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U.S. Nuclear Regulatory Commission
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Subject: Oconee Nuclear Station Units 1, 2 & 3
Docket Nos. 50 -269, 270, 287
Response to NRC Bulletin 2001-01: Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles

Pursuant to 10 CFR 50.54(f), this letter and the attached enclosure provide Duke Energy Corporation's (Duke's) response to NRC Bulletin 2001-01 for Oconee Nuclear Station (Oconee).[1] This bulletin requested plant-specific-information as a result of NRC staff concerns regarding recent discoveries of cracked Alloy 600 reactor pressure vessel head penetration (VHP) nozzles. These recent discoveries include axial through-wall cracking of VHP nozzles in all three Oconee units and circumferential cracking of VHP nozzles in Oconee Units 2 and 3.

Duke believes that the commitment to safe operation of Oconee is maintained through proactive actions such as those begun in 1992. Duke began a program to address Primary Water Stress Corrosion Cracking (PWSCC) in Alloy 600 VHP nozzles in 1992. Through the development of an effective visual inspection method of VHP nozzles, Oconee has identified and characterized VHP nozzle cracking in all three Oconee units. A thorough root cause analysis was completed and shared with both industry and NRC staff. The results of this root cause analysis have confirmed Alloy 600 PWSCC and are consistent with the mechanism and conclusions discussed in Generic Letter 97-01.[2] In addition, the phenomenon of circumferential cracking was discovered. Duke's examination and analysis indicates that a through-wall

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[1] NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," dated August 3, 2001.
[2] Generic Letter 97-01, "Degradation of Control Rod Drive Mechanism Nozzle and other Vessel Closure Head Penetrations," dated April 1, 1997.

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axial crack precedes the formation of these circumferential cracks. Analysis has concluded that it is very unlikely that a circumferential crack can be expected to develop to a critical flaw size during an 18-month operating cycle. Therefore, Duke believes that with the recent effective visual inspection and characterization of the Oconee reactor vessel heads, there currently are no immediate safety concerns.

Duke has decided to replace reactor vessel heads. Duke believes reactor vessel head replacement is the most effective corrective action to preclude recurrence. Reactor vessel head replacement has been planned for the three Oconee units, beginning with Unit 3 in the spring of 2003, Unit 1 in the fall of 2003, and completing with Unit 2 in the spring of 2004. Key factors in the decision to replace these heads were "as low as reasonably achievable" occupational exposure goals and the uncertainties for long-term planning and unit availability.

Duke believes that additional volumetric inspections of non-leaking VHP nozzles are unnecessary and will result in significant occupational exposure and economic impact with no substantial increase in the overall protection of the public health and safety. Oconee has had extensive experience to date with inservice VHP nozzle nondestructive examination (NDE) and repair techniques. While this experience has been at a significant occupational exposure and economic cost, it has resulted in establishing an understanding of the condition of the Oconee reactor vessel heads and advancing the industry understanding of detection, repair, and cause of VHP nozzle cracking. Performing additional volumetric inspections would likely result in increased occupational exposure without significant long term benefit to preventing the recurrence of through wall cracking of control rod drive mechanism (CRDM) nozzles. Additionally, as of the writing of this response, Duke is not aware of any qualified NDE technology that can ensure detection of indications to preclude recurrence of through-wall cracking of Alloy 600 VHP nozzles.

A risk assessment has been completed for the three Oconee units to evaluate the time period prior to reactor vessel head replacement. The 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 is below the point of being risk significant for any of the Oconee units during each of these reactor years.

The effectiveness of the above described program, the NDE performed to date, engineering analysis, and planned corrective actions provide reasonable assurance that compliance with applicable regulatory requirements will continue to be maintained for the Oconee units. Duke strongly believes that these proactive efforts meet the full extent of reasonable and appropriate actions intended by issuance of the Bulletin, and will best ensure the health, safety, and welfare of the public.

In summary, Duke commits to the following.

- A qualified visual inspection of all CRDM nozzles will be performed at the next scheduled refueling outages for each Unit.
- If any CRDM nozzle fails to meet the visual inspection criteria, additional NDE will be performed on the suspect nozzle to identify required repairs.
- Any required repairs will be completed prior to restart of the unit.
- Any CRDM nozzle that is not verified by analysis of the shrink fit annulus to have a positive gap, will be volumetrically inspected during the next refueling outage.
- A thirty day report will be submitted as requested by Bulletin 2001-01 for any other leakage events.
- The reactor vessel heads will be replaced for all Oconee units by the spring of 2004.

Although not required by Duke internal procedures and the quality assurance program topical report, this bulletin response has been reviewed and approved by the Oconee Plant Operating Review Committee and the Duke Nuclear Safety Review Board.

If you have questions or need additional information, please contact Michael Robinson at (704) 373-3522.

Very truly yours,

W. R. McCollum

Enclosure

xc:

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AFFIDAVIT

William R. McCollum, Jr. states that he is Vice President, Oconee Nuclear Site, of Duke Energy Corporation; that he is authorized on the part of said corporation to sign and file with the Nuclear Regulatory Commission this response to the information request filed pursuant to 10 CFR 50.54 (f); and that all statements and matters set forth herein are true and correct to the best of his knowledge.

William R. McCollum, Vice President, Oconee Nuclear Site

Subscribed and sworn to me: August 28, 2001
Date

Robert C. Douglas, Notary Public

My Commission Expires: August 13, 2009
Date

SEAL

ENCLOSURE
Oconee Nuclear Station
Response to NRC Bulletin 2001-01

REQUESTED ACTION:

1. **All addresses are requested to provide the following information:**
   a. **the plant specific susceptibility ranking for your plant(s) (including all data used to determine each ranking) using the PWSCC susceptibility model described in Appendix B to the MRP-44, Part 2, report;**
   b. **a description of the VHP nozzles in you plant(s), including the number, type, inside and outside diameter, materials of construction, and the minimum distance between VHP nozzles;**

Response:
By letter dated, August 21, 2001, Nuclear Energy Institute (NEI) submitted report, EPRI Report TP-1006284,[1] on behalf of the industry to the NRC. This report provided an industry response to information requested in Items 1a, and 1b of Bulletin 2001-01. The Oconee Units 1, 2 and 3 responses for 1c, 1d, and 1e are contained in this report.

1. **All addresses are requested to provide the following information:**
   c. **a description of the RPV head insulation type and configuration;**

Response:
Each Oconee unit has metal reflective insulation that is located on a horizontal plane a minimum of 2 inches above the highest point on the reactor vessel head. The accessibility under the insulation permits good visual access of the VHPs from several different angles and allows for ease of access to clean the head of old boron deposits and other debris. Refer to Figure 1 for a schematic of this configuration.

1. **All addressees are requested to provide the following information:**
   d. **a description of the VHP nozzle and RPV head**

[1] PWR Materials Reliability Program Response to NRC Bulletin 2001-01 (MRP-48), EPRI, Palo Alto, CA: 2001. 1006284

inspections (type, scope, qualification requirements, and acceptance criteria) that have been performed at your plant(s) in the past 4 years, and the findings. Include a description of any limitations (insulation or other impediments) to accessibility of the bare metal of the RPV head for visual examinations;

Response:

Each unit at Oconee has performed a visual inspection of all CRDM nozzles since 1993. Oconee Nuclear Station (Oconee) Unit 2 has performed three separate Eddy Current (EC) and ultrasonic (UT) inspections on the inside diameter (ID) of the control rod drive mechanism (CRDM) nozzles since 1994. The first of these inspections was of 100% of all the Unit 2 CRDM nozzles.

The design of the Babcock and Wilcox (B&W) CRDM nozzle flange joint is susceptible to leakage and may result in an accumulation of boric acid crystals on top of the vessel head. Additionally, the reactor head design incorporated an enclosure around the head top surface (service structure) that limited direct visual access. Recognizing these original design limitations, Oconee implemented modifications to the service structure to allow access for enhanced visual inspections and removal of any boron accumulation from the top of the vessel heads. The modifications consisted of cutting nine, 12 inch diameter access ports into the service structure.

Visual supplemental bare-metal inspections of the vessel head have been performed each refueling outage on each unit since adding the inspection ports. The inspections were followed by activities to clean the accumulation of boron typical of CRDM flange leakage from the heads. By changing to a different flange gasket design, the amount of CRDM flange leakage has been decreased significantly over the years.

All Oconee units have reflective metal insulation that is located on a horizontal plane 2 inches above the highest point on the head. The accessibility under the insulation, along with the inspection ports, allows for a thorough visual inspection of the head surface surrounding the CRDM nozzles.

The acceptance criteria for the visual inspections is the absence of boric acid crystal deposits adjacent to the reactor pressure vessel head penetration (VHP), or boric acid deposits adjacent to the VHP and determined to be from another source other than VHP leakage.

The acceptance criteria for the 1994 CRDM nozzle inspections were per NRC letter.[2] All inspections were performed and qualified in accordance with ASME Section XI.

Three inspections have been performed on the ID of Oconee Unit 2 CRDM nozzles. The first inspection was performed in October 1994 from under the head and utilized blade probe EC (BPEC), motorized rotating pancake coil (MRPC) EC, water washable liquid penetrant (PT) and UT non-destructive test methods. The EC examination consisted of a 100% inspection of the ID for all sixty nine CRDM nozzles. The results of the EC inspection determined that several nozzles (16, 23, 28, 45, 46, 50, 52, 56, 57, 60, 62, 63, 65) contained small shallow indications near the j-groove weld. These small indications were located both above and below the weld areas. The qualification and acceptance criteria for the EC and UT inspections that were performed in 1994, 1996 and 1999 are the same inspections that are described in item 2.b of this response.

A second inspection was performed in April of 1996 from the top of the head on nozzles 23 and 63 utilizing MRPC EC and solvent removable PT non-destructive test methods. The conclusion from the 1996 inspection was that there was no significant change in the signal from the indications since 1994.

The third inspection on the Unit 2 nozzles was performed in November of 1999 from the top of the head on nozzles 16, 21, 23, 46, 50, 62, 63, and 68 utilizing MRPC EC. Indication signal response comparisons among the three inspections in 1994, 1996,and 1999 showed no significant change.

1. All addresses are requested to provide the following information:

e. a description of the configuration of the missile shield, the CRDM housings and their support/restraint system, and all components, structures, and cabling from the top of the RPV head up to the missile shield. Include the elevations of these items relative to the

[2] NRC letter to Bill Rasin of NUMARC, dated November 19, 1993.

bottom of the missile shield.

Response:

The missile shields are 3 feet thick reinforced concrete, 32 feet long by 28 feet wide (in four sections), centered over the RV. The distance from the top of the shields to the top of the CRDM mating flange is approximately 37 feet.

The CRDM housing is a 17.5 foot long pressure retaining tube, containing the mechanical components, surrounded by a separate stator and stator cooling water jacket. The housing provides for RCS pressure integrity. The total weight of the entire CRDM assembly is approximately 935 pounds. The housing is bolted to the reactor vessel (RV) head nozzle by eight bolts, with a double gasket flange configuration.

The CRDMs are mounted inside a protective cylinder (service structure) bolted to and projecting up from the RV head. Twelve small diameter fans are mounted externally on the cylinder for cooling of the CRDM electrical components. The top ends of the CRDMs are restrained for seismic loading purposes. A grid of steel channel and perforated metal plate securely attached to the service structure at the top of the CRDMs provide a working floor.

Other than the CRDMs, no other safety related components are mounted within the service structure. All electrical cabling for the CRDMs (power, thermocouple, and position indication cables) is supported within or lying on top of the steel channel forming the top working surface of the service structure. No safety related components lie between the upper ends of the CRDMs and the bottom of the missile shields.

From one of the CRDMs, an attachment is provided in the top closure for the RV head vent line to assure void removal during natural circulation conditions.

From the center CRDM, at the lower (flange) elevation, an instrument line is tapped into the CRDM flange to provide RV level instrumentation.

REQUESTED ACTION:

2. **If your plant has previously experienced either leakage from or cracking in VHP nozzles addressees are requested to provide the following information:**
   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;**

Response:

A summary of the results of the inspections performed as a result of PWSCC of the RV head penetrations for the three Oconee units between November 2000 and June 2001 is given below for each unit.

Oconee Unit 1

On November 25, 2000,the beginning of the refueling outage, evidence of RCS leakage was found around CRDM nozzle 21 and five of eight thermocouple nozzles during visual inspection of the top of the RV head.[3]

The leak on CRDM nozzle 21 was through a single crack that originated in the J-groove weld and grew up through the weld and nozzle base material penetrating into the annulus region to create a leak path. The crack extended axially from the face of the filet weld cap to the root of the J-groove weld. The crack extended radially from about 0.40 inch deep in the outside diameter (OD) of the nozzle through the Alloy 600 weld butter to the alloy steel base metal where it was blunted. As the crack progressed to the weld butter, the crack branched and turned circumferential for a short distance (approximately 3/8 inch).

The thermocouple nozzles were each found to contain large axial crack-like indications originating on the inside of the nozzles. This was determined to be the leakage pathway for the thermocouples. EC and UT examination of the inside surfaces of the thermocouple nozzles showed that all eight nozzles contained deep crack-like indications that were predominantly axial in orientation and located adjacent to (extending both above and below) the J-groove weld elevation. The indications were

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[3] LER 269/2000-006, Revision 1, "Reactor Coolant System Pressure Boundary Leakage Due to Cracks Found In Several Small Bore Reactor Vessel Head Penetration," dated March 1, 2001.

located primarily at the high stress areas that are the uphill and downhill locations. The thermocouple axial indications ranged in length from about 0.25 inches to about 2.5 inches in length.

Oconee Unit 2

On April 28, 2001, the beginning of the refueling outage, a visual inspection of the top surface of the Oconee Unit 2 RV head performed as part of normal shutdown surveillance activity showed evidence of boric acid crystals on the vessel head surface. Boric acid crystals were identified around four CRDM nozzles (4, 6, 18 and 30).[4]

Results from a PT examination using a visible dye, solvent removable technique, of the suspected leaking nozzles 4,6,18,30 revealed multiple rejectable indications on each of the four nozzles.

As part of the pre-repair nondestructive examinations, an EC inspection of CRDM Nozzles 4, 6, 18 and 30 was performed. The results of the EC inspections did not identify any indications that suggested a through-wall leak path.

The results of the EC inspections on these four nozzles did identify clusters of multiple axial indications on the nozzle ID surfaces that were located both above and below the J-groove weld. The axial extent of the clusters ranged from about 0.90 inch in length to about 3.1 inches in length. The range of depths of the cluster indications was from about 0.0138 inch to about 0.0315 inch. No ID initiated circumferential indications were found.

Automated UT examinations were performed on the suspect leaking CRDM nozzles 4, 6, 18, and 30. The examinations detected 36 axial OD indications and 1 circumferential OD crack that was located above the weld on nozzle 18 (see Table 1 for details of UT crack indications). The circumferential crack on nozzle 18 was reported to be about 1.25 inches in length with a depth of about 0.07 inches. The leakage pathway for the Unit 2 nozzle

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[4] LER 270/2001-002, Revision 0, "Reactor Pressure Vessel Head Leakage Due To Stress Corrosion Cracks Found in Several Control Rod Drive Nozzle Penetrations," dated June 25, 2001.

leaks was determined to be through the cracks on the OD of the nozzle and weld interface.

Oconee Unit 3

On February 18, 2001, during EOC 18, a visual inspection of the top surface of the Oconee Unit 3 RV head showed evidence of fresh boric acid deposits on the vessel head surface. This inspection was performed as part of a special surveillance activity performed following plant shutdown to repair a leaking pressurizer safety relief valve. Boric acid deposits were identified around nine CRDM nozzles (Numbers 3, 7, 11, 23, 28, 34, 50, 56 and 63).[5]

PT examinations results, using a visible dye, solvent removable PT technique on the nine suspected leaking nozzles revealed multiple rejectable indications on all nine nozzles. 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 1 inch down the OD of the nozzle from the weld to nozzle interface.

EC inspections results of the nine leaking CRDM nozzles (3, 7, 11, 23, 28, 34, 50, 56, and 63) and nine non-leaking CRDM nozzles (4, 8, 10, 14, 19, 22, 47, 64, and 65) had signals indicating clusters of shallow axial type cracks located above the weld and below the weld or both. Results for nozzles 50 and 56 identified non-typical clusters above the weld. These clusters were later determined to be associated with the approximately 165 degree circumferential cracks that were found by post repair PT. Six of the leaking nozzles (11, 23, 28, 50, 56 and 63) had deep axial (slightly off axis) indications. Nozzles 50 and 56 had circumferential indications below the weld.

UT inspections of the nine leaking CRDM Nozzles (3, 7, 11, 23, 28, 34, 50, 56, and 63) and nine non-leaking CRDM nozzles (4, 8, 10, 14, 19, 22, 47, 64, and 65) were performed. The nine non-leaking nozzles inspected for extent of condition did not have any crack like axial or circumferential indications. All leaking nozzles had at least 1 axial indication connected to the

[5] LER 287/2001-001, Revision 0, "Reactor Pressure Vessel Head Leakage Due To Stress Corrosion Cracks Found in Nine Control Rod Drive Nozzle Penetrations," dated April 18, 2001.

OD surface of the nozzle. Thirty-six axial indications, nine circumferential indications below the weld, and three circumferential indications above the weld were found (see Table 2 for details of cracking) were found on the leaking nozzles. CRDM nozzle 23 had one circumferential indication above the weld and two circumferential indications below the weld. The circumferential crack above the weld on nozzle 23 was discovered as a result of the third party review of the ONS NDE data (This third party review was completed after the NDE data was initially interpreted on nozzle 50 and 56). The repair of nozzle 23 completely removed the J-groove partial penetration weld and the full 360 degrees of the nozzle circumference. CRDM nozzle 50 had one circumferential indication above the weld and one circumferential indication below the weld. CRDM nozzle 56 had one circumferential indication above the weld. The inspections included scanning for both axial and circumferential reflectors.

REQUESTED ACTION

2. If your plant has previously experienced either leakage or cracking in the VHP nozzles, addressees are requested to provide the following information:

b. a description of the additional or supplemental inspection (type, scope, qualification requirements and acceptance criteria), repairs and other corrective actions you have taken in response to identified cracking to satisfy applicable regulatory requirements;

Response:

A battery of inspections have been performed to locate and characterize the cracking found at Oconee. Those inspections include the visual inspection of the RV head for GL 88-05 and GL 97-01 purposes, PT inspections of suspect leaking nozzles, EC inspections of the ID surface of both suspect and non-suspect leaking nozzles, and ultrasonic inspection of both suspect and non-suspect leaking nozzles. Each of those inspections is described as requested below.

Type: Visual Inspection

The bare-metal visual inspection of the top of the RV head was performed to identify potentially suspect leaking nozzles. All Oconee units have reflective metal insulation that is located on a horizontal plane a minimum of 2 inches above the highest point on the head. The RV head service structure at each Oconee unit has been modified by the addition of nine inspection ports. The ports, as well as providing accessibility for the inspection, also allowed access for removing boric acid crystals from the top of the head that resulted from CRDM flange leaks.

The initial top of head inspection was performed as soon as the insulation was removed from around the service structure and the inspection ports were opened. The head was still on the vessel and the reactor coolant system was still at an elevated temperature and pressure. Follow-up visual inspections were performed once the head had been placed on the storage stand and scaffolding had been erected.

Scope: The area of inspection included the top of the RV head, inside as well as outside the support structure, and the outside surface of all sixty-nine CRDM nozzles. Areas above the insulation were also examined looking for sources of primary water leaks.

Qualification/Acceptance Criteria: For past head inspections, experience has served as the main qualification for those performing the visual inspections.

The acceptance criteria for the visual inspections is the absence of boric acid crystal deposits adjacent to the VHP on, or boric acid deposits adjacent to the VHP and determined to be from another source other than VHP leakage.

Type: PT of the Weld Surface and OD of the CRDM Nozzles

The manual PT of the J-groove weld surface and the outside of the CRDM nozzle from under the head was performed to determine possible leak paths.

Scope: 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 1 inch down the OD of the nozzle from the weld to nozzle interface. This test was applied only to nozzles that were suspected as potential leaking nozzles.

Qualification/Acceptance Criteria: The PT examination was qualified for use on ASME Class 1 components in accordance with applicable ASME Code rules (Section V). The personnel performing the examination were qualified in accordance with the procedure. The acceptance criteria complies with ASME Code (Section III or XI or other construction Code) requirements.

Type: EC Test From ID of CRDM Nozzle

The EC examination from the inside of the CRDM nozzles was performed to detect ID surface connected indications, determine ID flaw orientation (length, axial and circumferential extent), and to estimate depth for indications found in clusters that were too shallow for UT.

The ID EC inspection was performed using a top down delivery system and a motorized rotating pancake coil (MRPC) probe design with three coil configurations. One was a differential coil configuration, operated in the differential and absolute modes, containing two ferrite coils that have a 45 degrees orientation with respect to the penetration axis that can sense the position, orientation, and length of both axial and circumferential cracks. The other two coils consist of a plus point coil and an axial sensitive coil. All three coils were driven at multiple frequencies (600, 280 and 100 KHz). The EC data was acquired in a helical scan using the Framatome top down manipulator as demonstrated during the EPRI performance demonstrations in the summer of 1994 for crack detection and spring of 1996 to investigate depth sizing.

Scope: The area of coverage was the ID of the nozzle opposite the weld plus 2 inches above and 2 inches below the weld area. The ID EC test was applied to all nozzles suspected as leaking on each unit. On Oconee Unit 1, an additional seven nozzles were inspected for extent of condition purposes and on Unit 3, an additional nine nozzles were inspected for extent of condition using this inspection method.

Qualification/Acceptance Criteria: A qualified EC procedure was used to perform the examinations and the personnel performing the examinations were qualified according to the requirements within the procedure. Framatome ANP successfully completed the EPRI NDE Center blind CRDM demonstration using blade and rotating probe EC techniques. These techniques were qualified on B&W, Combustion Engineering, and Westinghouse CRDM nozzle mockups. These qualifications were to detect and size cracking on the ID of the tube surface.

The specific acceptance criteria from the qualified procedure was contained within the procedure but included criteria for lift-off and background noise, guidance for identifying scratch like indications, and the required criteria for defining crack like indications.

Type: Ultrasonic Test (UT) From ID of CRDM Nozzle

The automated UT examination from the ID surface of the CRDM nozzles was performed to detect and size ID and OD initiated flaws of all orientations.

The examinations were performed and analyzed using the Framatome ANP top-down inspection tool, the ACCUSONEX™ data acquisition system, and the ACCUSONEX™ data analysis system. For Oconee Units 2 and 3, the UT inspections included scanning for both axial and circumferential reflectors. The inspection for axial reflectors utilized longitudinal wave forward scatter time of flight diffraction (TOFD) search units with angles of 45, 55, and 65 degrees; backward scatter pulse echo, 60 degrees shear wave search unit, and a 0 degree search unit. The inspection for circumferential reflectors utilized dual element 70 degrees longitudinal wave search units as well as the forward scatter TOFD search units used for axial reflectors. The examination at Oconee Unit 1 did not include a scan for circumferential reflectors.

Scope: The UT examination scanned the inside surface of the nozzle opposite the weld plus 2 inches above and 2 inches below the weld area. The volume inspected covered the thickness of the nozzle except for within 2 mm of the inside surface. The inspection did not cover the weld volume; however, the weld fusion line between the J-groove weld and the nozzle was covered for weld defects such as lack of fusion and slag inclusions.

The ID UT test was applied to all nozzles suspected as leaking. For extent of condition purposes, on Unit 1 a limited UT inspection was performed on an additional seventeen nozzles and on Unit 3 an additional nine nozzles were UT inspected. All nozzles inspected for extent of condition did not show any significant signs of cracking and zero leakage.

Qualification/Acceptance Criteria: The CRDM nozzle UT used for Oconee Units 2 and 3 was performed using a combination of two

Framatome ANP procedures. One was for the remote UT examination for sizing axial flaws in CRDM nozzles and the other was for the remote UT examination for CRDM nozzle weld repairs. The qualification for the flaw sizing procedure was based upon the EPRI qualification performed in 1994. It utilized mockups to demonstrate sizing capabilities for axial oriented flaws initiating at the inside surface of the CRDM nozzle. The weld repair procedure qualification was based upon a successful calibration using the ID and OD surface notches ranging from 2 to 12 mm in depth to demonstrate adequate resolution and sensitivity of the reflectors.

The examination techniques used for the axial flaw detection and sizing were specifically designed for depth sizing ID surface connected axial flaws within the CRDM nozzle base material. The 70 degrees longitudinal wave examination technique for the circumferential flaws was developed for the examination of weld repair inspections within the nozzle material. The data analysis process of these two procedures has been adapted for the detection of flaws within the nozzle base material. Although these two procedures were not specifically developed or qualified for the detection of axial and circumferential oriented ID and OD flaws in the CRDM nozzle material, they have demonstrated reasonable detection capabilities based on field use.

Repairs

Oconee Unit 1: Repair of Leaking CRDM Penetration and Thermocouples

For Oconee Unit 1, manual repair methods were used for each of the leaking VHP nozzles. The NDE inspection data was utilized to develop the repair plan details for each of the suspect leaking nozzles. The repair plan for the thermocouples (T/C) nozzles involved removing the nozzles from service by machining out the existing nozzles and installing an Alloy 690 plug into the remaining penetration. The plug was then welded in place using an Alloy 690 weld filler material and the shielded metal arc welding process. The repairs that were exposed to the reactor water environment also received a protective Alloy 690 filler material weld pad to protect the repair.

The crack was completely ground out of the J-groove weld and nozzle material from CRDM nozzle 21. The repair plan restored CRDM nozzle 21 to original configuration, which was completed using Alloy 690 weld material (Alloy 152). After removal of the cracks and getting a clear PT of the excavated area, the J-groove weld was repaired using the shielded metal arc welding process. A protective Alloy 690 weld pad was applied to the repairs to protect and isolate any remaining original Alloy 600 from the reactor water environment. The final step in the repair process was the post repair PT inspection.

The repairs to the Unit 1 RV enclosure head nozzles were performed in accordance with the 1992 edition of Section XI of the ASME and the NRC approval of several requests for alternatives and ASME Code Cases.

Oconee Unit 1: Corrective Actions Taken

The immediate corrective action taken on Unit 1 was the formation of a failure investigation team to determine the root cause of the leakage and to develop and guide the repair plans and other details. Other corrective actions taken were to perform the above described examinations of the leaking nozzles to determine the extent of any cracking and to determine the expected leakage pathway. Also metallurgical samples were taken from the CRDM nozzle 21 weld and from several thermocouple nozzles. These samples were sent for analysis to determine the cause of the observed cracking. Other corrective actions included the performance of Oconee specific finite element analyses to assist in determining the source of the observed cracking. Further, seven additional randomly selected nozzles were selected for EC NDE and a total of eighteen nozzles including nozzle 21, were also inspected for lack of bond using a 0 degree UT scan. These inspections were performed to help with extent of condition determinations.

Other corrective actions taken for Unit 1 included the cleaning of the head to remove any new boron deposits as an aid to future head inspections.

The principal corrective action to preclude future leakage events for Oconee Unit 1 is the replacement of RV enclosure head in the fall 2003 Refueling and Steam Generator replacement outage.

Oconee Unit 2: Repair of Leaking CRDM Penetrations

For the Unit 2 repairs, a remote semi-automated repair method was used for each of the leaking CRDM nozzles. Using a remote tool from above the RV head, each of the subject nozzles was roll expanded into the RV head base material to ensure that the nozzle did not move during the repair operations. An automated machining tool from underneath the RV head was then used to remove the lower portion of the nozzle to a depth above the existing J-groove partial penetration weld. This operation severs the existing J-groove partial penetration weld from the CRDM nozzle. A semi-automated weld tool, utilizing the Gas Tungsten-Arc Welding (GTAW) process, was used to install a new Alloy 690 pressure boundary weld between the shortened nozzle and the inside bore of the RV head base material. A chamfer was then machined into the end of the penetration. The roll expanded area and weld were water jet conditioned for purposes of mitigating crack initiation.

The repairs to the Unit 2 leaking CRDM nozzles were performed in accordance with the 1992 edition of Section XI of the ASME and the NRC approval of several requests for alternatives and ASME Code Cases.

Oconee Unit 2: Corrective Actions Taken

The immediate corrective action taken on Unit 2 was to re-assemble the key team members from the Unit 1 and Unit 3 failure investigation team to guide the investigation and repairs for Unit 2. Other corrective actions were to perform the above described examinations of the suspect leaking nozzles to determine the extent of any cracking and to determine the expected leakage pathway. The same team of experienced station and vendor personnel were re-assembled to investigate the nature of this pressure boundary leakage. The inspection information gathered for the Unit 2 nozzles was evaluated and compared to inspection information and data collected as part of the investigations into the Units 1 and 3 events. This evaluation concluded that the leakage and crack characteristics on Unit 2 were similar to what had been found and characterized on Units 1 and 3. No additional inspections were performed based on this conclusion.

Other corrective actions taken for Unit 2 included the cleaning of the head of any new boron deposits to aid future head inspections.

The principal corrective action to preclude future leakage events for Oconee Unit 2 is the replacement of RV head in the spring 2004 Refueling and Steam Generator replacement outage.

Oconee Unit 3: Repair of Leaking CRDM Penetration

For Unit 3, manual repair methods were used for each of the leaking CRDM nozzles. The NDE inspection data was utilized to develop the repair plan for each of these nozzles. The approach used for the Unit 3 repairs began with the removal of the lower portion of the nozzle using a plasma and air-arc process. This process was followed by manual grinding of the nozzle and J-groove weld material to completely remove all of the cracks from service. After removal of the cracks and getting a clear PT of the excavated area, the nozzle wall and the J-groove weld were made using the shielded metal arc welding process. Alloy 690 filler materials were used for the Unit 3 welding repairs. A protective Alloy 690 weld pad was applied to the repairs to protect and isolate any remaining original Alloy 600 from the reactor water environment. The final step in the repair process was the post repair PT inspection.

The repairs to the Unit 3 RV enclosure head were performed in accordance with the 1992 edition of Section XI of the ASME and the NRC approval of several requests for alternatives and ASME Code Cases.

Oconee Unit 3: Corrective Actions Taken

The immediate corrective action taken was to re-assemble the failure investigation team that had completed the investigations and repairs on Unit 1. Other corrective actions were to perform the above described examinations of the leaking nozzles to determine the extent of any cracking and to determine the expected leakage pathway. The same team of experienced station and vendor personnel were re-assembled to investigate the nature of this pressure boundary leakage. The inspections also determined if circumferential cracking was found in the leaking nozzles. Metallurgical evaluations and quantitative chemical analyses were also performed on CRDM nozzle samples that were removed as part of the repair process. These metallurgical and chemical analysis results were compared to un-irradiated nozzle samples that were removed from the abandoned Midland RV head. Further finite element analyses were performed to assist in the root cause determination for these Unit 3 leaking CRDM. Further, an additional nine randomly selected CRDM locations were chosen for nondestructive examination by EC and UT. This inspection was performed for extent of condition determinations.

Other corrective actions taken for Unit 3 included the cleaning of the head to remove any new boron deposits and to aid future head inspections.

The principal corrective action to preclude future leakage events for Oconee Unit 3 is the replacement of RV head in the spring 2003 refueling outage.

REQUESTED ACTION:

2. If your plant has previously experienced either leakage from or cracking detected in VHP nozzles, addressees are requested to provide the following information:

c. your plans for future inspections (type, scope, qualification requirements, and acceptance criteria) and the schedule:

Future Inspections: The next scheduled inspections at Oconee coincide with each of the Oconee units refueling outages (RFO). The current refueling outage schedule for the Oconee units is as follows

- Oconee Unit 3: RFO scheduled to begin November 2001
- Oconee Unit 1: RFO scheduled to begin April 2002
- Oconee Unit 2: RFO scheduled to begin October 2002

Type of Inspection: At a minimum, qualified visual inspections will be performed on each RV head to identify any suspicious boron deposits that may exist on the head. This "qualified visual" inspection is defined in the same terms as specified by the NRC: 1) through wall cracking which will result in leakage reaching the head surface, and 2) the effectiveness of visual inspections of the head will not be compromised by insulation, existing deposits or other factors.

Visual inspections will be performed by VT-2 qualified personnel experienced with VHP issues and familiar with recent Oconee observations. The visual inspection that will be performed will be effective in identifying CRDM nozzle leakage and will not be compromised by existing deposits of boric acid. The capability to view the CRDM nozzles with minimum obstructions is enhanced by the access openings that were cut into the service structure as discussed previously. These openings permit the inspector to view each nozzle from multiple angles.

Scope: The scope of the qualified visual inspections will be essentially 100% of all CRDM nozzles. However, if any CRDM nozzle fails to meet the visual inspection acceptance criteria noted above, then additional NDE will be performed on the suspect leaking CRDM nozzle to determine the potential leakage source. Similar NDE (PT, EC and UT examinations) as described in this Bulletin response will be completed on suspect leaking nozzles to characterize the nature of and extent of any cracking. All leaking CRDM nozzles, will be repaired in accordance with approved methods, procedures, and processes, using the 1989 or later NRC approved edition of the ASME Section XI Code.

Decisions on additional inspections of other CRDM nozzles beyond those identified as leaking will be based primarily on the nature of the observed cracking, the extent and severity of the cracking, the occupational exposure rates, the availability of NDE equipment and a trained and qualified workforce.

Qualification Requirements: An Oconee procedure will be completed for use for future visual inspections of CRDM nozzles. Personnel performing the visual inspection will be VT-2 qualified and will meet other requirements and conditions set forth in the procedure. For the PT, ECT, and UT inspections, both the procedures and personnel completing the inspections will be qualified as required and specified by the particular procedure. The NDE inspections to be completed on suspect leaking CRDM nozzles will be equivalent to the inspections that were completed during the most recent Unit 1, 2 and Unit 3 inspections. Should enhancements to those inspection methods and procedures be made and the techniques demonstrated and be available for field use, then Oconee would plan to use the best available technology for any future inspection.

Acceptance Criteria: The acceptance criteria for the visual inspection is the absence of boric acid crystal deposits adjacent to the CRDM nozzle on the top of the RV head, or boric acid deposits adjacent to the CRDM nozzle determined to be from another source other than CRDM nozzle leakage.

The NEI and NRC acceptance criteria from GL 97-01 will be used for ID connected axial flaws found in a non-leaking CRDM nozzle. These criteria require NRC notification following the identification of any circumferential flaw that may be left in place.

Other acceptance criteria for the PT, EC, and UT examinations are as discussed in section 2.b of this response.

REQUESTED ACTION:

2.d Your basis for concluding that the inspections identified in 2.c will assure that regulatory requirements are met (see applicable Regulatory Requirements section). Include the following specific information in this discussion:

(1) If your future inspection plans do not include performing inspections before December 31,2001, provide your basis for concluding that the regulatory requirements discussed in the Applicable Regulatory Requirements section will continue to be met until the inspections are performed.

(2) If your future inspections plans do not include volumetric examination of all VHP nozzles, provide your basis for concluding that the regulatory requirements discussed in the Applicable Regulatory Requirements section will be satisfied.

Response:

Oconee Units 1 and 2 will not be inspected before December 31, 2001. Both of these units have within the past eight months undergone a scheduled refueling outage which included an effective 100% visual inspection of each head. For Oconee Unit 3, a 100% qualified visual inspection of the top of the RV head will be completed before December 31, 2001.

Due to the extensive efforts undertaken by Duke, the technical evaluations and other activities conducted to characterize and understand the situation at Oconee, Duke believes that a volumetric examination by the end of the year is not necessary to provide assurance that the Oconee units will not experience significant leakage, rapidly propagating failure or gross rupture. Duke believes that safe operation of Oconee is maintained, that the plant's defense in depth barriers are in tact, and that nuclear safety is in no way being compromised.

In addition, Duke believes the past corrective actions described in this response for Oconee Units 1, 2, and 3 have been reasonable and appropriate. Further, as of this writing, Duke believes there are limitations with the availability of NDE technologies, especially, as it relates to volumetric inspections of these CRDM nozzles. Duke is not aware of any existing qualified volumetric examination technique that can ensure detection of indications on the nozzle OD. There are numerous techniques being developed by vendors. Duke is working closely with these vendors to evaluate what capabilities may become available. It would not be appropriate to commit to these untested techniques without full benefit of demonstration, qualification and acceptance standards for the examinations. These examinations could subject plant and vendor personnel to significant occupational exposure without a compensating increase in quality or plant safety. Further, the potential for false calls could result in other exposure intensive repairs or investigations without a compensating increase in safety or quality.

Additionally, it is important to note the potential impacts of having the Oconee units perform volumetric inspections of CRDM nozzles as requested by the NRC. The most promising volumetric inspection technique that has a potential to interrogate the nozzle OD for evidence of axial and circumferential cracking involves a top down delivery system. This technique requires that the drive mechanism be pulled to perform the inspection. The projected outage impact to perform a 100% volumetric inspection of the sixty-nine CRDM nozzles is about thirty-three days of critical path time. To complete 100% inspection of all Oconee CRDM nozzles using this technique will approach one hundred days of outage critical path time for Oconee. Further, under the head automated blade probe volumetric inspection capabilities to search for both axial and circumferential cracks currently does not exist. UT blade probe techniques do exist for the detection of axial flaws for ID initiated damage. These techniques may be capable of detecting OD axial flaws; however, these techniques have yet to be utilized or qualified for OD initiated damage. This technique would not require removal of the drive mechanism; however, these capabilities are still under development. The availability of this technique for an Oconee outage is yet to be determined. The extended outage durations would create a significant hardship both in terms of financial impact and radiation exposure. Using a top down delivery system, the estimated occupational exposure to complete 100% volumetric inspections is between 40-50 REM per Oconee unit (120-150 REM total). Duke believes that the NDE technology is advancing to improve the quality of the NDE itself as well as the delivery systems. Eventually, this should reduce the associated occupational exposure and other impacts on plant operation.

It is Duke's position that the corrective actions taken in response to the described leakage events have been appropriate and reasonable to address this condition. The individual regulatory requirements cited in Bulletin 2001-01 are summarized below along with Duke's response to how these requirements have been and continue to be met.

The general design criteria (GDC), as outlined in this Bulletin, came into effect after the licensing of the Oconee Nuclear Station. Consequently, the draft GDC that ONS was licensed to was addressed in the UFSAR at the time of issuance of the Facility Operating License. The draft GDC is provided in concert for comparison.

DESCRIPTION OF REGULATORY REQUIREMENTS

10 CFR 50, Appendix A
Criterion 14 - Reactor Coolant Pressure Boundary
The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.

Corresponding Oconee Criterion 9 - Reactor Coolant Pressure Boundary (Category A)
The reactor coolant pressure boundary shall be designed and constructed so as to have an exceedingly low probability of gross rupture or significant leakage throughout its design lifetime.

Staff's Interpretation - " the presence of cracked and leaking Vessel Head Penetration (VHP) nozzles is not consistent with this GDC"

Compliance

As described in the Oconee UFSAR, the Reactor Coolant System pressure boundary at ONS meets the criterion through the following:

1. Material selection, design, fabrication, inspection, testing, and certification in accordance with ASME codes for all components excluding piping. Piping is maintained in accordance with the USAS B31.1 and B31.7 codes.

2. Manufacture and erection is in accordance with approved procedures.

3. Inspection is in accordance with code requirements plus additional requirements imposed by the manufacturer.

4. System analysis accounts for cyclic effects of thermal transients, mechanical shock, seismic loadings, and vibratory loadings.

5. Selection of RV material properties give due consideration to neutron flux effects and the resultant increase of the nil ductility transition temperature. The materials, codes, cyclic loadings, and non-destructive testing are discussed further in Chapter 5 of the Oconee UFSAR.

The original materials and methods of construction have not been materially changed or altered as a result of the observed cracking. The CRDM nozzle materials are very flaw tolerant and through extensive field experience exhibit signs of degradation through small leakage events.

The small amount of observed leakage from the CRDM nozzles neither constitute a gross rupture or significant leakage in terms of inventory leaked and, therefore, Duke concludes that the GDC continues to be met.

Criterion 31 - Fracture Prevention of Reactor Coolant Pressure Boundary

The reactor coolant pressure boundary shall be designed with sufficient margin to assure that when stressed under operating, maintenance, testing, and postulated accident conditions (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation on material properties, (3) residual, steady state and transient stresses, and (4) size of flaws.

Corresponding ONS Criterion 34 - Reactor Coolant Pressure Boundary Rapid Propagation Failure Prevention (Category A)
The reactor coolant pressure boundary shall be designed to minimize the probability of rapidly propagating type failures. Consideration shall be given a) to the notch-toughness properties of materials extending to the upper shelf of the Charpy transition curve, b) to the state of stress of materials under static and transient loadings, c) to the quality control specified for materials and component fabrication to limit flaw sizes, and d) to the provisions for control over service temperature and irradiation effects which may require operation restrictions.

Staff's Interpretation - " the presence of cracked and leaking Vessel Head Penetration (VHP) nozzles is not consistent with this GDC"

Compliance
Any potential VHP pressure boundary leakage is detectable by visual inspections during planned refueling outages. As a result of this detection capability, any through-wall cracked VHP is successfully identified and subsequently repaired in accordance with ASME Section XI.

As described in the Oconee UFSAR, the reactor coolant pressure boundary design at ONS meets this criterion by the following:

1. Development of RV plate material properties opposite the core to a specified Charpy-V- notch test result of 30 ft-lb or greater at a nominal low NDTT.

2. Determination of the fatigue usage factor resulting from expected static and transient loading during detailed design

and stress analysis.

3. Quality control procedures including permanent identification of materials and non-destructive testing.

4. Operating restrictions to prevent failure towards the end of design vessel life resulting from increase in the nil-ductility transition temperature (NDTT) due to neutron irradiation, as predicted by a material irradiation surveillance program.[6]

Additionally, compliance with this criterion is achieved by the selection of materials for the CRDM nozzles that is flaw tolerant, very ductile with no known occurrences of gross failure.

Identification and analysis of the indications on the Oconee CRDM nozzles supports the conclusion that these flaws are not a rapidly propagating failure. All three root cause evaluations have concluded that the leaks are the result of a PWSCC degradation mechanism that will manifest itself by characteristic leaks that will be observed well before any potential gross failure of the component.

Further, evaluations of any flaws found by NDE can be evaluated for the period of expected operation to the flaw evaluation rules for piping contained in ASME Section XI. Further, all leakage that is discovered will be repaired in accordance with ASME Section XI, NRC approved ASME Code Cases or alternatives. In all cases, ASME safety margins are maintained during the specified period of operation; thereby assuring continued compliance with the intent of the GDC.

Duke believes the intent of this GDC was to address radiation damage to the low alloy steel and welded RV materials and to ensure that the performance of these materials are assessed as they embrittle.

Criterion 32 - Inspection of Reactor Coolant Pressure Boundary
Components which are part of the reactor coolant pressure boundary shall be designed to permit (1) periodic inspection and testing of important areas and features to assess their

[6] Oconee UFSAR Section 5.2.3.13.

structural and leaktight integrity, and (2) an appropriate material surveillance program for the reactor pressure vessel.

Corresponding Oconee Criterion 36 - Reactor Coolant Pressure Boundary Surveillance (Category A)
Reactor coolant pressure boundary components shall have provisions for inspection, testing, and surveillance by appropriate means to assess the structural and leak-tight integrity of the boundary components during their service lifetime. For the RV, a material surveillance program conforming with ASTM-E-185-66 shall be provided.

Staff's Interpretation - "inspection practices that do not permit reliable detection of VHP nozzle cracking are not consistent with this GDC"

Compliance
The reactor coolant pressure boundary components at Oconee meet this criterion. Oconee has facilitated RV head inspection by cleaning the heads, implementing service structure modifications that improve access under the RV head insulation, and the elevated design of the existing head insulation. Space is provided for NDE during plant shutdown. A reactor pressure vessel material surveillance program conforming to ASTM-E-185-66 has been established.[7]

Additionally, Oconee has been involved with supplemental proactive inspection and testing since the early 1990's, escalating the program as appropriate.

10 CFR 50.55a Codes and Standards - ASME Class 1 components (which include VHP nozzles) must meet the requirements of Section XI of the ASME Boiler and Pressure Vessel Code. Table IWA-2500-1 of Section XI of the ASME Code provides examination requirements for VHP nozzles and references IWB-3522 for acceptance standards.

Staff's Interpretation - 1) "Therefore, 10 CFR 50.55a, through its reference to the ASME Code, does not permit through-wall cracking of VHP nozzles. (2) "For through-wall leakage identified by visual examinations in accordance with the ASME Code, acceptance standards for the identified degradation are provided in IWB-3142. Specifically, supplemental examination (by

[7] ONS UFSAR Section 5.2.3.13.

surface or volumetric examination), corrective measures or repairs, analytical evaluation, and replacement provide methods for determining the acceptability of degraded components."

Compliance

As related to VHP cracking, Oconee is in compliance with 10 CFR 50.55a and code compliance criteria in IWB-3522. Oconee has detected leakage from insulated components, with detection being a result of identifiable boron deposits that had accumulated on the top of the head. As required, Oconee performed appropriate NDE of each of these leakage events to determine the source of the leakage/deposit and then performed repairs in accordance with rules stipulated by ASME Code and NRC approved Code alternatives.

For through-wall leakage identified by visual examinations in accordance with ASME Code, acceptance standards for the identified degradation are provided in IWB-3142. In accordance with these requirements, methods to determine the acceptability of degraded components include supplemental exams, corrective measures, or repairs, analytical evaluation and replacement have been completed.

As required by IWB-3142, all identified degraded and leaking components were repaired prior to returning the unit to service. Specifically, all crack-like indications were removed from the leaking nozzles, and other non-leaking nozzles inspected for extent of condition. Minor shallow indications were evaluated by ASME Section XI analytical flaw evaluation rules and determined to be acceptable for continued service.

Additionally, Oconee performs visual examinations of accessible and exposed surfaces during system pressure testing as part of their In-Service Inspection Program required by 10 CFR 50.55a. The visual examination may be conducted by looking for evidence of potential leakage. The acceptance standard for the examination is found in IWA-5250, "Corrective Measures." This subsection requires repair or replacement if a leak is identified as well as assessment of damage, if any, from corrosion of steel components by boric acid deposits.

The effectiveness of the supplemental bare-metal visual inspection, the NDE performed to date and engineering analysis provide reasonable assurance that compliance with code margins and acceptance criteria will continue to be maintained for the operating period between inspections.

10 CFR 50 Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants
Criterion IX- Control of Special Processes
Measures shall be established to assure that special processes, including welding, heat treating, and nondestructive testing, are controlled and accomplished by qualified personnel using qualified procedures in accordance with applicable codes, standards, specifications, criteria, and other special requirements.

Staff's Interpretation - "Within the context of providing assurance of the structural integrity of VHP nozzles, special requirements for visual examination would generally require the use of a qualified visual examination method. Such a method is one that a plant-specific analysis has demonstrated will result in sufficient leakage to the RV head surface for a through-wall crack in a VHP nozzle, and that the resultant leakage provides a detectable deposit on the RV head. The analysis would have to consider, for example, the as-built configuration of the VHPs and the capability to reliably detect and accurately characterize the source of the leakage, considering the presence of insulation, preexisting deposits on the RV head, and other factors that could interfere with the detection of leakage. Similarly, special requirements for volumetric examination would generally require the use of a qualified volumetric examination method, for example, one that has a demonstrated capability to reliably detect cracking on the OD of the VHP nozzle above the J-groove weld."

Compliance
Activities for characterizing and repairing reactor pressure vessel head CRDM nozzle defects are performed in accordance with the Duke Quality Assurance (QA) program which has been reviewed and approved by the NRC. The Duke QA Program, in general, maintains procedures for the control of a number of special processes including welding, heat treating, NDE, and cleaning. The program requires that approved, written procedures, qualified in accordance with applicable codes and standards, be utilized when the performance of the station's QA Condition 1 structures, systems and components. These procedures provide for documented evidence of acceptable accomplishment of these

special processes using qualified procedures, equipment and personnel as may be required by ASME Section XI for reactor coolant pressure boundary components.

Personnel performing such activities must be qualified in accordance with applicable codes and standards. Adequate documentation of personnel qualifications is required prior to performance of the applicable special process. NDE examination personnel are certified to required codes and standards.

To assure compliance with requirements, a procedure will be developed to document inspection plans and results. Also, nozzle specific evaluations have been completed using original as built head bore and nozzle dimensions to demonstrate that at normal plant operations, a positive gap will exist such that through-wall leakage evidence would be visible on the RV head. Further, any UT or other NDE examinations performed in support of leaking nozzles will have been subjected to sufficient demonstration testing to substantiate the capability of examination method.

Criterion V - Instructions, Procedures, and Drawings
Activities affecting quality shall be prescribed by documented instructions, procedures, or drawings, of a type appropriate to the circumstances and shall be accomplished in accordance with these instructions, procedures, or drawings. Instructions, procedures, or drawings shall include appropriate quantitative or qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

Staff's Interpretation - "Visual and volumetric examinations of VHP nozzles are activities that should be documented in accordance with these requirements."

Compliance
As previously discussed, activities for characterizing and repairing reactor pressure vessel head CRDM nozzle defects are performed in accordance with the Duke QA program. Procedures which address activities associated with QA Condition 1 structures, systems and components are subjected to a well-defined and established preparation, review, and approval process as defined in the Duke QA Program. This QA Program meets the above requirements.

Criterion XVI - Corrective Action
Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected. In the case of significant conditions adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.

Staff's Interpretation - "For cracking of VHP nozzles, the root cause determination is important to understanding the nature of the degradation present and the required actions to mitigate future cracking. These actions could include proactive inspections and repair of degraded VHP nozzles."

Compliance
As previously discussed, activities for characterizing and repairing reactor pressure vessel head CRDM nozzle defects are performed in accordance with the Duke QA program. Pursuant to this program, station personnel are responsible for the implementation of the quality assurance program as it pertains to the performance of their activities. Specific to this responsibility is the requirement for informing the responsible supervisory personnel and/or for taking appropriate corrective action whenever any deficiency in the implementation of the requirements of the program is determined.

Procedures require that conditions adverse to quality be corrected. In the case of significant conditions adverse to quality, the procedures assure that the cause of the condition is determined and action be taken to preclude repetition. Performance and verification personnel are to:

a) Identify conditions that are adverse to quality.

b) Suggest, recommend, or provide solutions to the problems as appropriate.

c) Verify resolution of the issue. Additionally, performance and verification personnel are to ensure that reworked, repaired, and replacement items be inspected and tested in accordance with the original inspection and test requirements or specified alternatives.

In the event of the failure of QA Condition 1 components (such as the occurrence of CRDM nozzle leaks) the cause of the failure is evaluated and appropriate corrective action taken. Items of the same type are evaluated to determine whether or not they can be expected to continue to function in an appropriate manner. This evaluation is documented in accordance with applicable procedures. The determination of an item's nonconformance is documented and is retained on file.

Specifically, root cause determinations were conducted upon the identification of VHP leakage for each Oconee unit. Corrective actions were identified and are being implemented to preclude future recurrence. Further, to fully evaluate the nature and transportability of the failure mechanism, other susceptible Alloy 600 components in the Reactor Coolant System were inspected for signs of leakage. Also, an additional twenty-six non-leaking nozzles were examined for signs of cracking. In each of the twenty-six nozzles, the results did not find any signs of significant cracking. It is important to point out that the additional number of nozzles that were inspected go beyond what the ASME Code requires for sample expansion for this code examination category. Specifically, the Code does not require a sample expansion if an indication is found in the J-groove attachment weld.

The above described actions are appropriate and reasonable in the prompt identification and correction of VHP leakage.

Technical Specifications - The current limiting condition of operation (LCO) for ONS, TS 3.4.13, requires that RCS operational LEAKAGE be limited to no pressure boundary LEAKAGE; 1 gpm unidentified LEAKAGE; 10 gpm identified LEAKAGE; 300 gallon per day total primary to secondary LEAKAGE through all steam generators (SGs) and 150 gallon per day primary to secondary leakage through any one SG. These limits are applicable in operational modes 1 through 4.

Staff's Interpretation - "Plant technical specifications pertain to the issue of VHP nozzle cracking insofar as they require no through-wall reactor coolant system leakage."

Compliance

The technical specifications (TS) leakage limits are complied with through various means of monitoring and leak detection systems (e.g., the radiation monitoring systems, periodic system inventory balances and scheduled operator system walk-downs). Indicators and alarms for each leakage detection system are provided in the control room along with procedures for converting various indications to leakage rate equivalents. The leakage detection systems are also equipped with provisions for testing and calibration during operation. Leakage from the reactor coolant pressure boundary into connected systems is indicated by various radiation monitors, tank levels and other methods. A control room alarm is actuated in all cases. Because of the diverse detection methods, location of sensors, and alarms, when reactor coolant pressure boundary leakage occurs, the operator is provided with sufficient information to take corrective action in compliance with TS.

If a rapidly propagating crack resulted in reactor coolant pressure boundary leakage, the various leakage detection methods would provide indication of the leakage. However, the VHP nozzle cracking does not manifest into a rapidly propagating crack, and because of the small amount of leakage from the cracked nozzles (estimated less than 1 gallon per year), the existing leakage detection system is unable to detect leakage at that threshold. The most reliable evidence of VHP nozzle cracking leakage is the small amount of boric acid deposits that will be detected during visual inspections.

Therefore, a qualified 100 % visual inspection of the top of the RV head will be completed during each refueling outage until RV head replacement. Based on the previous Oconee inspection and repair data, boric acid crystal deposits will be visible on the top of the RV head. The cleaning of the top of the RV head and the installation of service structure modifications to improve access, have contributed to the effectiveness of these visual inspections as demonstrated in previous outages. As in previous outages, CRDM nozzles identified with potential leaks will receive additional inspections and any necessary repairs. All suspect leaking nozzles are fully investigated and repaired to meet all applicable code and regulatory requirements. All repairs are completed before the unit is returned to service. As mentioned earlier in this response, any decision to expand and perform other NDE inspections of non-leaking nozzles will be based on the nature of the observed cracked conditions, the extent and severity of the cracking, the occupational exposures involved in performing additional inspections and examinations, the availability of qualified NDE techniques, equipment, procedures, personnel, and the impact to the refueling outage.

Compliance with Oconee TS 3.4.13 will be maintained through continued performance of the above described leakage detection surveillance and qualified visual inspection of the CRDM nozzles. The previously performed, effective visual inspections identified evidence of leaking CRDM nozzles and provided for qualified repair of those nozzles. This provided assurance that all CRDM nozzles were leak-tight upon return of each unit to service. The qualified visual inspections to be performed during each Oconee unit's upcoming refueling outage will provide reasonable assurance of the discovery of conditions that could contribute to future CRDM nozzle leakage. Discovery of these conditions will ensure required repairs are completed prior to returning a unit to service. A corrective action to replace RV heads in all three units by spring of 2004 limits the period of time that the units will operate with the existing heads. The combination of the characterization of the existing RV heads (by the previously performed visual inspection and supplemental NDE) and this limited time period provides a basis for assuring conformance with the Oconee current licensing basis. The following section of this response provides a more detailed basis that this continued operation conforms to applicable criteria in the current licensing basis, which supports that the above-described surveillance and visual inspection are adequate to provide reasonable assurance of Technical Specification compliance.

Detailed Basis for Continued Safe Plant Operation

For the Oconee units, CRDM nozzles are robust in design. The components were fabricated using Alloy 600, which has excellent general corrosion resistance and extremely high fracture toughness. The cracks were primarily in the nozzle base metal and had axial or circumferential locations and orientations that would resist nozzle ejection. Resulting boron crystal deposits were evident, but were minimal due to the relatively tight cracks as confirmed by previous Oconee leakage. The penetrations are designed to permit either visual, surface, or volumetric inspection.

For each unit at Oconee, a nozzle-by-nozzle analysis of the shrink fit annulus is being completed for each of the 69 CRDM nozzles to evaluate the existence of a gap while the Reactor Coolant System is pressurized. The purpose of this analysis is to prove that during unit operation, boron crystal deposits from a through-wall crack would be visible on the top of the RV head. A concern had existed that these boron crystal deposits would be precluded from reaching the top of the RV head by the CRDM nozzle shrink fit above the J-groove weld, thus not evidencing an existing crack. Using original measurements from fabrication documents, and full power operation parameters for pressure and temperature, an analysis of the gap between the CRDM nozzle and RV head penetration at the shrink fit area is being performed by Structural Integrity Incorporated. This analysis consists of a finite element model to include the upper hemispherical head, the upper closure flange, and the CRDM housing tubes. Due to the symmetrical nature of the upper head and layout of the CRDM tubes, only a 45-degree segment of the total circumference was modeled. A positive gap value (open gap clearance) calculated for each CRDM nozzle location will verify that leakage will be present on the top of the RV head if a nozzle had a through-wall leak in the J-groove area. The calculation of the existence of this gap provides evidence that boric acid crystals from a through-wall leaking indication would be visible on the top of the RV head. Any CRDM nozzle that is not verified by this analysis to have a positive gap, will be volumetrically inspected during the next refueling outage.

The expanded Oconee inspections for extent of condition support the completion of this analysis with empirical field data since no through wall indications were identified on nozzles without boric acid crystals on the top of the RV head. At Oconee, a total of twenty-six non-leaking nozzles have been randomly selected for volumetric inspection. The additional inspections found the nozzles to be essentially clear of any significant cracking. The indications that were found were evaluated as minor shallow craze-type indications.

The annulus gap calculations during normal power operation were also used to compare the gaps on the nozzles identified as leaking on Oconee Units 1, 2 and 3. The most restrictive gap on a leaking nozzle during power operation was calculated to be 0.0017 inch. Comparing this value to the overall nozzle population indicates that more than 85% of the nozzles for the three Oconee units have gaps greater than or equal to 0.0017 inch during normal power operation. This analysis provides additional assurance that a through-wall leak in a CRDM nozzle would be identified by the top of the head visual inspections. The Oconee experience continues to prove the point that clean heads with good visual access, using experienced and knowledgeable personnel, can locate suspicious penetrations.

Further, based on a Finite Element Analysis (FEA) model of the J-groove nozzle weld, postulated axially oriented cracks will form, propagate through the pressure boundary, causing leakage, and then may produce circumferential cracking. Using conservative crack growth rates based on the Peter Scott crack growth rate formula, it has been evaluated that these circumferential cracks will not grow to a critical flaw size in less than one operating cycle (18 months) at Oconee. The maximum crack growth rate needed for a single circumferential flaw to reach critical flaw size in one 18-month operating cycle (assuming only 1 initiation site) is greater than 50 mm/year compared to the generally accepted 4 mm/year from the Peter Scott model.

The critical flaw size for this evaluation was defined as 270 degrees, assuming a safety factor of three per the ASME Code. This value indicates that a remaining ligament of about 30 degrees of the CRDM nozzle will be sufficient to secure the nozzle from failure. With a Code safety factor of three assumed, the remaining ligament must be a minimum of 90 degrees to prevent a safety concern. The largest circumferential flaw identified during the Oconee Unit 3 work had propagated to approximately 165 degrees around the nozzle with a remaining ligament of 195 degrees. Therefore, a significant margin of safety existed for the largest circumferential flaw found at Oconee.

Combining the above analysis with the planned visual inspections of the top of the RV head provides reasonable assurance that a circumferential flaw will not reach the critical flaw size in the period of interest prior to the replacement of the Oconee RV heads. Therefore, by completing the top of the RV head visual inspections in the interim refueling outage for each unit, a leaking CRDM nozzle will be identified and repaired to comply with applicable regulatory requirements and prior to the onset of any nuclear safety concern.

For additional assurance, an Oconee-specific risk assessment has been completed for the three Oconee units to estimate the core damage frequency (CDF) associated with operation with potentially undetected CRDM nozzle cracks for the time period prior to RV head replacement.[8] This risk analysis was performed to supplement the deterministic work that has been completed. Since axial cracks in a CRDM nozzle are not considered a near-term concern for nuclear safety, the failure evaluated was an OD circumferential crack that would grow to critical flaw size and fail, thus causing a LOCA. From a risk point of view the only CRDM nozzle cracks that are significant are the flaws where detectable symptoms of the degradation are not identified and the degradation is not repaired prior to a catastrophic failure.

The Oconee-specific risk assessment is a refinement of the B&W Owners' Group risk assessment completed by Framatome-ANP for the B&W Owners' Group member utilities.[9] The B&W Owners' Group risk assessment explicitly considered four operating cycles, approximately eight years, as the time period of interest. The Oconee-specific risk assessment truncated the period of interest to the time at each Oconee unit prior to the RV head replacement for that unit. Other information included in the Oconee-specific report to further refine the B&W Owners' Group risk assessment were Oconee-specific outage dates and Oconee-specific values regarding the conditional core damage probability of a medium break LOCA.

Factors considered in the estimation of the CDF at Oconee as a result of CRDM nozzle cracking were:

1. The number of leaking nozzles assumed per reactor-year.
2. The probability of not detecting an existing leaking nozzle as a result of human error.
3. The probability of having an OD flaw initiate and grow to catastrophic failure in less than one operating cycle.
4. The probability that a medium break LOCA would lead to core damage.

The number of flaws found by inspection that resulted in leaking nozzles experienced at Oconee and Arkansas Nuclear One Unit 1

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[8] Engineering Calculation, Framatome-ANP Document Identifier 51-5013694-01, Oconee-Specific Risk Assessment for CRDM Nozzle PWSCC.
[9] Engineering Calculation, Framatome-ANP Document Identifier 51-5013347-01, Risk Assessment for CRDM Nozzle PWSCC.

(ANO-1) was 14 and 1, respectfully. Conservatively assuming these flaws initiated over the last two operating cycles, an initiating frequency of 1.25 CRDM leaks can be estimated from fifteen leaks identified in twelve reactor-years (four units at three reactor years each - two operating cycles at 1.5 year operating cycle). This estimate is also conservative because ANO-1 fuel cycles are longer than 1.5 years. An alternate method of calculating the number of CRDM nozzle leaks per reactor-year was to use the CHECWORKS model. The results of this analysis shows corresponding values of 0.31, 0.41 and 0.29 for each of the Oconee units. By selecting the value of 1.25 as discussed above, conservatism was added to this assumption.

The probability of having a leaking nozzle with boric acid crystals present, but not identifying the leak as a result of human error (either failing to conduct the test or failing to detect evidence of a leak during an inspection) is estimated to be 6.0E-2. This estimate is conservative because it assumed that a RV head inspection procedure was not in place. For future visual inspections of the Oconee RV heads, a procedure will be implemented. The potential addition of an independent verification of the presence of boric acid crystals would further increase the conservatism. Relative to standard PRA assumptions, the assumed probability of 6.0E-2 may be as much as an order of magnitude too high, therefore significant conservatism has been added to this assumption.

The probability of having an OD flaw propagate in one fuel cycle to be large enough to cause catastrophic failure is 1.3E-5. This estimate is conservative because the shortest time in which a flaw can propagate to failure is estimated in a Monte Carlo simulation to be 3.56 years.[10] Framatome performed the Monte Carlo simulation with a conservative set of assumptions to account for the acknowledged uncertainties in PFM data for OD PWSCC. Since the longest time period between refueling outages for Oconee is listed at 1.48 years, in theory, no occurrences of a flaw propagating to failure will be experienced. A conservative estimate of one failure (out of 80,000 Monte Carlo simulations) was used to estimate the 1.3E-5 value.

The conditional core damage probability (CCDP) of a medium break LOCA is estimated from the Oconee PRA to be 3.5E-3. Using the

[10] Engineering Calculation, Framatome-ANP Document Identifier 51-5013347-01, Risk Assessment for CRDM Nozzle PWSCC.

CCDP of a medium break LOCA may be conservative since a partial CRDM nozzle failure could be considered a small break LOCA, which has a smaller CCDP than a medium break LOCA.

Additionally, the Oconee level III PRA was used to evaluate the public health risk associated with operation of Oconee units with potentially undetected CRDM nozzle cracks. The conditional population dose associated with a medium break LOCA type core melt accident is 1.1E4 person-rem. This is a relatively low value when compared to other types of accidents because core damage accidents associated with a failed CRDM nozzle would not directly affect containment safeguard functions. Thus the public health effects as well as the potential for a large early release would be very low.

Using the described values as inputs, the Oconee-specific risk assessment combined the initiating event frequency and separate probability values estimating the frequency of a circumferential crack reaching the critical flaw size and causing an RCS LOCA that results in core damage to be 6.0E-8/reactor-year. This estimated value is well below the RG 1.174 threshold value for risk significance. Additionally, the public health risk associated with this concern is 6.6E-4 person-rem/yr. This is well below the expected exposure for plant personnel who would perform a volumetric inspection if it were required.

These results show that OD PWSCC of the CRDM nozzles is not risk significant for any of the Oconee units during each reactor year prior to RV head replacement.

Updates to this analysis will be completed as needed based on industry information and Oconee inspection results as received following the spring and fall outages of each calendar year.

As an additional measure to support the other deterministic and risk analysis work discussed in earlier sections of this response, Duke has performed an analysis to evaluate the potential impacts to the Oconee reactor cores should a nozzle fail and be ejected from the RV. The damage experienced following the failure of a CRDM nozzle has been reviewed to evaluate the potential for this event to cause fuel rod damage or failures. The rod ejection accident (REA) has been performed for the current operating cycles and the subsequently designed cycles of all three Oconee units. This includes all of the cycles until the projected RV head replacements with the exception of Unit 2, Cycle 20. A similar analysis will be performed for the Oconee 2 Cycle 20 core design once that design has been completed to ensure similar results are obtained. These analyses have been performed in accordance with the NRC-approved methodology of topical report DPC-NE-3005-PA.[11]

The analyses include simulations of the beginning-of-cycle (BOC), 4 reactor coolant pump (RCP) initial condition rod ejection for all of the cycles. A representative cycle simulation was performed at BOC 3 RCP initial conditions and another at end-of-cycle (EOC) 4 RCP initial conditions, to demonstrate that the BOC 4 RCP case is the most limiting. The BOC 3 RCP case and the EOC 4 RCP cases yielded more margin to departure from nucleate boiling ratio (DNBR) than the BOC 4 RCP case. For the HZP core conditions the cycle-specific ejected rod worth is insufficient to achieve prompt criticality. Consequently, the rapid power excursion shown in DPC-NE-3005-PA for the HZP case does not occur and the resultant transient is easily bounded by the 4 RCP case.

The peak core power for the BOC 4 RCP case analyzed for Unit 1, Cycle 20 is 112% of full power. This is in contrast to the similar case in DPC-NE-3005-PA; which yielded a maximum core power of 140% full power. The results of this conservative analysis of the rod ejection accident indicate that no fuel rod failures due to DNB or any other reason would be anticipated for the cycles in question. This is in contrast to the highly conservative 40.6% fuel pin census results shown in Table 14-4 of DPC-NE-3005-PA or the ~50% fuel failures assumed in the offsite dose calculations. The calculation of peak pressure and peak fuel enthalpy were not performed in these analyses as neither limit was violated in the current UFSAR Chapter 15 analyses. These relatively benign results are due to the small ejected rod worth values for the Oconee core designs of concern.

Risk associated with maintenance activities is managed and documented for Oconee systems, structures and components as required by 10 CFR Part 50.65 and Duke policies and procedures.[12] This includes compliance with paragraph (a)(4) to assess and manage the increase in risk that may result from proposed maintenance activities. Work activities are performed to

[11] Oconee UFSAR Chapter 15 Transient Analysis Methodology
[12] 10 CFR Part 50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, or the Maintenance Rule.

provide the level of plant equipment reliability necessary for safety, and are carefully managed to achieve a balance between the benefits and potential impacts on safety, reliability and availability. Prior to performing work activities risk assessments are performed to assess and manage the increased risk that may result from proposed work activities. Assessment of proposed work activities determines the effect of maintenance on the availability of high safety significant plant systems that have been modeled in the ORAM-SENTINEL risk assessment tool. When the proposed maintenance renders these systems unavailable, the work is coded as causing unavailability of the systems. The plant configurations that occur during maintenance are then assessed using the ORAM-SENTINEL risk assessment software tool.

REQUESTED ACTION:

5. Addressees are requested to provide the following information within 30 days after plant restart following the next refueling outage:

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;

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

Response:

A thirty day report will be submitted as requested for any other leakage events.

Conclusion

Duke believes that the commitment to safe operation of Oconee is maintained through proactive actions such as those begun in 1992. Duke began a program to address PWSCC in Alloy 600 VHP nozzles in 1992. Through the development of an effective visual inspection method of VHP nozzles, Oconee has identified and characterized VHP nozzle cracking in all three Oconee units. A thorough root cause analysis was completed and shared with both industry and NRC staff. The results of this root cause analysis have confirmed Alloy 600 PWSCC and are consistent with the mechanism and conclusions discussed in Generic Letter 97-01. In addition, the phenomenon of circumferential cracking was discovered. Duke's examination and analysis indicates that a through-wall axial crack precedes the formation of these circumferential cracks. Analysis has concluded that it is very unlikely that a circumferential crack can be expected to develop to a critical flaw size during an 18-month operating cycle. Therefore, Duke believes that with the recent effective visual inspection and characterization of the Oconee reactor vessel heads, there currently are no immediate safety concerns.

The conclusion of no immediate safety concerns is further confirmed by a risk assessment that has been completed for the three Oconee units to evaluate 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 is below the point of being risk significant for any of the Oconee units during each of these reactor years.

Duke believes that replacement of RV heads is the most effective corrective action to preclude recurrence of VHP nozzle cracking. All RV Heads will be replaced at Oconee by the spring of year 2004. This decision not only limits the period of time that the units will operate with the existing heads, but also provides new heads using upgraded Alloy 690 CRDM nozzles that are more highly resistant to PWSCC. Key factors considered in the decision to replace these heads include current available NDE technology, "as low as reasonably achievable" occupational exposure goals and the uncertainties for long term planning and unit availability.

The effectiveness of the above described program, the NDE performed to date, engineering analysis and planned corrective actions provide reasonable assurance that compliance with applicable regulatory requirements will continue to be maintained for the Oconee units. Duke strongly believes that these proactive efforts meet the full extent of reasonable and appropriate actions intended by issuance of the Bulletin, and will best ensure the health, safety, and welfare of the public.

Table 1: Oconee Unit 2 CRDM Nozzle UT[1] Results

Noz #	Ind #	Type	Circumferential Extent[2] (0° = downhill side) Min.	Max.	Remaining Ligament From ID Surface (in.)	Surface (ID/OD)	Location (B/W/A)[3]	Axial Length (in.)	Circum. Length OD (in.)
4	1	Axial	206°		0.52"	OD	B,W,A	2.3"	
4	2	Axial	187°		0.51"	OD	B	0.4"	
4	3	Axial	171°		0.52"	OD	B,W,A	1.9"	
4	4	Axial	147°		0.54"	OD	B	1.8"	
4	5	Axial	136°		0.59"	OD	B	0.4"	
4	6	Axial	105°		NM*	OD	B	0.3"	
4	7	Axial	67°		NM*	OD	B	0.3"	
4	8	Axial	30°	39°	0.47"	OD	B,W,A	2.0"	0.3"
4	9	Axial	17°		NM*	OD	B,W,A	1.4"	
4	10	Axial	344°		NM*	OD	B,W,A	1.5"	
4	11	Axial	329°		NM*	OD	B	0.2"	
4	12	Axial	318°		NM*	OD	B	0.4"	
4	13	Axial	298°		NM*	OD	B	0.3"	
4	14	Axial	285°	303°	0.49"	OD	B,W,A	1.7"	0.6"
4	15	Axial	265°	286°	0.53"	OD	B,W,A	1.8"	0.7"
4	16	Axial	232°		0.55"	OD	B	0.4"	
4	17	Axial	220°		0.53"	OD	B	0.3"	
6	1	Axial	78°	90°	0.42"	OD	B	1.1"	0.4"
6	2	Axial	51°		0.43"	OD	B	1.4"	
18	1	Axial	152.7°		0.54"	OD	B	0.6"	
18	2	Axial	128.7°		0.50"	OD	B	0.5"	
18	3	Axial	105.7°		NM*	OD	B	0.3"	
18	4	Axial	86.9°	95°	0.52"	OD	B	0.8"	8.1"
18	5	Axial	54.7°		0.55"	OD	B	0.5"	
18	6	Axial	39.7°		0.43"	OD	B	1.0"	
18	7	Axial	11.1°		NM*	OD	B	0.3"	
18	8	Axial	343.7°	353.7°	0.48"	OD	B,W	1.6"	0.3"
18	9	Axial	327.7°	333.7°	0.43"	OD	B	0.8"	0.2"
18	10	Axial	308.7°	317.7°	0.45"	OD	B	1.0"	0.3"
18	11	Axial	281.7°	293.7°	0.45"	OD	B,W	1.0"	0.4"
18	12	Axial	238.7°	249.7°	0.48"	OD	B	0.9"	0.4"
18	13	Axial	233.7°		NM*	OD	B	0.1"	
18	14	Axial	213.7°	224.7°	Lack of Bond	OD	W	0.3"	0.4"
18	15	Circ	302.5°	338.3°	0.55"	OD	A	0.5"	1.25"
30	1	Axial	278.2°	289.2°	0.58"	OD	B,W	0.5"	0.4"
30	2	Axial	163.2°		NM*	OD	B	0.7"	
30	3	Axial	121.7°	132.7°	0.57"	OD	B	0.9"	0.4"

1 The UT was performed as a best effort not having been demonstrated on PWSCC cracks.
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.
* Not deep enough to measure (shallow crack on the OD of the nozzle).

Table 2: Oconee Unit 3 CRDM Nozzle UT[1] Results (enclosure pages 42 & 43)

Noz #	Ind #	Type	Circumferential Extent[2] (0° = downhill side)		Remaining Ligament From ID Surface (in.)	Surface (ID/OD)	Location (B/W/A)[3]	Axial Length (in.)	Circum. Length OD (in.)
			Min.	Max.					
3	1	Axial	277°		0.32	OD	B,W,A	2.39"	
3	2	Axial	322°		0.33	OD	B,W,A	2.41"	
3	3	Axial	354°		0.51	OD	B	0.30"	
3	4	Axial	56°		0.57	OD	B	0.34"	
3	5	Axial	80°		0.53	OD	B	0.45"	
3	6	Axial	100°		0.55	OD	B	0.47"	
3	7	Axial	204°		0.35	OD	B	0.82"	
4	1	Axial	312°		Shallow	ID	A[4]	0.26"	
4	2	Axial	323°		Shallow	ID	A	0.22"	
4	3	Axial	344°		Shallow	ID	A	0.35"	
4	4	Axial	10°		Shallow	ID	A	0.35"	
7	1	Axial	0°		0.11	OD	W,A	2.34"	
11	1	Axial	270°		0.41	OD	B	0.57"	
11	2	Axial	328°		0.12	OD	B,W,A	3.15"	
11	3	Axial	351°		Through-wall	ID/OD	B,W,A	2.95"	
11	4	Axial	25°		Through-wall	ID/OD	B,W,A	3.02"	
11	5	Axial	68°	88°	Through-wall	ID/OD	B,W	2.68"	0.68"
11	6	Axial	147°		0.21	OD	B,W,A	2.83"	
11	7	Axial	222°		0.40	OD	B	0.83"	
11	8	Circ	192°	217°	0.084 depth	ID	B		0.87"
11	9	Circ	267°	60°	0.27	OD	B/W Interface		5.34"
11	10	Circ	85°	198°	0.38	OD	B/W Interface		3.93"
23	1	Axial	216°	275°	Through-wall	ID/OD	B,W,A	3.79"	2.04"
23	2	Axial	109°		0.60	OD	B	1.09"	
23	3	Axial	62°		0,60	OD	B,W	1.70"	
23	4	Axial	23°		Through-wall	ID/OD	B,W,A	2.53"	
23	5	Circ	314°	16°	0.20	OD	B		2.17"
23	6	Axial	334°		0.50	OD	B,W	1.64"	
23	7	Axial	301°		0.62	OD	B,W	1.29"	
23	8	Circ	150°	208°	0.29	OD	B		2.02"
23	9	Circ	317°	23°	0.40	OD	A	0.22"	2.30"
28	1	Axial	358°		Through-wall	ID/OD	B,W	1.66"	
28	2	Axial	55°		Through-wall	ID/OD	B,W	1.35"	
28	3	Axial	101°	114°	Through-wall	ID/OD	B	1.16"	0.45"
28	4	Axial	136°	165°	Through-wall	ID/OD	B,W	1.96"	1.02"
28	5	Axial	246°	258°	Through-wall	ID/OD	B	1.71"	0.42"
34	1	Axial	139°	146°	0.57	OD	B,W	0.92"	0.24"
50	1	Circ	123°	201°	0.05	OD	B	1.22"	2.73"
50	2	Circ	299°	9°	0.35	OD	B		2.43"
50	3	Axial	174°	183°	Through-wall	ID/OD	B	1.78"	0.33"
50	4	Axial	304°	330°	Through-wall	ID/OD	B,W	2.95"	0.90"
50	5	Circ	187°	246°	Through-wall	ID/OD	A	1.31"	2.06"

Table 2: Oconee Unit 3 CRDM Nozzle UT[1] Results (enclosure pages 42 & 43)

56	1	Axial	59°	98°	Through-wall	ID/OD	B,W	1.67"	1.41"
56	2	Circ	148°	205°	0.1 depth	ID	B	1.58"	1.96"
56	3	Circ	335°	259°	0.54	OD	B,W	0.74"	0.83"
56	4	Circ	137°	302°	Through-wall	ID/OD	A	2.08"	5.74"
63	1	Axial	296°		Through-wall	ID/OD	B,W	2.97"	
63	2	Axial	347°		0.45	OD	B	0.88"	
63	3	Axial	62°	97°	Through-wall	ID/OD	B,W	3.28"	1.22"
63	4	Axial	102°	140°	Through-wall	ID/OD	B	1.66"	1.33"
63	5	Axial	136°	152°	0.15	ID	B	0.84"	0.56"
63	6	Axial	152°	188°	0.15	ID	B	3.10"	1.26"

[1] The UT was performed as a best effort not having been demonstrated on PWSCC cracks. (UT report is being finalized and data subject to minor changes.).

[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.

[4] Nozzle 4 inspected for extent of condition only, i.e. not a leaking nozzle

Figure 1

Schematic of B&W-Design Reactor Vessel Head, CRDM Nozzles, Thermocouple Nozzles, and Insulation