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Subject: Duke Power Company, Oconee Nuclear Station, Unit 1
Docket No. 50-269
Reactor Vessel Head and Penetration Nozzle Condition Report

Enclosed is the Duke Energy Corporation report on the condition of the Reactor Vessel Head and Penetration Nozzles for the recently completed Oconee Nuclear Station end-of-cycle 20 refueling outage. This report provides the information requested by NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," dated August 3, 2001, "Requested Action 5," and NRC Bulletin 2002-01, "Reactor Pressure Vessel Head Degradation and Reactor Coolant Pressure Boundary Integrity," dated March 18, 2002, items 2.A and 2.B.

These bulletins requested that licensees provide information concerning the results of reactor vessel head and head penetration nozzle inspection, repairs and other corrective actions in addition to a description of any leakage.

If there are any questions, you may contact R. C. Douglas at (864) 885-3073.

Very Truly Yours,

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Site Vice President

Enclosure

A088

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Oconee Unit 1
End-of-Cycle 20 Refueling Outage
Reactor Vessel Head Penetration Nozzle Indication Report

Background

This following provides the Duke Energy Corporation (Duke) response to NRC Bulletin 2001-01, "Requested Action 5" and NRC Bulletin 2002-01 "Requested Action 2" for the reactor vessel head inspection and repair activities associated with the above titled refueling outage.

Reactor Vessel Head Design and Fabrication Information

There are 69 Control Rod Drive Mechanism (CRDM) nozzles that penetrate the Reactor Vessel (RV) head. The CRDM nozzles are approximately 5-feet long and are welded to the RV head at various radial locations from the centerline of the RV head. 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 RV head.

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 ASME B&PV Code. The product form is tubing and the material manufacturer for the Oconee Nuclear Station Unit 3 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 RV head 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 RV head was accomplished by machining and buttering the J-groove with 182-weld metal. The RV head was subsequently stress relieved prior to the final installation of the nozzles.

Recent RV Head Inspection History

During the previous refueling outage, a periodic visual inspection of the top surface of the RV head performed in November 2000 revealed small amounts of boric acid deposited on the vessel head surface. These deposits were located at the base of unused thermocouple (T/C) nozzles and the CRDM nozzle 21 where they penetrate the upper RV head surface. Subsequent eddy current testing revealed axial crack-like indications on the ID of the nozzles in the vicinity of the partial penetration weld (on the underside of the RPV head). Dye penetrant (PT) testing on CRDM nozzle 21 identified two very small pinhole indications. After lightly grinding and performing another PT, a 0.75-inch radial indication running at a slightly skewed angle across the fillet weld was identified. The T/C and CRDM 21 nozzles were repaired prior to restart. Primary Water Stress Corrosion Cracking was later determined to be the root cause.

Report

Note: The following bold text provides the two NRC information requests followed by the Duke response.

NRC Bulletin 2001-01

5.a A description of the extent of VHP nozzle leakage and cracking detected at your plant, including the number, location, size, and nature of each crack detected.

NRC Bulletin 2002-01

2.A. The inspection scope (if different than that provided in response to item 1.D.[1]) and results, including the location, size, and nature of any degradation detected.

Methods Used to Inspect VHP Nozzle and Nozzles Inspected During ONS-1, EOC-20 Refueling Outage:

The methods used to inspect the reactor vessel closure head penetrations and the nozzles inspected by each method are given below:

Inspection Method	Nozzles Inspected
Qualified Bare Metal Visual Inspection of the Top of the RV Closure Head (One inspection with the Head still on the vessel to Identify Boron Deposits and One After Removal of Deposits on the Head Stand to Identify Wastage).	CRDM Nozzles #1 through #69 (100% of the RV Closure Head Penetrations)
Ultrasonic Inspections using the Framatome-ANP "Top Down Tool"	CRDM Nozzles #1, #5, #7, #8, and #9
Liquid Penetrant Inspection of the surface of the J-groove weld and OD surface of the CRDM Nozzle	CRDM Nozzle #1

Results of Qualified Bare Metal Visual Inspection of the Top of the RV Closure Head:

On March 24, 2002, during the End-of-cycle (EOC) 20 refueling outage, a visual inspection of the top surface of the Oconee Unit 1 reactor vessel closure head while the head was still on the vessel showed two nozzles where boron deposits were evident and their source inconclusive. These nozzles were classified as "masked". This inspection was performed in accordance with Duke's response to NRC Bulletin 2001-01[1] as a "Qualified Visual" inspection. Examination of the eight repaired thermocouple locations did not identify any leakage. Nozzle 1 had a thin film of boric acid crystals surrounding it which appeared to come from an old flange leak. A quantity of boric acid crystal deposits was seen on nozzle 7, however the source of the leakage was not immediately apparent. Three additional CRDM Nozzles (Number 5, 8, and 9) were identified as not being able to see completely 360° around the nozzle and were also examined.

[1] Letter Duke to NRC, Response to NRC Bulletin 2001-01: Circumferential Cracking of Reactor Vessel Head Penetration Nozzles, dated August 28, 2001.

Nozzle 7 was masked by a fresh looking deposit (white) with a band going up the side of the nozzle. The band extending up the nozzle, shown in Figure 1, opened the possibility that the boric acid crystals may have originated from a CRDM flange leak. Further video inspections, after the head was placed on the stand, disclosed that the band stopped before tying into any leakage indications from above (which would be more indicative of a CRDM flange leak). Ultrasonic inspection looking for indications in Nozzle 7, showed 5 axial indications (none of which constituted a leak path within the nozzle) extending from below the J-groove weld up into the nozzle area adjacent to the weld. The longest of the indications extended up about 2/3 of the length through the adjacent weld thickness. The liquid penetrant examination of the bore of Nozzle 7 after removal of the nozzle revealed two axial indications high in the original weld. This could indicate a leak path through the weld. The video inspection for CRDM flange leaks found no leaking flanges, and a review of a video of the top of the head made during the previous outage did not show evidence of the new deposit around nozzle 7. All the evidence above make a circumstantial case that Nozzle 7 was leaking through the weld and that the leak initiated during the past operating cycle.

After the head was cleaned and placed on the reactor vessel head stand, a visual inspection was performed looking for wastage. The inspection using fiber scopes where needed was able to see 360° around each nozzle and no wastage was identified. Figure 2 shows the location of the above described CRDM nozzles on RV head for this outage (EOC-20) and the location of Nozzle 21, which was found to be leaking in November 2000.

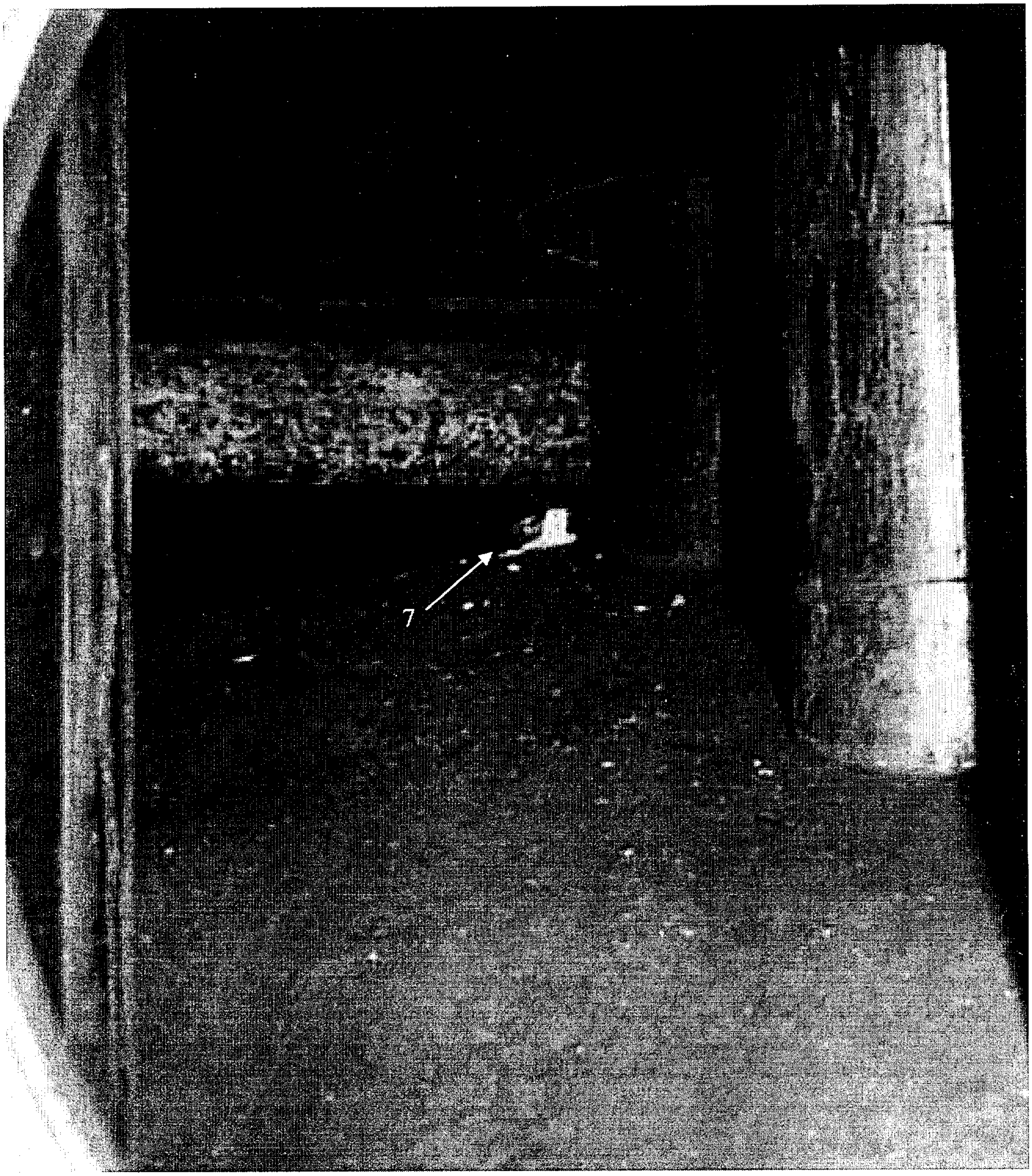
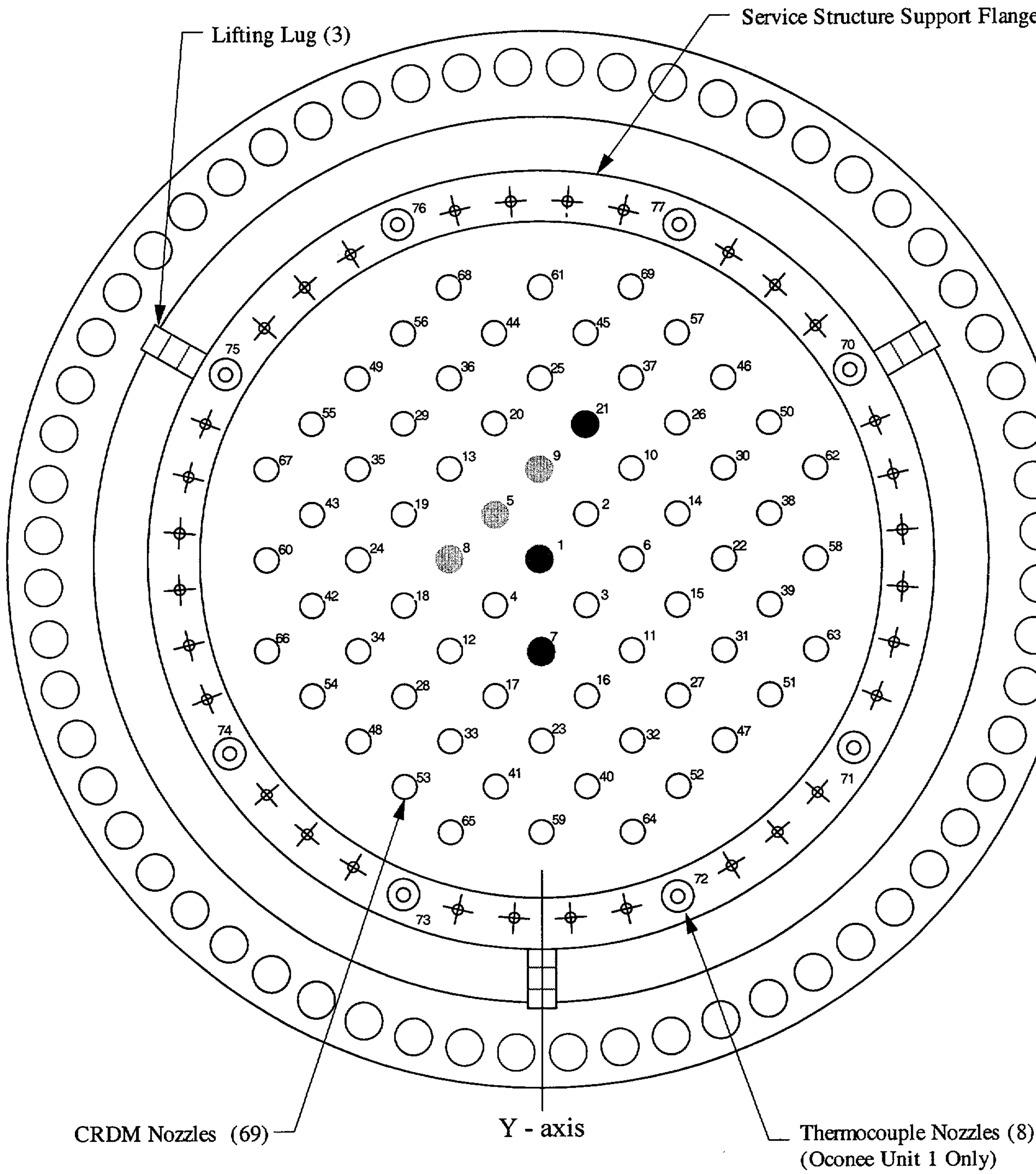


Figure 1 Oconee Unit 1 CRDM Nozzle 7, Top of RV head inspection for Boric acid crystals, 03/31/02



● Nozzles 1 and 7 identified as masked during EOC-20

● Nozzles 5, 8 and 9 identified as not being able to see 360° around nozzle

● Nozzle 21 identified as leaking by top of head visual inspection during EOC-19 and repaired

Figure 2 Bare metal visual inspections of RV head, Oconee Unit 1 CRDM nozzles identified as suspect, during EOC-20 refueling outage, March 31, 2002

<u>Results of Ultrasonic Inspections of CRDM Nozzles Using the Framatome-ANP "Top Down Tool" to Identify Indications Within the Nozzles:</u>

Ultrasonic inspections (UT) from the inside diameter (ID) of five CRDM housings were performed using the Framatome-ANP "Top Down Tool". Nozzles 1 and 7 were UT inspected due to masking by boric acid crystals; and Nozzles 5, 8, and 9 to supplement the less than 360° visual inspection. The UT scans were performed using a battery of 10 transducers. Five of the transducer's beams were directed in the circumferential direction, four were directed in the axial direction, and one was a straight beam 0 degrees transducer.

Nozzles 5 and 9 had no UT indications. Nozzles 1, 7, and 8 all had indications in the nozzles centered at the toe of J-groove weld. None of the indications within the nozzles formed a leak path within the nozzles. Table 1 provides a summary of the UT results giving the indications location within the nozzle with respect to the J-groove weld and its circumferential location with respect to downhill, along with estimated through nozzle wall dimension and indication length within the nozzle. An adjustment was made to the circumferential location such that the downhill location is at 0° and the positive direction is clockwise looking down from the flange.

Table 1 Oconee Unit 1 CRDM Nozzle Top-Down UT Results, November 2001

Noz #	Ind #	Type	Circumferential Extent[z] (0° = downhill side)		Flaw Through Nozzle Wall Thickness (in.)	Surface (ID/OD)	Location (B/W/A)[b]	Axial Length (in.)	Circum. Length (in.)
			Min.	Max.					
1	1	Axial	344.7°		0.07"	OD	B/W Interface	0.33"	~0
1	2	Axial	9.3°		0.08"	OD	B/W Interface	0.30"	~0
1	3	Axial	24.9°		0.08"	OD	B/W Interface	0.38"	~0
7	1	Axial	193.7°	195.2°	0.07"	OD	B/W	0.87"	0.05"
7	2	Axial	65.0°	66.3°	0.13"	OD	B/W	0.53"	0.04"
7	3	Axial	111.5°	112.3°	0.09"	OD	B/W	0.93"	0.03"
7	4	Axial	137.8°	143.3°	0.16"	OD	B/W	1.58"	0.19"
7	5	Axial	183.5°	186.1°	0.16"	OD	B/W	0.98"	0.09"
8	1	Axial	260.2	264.4°	0.25"	OD	B/W	0.79"	0.15"

a 0° = downhill side, 180° = uphill side. The positive direction is clock-wise looking down.

b B = area of nozzle below the weld. W = area of nozzle opposite weld. A = area of nozzle above the weld. Only the Nozzle was volumetrically inspected.

<u>Results of Liquid Penetrant Inspection of the surface of the J-groove weld and OD surface of the CRDM Nozzle:</u>

From the underside of the head, a manual liquid penetrant (PT) examination of nozzle 1 was performed on April 2, 2002 by Framatome-ANP. The examination revealed no relevant indications. The liquid penetrant examination did not confirm the ultrasonic examination results on nozzle 1.

The PT covered an area 3 inches in diameter from the nozzle that included the J-groove weld surface, filet weld cap, and part of the vessel head cladding. It also extended down the OD of the nozzle from the weld to nozzle interface to the end of the nozzle. The visible dye, solvent removable PT technique was in accordance with ASME Section XI and Section V.

<u>Results of Ultrasonic Inspections of CRDM Nozzles Using the Framatome-ANP "Top Down Tool" to Identify a Leak Path in the Annulus Above the J-groove Weld:</u>

The length of coverage of the ultrasonic inspection from the ID of the CRDM nozzle was lengthened to include the annulus region above the J-groove weld in order to look for leakage through the annulus to the top of the head. The evidence of a leak path in this region has been seen in nozzles with known leakage, but the amount of leakage through the annulus to assure that a leak path will be apparent is not quantified. Out of the five nozzles inspected with the "Top Down Tool" only nozzle 7 showed evidence of a leak path, and it was characterized as a faint indication of a <u>possible</u> leak.

<u>NRC Bulletin 2001-01</u>

5.b If cracking is identified, a description of the inspection (type, scope qualification requirements, and acceptance criteria) repairs, and other corrective actions you have taken to satisfy applicable requirements. This information is requested only if there are changes from prior information submitted in accordance with the bulletin.

<u>NRC Bulletin 2002-01</u>

2.B. The corrective action taken and the root cause of the degradation.

<u>Inspections Performed During the ONS-1, EOC-20 Refueling Outage for Detection of RV Closure Head PWSCC:</u>

Three inspection methods were used to determine the state of condition of RV head penetrations during the Oconee Unit 1 EOC-20 refueling outage:

- A qualified bare metal visual inspection of the of the top of the RV closure head,
- Ultrasonic inspections using the Framatome-ANP "Top Down Tool" (five nozzles), and
- Liquid penetrant inspection of the surface of the J-groove weld and the OD surface of the nozzle 1.

The qualified top of RV head visual inspection was performed in accordance with Duke Energy's response to the NRC Bulletin 2001-01. The liquid penetrant inspection of the weld surfaces were performed in accordance with Duke's response to the NRC Bulletin 2001-01. The ultrasonic inspection using the "Top Down Tool" was essentially the same inspection described in the Duke Energy Bulletin response with the exception of some enhancements to the delivery system and the transducers. The enhanced ultrasonic methods were demonstrated to the NRC, EPRI, and industry in September 2001 at Lynchburg, VA. Usage of these methods is described below.

Improved Ultrasonic Inspections Using the Framatome-ANP "Top Down Tool":

An automated Ultrasonic examination of five CRDM nozzles (numbers 1, 5, 7, 8 and 9) was performed using the "Top Down Tool" and a qualified Framatome-ANP examination procedure. This Framatome-ANP procedure governs the remote automated contact ultrasonic examination of CRDM nozzles using the ACCUSONEX™ automated data acquisition and analysis system. The techniques utilized for the examination are intended for the detection and through-wall (depth) sizing of axial and circumferential ID and OD initiating flaws in the nozzle base metal. Forward scatter, longitudinal-wave, and backward scatter shear wave techniques were used. The examinations were conducted from the bottom of the CRDM nozzle bore up through the region of the J-groove weld to above the top of the RV head with water couplant.

The inspections consisted of scanning for axial and circumferential reflectors within the nozzle. The tooling consisted of a transducer head that holds 10 individual search units. These search units were divided into two sets, one for the axial beam direction and one for the circumferential beam direction. The axial beam direction set of search units consisted of 5.0 MHz, longitudinal wave forward scatter time of flight search units with angles of 30° and 45°; backward scatter pulse echo, 2.25 MHz 60° shear wave search units; and a 5.0 MHz 0° search unit (see Appendix A for calibrations files and scan parameters). The circumferential beam direction set of search units consisted of 5.0 MHz, longitudinal wave forward scatter time of flight search units with angles of 45°, 55°, and 65°; backward scatter pulse echo, 2.25 MHz 60° shear wave search units; and a 5.0 MHz 0° search unit.

The detection of flaw indications is based upon the expected responses for each search unit and technique. The 0° transducer provides weld position information and reflector positional information due to lack of backwall response in the region of the reflector. The forward scatter time of flight techniques provides reflector detection and sizing information. For the forward scatter transducers, reflector detection is identified by loss of signal response either from the lateral wave or backwall responses as well as from crack tip diffracted responses. The 60° shear wave transducer provides detection by means of corner trap responses between the flaw and nozzle surface and sizing with tip diffracted signals.

The top-down tool was positioned with the "Y" axis (axial) zeroed at the top of the nozzle flange with the positive direction extending down the nozzle. The "Theta" axis was zeroed at the dowel pinhole in the flange with the positive direction in the clockwise direction while looking down from the top of the nozzle. The ultrasonic data is adjusted for individual transducer offsets in the transducer head to provide actual reflector location in the nozzle. The acceptance criterion was that any indication not considered geometrical was considered a flaw.

The changes made to the rotating probe used by the "Top Down Tool" are the result of technique optimization in preparation for detection and sizing of OD initiated flaws.

Repairs and Other Corrective Actions Taken to Satisfy Applicable Requirements:

Two CRDM Nozzles (numbers 7 and 8) were repaired during this outage using the automated Framatome-ANP "ID Ambient Temper Bead Repair" technique as described in the Relief Requests 02-02 and 02-03. Corrective action taken and future outage plans remain consistent with Duke's NRC Bulletin 2001-01 and 2002-01 submittals.

Root Cause of the Degradation:

The root cause of the degradation found in the Alloy 600 CRDM nozzles during the Unit 1 EOC-20 outage is primary water stress corrosion cracking (PWSCC). This conclusion is based on:

- Comparison of the Unit 1 NDE data with previous Oconee CRDM inspections documented in the Oconee corrective action program for Units 1, 2, and 3.
- Correlation of the current crack location and orientation with previous Finite Element Analyses (FEA) documented in the corrective action program.
- The recent history of CRDM cracking found in Alloy 600 weld metal attributed to PWSCC at ONS and other Pressurized Water Reactors.