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

Subject: Oconee Nuclear Station
Docket No. 50-270
Licensee Event Report 270/2002-02, Revision 0
Problem Investigation Process No.: O-02-05496

Gentlemen:

Pursuant to 10 CFR 50.73 Sections (a)(1) and (d), attached is Licensee Event Report 270/2002-002, Revision 0, addressing the discovery of reactor pressure vessel head leakage due to Primary Water Stress Corrosion Cracking of Alloy 600 Control Rod Drive Nozzles.

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 of this event was minimal and there was no actual impact on the health and safety of the public.

Very truly yours,

R. A. Jones

Attachment

IE22

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INPO (via E-mail)

NRC FORM 366 (7-2001) 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
Oconee Nuclear Station, Unit 2	050- 0270	1 OF 8

4. TITLE

Reactor Pressure Vessel Head Leakage Due to Primary Water Stress Corrosion Cracking of Alloy 600 Control Rod Drive Nozzles

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MO	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO	MO	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
									None	
10	15	02	2002	- 02	- 00	12	03	02	FACILITY NAME	DOCKET NUMBER

9. OPERATING MODE: 5

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)(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 Specify in Abstract below or in NRC Form 366A
	20 2203(a)(2)(iii)		50 46(a)(3)(ii)		50.73(a)(2)(v)(C)		
	20.2203(a)(2)(iv)		50.73(a)(2)(i)(A)		50 73(a)(2)(v)(D)		
	20 2203(a)(2)(v)	X	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)
L.E. Nicholson, Regulatory Compliance Manager	(864) 885-3292

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
B6a	RCS	NZL	B&W	Y					

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)

Unit 2 entered its scheduled end-of-cycle 19 refueling outage on October 12, 2002. On October 15, 2002, a qualified visual inspection of the bare reactor vessel (RV) head was performed per NRC Bulletin 2001-01. Results of the visual inspection revealed several control rod drive mechanism (CRDM) nozzles were either classified as “masked” or leaking. Per Duke’s response to NRC Bulletin 2001-01, nondestructive examinations of these and other CRDM nozzles were subsequently performed.

Using conservative repair decisions supported by ultrasonic test and liquid dye-penetrant inspection techniques, a total of fifteen CRDM nozzles were categorized as appropriate for repair. All of the flaws identified in the nozzle base material were axial. The apparent root cause of the nozzle leaks is primary water stress corrosion cracking (PWSCC).

The 15 nozzles were repaired prior to unit restart. The RV heads for all three units will be replaced as a long-term PWSCC solution. For this event, the overall safety significance of this event was minimal and there was no actual impact on the health and safety of the public.

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

EVALUATION:

BACKGROUND

There are 69 Control Rod Drive Mechanism (CRDM) [EIIS:AA] nozzles [EIIS:NZL] that penetrate the Reactor Vessel Head (RVH) [EIIS:RCT]. The CRDM nozzles are approximately 5-feet long and are welded to the RVH at various radial locations from the centerline of the RVH. The nozzles are constructed from 4-inch outside diameter (OD) Alloy 600 material. The lower end of the nozzle extends about 6-inches below the inside of the RVH.

The Alloy 600 used in the fabrication of CRDM nozzles was procured in accordance with the requirements of Specification SB-167, Section II to the 1965 Edition including Addenda through summer 1967 of the American Society of Mechanical Engineers Boiler and Pressure Vessel (ASME B&PV) Code. The product form is tubing and the material manufacturer for the Oconee Nuclear Station (ONS) Unit 2 CRDM nozzles was the Babcock and Wilcox (B&W) Tubular Products Division.

Each nozzle was machined to final dimensions to assure a match between the RVH bore and the OD of each nozzle. The nozzles were shrunk fit by cooling to at least minus 140 degrees F., inserted into the closure head penetration and then allowed to warm to room temperature (70 degrees F minimum). The CRDM nozzles were tack welded and then permanently welded to the closure head using 182-weld metal. The manual shielded metal arc welding process was used for both the tack weld and the J-groove weld. During weld buildup, the weld was ground, and dye penetrant test (PT) inspected at each 9/32 inch of the weld. The final weld surface was ground and PT inspected.

The weld prep for installation of each nozzle in the RVH was accomplished by machining and buttering the J-groove with 182-weld metal. The RVH was subsequently stress relieved prior to the final installation of the nozzles.

EVENT DESCRIPTION

Unit 2 (ONS-2) entered its scheduled end-of-cycle 19 refueling outage on October 12, 2002. Based on Duke's practices and per NRC Bulletin 2001-01, on October 15, 2002, a qualified visual inspection was performed of the [bare] reactor vessel (RV) head while bolted to the vessel in order to identify any indications of leakage from the Control Rod Drive Mechanism (CRDM) nozzle penetrations. The inspection was performed looking through the nine access ports in the service structure support skirt on the RV head.

Results of the visual inspection revealed seven CRDM nozzles (Nos. 8, 9, 19, 24, 31, 42 and 67) with boron deposits potentially associated with CRDM nozzle leaks. Five additional CRDM nozzles (Nos. 1, 4, 18, 60 & 63) were classified as being "masked," i.e., there was boron residue present but a conclusive leak path from these nozzles could not be seen. CRDM nozzles No. 4 and 18 (along with Nos. 6 and 30) had previously been repaired during the cycle 18 refueling outage (See Figure 1). On October 15, 2002, after confirming that during power operations the Reactor Coolant System [EIIS: RCS] pressure boundary had been degraded, an 8-hour notification was made at 1754 hours in

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accordance with 10 CFR 50.72(b)(3)(ii)(A) reporting requirements. In association with Duke's response to NRC Bulletin 2001-01, nondestructive examinations (NDE) of these and other CRDM nozzles were subsequently performed using either ultrasonic test (UT) or liquid dye-penetrant (PT) inspection techniques.

NDE Results

Due to improvements in the UT inspections techniques in identifying leakage paths along the nozzle outer diameter volume and the increased radiation dose to inspection personnel, Eddy Current (EC) inspections were not performed during this inspection campaign and the decision to repair was made using the visual, UT and PT inspection results alone.

Utilizing an Aramis Blade Probe with a mid-wall focus, under-the-reactor vessel-head UT inspections were performed on 65 of the 69 total CRDM nozzles. The purpose of the UT inspections was to determine if circumferential and/or large axial flaws existed in the nozzles. The remaining four nozzles that had previously been repaired during the last refueling outage were UT inspected using a different method as described below. Results of the inspections revealed no circumferential cracks but did identify ten (Nos. 11, 15, 19, 21, 24, 31, 33, 36, 38 & 42) CRDM nozzles with axial flaws.

Dye penetrant (PT) examinations were performed on the two previously repaired CRDM nozzles that were masked (Nos. 4 and 18). The PT examinations did not reveal any recordable indications. Four additional CRDM nozzles (Nos. 1, 60, 63 & 67) were also PT inspected and were conservatively identified for repair based on the PT results.

Additional NDE inspections were performed using a Framatome-ANP (FANP) Top-Down Tooling (TDT) UT method to look for both axial and circumferential flaws. Top-Down Tooling UT inspections were performed on the four previously repaired CRDM housing regions (Nos. 4, 6, 18 & 30); No reportable axial or circumferential indications were identified. These results confirmed the adequacy of the previous CRDM nozzle repairs and eliminated the two masked nozzles (Nos. 4 & 18) from further repair consideration.

Eleven additional CRDM nozzles were also examined using the TDT UT method. Four were confirmed leaking nozzles (Nos. 8, 9, 42 & 67) and six had flaw indications from the Aramis blade probe UT inspections (Nos. 11, 15, 21, 33, 36 & 38). CRDM nozzle 28 was also examined using the TDT UT method due to a problem that prohibited examination using the Aramis blade probe. Results of the TDT inspections showed no flaw indications for CRDMs nozzles 28 and 33. Since these nozzles showed no indication of leakage and had no recordable TDT UT indications, no further inspection or repair was warranted.

Partial through-wall cracks were identified from the Aramis blade probe UT inspections on CRDMs nozzles 11, 15, 19, 21, 24, 31, 33, 36, 38 & 42. As described above, since additional TDT UT examination showed no indications in CRDM nozzle 33, it was removed from repair consideration. The TDT inspections confirmed an identical number of flaws for the five CRDMs without visual leakage (Nos. 11, 15, 21, 36 & 38). CRDM nozzles 8, 9 & 67 did not show any UT indications, but had obvious visual leakage (leak paths for nozzles 8 and 9 were identified). The masked CRDM nozzles (Nos. 1, 60

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& 63) were UT clear, but the under head surface PT inspection results showed unacceptable indications for these as well as for leaking CRDM nozzle 67.

Nozzle Repair Process

A total of 15 CRDM nozzles were repaired (Nos. 1, 8, 9, 11, 15, 19, 21, 24, 31, 36, 38, 42, 60, 63 and 67; See Figure 1). The repair configuration was identical to that used for the ONS-1 CRDM nozzle repairs in the spring of 2002, the ONS-2 CRDM nozzle repairs in the spring of 2001 and the ONS-3 repairs in the fall of 2001. The protruding portions of the CRDMs and a length about 5 inches into the RV Head bore were removed by machining. A new pressure boundary weld was installed within the bore, inspected and surfaced conditioned with a water jet peening process.

Reportability

Technical Specification Limiting Condition for Operation 3.4.13(a) limits RCS operational leakage to "No pressure boundary leakage" while in MODES 1 through 4. This event also represents a degradation of one of the plant's principal safety barriers. Consequently, this event is being reported pursuant to 10CFR50.73(a)(2)(i)(B) and 10CFR50.73(a)(2)(ii)(A) reporting requirements.

No operator intervention was required as a result of this event. Prior to the discovery of this event, Unit 2 was in cold shutdown (Mode 5) at 0 percent power and Units 1 and 3 were in Mode 1 operating at approximately 100 percent power.

CAUSAL FACTORS

The apparent root cause of the leaking Alloy 600 CRDM nozzles was Primary Water Stress Corrosion Cracking (PWSCC).

General cause of event discussion:

Alloy 600 is used extensively in nozzle applications in reactor vessel, pressurizer [EIIS: PZR], hot and cold leg piping, and steam generator [EIIS: SG] tubing. It is recognized that small-bore nozzles have succumbed to numerous cracking incidents and the industry has evaluated and documented the results of many failure analyses. The conclusion resulting from this work is that the failure mechanism is pressurized water stress corrosion cracking (PWSCC).

PWSCC can initiate on Alloy 600 surfaces exposed to primary water at high temperatures that have high residual stresses due to welding. Cold working of the surface by machining, grinding or reaming operations prior to welding may result in higher residual stress.

It is well established that PWSCC can occur in materials provided that three conditions are present:

1. Susceptible material,
2. High tensile stress, and
3. An aggressive environment.

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Virtually any small-bore Alloy 600 nozzle (including CRDM nozzles) attached with a partial penetration weld possesses these characteristics. In PWR applications, numerous small-bore Alloy 600 nozzles and Pressurizer heater sleeves have experienced leaks attributed to PWSCC. Generally, these components are exposed to 600 degree F. or higher temperatures and primary water, as were these CRDM nozzles.

Specific discussion regarding the apparent cause of event reported in this LER:

The apparent cause of the Alloy 600 CRDM Nozzle leaks is PWSCC. The investigation into the current ONS-2 RV head leakage continued to support the conclusions documented during previous ONS-1, ONS-2 and ONS-3 RV head repairs since the initial discovery of this issue in the fall of 2000. Five supporting points from this most recent ONS-2 outage include:

1. No circumferential cracking was found in the nozzle base material.
2. All of the observed nozzle cracks were axial.
3. Seven of the CRDMs exhibited the boron deposits indicative of past leakage.
4. PT indications on the J-groove weld surface were used to supplement NDE results.
5. Conservative repair decisions were made based on available NDE information that increased the number of repaired CRDM nozzles to a total of 15.

CORRECTIVE ACTIONS

Immediate:

An assessment team was assembled to investigate the event including apparent cause(s), necessary corrective actions, and past/future unit operational impacts.

Subsequent:

Fifteen CRDM nozzles were repaired prior to unit restart.

Planned

ONS is planning to replace the RV Heads for all three units as a long-term Alloy 600 PWSCC solution. The Oconee Corrective Action Program includes additional long-term programmatic actions to manage PWSCC susceptibility at Oconee until the start of initial RV Head replacement (ONS-3) scheduled for the spring of 2003.

These short and long-term corrective action commitments have previously been furnished to the NRC and there are no new commitments being made in this report. These as well as other pertinent corrective actions are addressed and being managed via the Oconee Corrective Action Program.

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SAFETY ANALYSIS

Actual Safety Consequences

There were no actual safety consequences as a result of this event. The leakage of primary reactor coolant through the CRDM nozzles was so small that it was detectable only by the extremely small accumulation of boric acid crystals observed on the RV head. The total leakage from the CRDM nozzles did not exceed Technical Specification limits for unidentified RCS inventory loss. At no time during the operating cycle did the reactor building or area radiation alarms actuate as a result of this event. The small amounts of boric acid crystal deposits observed around the nozzles had caused no visible corrosion damage to the RV head.

Potential Safety Consequences

Ultrasonic test NDE revealed potential leak paths within the wall region of nine of the repaired CRDM nozzles. This is a region where Finite Element Analysis (FEA), including the effects of welding residual stresses and operating conditions, predicts high hoop stresses. The CRDM axial crack geometries are consistent with the analysis that shows the hoop stress (that drives cracks in the axial orientation) is higher than the axial stress (that drives cracks circumferentially) at high stress locations. Crack growth into the nozzle wall (although small) is also consistent with analysis predictions that high hoop stresses extend through the weld material and into the nozzle wall. The axially oriented OD cracks are consistent with FEA results, and with a root cause determination of PWSCC. There were no circumferential CRDM nozzle flaws.

Framatome-ANP previously performed an analysis assuming an above the weld circumferential flaw was through wall and extended 180° around. This analysis showed there was sufficient margin (with a safety factor of 3) to preclude gross net-section failure. UT examination identified no circumferential flaws. Even if circumferential flaws had been found, the latest revision of Framatome-ANP's Safety Evaluation asserts that nozzle cracking will be identified by leakage before circumferential flaws become a safety issue. The basis for this conclusion is the fact that an axial through-wall or through-weld flaw is required before the circumferential flaw can initiate and begin to grow.

A rod ejection accident is possible if nozzle leakage is not detected and repaired. At ONS, all the RV heads are maintained essentially free of boron deposits. Large openings have been made in the service structure to facilitate the RV bare head inspections. All suspected leaking nozzles have been repaired. The potential for a rod ejection accident has not increased as a result of these axial cracks. Also, a rod ejection accident has been thoroughly evaluated in the ONS UFSAR and the ONS operators have been trained on the procedure and response to this accident.

Conditions leading to gross corrosion of the RV head (observed on the Davis Bessie RV Head) are not a legitimate concern at Oconee as described below:

- The top of the head bare metal visual was a complete head inspection, 360-degrees around each nozzle. The inspection did not show any signs of corrosion or wastage on the head surface.

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- Leaking penetrations produce boric acid on the top of the head that can be found by visual inspection.
- Post-machining NDE and the actual weld repair method would identify any occurrence of head wastage due to either corrosion or erosion. This method would also find any wastage below the surface of the head between the nozzle exterior wall and the head bore inside diameter.
- The PT of the repair surfaces would identify any cracks or voided areas in the RV material.

A unit 2 risk assessment was completed that supported restart from the current refueling outage. In addition, a risk assessment was completed for all the Oconee units that evaluated the time period prior to reactor vessel head replacement. This risk assessment concluded that the increase in core damage frequency, due to the probability of a circumferential crack reaching the critical flaw size and causing a loss of coolant accident, would be below the point of being risk significant for any of the Oconee units during each of these reactor years. Additionally, the revised ONS UFSAR Chapter 15 accident analysis using actual ONS core data concluded that there would be no failed fuel due to a postulated Rod Ejection Accident from a failed CRDM nozzle.

ADDITIONAL INFORMATION

This event did not include a Safety System Functional Failure nor involve a personnel error. There were no releases of radioactive materials, radiation exposures in excess of limits or personnel injuries associated with this event. This event is considered reportable under the Equipment Performance and Information Exchange (EPIX) program.

SIMILAR EVENTS

Over the last two years, similar event LERs have been submitted for all three Oconee units beginning with ONS-1 in December 2000 (LER 269/2000-06) and the last for ONS-1 in May 2002 (LER 269/2002-03). To date, three LERs (including 1 supplement) have been submitted for ONS-1, two LERs (including this report) for ONS-2, and two LERs for ONS-3, which reported PWSSC of Alloy 600 CRDM and/or thermocouple nozzles (ONS-1 only). Prior to these LERS, there have been no other reportable events that involved PWSCC of Alloy 600 components or RVH penetration leaks.

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

LICENSEE EVENT REPORT (LER)

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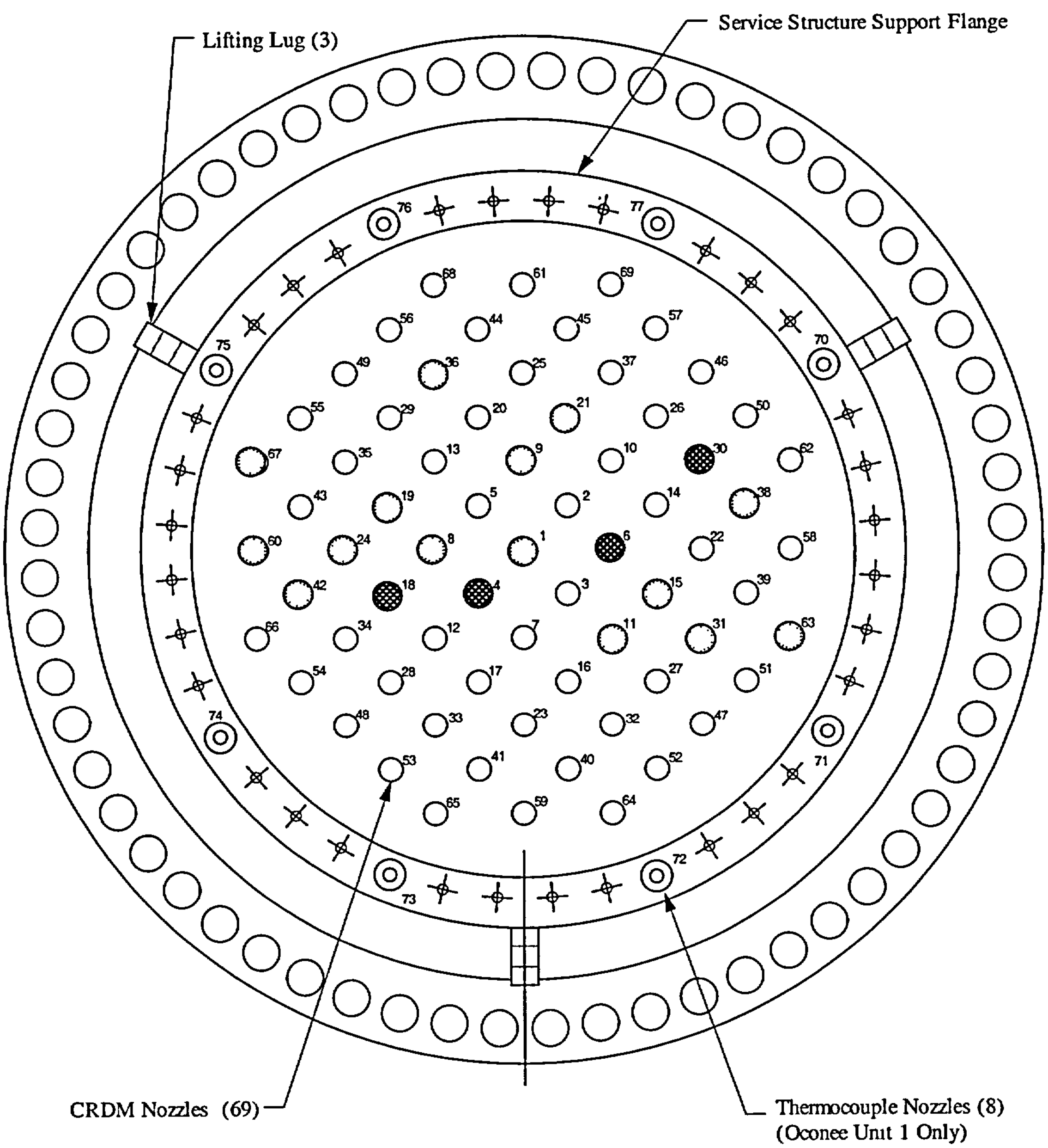
Figure 1 – Oconee Unit 2 RVH Map



○ Nozzles 1, 8, 9, 11, 15, 19, 21, 24, 31, 36, 38, 42, 60, 63, and 67 were repaired

● Nozzles 4, 6, 18 and 30 were previously repaired during 2EOC18 refueling outage