanism (CRDM) nozzles. Based on the visual examination, engineering evaluation determined that all eight of the T/C nozzles were a source of Reactor Coolant System (RCS) pressure boundary leakage. Additional non-destructive examinations on the CRDM nozzles identified that five CRDM nozzles were also a source of RCS pressure boundary leakage and one non-leaking CRDM nozzle that contained unacceptable flaws. The cause of the cracks was determined to have been Primary Water Stress Corrosion Cracking (PWSCC). Prior to exiting the refueling outage, these nozzles were repaired. The RCS unidentified leak rate before the shutdown did not indicate any significant leakage. A safety assessment concluded that the nozzle cracks did not pose any risk for catastrophic nozzle failure or boric acid damage to the RPV head. Routine qualified visual inspections were determined to be adequate to detect future similar cracks before any significant impact on safe operations can occur. There were no adverse safety consequences from this event, and the event did not affect the health and safety of the public.

BACKGROUND

Thermocouple (T/C) Nozzles

A thermocouple (T/C) nozzle is a one inch diameter schedule 160 pipe machined to a controlled diametrical fit with the bore in the reactor pressure vessel (RPV) head *[RCT]. The nozzle material *[NZL] is SB-167 (alloy 600). A total of eight thermocouple *[THC] nozzles were installed in the RPV head. These nozzles are located outboard of the RPV head's Control Rod Drive *[DRIV] Mechanisms (CRDMs).

The original T/C nozzles were intended to provide instrumentation access into the vessel in order to verify that the internal reactor vessel plenum vent valves were not leaking. This was later determined to be unnecessary and blind flanges were added to the T/C nozzles that established the Reactor Coolant System (RCS) *[AB] pressure boundary. Two of the T/C nozzles were subsequently modified to support the Reactor Coolant Inventory Tracking System (RCITS) and Reactor High Point Vent System. The other six T/C nozzles serve no current function other than RCS pressure boundary.

A typical T/C nozzle head penetration consists of an approximate 1 inch outside diameter (OD) by 0.218 inch nominal wall alloy 600 pipe that is inserted vertically into the RPV head. The T/C pipe is connected to the inside surface of the RPV head by a J-groove partial penetration weld. The thermocouple nozzles have an overall length of approximately 62 inches. About 8 inches of each T/C nozzle extends past the J-groove weld on the inside surface of the RPV head.

Control Rod Drive Mechanism (CRDM) Nozzles

There are 69 Control Rod Drive Mechanism (CRDM) *[AA] nozzles that penetrate the RPV head. The CRDM nozzles are approximately 5 feet long and are welded to the RPV head at various radial locations from the centerline of the RPV head. The nozzles are constructed from 4 inch OD alloy 600 material. The lower end of the nozzle extends about 6 inches below the inside of the RPV head.

Each CRDM nozzle was machined to final dimensions to assure a match between the RPV head bore and the OD of each nozzle. The nozzles were tack welded and then permanently welded to the RPV head using 182 weld metal. The final weld surface was ground and PT inspected.

NRC Bulletin 2001-01

Based on past RPV head penetration leakage found at the Oconee and ANO plants, the NRC issued Bulletin 2001-01 to solicit input from each Pressurized Water Reactor (PWR) to determine the various Utility response and actions to address this issue. TMI Unit-1 response stated that all RPV head penetrations would be visually inspected, and any "suspect" nozzles would be subsequently examined by liquid dye penetrant (PT) and Ultrasonic (UT) inspections. Any RPV head penetration determined to be leaking would be repaired.

In accordance with approved plant procedures, the initial results of the visual inspection classified the "as-found" condition of the RPV head penetrations into three categories:

1. Acceptable. Those in the Acceptable category showed no evidence of leakage at the base of the nozzle and the outer RPV head surface.
2. Masked. This is an interim category. Those in the Masked category had loose debris or obstructions around the nozzle that prevented an entire 360-degree inspection. The obstruction or loose debris was vacuumed (while videotaping the area) to allow for complete inspection. Based on the results of leaking RPV nozzles at other stations, the boric acid residue associated with leaking penetrations is characterized as tightly adhering to the nozzle/head interface area. Vacuuming would not remove this type of boric acid residue. After vacuuming, the nozzle was classified as either Acceptable or Suspect. Any nozzle that remained "masked" in the area of interest (annular gap) would be determined to be Suspect and subject to subsequent UT and PT inspections.

3. Suspect. Those in the Suspect category showed signs of boric acid residue at the nozzle base.

Leakage would be confirmed by additional PT and UT inspections.

The suspect CRDM locations were evaluated with visible dye penetrant (PT) method at the surface of the J-groove weld, the OD of the CRDM nozzle protruding into the RPV, and at the end of the CRDM nozzle. All suspect CRDMs had the drives removed and a top down inspection was performed utilizing the EPRI demonstrated Framatome ANP ultrasonic inspection equipment. The ultrasonic inspection consisted of two complete scans of each suspect nozzle. One axial scan was used to identify circumferential flaws, and one circumferential scan identified any axial flaws.

Since no additional PT or UT inspections were planned for the T/C nozzles, any masked condition placed the T/C nozzle into the Suspect category. Videotapes of previous inspections were available to identify any prior boric acid residue conditions.

Additionally, if any circumferential cracking was found above the J-groove weld in CRDMs, then the UT inspection would be expanded to include those CRDM nozzles that are made accessible (i.e. had CRDM motor tubes removed as a result of visual inspections or to permit repairs). Repairs would be made to any leaking RPV nozzle and any flaws found not acceptable. These repairs would use Framatome ANP repair techniques similar to the repairs completed at the Oconee and Crystal River Units.

EVENT DESCRIPTION

On October 11/12, 2001 with Three Mile Island Nuclear Station (TMI-1) Unit 1 in refueling outage, 1R14, a periodic, qualified visual inspection of the top surface of the RPV head revealed boric acid deposited on the head surface. The RPV head inspection was performed in response to Generic Letter 88-5, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants", and NRC Bulletin 2001-01, " Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles".

Boric acid deposits were located at the base of all eight T/C nozzles. After reviewing tapes of the last T/C nozzle inspection, all thermocouple nozzles were deemed to be leaking (since no additional PT or UT inspections were planned for the T/C nozzles). At approximately 1230 on October 12, 2001, Engineering evaluation of the thermocouple nozzle visual inspection results confirmed that the boron deposits around the eight T/C nozzles indicate a RCS pressure boundary leak. The T/C nozzle leakage was reported [EN # 38383] as a non-emergency [8-hour] in accordance with 10 CFR 50.72(b)(3)(ii)(A).

The initial visual inspection of the CRDM nozzles only categorized two (2) to be “Suspect”. These were CRDM numbers 35 and 37. However, forty-five (45) CRDM nozzles were categorized as “Masked”. These locations were videotaped as the loose debris was vacuumed to allow for complete inspection of the base of the CRDM nozzles. Subsequently an additional ten (10) CRDM nozzles were deemed to be “Suspect” from the population of forty-five (45) masked. These were CRDM numbers 11, 20, 29, 32, 41, 44, 48, 51, 64,and 65. This brought the total number of CRDM nozzles requiring additional PT and UT inspections to twelve (12).

After the RPV head was removed and placed on the storage stand, additional PT and UT inspections were performed on the twelve (12) suspect CRDM nozzles. At approximately 1357 on October 22, 2001, Engineering evaluation of the visual inspection, Liquid Penetrant Test (PT) data and Ultrasonic Test (UT) data identified through-wall indications on three (3) CRDM nozzles. This initial engineering evaluation concluded that the visual indications around CRDM numbers 35, 37, and 44 indicate a RCS pressure boundary leak. Since the condition resulted in leakage through the RCS pressure boundary, it was reported [EN # 38416] as a non-emergency [8-hour] report in accordance with 10 CFR 50.72(b)(3)(ii)(A). Two days later, a revised non-emergency 8-hour report stated that CRDM nozzles number 29, and 64 were also determined to be leaking.

Details

<u>PT Inspection Results</u>

The results of the PT inspection identified four CRDM locations with positive indications. None of the

indications detected were safety significant, and no indications were found which could contribute to loose parts. However, all CRDM locations with positive PT indications were repaired. The other eight nozzles exhibited no PT indication. The PT indications are as follows:

1. CRDM nozzle 35 had two (2) axial indications in the weld and one circumferential indication approximately 23 degree in the weld toward the RPV cladding.
2. CRDM nozzle 37 had one axial indication in the weld and one circumferential indication approximately 100 degree in the weld toward the RPV cladding.
3. CRDM nozzle 44 had four (4) axial indications, one in the weld and three at the end of the nozzle; and one circumferential indication approximately 23 degree in the weld toward the RPV cladding.
4. CRDM nozzle 64 had one circumferential indication approximately 60 degree in the weld toward the RPV cladding.

<u>UT Inspection Results</u>

The results of the UT inspection identified seven (7) CRDM nozzles with axial flaws. No circumferential flaws were detected either above or below the J-groove weld in the nozzle material. The identified flaws were evaluated in accordance with the acceptance criteria contained in the September 24, 2001 draft letter from J. Strosnider (NRC NRR) to A. Marion (NEI). Three of the CRDM nozzles were determined to require repair based on the ultrasonic inspections. These CRDM locations were nozzles 44 (also determined to be leaking based on PT), 29, and 51. CRDM #29 was the only nozzle to show an OD flaw, the other flaws were all located on the ID. Based on fracture mechanics and crack growth it was determined that the flaw in CRDM nozzle 51 required repair. ID flaws in the other four (4) CRDM nozzles were analyzed to be acceptable. Note that CRDM #35 and #64 were repaired based on PT results. The other five nozzles had no flaws based on UT. The UT indications are as follows:

1. CRDM nozzle 11 had one ID axial indication. The flaw was 0.12 inch in depth and 0.36 inch long. The flaw was located 1.91 inch below the J-groove weld. The flaw was analyzed as acceptable for at least an additional cycle of operation.
2. CRDM nozzle 29 had one OD axial indication. The flaw was 0.11 inch in depth and 0.91 inch long.

The flaw was located 0.13 inch above the J-groove weld and extended to 0.34 inch above the face of the weld. It was determined that the flaw most likely entered the weld material and was too small to be seen as a PT indication. The flaw was determined to be unacceptable and repaired.

3. CRDM nozzle 35 had three (3) ID axial indications. Flaw #1 was 0.35 inch in depth and 0.44 inch long. The flaw was located 1.49 inch below the J-groove weld. Flaw #2 was 0.21 inch in depth and 0.61 inch long. The flaw was located 1.08 inch below the J-groove weld. Flaw #3 was 0.21 inch in depth and 0.52 inch long. The flaw was located 1.32 inch below the J-groove weld. The three flaws were closely spaced and evaluated as a combination, the combined flaw was analyzed as acceptable for an additional cycle of operation.
4. CRDM nozzle 44 had one ID axial indication. The flaw was 0.34 inch in depth and 1.53 inch long. The flaw was located 0.33 inch below the J-groove weld. The flaw growth was analyzed and was deemed unacceptable and repaired.
5. CRDM nozzle 51 had five (5) ID axial indications. Flaw #1 was 0.35 inch in depth and 1.7 inch long. The flaw was located 0.97 inch below the J-groove weld. Flaw #2 was 0.43 inch in depth and 2.06 inch long. The flaw was located 0.48 inch below the J-groove weld. Flaw #3 was 0.15 inch in depth and 0.47 inch long. The flaw was located 1.99 inch below the J-groove weld. Flaw #4 was 0.17 inch in depth and 0.55 inch long. The flaw was located 0.75 inch above the J-groove weld. Flaw #5 was 0.12 inch in depth and 0.33 inch long. The flaw was located 1.1 inch above the J-groove weld. Flaws #1, #2, and #3 were closely spaced and evaluated as a combination, the combined flaw was analyzed as unacceptable and repaired.
6. CRDM nozzle 64 had one ID axial indication. The flaw was 0.24 inch in depth and 01.17 inch long. The flaw was located 1.03 inch below the J-groove weld. The flaw was analyzed as acceptable for an additional cycle of operation (this nozzle was repaired based on PT results).
7. CRDM nozzle 65 had one ID axial indication. The flaw was 0.12 inch in depth and 0.4 inch long. The flaw was located 0.89 inch below the J-groove weld. The flaw was analyzed as acceptable for at least an additional cycle of operation.

CAUSAL FACTORS

The apparent root cause of the RPV head penetration nozzle crack was Primary Water Stress Corrosion Cracking (PWSCC). Previous industry experience with PWSCC in Alloy 600 components was evaluated as part of NRC Generic Letter 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and Other Closure Head Penetrations." The findings from TMI Unit 1 are similar to the PWSCC cracking previously experienced at the Oconee Nuclear Stations, Crystal River, and Arkansas Nuclear. However, no circumferential cracking was found either above or below the J-groove weld on any of the twelve CRDM nozzles that were ultrasonically inspected.

TMI and Exelon will continue to participate with industry owner groups, NEI, and EPRI to better understand the PWSCC issues with alloy 600 component failures.

Discussion

Alloy 600 is used extensively in nozzle applications in the reactor vessel. It is also used in the pressurizer, hot and cold leg piping as well as steam generator tubing in Babcock & Wilcox fabricated plants. It is generally recognized that these small-bore nozzles have experienced cracking, and the industry has evaluated the results of multiple failure analyses. The result from these analyses is that the failure mechanism is a form of stress corrosion cracking referred to as PWSCC.

PWSCC has been assumed to initiate at the inside surface of the nozzle that is adjacent to the partial penetration J-groove welds. This area has been shown to have high residual stresses as a result of the welding process. Additional stress can result from machining, grinding, or reaming operations. In thin wall products, this area could also have an altered microstructure from welding. It has been established that PWSCC can occur in materials provided that three conditions exist:

1. susceptible material
2. high tensile stress, and

3. an aggressive environment.

Almost all small-bore alloy 600 nozzle (including thermocouple and CRDM nozzles) attached with a partial penetration weld possesses these above characteristics. In PWR applications, numerous small bore alloy 600 nozzles and pressurizer heater sleeves have experienced leaks attributed to PWSCC. These components in B&W designed plants are normally exposed to 600 degree F or higher temperatures and primary coolant water, as are the TMI Unit 1 RPV penetration nozzles.

CORRECTIVE ACTIONS

Immediate:

Based on prior RPV nozzle leakage found at other Babcock & Wilcox plants, TMI Unit 1 organized a project team in January 2001 to deal with establishing personnel and equipment to inspect and subsequently repair any leaking RPV nozzles.

Subsequent:

Prior to exiting TMI Unit 1 refueling outage, the 14 identified RPV nozzles (8 T/C and 6 CRDM) were repaired.

1) For the CRDM nozzles the initial repair action was to roll the nozzle above the J-groove weld, then to machine the lower portion of the CRDM nozzle including portions of the J-groove weld. The final surface was PT examined prior to the weld repair process. A new pressure boundary weld was formed between the CRDM nozzle and the RPV head low alloy steel at a location above the previous J-groove weld and below the rolled nozzle area. Protective compression surface stress remediation was performed after the repair was PT and UT examined.
2) For the thermocouple nozzles, the nozzles were cut approximately 1 inch from the outside surface of the RPV head. The remaining nozzle portion inside the RPV head was machined out of the

head. Six T/C nozzles were plugged by installing an Inconel 690 nozzle plug in the RPV head bore. After the nozzle plug was tack welded, a nozzle plug weld dam was inserted into the cavity in the top of the nozzle plug and tack welded to the nozzle plug. A weld pad build up of Inconel 152 was welded over the nozzle plug and weld dam using a temper bead welding process. The other two T/C locations that are used for operation of the RCITS and Reactor High Point Vent had an Inconel 690 sleeve installed into the RPV head bore. The sleeve was secured with a weld pad build up of Inconel 152. Afterwards, a nozzle assembly was inserted into the sleeve and the circumference of the nozzle assembly was welded to the bottom of the sleeve. A replacement T/C flange assembly (consisting of a new flange, ¾ inch schedule 160 stainless steel pipe welded to the flange and an Inconel tube welded to the stainless steel pipe) was inserted into the Inconel sleeve and welded in place.

In addition, a video inspection of the RPV head surface was completed after cleaning activities to provide a baseline for future visual inspections.

Planned:

Although repairs have been completed for the 14 identified RPV head nozzles, the potential for future leakage events of alloy 600 CRDM nozzles on the existing RPV head due to PWSCC will be addressed through continued RPV head nozzle inspections and repairs as necessary. Corrective actions are in place to re-examine CRDM nozzles 11 and 65 during the next refueling outage if they remain in service after the next refueling outage. In the long term, the RPV head may be replaced to prevent recurrence of this event.

TMI-1 plans to continue to participate in industry activities regarding PWSCC.

SAFETY ANALYSIS

The degraded condition of the eight T/C and six CRDM nozzles did not represent a challenge to the nuclear safety of the plant. The cracks were primarily in the J-groove weld metal. No circumferential cracking was found either above or below the J-groove weld therefore eliminating any CRDM nozzle ejection. These cracks propagated until they resulted in leaks that were detected during a planned RPV head surveillance.

Primary coolant leakage from the cracks was minimal due to the relatively tight cracks. The total leakage from the 13 RPV head nozzles was significantly less than the Technical Specification limits for unidentified RCS inventory loss nor were there obvious increases in the Reactor Building (RB) normal sump levels or increases in Reactor Building air sampling radiation activity. No RB or area radiation monitors alarms sounded. The small amounts of boric acid deposits that were observed around the RPV head nozzles had caused no observable corrosion to the RPV head.

Inspections of the top surface of the RPV head are performed at each scheduled refueling outage. The results of the 1R14 RPV head inspection supports the conclusion that the CRDM nozzles would leak first and be discovered by station personnel during normal RPV head inspections. Finally, fracture mechanics analysis has shown that the ID nozzle flaw on CRDM # 11 and #65 will be acceptable for at least 5 Effective Full Power Years of operation.

In conclusion, PWSCC of the TMI-1 nozzles did not pose a nuclear safety risk. The basis for RPV head nozzle cracking not being a safety risk include:

1. Leak rates from cracks within the annulus region of the nozzle are low,
2. No circumferential cracks were found either above or below the J-groove weld which also makes the potential for complete nozzle failure and control rod ejection a low probability event,
3. Leakage from cracked nozzles will result in visible boric acid deposits around the nozzle that would be discovered during normal refueling inspections,

4. The RPV head has been cleaned in order to enhance the ability to identify any nozzle leaks that may develop in the future.

ADDITIONAL INFORMATION

There were no releases of radioactive materials, radiation exposures, or personnel injuries associated with this event.

This event is considered reportable under the Equipment Performance and Information Exchange (EPIX) program.

SIMILAR EVENTS

TMI Unit 1 has had no LERs over the past 3 years that reported PWSCC of alloy 600 components or leaks involving RPV head penetration nozzles.

PWSCC is not new either to the domestic or worldwide nuclear industry. As evidenced from the similar PWSCC discoveries at the other B&W nuclear stations and TMI Unit 1, TMI will remain susceptible to future PWSCC cracking of alloy 600 components. Until a planned corrective action to replace the RPV head is implemented, this type of event may be expected to recur.

* The 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).