Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

October 15, 2003
NOC-AE-03001610
10CFR50.73

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

South Texas Project
Unit 1
Docket Nos. STN 50-498, STN 50-499
Supplement to Licensee Event Report 03-003
Bottom Mounted Instrumentation Penetration Indications

Reference: STP Unit 1 Licensee Event Report (LER) 03-003, dated June 11, 2003
(NOC-AE-03001548)

Pursuant to 10CFR50.73, the South Texas Project submits the attached supplement to Unit 1 Licensee Event Report 03-003 regarding boric acid residue discovered on two bottom-mounted instrumentation nozzles of the Unit 1 reactor vessel on April 12, 2003. This event did not have an adverse effect on the health and safety of the public.

Commitments are listed in the Corrective Actions section of the attached report.

If there are any questions on this submittal, please contact S. M. Head at (361) 972-7136 or me at (361) 972-7849.

E. D. Halpin
Plant General Manager

awh

Attachment: Supplement to LER 03-003 (South Texas, Unit 1) cc:

(paper copy)

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NRC FORM 366 (7-2001)	U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB NO. 3150-0104	EXPIRES 7-31-2004

LICENSEE EVENT REPORT (LER)

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

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
South Texas Unit 1	05000 498	1 OF 7

4. TITLE

Bottom Mounted Instrumentation Penetrations Indications – Supplement to LER dated 6/11/2003

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO	MO	DAY	YEAR	FACILITY NAME	DOCKET NUMBER 05000
04	12	2003	2003 -	03 -	01	10	15	2003	FACILITY NAME	DOCKET NUMBER 05000

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

12. LICENSEE CONTACT FOR THIS LER

NAME	TELEPHONE NUMBER (Include Area Code)
Albon W. Harrison	361-972-7298

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

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

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

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

On April 12, 2003, with South Texas Project Unit 1 in a refueling outage, personnel discovered deposits at two Bottom Mounted Instrument (BMI) nozzles of the reactor vessel. This condition was identified during the station’s regular bare metal inspection of the reactor vessel bottom penetrations, which is done as part of the RCS Pressure Boundary Inspection for Boric Acid Leaks Program. A small amount of residue was noted around the circumference of BMI nozzle Penetrations #1 and #46 where they enter the reactor vessel.

The residue consisted of approximately 150 milligrams of material from penetration number 1 and approximately 3 milligrams from penetration number 46. No wastage was observed on the outside of the bottom head, and samples of the residue were collected and analyzed. Both deposits contained boron and elevated levels of lithium consistent with reactor coolant system (RCS) leakage. Cesium isotopic analysis indicated an approximate age of 4 years for each sample.

Ultrasonic testing was performed on all of the 58 BMI penetrations. Cracks were found in Penetrations #1 and #46, however, no cracks were found in any other penetration. The root cause is the use of Alloy 600 combined with nozzle manufacturing and installation methods that further increased the susceptibility of the metal to stress corrosion cracking when in contact with primary water.

The nozzles at Penetrations #1 and #46 were repaired prior to restart of Unit 1.

This event resulted in no personnel injuries, no offsite radiological releases, and no damage to safety-related equipment other than the affected BMI penetrations. There were no challenges to plant safety.

DESCRIPTION OF EVENT

The bottom head of the reactor was visually inspected on April 12, 2003, as a routine part of the refueling outage. The bottom head of the reactor is contained in an insulating box structure with no insulation directly in contact with the bottom head. The inspection is accomplished by removing three of the insulation panels forming the insulating box. Three different vantage points are used to inspect all 58 BMI nozzles. The inspection found small amounts of white residue around BMI Penetrations #1 and #46 at the point where the nozzle enters the reactor vessel bottom head.

The BMI nozzles are Inconel Alloy 600 machined from 1.75-inch diameter bar stock. The nozzles have a nominal outside diameter of 1.5 inches and an inside diameter of 0.60 inches. The nozzles are attached to the interior of the reactor vessel by an Alloy 82/182 J-groove weld. The reactor vessel itself is 5.38-inch thick low alloy carbon steel with 0.22 inches of stainless steel cladding on the interior surface. There is an annulus between the nozzle and the reactor head below the J-groove Weld of 0.001 to 0.004 inches.

The residue at Penetrations #1 and #46 was collected for laboratory analysis to determine the source of the residue material. Approximately 150 milligrams and 3 milligrams were collected from penetrations number 1 and 46, respectively. The presence of elevated concentrations of lithium in addition to boron in the samples was the initial indicator that the source of these samples was operational reactor coolant rather than some other source of borated water, such as the reactor cavity.

To determine the approximate age of the residue, the ratio of Cesium -134/ Cesium -137 was calculated. Cesium-134 has a half-life of 2.06 years and Cesium-137 has a half-life of 30.10 years. The ratio of Cesium-134 to 137 in the primary cooling system is approximately 1. The Cesium -134/ Cesium -137 ratios in the samples were 0.30 and 0.25 for penetrations number1 and 46, respectively. These Cesium ratios indicate that the average age of the residues collected is between 3 and 5 years. Although, the bottom of the reactor vessel head is inspected every outage[1], no residues were visible during the most recent previous inspection on November 20, 2002, confirming very small leak rates. The bottom head of the reactor is inspected every refueling outage. It is important to note that the inspection program did discover these extremely small leaks long before wastage of the carbon-steel could take place and well within structural safety margins for the nozzle material and wall thickness.

Nondestructive Examination (NDE)

Ultrasonic inspections and visual inspections of all 58 BMI nozzles were performed. Cracks were identified only in Penetrations #1 and #46, the two leaking nozzles identified by the April 12, 2003, visual inspection. Penetrations #1 and #46 contained a total of five cracks. No cracks were identified in any other BMI nozzle.

Penetration #1 contains three axial cracks. One crack in Penetration #1 penetrated the inside diameter (ID) of the nozzle and extended from just above to just below the J-groove weld. The other two cracks were small and just penetrated the outside diameter (OD) of the nozzle.

Penetration #46 contains two axial cracks. Neither of the cracks in Penetration #46 penetrated the ID of the tube, as verified by a supplemental eddy current (ET) examination. One crack extended from just above to just below the J-groove weld.

[1] If the unit has been at operating temperature and pressure for more than 90 days since the last bottom head inspection and the outage is expected to last more than 72 hours.

The UT examination also found anomalies at the nozzle/weld interface in all of the nozzles. Examination of a boat sample specimen from Penetration #1 identified the anomalies as areas of lack of fusion (LOF) between the nozzle and weld.

Eddy current testing was also performed on the surface of the J-groove welds for eight nozzles. No surface breaking cracks were identified.

Other Testing

A helium leak test was performed on the two leaking penetrations by pressurizing the annulus between the nozzle and the vessel. No bubbles were observed in Penetration #46. In Penetration #1 a small helium bubble was observed about every two seconds rising from a location outside the nozzle in the J-groove weld fillet at the tube interface.

Sampling and Destructive Examination

To facilitate metallurgical analysis of the actual cracks, boat samples were removed from Penetrations #1 and #46 employing an Electric Discharge Machining (EDM) cutting technique. In the case of the BMI nozzles inside the reactor pressure vessel, the boat sample excavations could not be repaired. The desire for the largest possible boat sample was balanced against conservative structural limitations.

The boat sample from Penetration #46 was designed to capture as much tube material as possible in an attempt to harvest a portion of a crack not connected to the ID of the nozzle. The margins for error associated with positioning the EDM equipment through 70 feet of water resulted in a shallow cut in Penetration #46. The resulting undersized sample was either inadvertently discarded or completely consumed in the margins of the EDM cutting tool. The boat sample from Penetration #1 captured material and defects from the J-groove weld and J-groove/tube interface, as designed. A composite drawing showing the axial crack, weld flaw and weld crack is attached.

The boat sample from Penetration #1 contained a portion of the large through-wall axial crack in the tube, three “discontinuities” which were confirmed to be lack of fusion resulting from slag inclusions, and one crack at the helium bubble location which connects the surface of the J-groove weld to the largest area of lack of fusion.

The crack in the weld that connects the surface of the J-groove weld to the largest area of lack of fusion is singular and unique. The 0.2-inch long crack spans an 80 mil ligament separating the lack of fusion void from the surface of the J-groove weld in the ground fillet transition at the tube/J-groove weld interface. The length of the crack spans and is limited to the width of the lack of fusion void. The section of the boat sample containing this crack was broken in the laboratory to expose the crack face for examination. Tenacious deposits obscured the crack face, and gradually more aggressive attempts to remove the deposits also attacked and distressed the metal surface. The crack exhibits some intergranular characteristics. To some reviewers, the nature of the oxide deposits suggests hot cracking. Fatigue could also be a factor in the development of this crack. However, the precise mechanism responsible for initiating and propagating this crack could not be determined.

Earlier UT results identified an axial crack in Penetration #1 which penetrated the ID of the nozzle and extended from just above to just below the J-groove weld. The boat sample from Penetration #1 successfully captured a part of the upper portion of this crack in the region of the tube/J-groove weld interface. The intergranular nature of this crack exhibits classic primary water stress corrosion cracking (PWSCC) characteristics. The extent of the crack was examined by progressively grinding away thin layers of the section of the boat sample. The orientation of the ground surface was such that more weld material and less

1. FACILITY NAME	2. DOCKET	6. LER NUMBER			3. PAGE
		YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	
South Texas Unit 1	05000 498	2003	03	01	4 OF 7

NARRATIVE *(If more space is required, use additional copies of NRC Form 366A)* **(17)**

tube material was exposed at each successive grind. The initial exposed surface consisting of nearly all tube material contains a crack that extends into the weld material then stops. As successive layers are ground away, exposing more weld and less tube, the extent of the crack becomes smaller and smaller. The final ground surface, which consists almost entirely of weld material, reveals no crack at all in the weld and a small vestige of crack in the remaining small bit of tube. Photographs of the grinds of the first face and the last face are attached.

The axial crack in the tube appears to grow from the EDM surface out to the tube/J-groove interface since it branches and connects two of the three voids, at least at this location in the boat sample. This fact might suggest ID initiated PWSCC. However, neither of the two cracks in Penetration #46, the other leaking BMI penetration, connects to the ID of the tube. A supplemental ET examination of the ID surface was performed specifically to confirm the UT results that the flaws did not penetrate the ID. ET established that the cracks did not connect to the ID. Based on this fact STPNOC has concluded that the PWSCC axial crack in the tube is OD initiated. The crack most likely originated on the OD of the tube in the highly stressed region of the flooded weld defects.

The boat sample also contained numerous small cracks around the periphery of the LOF flaws to a depth of 1 or 2 grains. Although hot cracking in the weld material is a possibility, this intergranular cracking also appears in the nozzle, where hot cracking is not possible. Therefore, STPNOC has concluded that this cracking is PWSCC resulting from flooding of the LOF voids.

In summary, metallurgical analysis of a sample removed from one of the leaking BMI penetrations confirmed the presence of weld defects on the highly stressed interface between the Alloy 600 tube and the connection weld to the pressure vessel. The sample revealed one small additional crack that connected the lack-of-fusion weld defect to the surface of the weld and primary water. Once the lack-of-fusion void became flooded with primary water, all of the requisite conditions to support stress corrosion cracking existed at the nozzle OD at a location of predicted high residual stress.

The penetration leakage at South Texas demonstrated that the Alloy 600 BMI nozzles are susceptible to PWSCC and will crack under the right conditions. Even at the lower temperatures of the bottom head, PWSCC is possible. Additionally, the shielded metal arc welding (SMAW) process used to construct the J-groove welds is prone to leaving weld defects in service and creating high residual stresses. STPNOC did not identify any materials or fabrication techniques unique to the construction of the STP Unit 1 reactor vessel related to the occurrence of these cracks.

The STP Unit 1 experience also demonstrates that visual examination of bare metal BMI penetrations is an effective mechanism for detecting minor leakage long before flaws become structurally significant.

Event Significance

There were no adverse safety or radiological consequences associated with this event. Other than the degradation of the two affected BMI penetrations, no equipment damage occurred as a result of this event and the event did not affect the operability of any other safety-related equipment. This event is reportable pursuant to 10CFR50.73(a)(2)(ii)(A).

Since the Unit 1 leak indications were discovered during a refueling outage and did not require additional RCS inventory control actions or a plant shutdown evolution, there was no actual risk increase associated with this condition.

Causes of the Event

The root cause is the use of Alloy 600 combined with nozzle manufacturing and installation methods that further increased the susceptibility of the metal to stress corrosion cracking when in contact with primary water.

The SMAW process used to construct the J-groove welds is prone to leaving weld defects in service and creating locally high residual stresses. Metallurgical analysis of the Penetration #1 boat sample confirmed the presence of weld defects on the highly stressed interface between the Alloy 600 tube and the connection weld to the pressure vessel. Already located in high stress areas on the OD of the penetration, these weld defects act as stress risers. The sample revealed one small additional crack that connected the lack-of-fusion weld defect to the surface of the weld and primary water. Once the lack-of-fusion void became flooded with primary water, all of the requisite conditions to support stress corrosion cracking existed, as evident from the intergranular cracking around the periphery of the defect. Thus, the penetration leakage at South Texas demonstrated that the Alloy 600 BMI nozzles are susceptible to PWSCC and will crack under the right conditions.

Corrective Actions

1. Prior to restart of Unit 1, BMI penetrations 1 and 46 were repaired using Alloy 690 half-nozzles and 52/152 weld material that is resistant to PWSCC.
2. Perform future inspections per commitments made in STPNOC's July 11, 2003 letter to the NRC (NOC-AE-03001557).

Generic Implications

The STP BMI nozzle cracks show Alloy 600 is susceptible to PWSCC even at relatively low temperatures if high stress conditions induced during fabrication are present. STPNOC did not identify any materials or fabrication techniques unique to the construction of the STP Unit 1 reactor vessel related to the occurrence of these cracks.

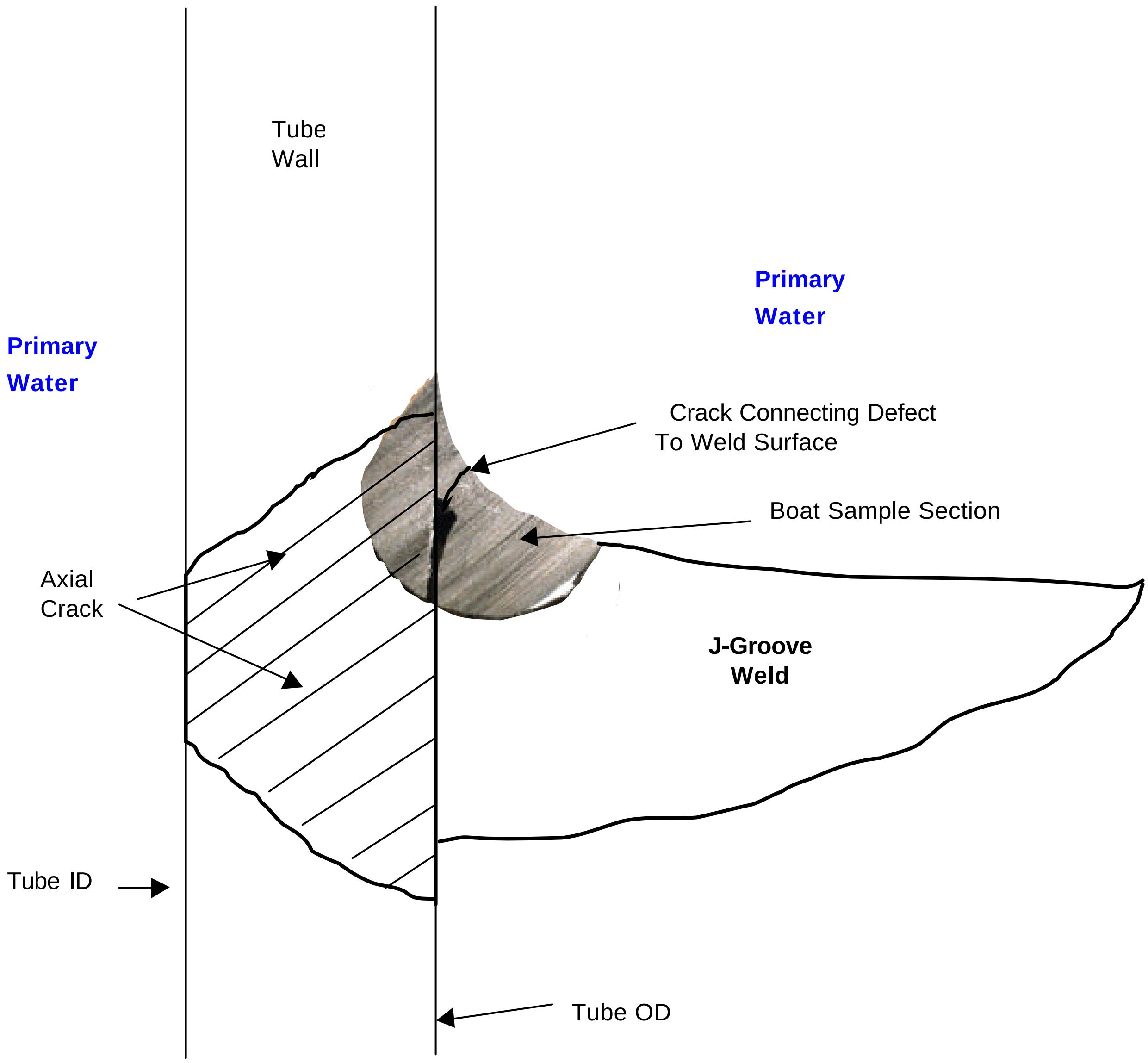
Recent bare-metal inspections of the Unit 2 bottom-mounted instrumentation penetrations showed no evidence of leakage. Due to the slow growth and low safety significance of the cracks in the affected Unit 1 penetrations, the fact that the other 56 penetrations on Unit 1 showed no indications, and the absence of leakage in Unit 2, STPNOC concluded that no immediate action is required for Unit 2. As a conservative measure, STPNOC plans to perform non-destructive examination of the Unit 2 BMI penetrations as described in Corrective Action 2 above.

Additional Information

There have been no previous bottom-mounted instrumentation tube leaks at the South Texas Project.

Service experience with bottom mounted instrumentation nozzles has generally been excellent to date, with only a few incidents reported. Until the year 2000, with only one exception, the only incidents involved thimble tubes bent during handling. The exception was at Catawba Unit 1, which occurred during hot functional testing in February 1984. A part of the lower internals (instrumentation column) into which one of the BMI tubes had been inserted, came loose, with the result that the BMI penetration eventually suffered a fatigue failure and was severed. After the repair of this condition, there were no recurrences of the problem at Catawba.

Composite Drawing Showing Axial Crack, Weld Flaw, and Weld Crack



Photographs of First and Last Face Grind