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Subject: Duke Power Company, Oconee Nuclear Station, Unit 3
Docket No. 50-287
Vessel Head Penetration Nozzle Condition Report

In response to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," dated August 3, 2001, the enclosed report provides the Duke Energy Corporation response to the Bulletin's "Requested Action 5." This action requested that licensees provide information concerning the results of reactor vessel head penetration nozzle inspection, repairs and other corrective actions in addition to a description of any leakage. Enclosed is the Duke Energy Corporation report for the recently completed Oconee Nuclear Station end-of-cycle 19 refueling outage.

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

Very Truly Yours,

W. R. McCollum, Jr.
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Enclosure

A088

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Oconee Unit 3
End-of-Cycle 19 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" 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.

Report

Note: The following bold text provides the two specific NRC "Action Requests" followed by the Duke response.

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.

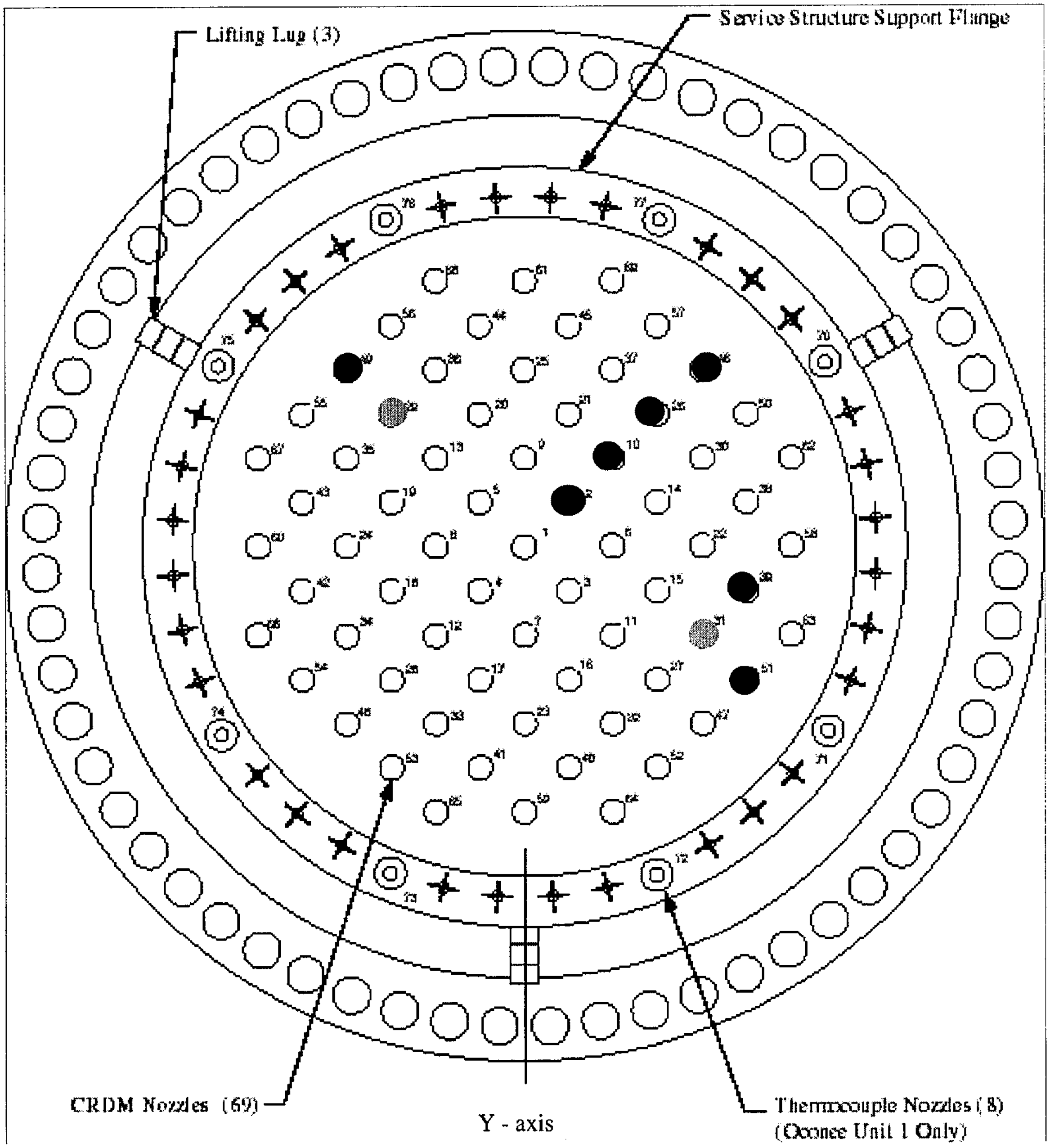
Methods Used to Inspect VHP Nozzle and Nozzles Inspected During ONS-3, EOC-19 Refueling Outage:

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	CRDM Nozzles #1 through #69 (100% of the RV Closure Head Penetrations)
Ultrasonic Inspections using the Framatome-ANP "Top Down Tool"	CRDM Nozzles #2, #10, #26, #29, #31, #39, #46, #49, and #51
Liquid Penetrant Inspection of the surface of the J-groove weld and OD surface of the CRDM Nozzle	CRDM Nozzles #10, #31, and #46
Ultrasonic Inspection using the ARAMIS delivery tool and circumferential blade probe.	CRDM Nozzle #1, #5, #6, #9, #12, #13, #15, #16, #17, #18, #20, #21, #24, #25, #27, #30, #32, #33, #35, #36, #37, #38, #40, #41, #42, #43, #44, #45, #48, #52, #53, #54, #55, #57, #58, #59, #60, #61, #62, #66, #67, #68, #69 (43 nozzles)

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

On November 12, 2001, during the EOC 19 refueling outage, a visual inspection of the top surface of the Oconee Unit 3 reactor vessel closure head showed evidence of primary water leakage on the vessel head surface. This inspection was performed in accordance with Duke Energy's response to NRC Bulletin 2001-01 as a "Qualified Visual" inspection. Boric acid deposits with a wet appearance were identified around four CRDM Nozzles (Numbers 26, 39, 49, and 51) and determined to be probable leak locations. Three additional CRDM Nozzles (Number 2, 10, and 46) were identified as being masked by boric acid crystals from an indeterminate leakage flow path and are therefore classified as possible leaking nozzles. Nozzles 2, 10, 26, and 46 all lie in a straight line running radially down the slope of the head such that if a nozzle were leaking the flow path could include the other three nozzles. This is the same visual inspection performed during the previous outages except that a VT-2 qualified inspector participated. The visual inspection was witnessed by a NRC resident inspector. Figure 1 shows the location of nozzles on RV head and the result of the visual inspection. Figures 2 through 4 provide digital photographs of the boric acid deposits associated with Nozzles 2, 10, 26, 39, 46 and 51.



- Four nozzles identified as possible leakers by top of head visual inspection (26, 39, 49, 51)
- Three nozzles masked by flow (2, 10 and 46)
- Additional CRDMs being removed for access to perform repairs (29, 31)

Figure 1 Oconee Unit 3 CRDM Nozzles Identified as Possible Leakers during RV Head Visual Inspection, During EOC 19 Refueling Outage, November 12, 2001

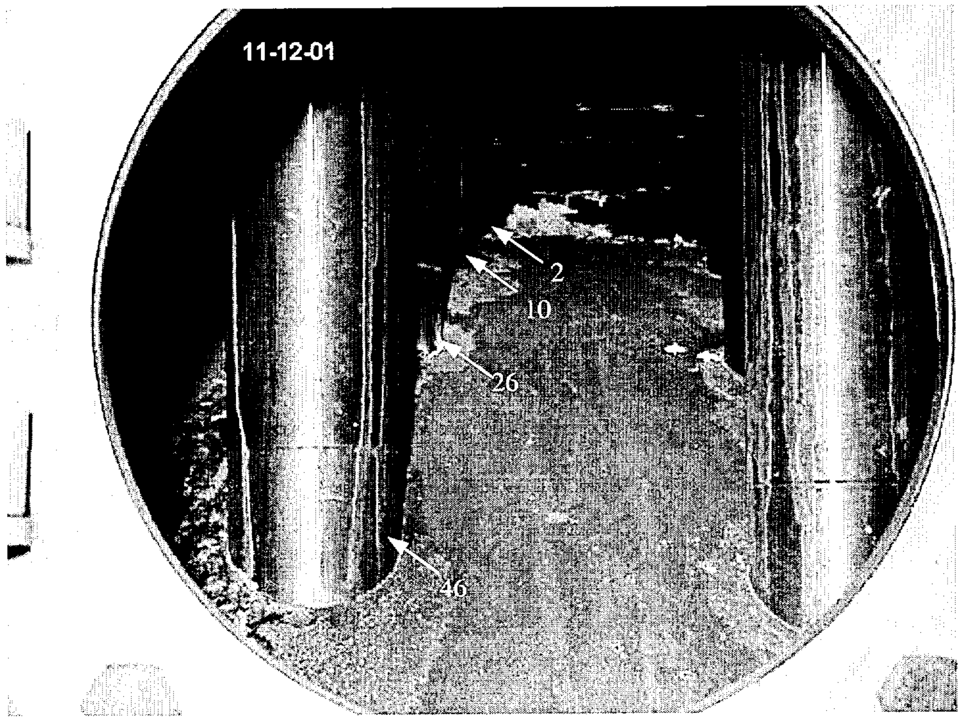


Figure 2 Oconee Unit 3 CRDM nozzles 2, 10, 26, and 46, Top of RV head inspection for boric acid crystals, November 12, 2001

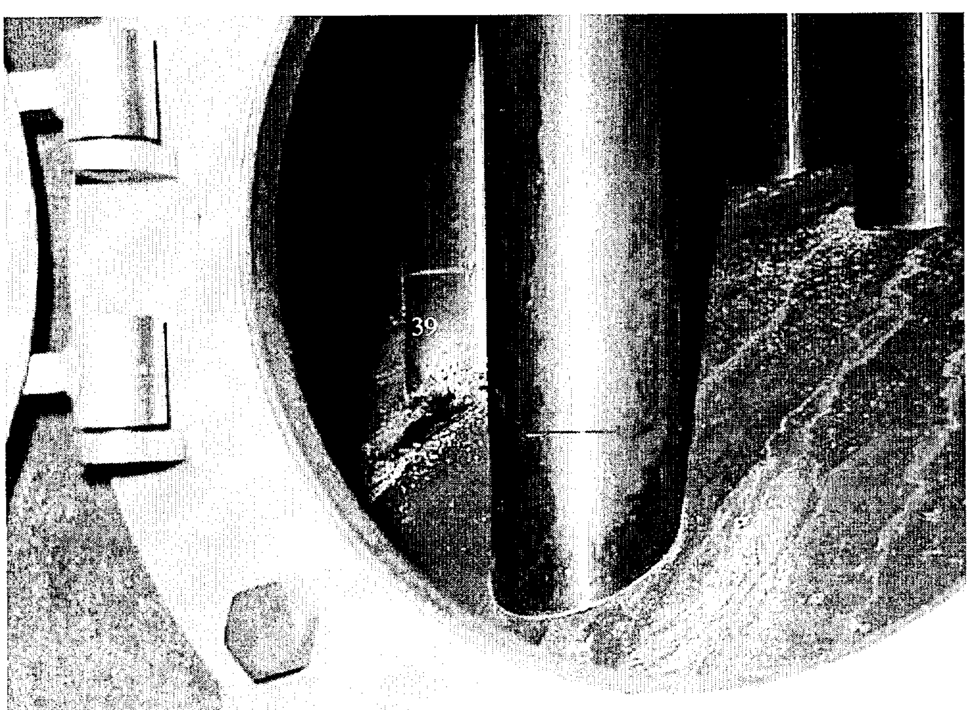


Figure 3 Oconee Unit 3 CRDM nozzle 39, Top of RV head inspection for boric acid crystals, November 12, 2001

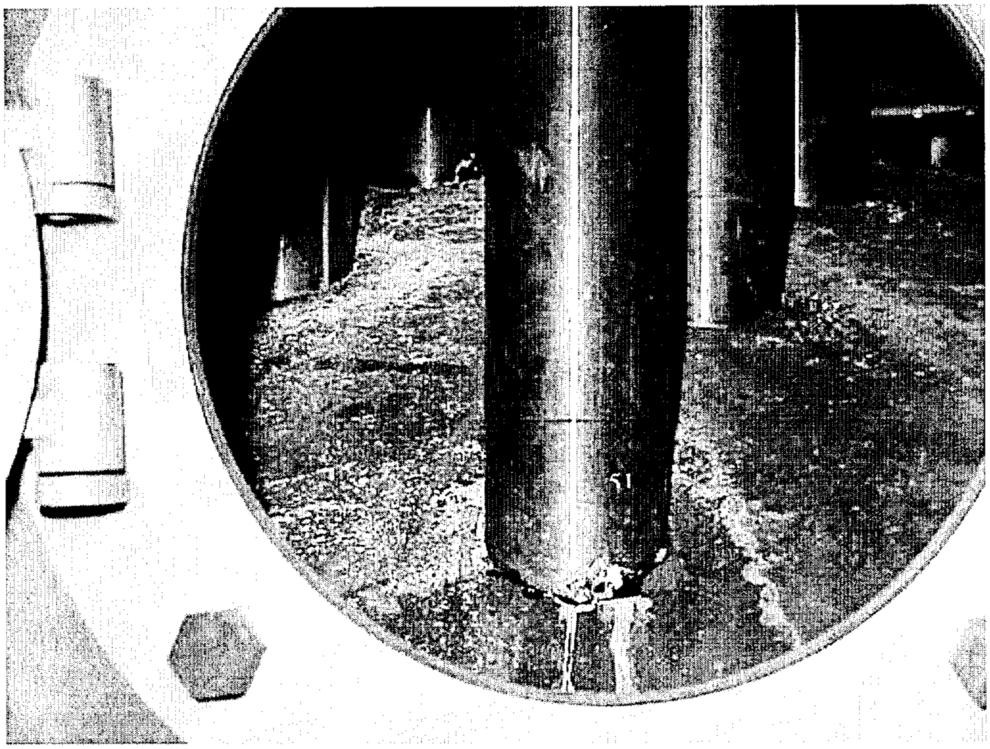


Figure 4 Oconee Unit 3 CRDM nozzle 51, Top of RV head inspection for boric acid crystals, November 12, 2001

Results of ONS-3, EOC-19 Refueling Outage Ultrasonic Inspections of CRDM Nozzles Using the Framatome-ANP "Top Down Tool":

Ultrasonic inspections (UT) from the inside diameter (ID) of nine CRDM housings were performed using the Framatome-ANP "Top Down Tool". Nozzles 26, 39, 49 and 51 were UT inspected due to being identified as having a high probability of leakage by the visual inspection; Nozzles 2, 10 and 46 due to masking by boric acid crystals; and Nozzles 29 and 31 for extent of condition (CRDMs at these locations were removed to allow access for repair equipment). 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 29 and 46 had no UT indications. Nozzles 2, 26, 39, 49, and 51 all had indications in the nozzles that extended from below the weld to above the weld indicating a leak path in addition to various other ID and OD indications. Nozzle 2, in addition, had a circumferential indication in the nozzle above the weld. Nozzles 10 and 31 each contained several OD nozzle indications located below the weld and extending slightly into the weld area, but they show no leak path. 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. A reactor vessel head map showing the UT results is given in Figure 5.

Table 1 Oconee Unit 3 CRDM Nozzle UT[1] Results, November 2001

Noz #	Ind #	Type	Circumferential Extent[2] (0° = downhill side)		Flaw Through Nozzle Wall Thickness (in.)	Surface (ID/OD)	Location (B/W/A)[3]	Axial Length (in.)	Circum. Length (in.)
			Min.	Max.					
2	1	Axial	223.85°		TW	OD	B/W	2.82"	
2	2	Axial	277.3°	287.0°	0.438"	OD	B/W	2.54"	0.34"
2	3	Axial	313.2°	324.0°	TW	OD	B/W/A	3.35"	0.38"
2	4	Axial	38.4°	41.8°	TW	OD	B/W/A	3.22"	0.12"
2	5	Axial	110.74°	113.0°	0.528"	OD	B/W/A	2.69"	0.08"
2	6	Axial	145.3°	154.5°	0.588"	OD	B/W/A	3.13"	0.32"
2	7	Axial	194.6.6°		0.368"	OD	B/W	1.83"	
2	8	Axial	9.2°		0.088"	OD	W	0.10"	
2	9	Circ.	24.95°	73.09°	0.18"	OD	A	0.21"	1.68"
10	1[4]	Axial	0°	360°	0.07" - 0.14"	ID	A	1.09"	8.64"
10	2[5]	Axial	156°	214°	0.06" – 0.13"	ID	B	1.15"	1.39"
10	3	Axial	12°		0.098"	OD	B	0.37"	
10	4	Axial	246°		0.118"	OD	B/W	0.26"	
26	1	Axial	267.9°	292.8	0.498"	OD	B/W/A	2.6"	0.86"
26	2	Axial	296.1°	303.1°	0.308"	OD	B/W/A	2.0"	0.24"
26	3	Axial	319.3°	331.8°	0.498"	OD	B/W/A	2.9"	0.44"
26	4	Axial	352.0°	10.0°	0.538"	OD	B/W/A	3.0"	0.63"
26	5	Axial	165.9°		0.348"	OD	B/W	0.9"	
26	6[8]	Circ.	351.6°	35.7°	0.068"	OD	W	0.2"	1.54"
29	No Recordable Indications								
31	1	Axial	292°		0.21"	OD	B/W	1.35"	
31	2	Axial	358°		0.34"	OD	B/W	0.9"	
31	3	Axial	96°		Shallow[6]	OD	B	0.3"	
39	1	Axial	178.0°		0.12"	ID	B	0.5"	
39	2	Axial	192.0°		0.13"	ID	B	0.6"	
39	3	Axial	240.2°	251.9°	0.25"	OD	B/W	1.0"	0.41"
39	4	Axial	273.0°	296.2°	0.48"	OD	B/W/A	2.4"	0.81"
39	5	Axial	73.0°		0.088"	OD	W	0.5"	
46	No Recordable Indications								
49	1	Axial	246.7°	286.4°	0.35"	OD	B/W/A	2.3"	1.39"
49	2	Axial	236.4°	260.7°	0.25"	OD	B/W/A	1.7"	0.85"
49	3	Axial	226.4°	261.4°	0.18"	OD	B/W	1.4"	1.22"
49	4	N/A	35.2°	128.9°	N/A	Weld[7]	J-Weld	2.9"	N/A
51	1	Axial	202.0°		0.12"	ID	B	0.6"	
51	2	Axial	278.7°	295.7°	TW	OD	B/W	1.8"	0.59"

Noz #	Ind #	Type	Circumferential Extent[2] (0° = downhill side) Min.	Max.	Flaw Through Nozzle Wall Thickness (in.)	Surface (ID/OD)	Location (B/W/A)[3]	Axial Length (in.)	Circum. Length (in.)
51	3	Axial	321.0°	332.4°	0.188"	OD	B/W/A	2.1"	0.40"
51	4	Axial	14.0°		0.048"	OD	B	0.4"	
51	5[9]	N/A	349.5°	5.1°	N/A	Weld	W		N/A
51	6[10]	N/A	207.9°	257.0°	N/A	Weld	W	1.3"	N/A

1 The UT was performed as a best effort inspection. A finalized UT report has not been completed (numbers may change slightly).

2 0° = downhill side, 180° = uphill side. The positive direction is clock-wise looking down.

3 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.

4 This flaw is an elongated group of small axial orientated flaws located at the weld profile extending intermittently around the nozzle.

5 This flaw is a circular grouping of small ID axially orientated flaws located at the bottom of the weld profile.

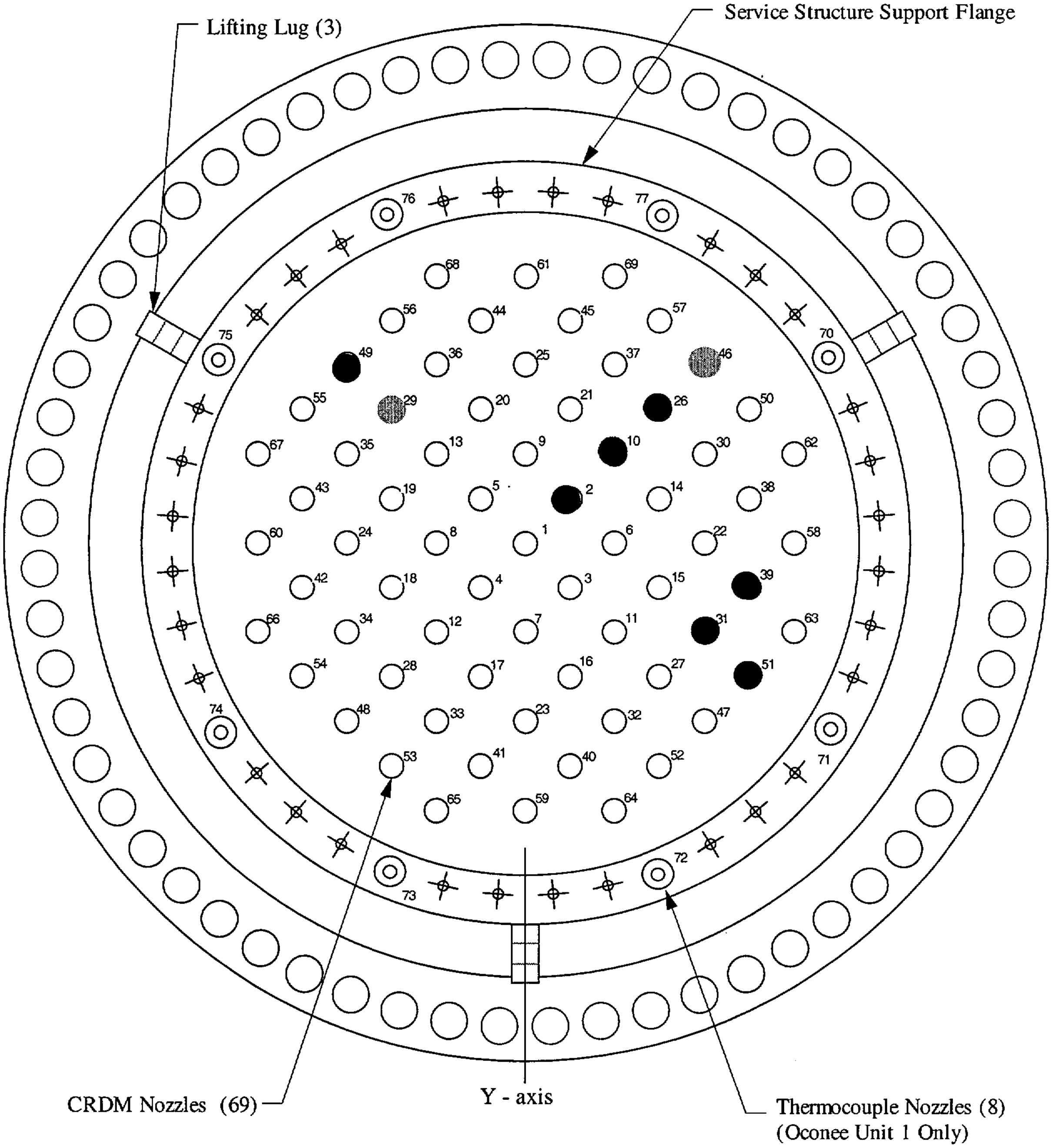
6 No measurable through wall dimension.

7 Flaw #4 nozzle 49 is located in the J-groove weld and is not within the scope of the procedure qualification. This indication is noted for supplemental information only and it has not penetrated the nozzle wall.

8 The majority of flaw # 6 is in the J-groove weld. However mapping of the extent into the weld is beyond the scope of the UT procedure.

9 Flaw # 5 is a weld inclusion

10 Flaw # 6 is in the weld and is not in the nozzle wall. Mapping of this indication is outside the scope of the UT procedure.



Five nozzles with UT results showing a leak path (2, 26, 39, 49, 51)

Two nozzles with UT results showing short shallow axial indications on the nozzle OD (10, 31)

No UT indications (29, 46)

Figure 5 Oconee Unit 3 CRDM Nozzles "Top-Down" Ultrasonic Inspection Results, November 12, 2001

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

From the underside of the head, a manual liquid penetrant (PT) examination of nozzles 10, 31, and 46 was performed on November 18, 2001. Nozzle 10 was reported as having one linear indication 0.75 inches long running axial on the nozzle base material beginning at the toe of the weld and was located at the 12:00 o'clock position. The 12:00 o'clock position is located on the downhill side of the nozzle weld with subsequent locations clockwise looking up. Nozzle 31 was reported as having two linear indications, one 0.625 inches long at 1:00 o'clock and the second was 0.375 inches long at 2:00 o'clock. Both ran axially down on the nozzle base material beginning at the toe of the weld. No indications were found on Nozzle 46.

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. A visible dye, solvent removable PT technique was performed using Duke's PT Procedure, NDE 35. This is the same PT procedure as used during the previous Winter and Spring outages.

Results of Ultrasonic Inspection using the ARAMIS delivery tool and circumferential blade probe:

As a result of the circumferential flaw found above the weld on Nozzle 2, an extended scope inspection of 43 nozzles was performed using a Framatome-ANP ARAMIS inspection tool equipped to deliver a circumferential blade probe between the ID of the nozzle and the lead screw support tube (thermal shield). The 43 nozzles within the scope of the inspection had not been previously repaired or volumetrically inspected. The nozzle area inspected was a minimum of one inch below the J-groove weld to one inch above the J-groove weld. Thirty-six nozzles were inspected with 100 percent of the coverage area being examined. Due to limiting gap clearance between certain nozzles and their lead screw support tube, there were seven nozzles that 100 percent inspection coverage could not be obtained. The approximate percentage of the coverage area inspected for these nozzles were:

Nozzle 42	94%
Nozzle 45	94%
Nozzle 48	99%
Nozzle 60	76%
Nozzle 62	82%
Nozzle 66	89%
Nozzle 69	75%

Overall results revealed no recordable indications within the nozzle material for the 43 nozzles inspected. In Nozzle 43, an indication in the weld was detected from approximately 84º to 105° at the nozzle to weld interface and was located about 0.4 inches above the fillet intersection with the nozzle OD. This indication follows the weld contour but is not surface connected. The signal characteristics of the indication suggest a weld fabrication flaw volumetric in nature, possibly slag trapped at the interface. This nondestructive examination was performed as an added assurance that there were no existing circumferential flaws that could potentially pose a safety risk during the upcoming operating cycle.

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.

Inspections Performed During the ONS-3, EOC-19 Refueling Outage for Detection of RV Closure Head PWSCC:

Four inspection methods were used during the Oconee Unit 3 end-of-cycle 19 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",
- Liquid penetrant inspection of the surface of the J-groove weld and the OD surface of the nozzle, and
- Ultrasonic inspection using the Framatome-ANP ARAMIS delivery tool and circumferential blade probe.

The qualified top of RV head visual inspection and the liquid penetrant inspection of the weld surface were performed in accordance with Duke Energy'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 ultrasonic inspection method using ARAMIS and the circumferential blade probe was used for the first time by Duke during this outage and is described in a following section. Both ultrasonic methods were demonstrated to the NRC, EPRI, and industry in September 2001 at Lynchburg, VA.

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

An automated Ultrasonic examination of nine CRDM nozzles (numbers 2, 10, 26, 29, 31, 39, 46, 49, and 51) 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 only. Forward scatter, longitudinal-wave, and backward scatter shear wave techniques are used. The examinations were conducted from the bore of the CRDM nozzles in the J-groove weld region of the nozzle.

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.

Ultrasonic Inspection Using the ARAMIS Delivery Tool and Circumferential Blade Probe:

Automated ultrasonic examinations of forty-three CRDM nozzles were performed using the ARAMIS inspection tool and a qualified Framatome-ANP examination procedure. This procedure governs the remote automated contact ultrasonic examination of CRDM nozzles using the ACCUSONEX™ automated data acquisition and analysis system. The techniques utilized for this examination are for the detection and through-wall (depth) sizing of circumferential ID and OD initiating flaws in the nozzle base metal only. Forward scatter, longitudinal-wave techniques are used. The examinations were conducted from the bore of the CRDM nozzles in the J-groove weld region of the nozzle.

The inspections consisted of performing axial scanning for circumferential flaws within the nozzle. The tooling consisted of a blade containing a nominal 7 MHz, 50 degree time-of-flight-detection transducer set. 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 acceptance criterion was that any indication not considered geometrical was considered a flaw.

The ARAMIS tool was positioned beneath each nozzle examined with the "X" axis (axial) zeroed at the bottom of the nozzle with the positive direction extending up the nozzle. The "RHO" axis

was zeroed at the downhill side of the nozzle with the positive direction in the clockwise direction while looking down from the top of the nozzle.

Two blade probes were used for these examinations. The probe was changed to examine the last nozzle and to perform the rescans of the limited examination areas. Ultrasonic performance remained consistent from start to finish with these probes and was verified by monitoring the lateral wave response for each of the nozzles examined.

Repairs and Other Corrective Actions Taken to Satisfy Applicable Requirements:

Seven CRDM Nozzles (numbers 2, 10, 26, 31, 39, 49, and 51) were repaired during this outage using the automated Framatome-ANP "ID Ambient Temper Bead Repair" technique as described in the Relief Requests RR 01-14. Corrective action taken and future outage plans remain consistent with Duke's NRC Bulletin 2001-01 submittal.