January 17, 2003

MEMORANDUM TO: Luis Reyes, Regional Administrator
Region II

FROM: John A. Zwolinski, Director ***/RA/***
Division of Licensing Project Management

SUBJECT: REACTOR PRESSURE VESSEL HEAD (RVHP) PENETRATION CONCERNS AT NORTH ANNA POWER STATION, UNIT 1

This memorandum, originally issued on December 27, 2002, as non-public correspondence, provides the Office of Nuclear Reactor Regulation (NRR) position on the continued operation of North Anna Power Station, Unit 1, with indications in the reactor vessel head penetrations. We are sending this revised memorandum to provide you with a publicly available version of the staff's basis. The issues that distinguish this version from the non-public version are a revision of the reference to the specific timing of the North Anna, Unit 1, refueling outage, and a clarification of the staff's evaluation of Virginia Electric and Power Company's (VEPCO's) responses to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," and NRC Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs."

In its response to Bulletin 2001-01, (ADAMS Accession No. ML020090491), dated November 5, 2001, VEPCO provided the following information based on inspections conducted at North Anna, Unit 1, in September 2001:

- No circumferential cracking or through-wall flaws were identified in the welds or in the tubes of any of the reactor pressure vessel head nozzles.

- Indications were identified on nine penetrations. One non-service-induced flaw (crater crack) and four indications in the cladding were discovered on one penetration (Penetration 50). The non-service-induced flaw was successfully excavated, and since the other four indications were non-recordable, they did not require repair. The indications associated with the remaining eight penetrations (i.e., Penetration Nos. 3, 11, 31, 33, 52, 57, 60, 66) were evaluated by fracture mechanics, and it was determined that these indications would not compromise structural integrity.

As part of its review of Bulletin 2002-02, NRR requested that VEPCO provide the staff with additional information related to the bases for concluding that the reactor pressure vessel head nozzles and welds at North Anna, Unit 1, do not have cracking that could jeopardize reactor coolant pressure boundary integrity, and provide its bases for assuring reactor coolant pressure boundary integrity and conformance with all regulatory requirements consistent with the terms of its operating license. The licensee provided its response to this request in a letter dated October 18, 2002, (ADAMS Accession No. ML023020066). NRR has completed its review of this response and the attached paper provides NRR's basis for concluding that North Anna, Unit 1, can continue to operate safely without the need for it to shut down to conduct reactor vessel head inspections before its next planned outage in the spring of 2003.

If you have questions regarding this information, please contact Stephen Monarque at 415-1544.

Attachment: Evaluation of Reactor Pressure Vessel Head

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Attachment: Evaluation of Reactor Pressure Vessel Head

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# EVALUATION OF REACTOR PRESSURE VESSEL HEAD

# NORTH ANNA POWER STATION, UNIT 1

In response to NRC Bulletin 2001-01, "Circumferential Cracking of Reactor Pressure Vessel Head Penetration Nozzles," dated August 3, 2001, Virginia Electric and Power Company (the licensee) for North Anna Power Station, Units 1 and 2, identified both of these units as having high susceptibility to primary water stress corrosion cracking (PWSCC) of the reactor vessel head penetration (VHP) nozzles. Based on results from a recent inspection of the VHP nozzles and associated J-groove welds at North Anna, Unit 2, the licensee decided to replace the reactor pressure vessel head (RPVH). As described below, this inspection identified numerous indications in most of the J-groove welds along with some cracking in the VHP nozzle base material. This evaluation addresses the relevance of the North Anna, Unit 2, results, along with prior inspection findings at North Anna, Unit 1, to the continued operation of North Anna, Unit 1. This evaluation also considers the licensee's plan to perform a volumetric examination of the VHP nozzles of North Anna, Unit 1, during the next refueling outage in the spring of 2003.

## SEQUENCE OF EVENTS

Since the issuance of Bulletin 2001-01, the following inspections and other events have occurred at North Anna, Units 1 and 2:

September 2001 - North Anna, Unit 1, examination at refueling outage

November 2001 - North Anna, Unit 2, examination at mid-cycle outage

September 2002 - North Anna, Unit 2, examination at refueling outage

October 2002 - North Anna, Unit 2, RPVH replacement announced

For the upcoming North Anna, Unit 1, refueling outage, the licensee has committed to perform inspections of the RPVH consistent with the discussion of NRC Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs," dated August 9, 2002.

## COMPARISON OF NORTH ANNA, UNITS 1 AND 2

The RPVHs of North Anna, Units 1 and 2, were manufactured within the same timeframe, using nozzle material from the same supplier, at the same fabrication facility in Rotterdam, The Netherlands. As of September 2002, North Anna, Units 1 and 2, have similar operating histories, including RPVH temperature (600.1 °F to 607.1 °F over the plant history), and operating time (about 18.5 effective full power years (EFPY) for North Anna, Unit 1, and 18.2 EFPY for North Anna, Unit 2), with the result that both units have similar effective degradation years (EDY) when calculated in accordance with Bulletin 2002-02 (about 20.9 for North Anna, Unit 1, and 19.8 for North Anna, Unit 2, as of September 2002). As indicated, North Anna, Unit 1, actually has operated for a slightly longer amount of time and has a slightly higher susceptibility ranking, in terms of EDY, than North Anna, Unit 2.

INSPECTION FINDINGS

In September 2001, the licensee performed an inspection of the VHP nozzles at North Anna, Unit 1, in accordance with its response to NRC Bulletin 2001-01, dated August 31, 2001. The licensee's inspection plan was to perform a visual examination of the top of the RPVH and conduct eddy current testing (ECT) of the J-groove welds, and the inside diameter (ID) and outside diameter (OD) of each of the VHP nozzles. Because of equipment performance issues, 26 out of 65 VHP nozzles and 26 J-groove welds were examined using ECT. Six nozzles were examined using ultrasonic testing (UT). In addition, some of the J-groove welds were examined using liquid penetrant testing (PT) to clarify indications identified by ECT. The results of this inspection are described in the licensee's submittal dated November 5, 2001, (ADAMS Accession No. ML020090491).

The visual examination of the North Anna, Unit 1, head identified large quantities of boric acid, attributed to conoseal leaks by the licensee. Several nozzles outside of the main conoseal leak area had deposits with an apparent volumetric appearance, inconsistent with the loose granular appearance of the boric acid from conoseal leaks. However, these deposits did not have the popcorn appearance that was identified at Oconee, which at the time was thought to be the form that provides direct evidence of nozzle leakage. Note that North Anna, Unit 1, was the first high-susceptibility plant to perform an inspection after issuance of Bulletin 2001-01.

During this inspection of North Anna, Unit 1, axial indications (part-through-wall) were identified on the IDs of several nozzles. These axial indications were dispositioned using crack growth calculations. In addition, indications in the J-groove welds for several nozzles were identified through the ECT and PT by the licensee. The licensee concluded, and the NRC staff agreed, that the location and appearance of these J-groove weld indications were consistent with cladding flaws that did not require repair. These conclusions were reached partly based on the lack of conclusive visual evidence of leakage from these nozzles on the top of the RPVH, and on limited knowledge and experience regarding how leakage actually manifests itself on the surface of the RPVH. After the RPVH was cleaned, a visual examination of the head surface found no wastage.

Subsequently, the licensee performed two inspections of the North Anna, Unit 2, VHP nozzles: first in November 2001, and recently in early September 2002. During the November 2001 inspection, the licensee concluded from visual inspection of the top of the vessel head that three nozzles had rejectable visual indications of leakage. Follow-up PT examinations of the J-groove welds for these three nozzles identified numerous indications. The initial disposition of these indications by the licensee was similar to that at North Anna, Unit 1, that is, the indications were contained within the cladding and did not require additional characterization. However, the NRC staff concluded that at least one of these nozzles had exhibited deposits on the top of the head that were definite indications of leakage. After the NRC staff presented its concerns, the licensee decided to excavate a portion of the weld on one of these nozzles (in addition to removing a boat sample from another of the welds). This excavation process revealed that the flaws penetrated deep into the welds, at the butter layer-to-weld interface; however, the licensee terminated the investigation prior to determining whether the flaws had penetrated through the weld, and instead decided to repair the three J-groove welds. These inspections and repairs are described in the licensee's submittal dated January 11, 2002, (ADAMS Accession No. ML020230052).

The more recent inspection at North Anna, Unit 2, in response to Bulletin 2002-02, identified two nozzles as leaking, four as possibly leaking, and an additional 21 as masked or obscured, i.e., the nozzle could not be identified as clean. Subsequent examinations identified numerous indications in the J-groove welds in 63 out of 65 of the VHP nozzles, including all three of the nozzles repaired in the fall of 2001. In addition, seven nozzles were identified with circumferential OD cracking at a location slightly below the top of the J-groove welds, ranging from 0.040 inches to more than 1 inch below the top of the weld. Although none of the J-groove weld indications were fully characterized, a decision was made to replace the head at North Anna, Unit 2, prior to restart based on the additional extensive examinations and potentially substantial repairs deemed to be necessary by the licensee. It should be noted that a visual examination of the surface of the RPVH found no wastage, and no circumferential cracking was identified above the J-groove weld on any nozzle.

ADDITIONAL INFORMATION PROVIDED BY THE LICENSEE

Because of the similarities in fabrication of the RPVHs of North Anna, Units 1 and 2, the extensive number of indications in the J-groove welds identified in North Anna, Unit 2, the age and operating history of the two plants, the unrepaired weld indications at North Anna, Unit 1, that are similar to those repaired at North Anna, Unit 2, in November 2001, and the potential safety implications of leaking reactor coolant from VHP nozzles, the NRC requested that the licensee address several issues relative to continued operation of North Anna, Unit 1. The licensee was requested to describe the bases for concluding that the VHP nozzles and welds at North Anna, Unit 1, do not have cracking that could jeopardize reactor coolant pressure boundary integrity, and provide assurance of reactor coolant pressure boundary integrity and conformance with all regulatory requirements consistent with the terms of the operating license. In particular regarding the first issue, the staff advised the licensee to address points that would differentiate the RPVH for North Anna, Unit 1, from that for North Anna, Unit 2, such that the recent findings at North Anna, Unit 2, could be considered not relevant to North Anna, Unit 1.

The licensee provided its response on October 18, 2002, (ADAMS Accession No. ML023020066). In this submittal, the licensee cited the prior inspections of North Anna, Unit 1, and the absence of any detectable reactor coolant system leakage as providing assurance of the integrity of its RPVH. Further, the licensee cited a low probability of VHP nozzle ejection or RPVH wastage, due to the lack of secondary indications (e.g., corrosion products, etc.).

OBSERVATIONS

The following observations can be drawn from the inspection results and the licensee's submittals:

- The North Anna, Units 1 and 2, RPVHs are similar in materials of fabrication, timeframe of fabrication and service history.

- There have been similar indications attributed to the cladding around several of the welds at the two plants. At North Anna, Unit 2, these indications were identified as the cause of nozzle leakage and required repair in November 2001 and, more recently, led to the licensee's decision to replace the RPVH at North Anna, Unit 2. (Note that the decision to replace the head was an economic decision to not perform additional inspection and repair

activities, and was not based on head wastage or circumferential cracking above the J-groove weld.)

- The weld indications were not more closely examined at North Anna, Unit 1, due to the lack of conclusive evidence of nozzle leakage. Due to an improved understanding of crack initiation and propagation phenomena, the identification of similar indications today would likely result in additional interrogation of the pertinent nozzles to conclusively establish the relevance of the visual indications and determine the need for additional actions (e.g., repairs).

- The OD circumferential cracks identified below the top of the J-groove welds at North Anna, Unit 2, indicate the possibility that such circumferential cracking could exist at North Anna, Unit 1.

- There was insufficient information available for the staff to conclude with certainty that the condition of the North Anna, Unit 1 and Unit 2, RPVHs are substantially different, nor that the North Anna, Unit 2, indications (e.g., below the top of the J-grove weld) bound those that could exist at North Anna, Unit 1 (e.g., above the top of the J-groove weld).

EVALUATION

To obtain the additional information from the licensee to allow the staff to assess whether the condition of the North Anna, Unit 1, RPVH was substantially different from the North Anna, Unit 2, RPVH, the staff conducted a conference call with the licensee on November 25, 2002. From the supplemental information provided by the licensee during this conference call, the limiting circumferential cracks identified at North Anna, Unit 2, were characterized in the following table.

| Nozzle # | Distance from Root of Weld (in.) | Circumferential Range | Maximum Depth (in.) |
|---|---|---|---|
| #54 | 0.040 | 119° to 198° | 0.226 |
| | 0.276 | 344° to 16° | 0.156 |
| #59 | 0.312 | 347° to 63° | 0.149 |
| | 0.320 | 156° to 206° | 0.149 |

Since the OD circumferential cracking identified at North Anna, Unit 2, demonstrates that the nozzle materials used at the North Anna Power Station are susceptible to PWSCC, there is a possibility that wet annulus conditions at North Anna, Unit 1, could initiate OD circumferential cracking above the J-groove weld. As one means of evaluating this likelihood, information on the residual stresses on the OD of the CRDM nozzles was extracted from WCAP-14552, Revision 2, “Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: North Anna and Surry Units.” This information indicates that the magnitude and direction of the stresses on the nozzle OD above the J-groove weld do not appear to be substantially different from those below the top of the J-groove weld. Therefore, it

is unlikely that circumferential cracks above the weld would grow at a rate, substantially greater than that for cracks below the top of the weld. Thus, notwithstanding the lack of absolute certainty described above, there is a low likelihood that North Anna, Unit 1, would have circumferential cracks above the J-groove weld that are substantially larger than those identified at North Anna, Unit 2, below the top of the weld. Although the cracks identified at North Anna, Unit 2, do not pose a significant safety concern because they are of limited depth and circumferential extent, the existence of larger cracks in a similar position cannot be ruled out for North Anna, Unit 1. However, ejection of a nozzle with circumferential cracking below the top of the J-groove weld is unlikely due to the restraining nature of the J-groove weld nugget and the need to completely shear the J-groove weld from the nozzle above the hypothetical circumferential crack. Further, this condition would require nearly complete severance of the VHP nozzle at the location of the circumferential crack. This condition is considered to be unlikely due to the limited extent of cracking at North Anna, Unit 2, and the similar operating histories of North Anna, Units 1 and 2. Therefore, there is a low likelihood that North Anna, Unit 1, would have circumferential cracks below the top of the J-groove weld sufficient to cause a nozzle ejection.

CONCLUSION

Based upon the available information, the NRC staff concludes that there is a high likelihood that North Anna, Unit 1, has one or more leaking VHP nozzles and/or J-groove welds, although this cannot be confirmed without an inspection of the RPVH. However, the NRC staff has determined that the continued operation of North Anna, Unit 1, does not present an undue risk to public health and safety. As such, the NRC staff has determined that supplemental inspections for North Anna, Unit 1, should be performed during the next scheduled refueling outage in the spring of 2003 in accordance with Bulletin 2002-02.

As noted above, the staff concludes that there is a likelihood, albeit small, that North Anna, Unit 1, could have circumferential cracking above the J-groove weld that could challenge the integrity of the VHP nozzle, although this type of cracking was not identified at North Anna, Unit 2. The low likelihood of this condition is supported by the inspection that was performed at North Anna, Unit 1, that did not identify any nozzle with circumferential cracking above the J-groove weld. If the results of the UT examination of the six penetrations at North Anna, Unit 1, are assumed to be indicative of the remaining 63 VHP nozzles that were not examined using UT methods, then nozzle ejection is considered to be unlikely at North Anna, Unit 1.

With respect to RPVH wastage, the RPVH cleaning and post-cleaning inspection performed at North Anna, Unit 1, demonstrated the integrity of the RPVH and confirmed the absence of pitting, thinning, or degradation indicative of wastage. Therefore, RPVH wastage is considered to be unlikely at North Anna, Unit 1, at this time.

Based on the evaluation provided above, no additional regulatory actions are recommended for North Anna, Unit 1.