POLICY ISSUE
(Information)

April 10, 2003 SECY-03-0054

FOR: The Commissioners

FROM: William D. Travers /RA/
Executive Director for Operations

SUBJECT: REPLACEMENT OF NORTH ANNA, UNIT 2, REACTOR PRESSURE VESSEL HEAD WITH A HEAD MANUFACTURED TO FRENCH STANDARDS

PURPOSE:

The purpose of this paper is to inform the Commission of the staff's review of the replacement of the North Anna, Unit 2, reactor pressure vessel head (RPVH).

SUMMARY:

In early 2003, Virginia Electric Power Company (VEPCO, the licensee) replaced the North Anna, Unit 2, RPVH with a head manufactured to the French Nuclear Construction Code (RCC-M) following the reconciliation process of Section XI of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (Code). This effort was unique, representing a first-of-a-kind activity for the staff and for the U.S. commercial nuclear power industry. In overseeing this effort, the staff interacted with French and Belgian regulators, the RPVH fabricator (Framatome ANP), conducted onsite inspections, and reviewed the licensee's design and reconciliation documentation. The staff determined there were no regulatory barriers that precluded procurement of a replacement RPVH manufactured to the RCC-M Code and believes other licensees, with licensing bases similar to North Anna, Unit 2, may adopt a similar process.

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One of the more important technical issues identified by the staff involved the use of friction welds to join the flange and tube portions of the vessel head penetration (VHP) nozzles. The staff determined that the use of a friction weld in the fabrication of the VHP nozzles produced high quality, repeatable welds when the requirements of the RCC-M Code are followed and that such welds can be acceptable for use in commercial U.S. pressurized water reactors (PWRs). Based on its oversight activities, the staff concluded that RPVHs fabricated to RCC-M Code are of sufficient quality to ensure safety is maintained and that the replacement of the RPVH enhanced the overall safe operation of North Anna, Unit 2.

BACKGROUND:

The licensee performed inspections of the North Anna, Unit 2, RPVH in the fall of 2002 in accordance with the provisions of Bulletin 2002-02, "Reactor Pressure Vessel Head and Vessel Head Penetration Nozzle Inspection Programs." During this inspection, VEPCO identified numerous indications in 64 of the 65 VHP nozzle J-groove welds. Most of these indications would require repair in accordance with the ASME Code. In addition, at several of the VHP nozzles there was evidence of through-wall leakage. However, none of the indications were of a size or location to cause a concern regarding the structural integrity of the welds. Therefore, adequate safety margins were maintained during plant operation.

Originally, the North Anna, Unit 2, RPVH was scheduled to be replaced in the spring of 2004. As such, repairing the existing head would have resulted in operation for a cycle with the repaired head, then replacement of the RPVH. However, to address these indications, VEPCO determined that the appropriate course of action was to accelerate its plans to replace the RPVH rather than repair the indications in the existing head. VEPCO's decision was, in large part, made with the knowledge that a replacement RPVH was available from Electricite de France (EdF) through Framatome ANP (EdF RV Head No. 28R). The replacement RPVH was manufactured by Framatome ANP in 1998 to the 1993 Edition, through the 1996 Addenda, of the French RCC-M Code as part of the French program of replacing RPVHs at its PWRs to address concerns with primary water stress corrosion cracking (PWSCC).

The licensee discussed various potential regulatory approaches to accomplish the RPVH replacement at North Anna, Unit 2, with the staff. These included seeking relief from or proposing alternatives to the requirements of ASME Section III, requesting exemptions from the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a that incorporate the requirements of the ASME Code by reference, and replacing the RPVH as a design modification using the reconciliation provisions of ASME Section XI seeking prior staff approval, as a license amendment, only if needed.

The original RPVH was manufactured in 1968 at the Rotterdam Shipyards, in the Netherlands. At that time, foreign suppliers were not certified ASME vendors (no ASME "N" stamps). As such, the head was procured to owner specifications that incorporated the technical requirements of ASME Section III, 1968 Edition, and Westinghouse design specifications, but was not "N" stamped. The important point of note is that the design and licensing basis for North Anna, Unit 2, is the Owner's Design Specification and not ASME Section III. Since the original design and licensing basis of the RPVH is not ASME Section III, seeking a relief or an alternative would not be appropriate, nor would exemptions from 10 CFR 50.55a. The

appropriate approach was to implement the change following the reconciliation process of ASME Section XI for procurement of replacement components. Under this approach, VEPCO could proceed without prior staff approval provided there were no design changes introduced that required a license amendment in accordance with the requirements of 10 CFR 50.59. Further, the replacement of the North Anna, Unit 2, RPVH was conducted in accordance with the licensee's Quality Assurance Program that meets the requirements of 10 CFR Part 50, Appendix B. This approach is also applicable to North Anna, Unit 1, and Surry, Unit 1, for which VEPCO plans a similar head replacement strategy, since the original design and licensing basis for these units are similar to North Anna, Unit 2. While this approach is also applicable to Surry, Unit 2, VEPCO plans to replace the Surry, Unit 2, RPVH with a head manufactured to the ASME Code.

DISCUSSION:

The replacement of the North Anna, Unit 2, RPVH in January 2003, represented the first time a major reactor component fabricated pursuant to the French RCC-M Code was used in a commercial U.S. PWR. Subsequently, VEPCO announced its plans to replace the North Anna, Unit 1, and Surry, Unit 1, RPVHs later in 2003 with heads that were manufactured for EdF pursuant to the RCC-M Code. To assess whether the design, fabrication, examination, and testing of the replacement RPVH were appropriately reconciled with the Owner's Specification through the ASME Code process, thereby providing reasonable assurance that adequate protection to the public health and safety was maintained, the staff performed reviews and inspections of the activities conducted by, or for, the licensee in the U.S. and in France. For example, the staff met with the French regulatory authority (Bureau de Contrôle des Chaudières Nuclèaires - BCCN) and Framatome ANP, and conducted inspections of replacement activities at North Anna, Unit 2. In addition, the staff evaluated the design engineering and reconciliation effort that the licensee performed for North Anna, Unit 2. The licensee followed the requirements of Article IWA-4000 of the 1995 Edition, with Addenda through 1996, of Section XI to the ASME Code, as incorporated by reference into 10 CFR 50.55a(b), to perform the reconciliation. Finally, the staff met with Belgian regulatory organizations (l'Agence Fèdèrale Contrôle Nuclèaire - FANC, Association Vinçotte Nuclear - AVN, and AIB-Vinçotte - AV) to discuss their experience with reconciling the RCC-M Code to the ASME Code for the replacement of the Tihange, Unit 1, RPVH.

Inspection activities were conducted using a draft inspection procedure prepared for RPVH replacements as guidance. Feedback from the staff's experience with the North Anna, Unit 2, RPVH replacement will be incorporated into this draft inspection procedure. An overview of the other activities conducted by the staff is provided below.

French Technical Exchange Visit

In December 2002, the U.S. Nuclear Regulatory Commission (NRC) staff held discussions with BCCN to discuss the regulatory framework under which RPVHs are designed and manufactured in France. The outcome of this meeting was that the NRC staff had a clearer understanding of the regulatory requirements for the design and fabrication, including quality assurance requirements, of the RPVHs that VEPCO plans to install at North Anna, Units 1 and 2, and Surry, Unit 1. In addition to holding discussions with BCCN, the staff met with

Framatome ANP to discuss the specific approach used to reconcile the differences in the design specification of the original North Anna, Unit 2, RPVH and the replacement head, and other activities being conducted for VEPCO to prepare the replacement head for use at the unit. VEPCO also participated in these discussions. As a result of these discussions, the NRC staff developed a clear understanding of the approach being used; the level of detail required to ensure that the reconciliation addressed all of the design, material, nondestructive examination (NDE), and fabrication differences; and the quality assurance controls that were in place when the replacement heads were manufactured. In addition, the staff toured the fabrication facility and observed the North Anna, Unit 2, replacement RPVH during the final stages of the preservice inspection being performed at the direction of VEPCO. Also, the staff observed the storage conditions of the replacement heads for North Anna, Unit 1, and Surry, Unit 1.

One of the more important technical issues identified by the staff involved the use of friction welds to join the flange and tube portions of the VHP nozzles. The welding process used is a continuous drive friction welding process. This is a solid state welding process that, simply put, rotates the flange portion while holding the tube portion still, aligning the pieces, pressing them together while the flange is rotating to create heat, quickly stopping the rotating piece, and pressing the pieces together under greater pressure. Section III of the ASME Code does not allow the use of friction welds in the fabrication of Class 1 vessels and piping. However, in France, of the approximately 5900 VHP nozzles manufactured using this process since 1981, following the requirements of the RCC-M Code, there have only been five nozzles rejected during the fabrication process due to a process variable being out of specification. None of the nozzles have been rejected during post-fabrication NDE, nor has there been any operational failure of these welds once in service. In addition, the French conducted extensive destructive tests (including impact tests, side bend tests, tensile tests, and Charpy U-notch tests) and nondestructive examinations of the product form of the weld during qualification of the process.

Key features of the replacement head highlighted by Framatome ANP were the fabrication materials and methods used to mitigate PWSCC. Materials selected for the fabrication (Alloy 690, Alloy 152, and Alloy 52) are considered more resistant to PWSCC than materials previously used in RPVH fabrication. Framatome ANP presented information to the staff that under laboratory conditions, Alloy 690 has been shown to have significantly more resistance to crack initiation than Alloy 600. Tests were conducted on Alloy 690 and Alloy 152 weld material at temperatures higher than encountered in reactor vessels. The tests were conducted using samples cut from the representative forms of the materials (microstructure, section thicknesses, primary water chemistry) used in replacement head fabrication. The tests were performed for extended periods (multiple-year duration accelerated aging tests) at the conclusion of which there was no evidence of crack initiation. It should be noted that the tests were not crack growth rate tests, but rather crack initiation tests. While the testing has shown improved resistance to crack initiation for Alloy 690 and the Alloy 152 weld materials, no information is available for stress corrosion crack growth of either Alloy 690 or Alloy 152 weld materials. The initiation tests suggest that Alloy 690 and Alloy 152 are generally more resistant to stress corrosion cracking than the Alloy 600 or Alloy 182 materials previously used. As part of the staff's action plan in response to the Davis-Besse Lesson Learned Task Force, the staff will collect information on nozzle cracking for Alloys 600 and 690, and other nickel-based alloys, in order to evaluate the need to revise the RPVH inspection requirements. In addition, the staff will evaluate the existing stress corrosion cracking models with respect to their continued use in

the susceptibility index. As additional data becomes available regarding crack initiation and growth in Alloys 690 and 152, the staff will re-evaluate what inspection requirements are appropriate to ensure that the integrity of RPVHs fabricated with Alloys 690 and 152 are maintained.

There are other metallurgical and welding issues that warrant confirmation to support the staff's long-term evaluation of these replacement heads (i.e., weldability of Alloy 152, potential degradation of fracture toughness at lower temperatures, and crack initiation and growth behavior at typical operating temperatures). These issues are being explored as part of the ongoing research program being conducted by the staff. Further, in response to the degradation observed on the Davis-Besse RPVH, and indications of throughwall cracks in RPVH penetrations at other PWRs, Orders were issued on February 11, 2003, to all PWR licensees requiring supplemental examinations of RPVHs (ADAMS Accession No. ML030380470). As licensees replace their RPVHs, the units would likely be categorized as low susceptibility plants based on the criteria specified in the Orders. This would allow the licensees to conduct bare metal visual examinations of the RPVH and penetrations once every third refueling outage or every five years (whichever is less), and to conduct ultrasonic examinations and dye penetrant examinations of the J-groove welds of the RPVH penetration nozzles every four refueling outages or seven years (whichever is less). The requirements of the Orders may be changed, as allowed by the Orders, based on continuing research and operating experience.

To establish baseline information for RPVHs fabricated for the French nuclear power industry, Framatome ANP examines the J-groove welds by ultrasonic testing (UT) (the fusion zone or heat-affected zone between the outer diameter of the VHP nozzle and the J-groove weld can be examined). During these examinations, Framatome has found rejectable defects requiring repair. Heads constructed at Framatome ANP to the ASME Code for the U.S. market do not receive this examination. Framatome ANP also employs a polishing and honing process on the J-groove welds. Framatome ANP believes this leaves only compressive residual stresses on the weld surface that prevents the propagation of cracks from the surface. Additionally, Framatome ANP changed the fabrication process for the form of the stock used to manufacture the VHP nozzles. The current form of the Alloy 690 sleeve portion of the nozzles is hot extruded round bar stock that has a well defined grain structure with little or no intragranular carbides, and high intergranular carbide precipitation.

The staff notes that the material and processes used by Framatome ANP are believed to provide a RPVH that offers improved resistance to PWSCC. However, the specifics of fabrication processes used by other vendors, even when similar or the same materials are used, will have to be evaluated to assure similar improvements in PWSCC resistance.

Belgian Technical Exchange Visit

In December 2002, the staff met with representatives of Belgian regulatory organizations. The purpose of the meeting was to gain insights into the reconciliation conducted by Tractebel in support of the Tihange, Unit 1, RPVH replacement. The replacement head was manufactured to the RCC-M Code, whereas the original head was manufactured in accordance with ASME Section III. The main differences identified in the Belgian reconciliation were (1) items

constructed to the RCC-M Code were not required to be inspected by an authorized inspection agency (AIA), however, inspections were conducted by EdF; (2) the allowance of friction welds by the RCC-M Code between the flange and tube portions of the VHP nozzle, whereas friction welds are not allowed to be used in the fabrication of pressure vessels or pipes by the ASME Code; (3) requirements for auditing of suppliers differed between the two Codes; (4) the ASME Code requires an overpressure protection report, whereas the RCC-M Code does not; (5) differences in the quality assurance requirements; (6) differences in material specifications between the two Codes; and (7) the hydrostatic test pressure is 1.25 times design pressure under ASME and 1.33 under RCC-M.

Each of the differences between the two Codes was reconciled by Tractebel as documented in a reconciliation report. In its reconciliation of the use of friction welds, AV inspectors conducted an audit of the manufacturers' facilities including Framatome ANP and SMFI (the subcontractor that fabricated the VHP nozzles using the friction welding process), reviewed the qualification files, reviewed the welding procedure qualification, reviewed the procedures for NDE, examined the test coupon results, and witnessed UT and dye penetrant testing performed by Framatome ANP. At the conclusion of the Belgian reviews, it was determined that the fabrication of the replacement RPVH for Tihange, Unit 1, to the RCC-M Code was equivalent to a RPVH fabricated to the ASME Code and acceptable for use.

During evaluation of VEPCO's reconciliation documentation, the staff reviewed the Belgian reconciliation report prepared by Tractebel. Based on this review, the staff found that the conclusions of the Belgian reconciliation effort were consistent with the staff's review, providing additional confidence that RPVHs fabricated to the French RCC-M Code are of sufficient quality to ensure safety is maintained.

Design Engineering and Reconciliation Inspection Activities

The staff found that VEPCO's efforts to reconcile the design, fabrication, and examination of the replacement RPVH with the current design requirements were acceptable, and provided reasonable assurance that adequate protection to the health and safety of the public continued to be maintained with the installation and use of the replacement RPVH. The staff noted that the Framatome ANP manufacturer's data report had been reviewed and accepted by Framatome ANP's Authorized Nuclear Inspector (ANI). The ANI stated: "The contents of this report are accurate and, as far as possible, are equivalent to the requirements of Section III, Division I of the ASME Code ...." The staff found that the records reviewed were of high quality, providing an auditable record of VEPCO's reconciliation and design change efforts.

There were no issues identified by the staff that required prior NRC approval before the replacement RPVH could be placed in service at North Anna, Unit 2, and the unit was returning to operation at the time the team completed its inspection activities. During the inspection there were a number of observations made by the staff for which the VEPCO and Framatome staffs provided prompt feedback to clarify how the reconciliation activities were conducted, to clarify the results of the reconciliation, or to develop additional documentation supporting the bases for reconciling the design, fabrication, examination, and testing of the replacement RPVH to the North Anna, Unit 2, RPVH design specification. For example, in response to the staff's observation, VEPCO prepared and included an overview in the reconciliation report of the

quality assurance processes and oversight activities related to VEPCO's and Framatome's activities. Similarly, a VEPCO addendum was prepared that described other activities that had been performed to support the reconciliation as it related to the NDE of the replacement RPVH.

The staff reviewed the welding procedures, processes, and records used in the fabrication of the replacement RPVH. Of particular interest to the staff was the application of a friction welding process in the fabrication of the VHP nozzles. As noted previously, the friction welding process has been used in France to fabricate the nozzles since about 1981 and only five of the approximately 5900 nozzles manufactured using this process have been rejected during the fabrication process. None of the nozzles have been rejected during post-fabrication NDE and there have been no failures of these welds once placed in operation. Based on the staff's review of the process and the operational experience of the French, the staff concluded that the friction welding process, as controlled by the RCC-M Code, produces high quality, repeatable VHP nozzle welds that can be used safely in commercial U.S. PWRs.

CONCLUSIONS:

Based on the staff's technical exchange visits with French and Belgian regulatory authorities, the tour and meeting with Framatome ANP, and staff inspection efforts, the staff made the following conclusions:

- VEPCO's actions to replace the North Anna, Unit 2, RPVH with a head manufactured in accordance with the RCC-M Code enhanced the overall safe operation of the unit.

- RPVHs fabricated to the 1993 Edition, through the 1996 Addendum, of the RCC-M Code are of sufficient quality to ensure safety is maintained for use in commercial U.S. PWRs provided an appropriate ASME, Section XI reconciliation process (i.e., Article IWA-4000) is adhered to.

- The use of a friction weld in the fabrication of the VHP nozzles produces high quality, repeatable welds when the requirements of the RCC-M Code are followed and such welds can be acceptable for use in commercial U.S. PWRs.

- For commercial U.S. PWRs with similar design and licensing bases to North Anna, Unit 2 (i.e., original RPVH procured without an ASME "N" stamp), there are no regulatory barriers that would preclude procurement of a replacement RPVH manufactured to the 1993 Edition, through 1996 Addendum, of the RCC-M Code.

RESOURCES:

The review of the reconciliation of the North Anna, Unit 2, RPVH replacement with a head fabricated to the requirements of the RCC-M Code required technical expertise in the areas of quality assurance; materials; welding; nondestructive examination; ASME, Sections III, IX, and XI; and design. The direct effort expended included the following resources:

- Technical Exchange Visits 0.19 FTE
- Onsite Inspection Activities 0.25 FTE
- Reconciliation Inspection Activities 0.30 FTE

There were unique aspects to the North Anna, Unit 2, RPVH replacement that should not be necessary for future replacements. For example, the technical exchange visits need not be repeated for other RPVH replacements. Further, for units that procure replacement RPVHs under ASME, Section III, the reconciliation inspection activities can be significantly reduced as there is no need to assess the impact of the differences between the RCC-M Code and ASME Code requirements. Similarly, units that procure replacement RPVHs under the 1993 Edition, through 1996 Addendum, of the RCC-M Code, provided this approach is consistent with their licensing basis, would not require the NRC staff to repeat its assessment of differences between the RCC-M and ASME Codes even though the licensee would need to follow the requirements of ASME, Section XI related to reconciliation. Therefore, staff review of the design aspects of RPVH replacements in these cases could be accomplished using about half of the effort expended during the North Anna, Unit 2, reconciliation inspection. Similar resources would be expended by the staff inspecting these activities for subsequent replacement heads and the staff estimates that future RPVH replacement activities at other units would require:

- Onsite Inspection Activities 0.25 FTE
- Design Engineering Inspection Activities 0.15 FTE

Inspections of the replacement of RPVHs have not been specifically budgeted. However, there are resources set aside for supplemental inspection activities in the current budget that can be used to conduct these emergent inspections. As licensees inform us of their plans to replace RPVHs, the staff will use the Planning, Budgeting, and Performance Management process to provide inspection resources that may be beyond the current budget allocation for supplemental inspection activities.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection to its contents. The Office of the Chief Financial Officer has reviewed this paper for resource implications and has no objections.

/RA by William F. Kane Acting For/

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Executive Director
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*See previous concurrence **concurred via email

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