VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

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United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 02-279
NL&OS/ETS R0
Docket No. 50-339
License No. NPF-7

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 2
RELIEF REQUESTS NDE-048 AND NDE-049 - ALTERNATIVE REPAIR TECHNIQUES
REQUEST FOR ADDITIONAL INFORMATION ON WCAP-14522

In an October 18, 2001 letter (Serial No. 01-638) Virginia Electric and Power Company (Dominion) requested relief from specific ASME Code requirements in order to repair penetrations (RVHPs) in the North Anna Unit 2 reactor vessel head. Additional information was provided to support the NRC staff's review in letters dated November 9 and 16, 2001. In a telephone conference call on April 17, 2002, the NRC staff requested additional information to complete the review of WCAP-14552, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: North Anna and Surry Units," which supports the relief requests. The requested information is provided in the attachment to this letter.

If you have any questions or require additional information, please contact Mr. Thomas Shaub at (804) 273-2763.

Very truly yours,

Leslie N. Hartz
Vice President - Nuclear Engineering

Attachments

1. Response to questions regarding WCAP-14552, Revision 2, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: North Anna and Surry Units."

A047

cc: U.S. Nuclear Regulatory Commission
Region II
Sam Nunn Atlanta Federal Center
61 Forsyth St., SW, Suite 23T85
Atlanta, Georgia 30303-8931

Mr. M. J. Morgan
NRC Senior Resident Inspector
North Anna Power Station

Mr. J. E. Reasor, Jr.
Old Dominion Electric Cooperative
Innsbrook Corporate Center, Suite 300
4201 Dominion Blvd.
Glen Allen, Virginia 23060

Mr. M. M. Grace
Authorized Nuclear Inspector
North Anna Power Station

Attachment 1

Response to Request for Additional Information
WCAP-14552, "Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Safe Operation of North Anna and Surry Units"
Revision 2

North Anna Power Station Unit 2
Virginia Electric and Power Company
(Dominion)

Response to North Anna RAIs on NDE-048 and NDE-049

Question 1:

Page 3-1. Provide the report for the detailed finite element stress analysis for the outermost row of penetrations nearest the head flange. Confirm that all three models – outermost row, next outermost row, and central tube – have considered loading due to pressure, thermal, interference-fit, and residual stresses. Using the model for the outermost row of penetrations as an example, explain how the findings of EPRI TR-103696 regarding residual stresses of the J-groove weld on the penetration tube were considered in your finite element model.

Response:

The detailed finite element stress analyses have been provided in WCAP-14552, Rev. 1. As stated in this report, the models developed considered all appropriate loadings in prediction of crack extension due to stress corrosion cracking. The loadings used were the steady state loads, which included internal pressure and residual stress. Thermal loadings were not included, because transient effects in the head region are negligible. The model used assumed a minimum interference fit for conservatism.

The finite element model was 3-D and elastic plastic, and was used to determine the residual stresses. The welding process was modeled as two weld passes followed by a hydrotest and then a second hydrotest after which the steady state pressure loading was applied. The residual stress distributions obtained for all three cases studied (outer-most row, next outermost row, and center) were similar in both magnitude and distribution to those obtained in the EPRI report discussed in the question.

Question 2:

Page 4-2. Provide fabrication history of the penetration tubes, demonstrating that proper heat treatment have been applied to eliminate the effect of cold work so that you could employ the crack growth rate for non cold-worked Alloy 600 material in this WCAP report. Your proposed crack growth rate is based on very limited test data on Alloy 600 steam generator tubes. Please provide additional test data to support the use of your proposed crack growth rate on reactor vessel upper head penetrations.

Response:

The crack growth rates used in the report were developed for annealed head penetration materials after their fabrication. These were lab tests of actual head penetrations, *not* steam generator tubing. In developing the original analytical model, steam generator tubing data was used. The cold working effects were subtracted from the lab tests done on steam generator tubing, however, that fact has nothing to do with the present model or results. The present model is based on actual tests of head penetration materials, and does not rely on any assumption with regard to cold working.

The present model is based on a large number of tests conducted in tightly controlled environments, as detailed in EPRI Report 109136, December 1997. Sixteen heats were tested, with a total of over 50 specimens. These results are consistent with those obtained by other labs in Sweden and France and are consistent with the original model developed by Scott, as detailed in the WCAP-14552, Rev. 2.

Question 3:

Page 6-2. Justify the use of solutions by McGowan and Raymund for predicting stress intensity factors for internal surface flaws in the penetration tubes, instead of the Raju-Newman solutions (listed as reference 5.B in your submittal), which has been used by Westinghouse in many earlier applications on various subjects.

Response:

The McGowan-Raymund expression was for a specific flaw shape, 6:1, and the results are identical to those of Raju and Newman for that shape. The original paper shows comparisons with other solutions that also agree.

Question 4:

Page 6-2. Are you proposing to use the stress intensity factor formula for a through-wall crack in an infinite plate in the current application for through-wall cracks with either an axial or circumferential crack configuration? If so, provide estimation of the error associated with this approximation.

Response:

The through-wall flaw in a plate is conservative relative to the actual case. This can be verified by comparison of the overall stiffness of a plate with the stiffness of a thick-walled tube. The stress intensity factor for a given size flaw is proportional to the crack opening, and the crack opening is inversely proportional to the stiffness. This part of the work contained in WCAP 14552 was not used in the evaluation of the flaws found, since they were surface flaws. As an example, the recently developed expression by Structural Integrity Assoc. for a through-wall circumferential flaw has been contrasted with the plate expression in the attached figure, "Stress Intensity Factor For Through-Wall Circumferential Flaw In CRDM," where it can clearly be seen that the plate expression is conservative.

Question 5:

Page 6-3. What was the crack configuration (aspect ratio) during crack growth for inside and outside surface axial flaws on the penetration tube? Provide justification for this assumption.

Response:

The flaw shape initially used was 6:1, which bounded the flaw shapes that have been observed in inspections up to the time of publication for the report. Some of the flaws found at North Anna were longer than this value, and a curve was prepared for flaw shapes of 15:1, 20:1, 30:1, 65:1 and 100:1. The chart "North Anna Stress Corrosion Crack Growth Prediction for CRDM Axial Inside Surface Flaws, Temperature = 600° F," is attached. The curve from the chart with the appropriate bounding aspect ratio was used for each of the flaws that were analyzed.

Question 6:

Page 6-5. Reference 5.B was mistakenly stated as the source for calculating the stress intensity factor for the circumferential surface crack on the outside surface of the penetration tube, because Reference 5.B only presents results for axial flaws. Provide the correct reference.

Response:

The correct reference was given. The solutions for axial and circumferential flaws are identical until the flaw gets large enough to affect the overall stiffness of the tube, and thus the crack opening. Since the tube is constrained by the hole in the head, any circumferential flaws in the tube at or above the weld would be adequately treated by the axial expression. Any flaws below the weld are not part of the pressure boundary.

This was verified in some unpublished work done by McGowan, as part of the work to support the development of the expressions in his paper, which was referenced above in Q3.

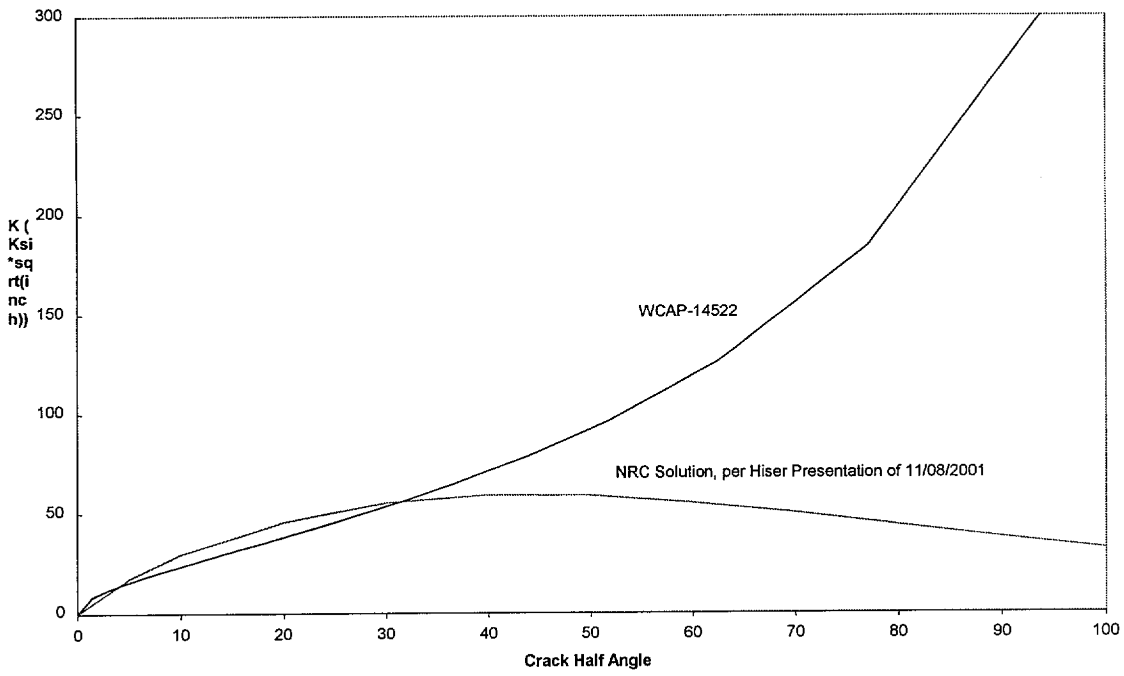
Question 7:

Is the reference to IWA-4310 from the 1986 edition of ASME Section XI a typo?

Response:

On page 1 of 11 of Attachment 1 to letter 01-638 of October 18, 2001, in paragraph III, reference is made to paragraph IWA-4310 of the 1986 Edition of ASME Section XI. The reference should have been to IWA-4310 in the 1989 Edition of Section XI. The paragraph does not exist in the 1986 Edition of the Code. While the 1986 Section XI is in fact applicable to North Anna Unit 2 for its second inspection interval, guidance from the 1989 Code was used because of the lack of similar guidance in the earlier Code edition.

STRESS INTENSITY FACTOR FOR THROUGH-WALL CIRCUMFERENTIAL FLAW IN CRDM



North Anna Stress Corrosion Crack Growth Prediction for CRDM Axial Inside Surface Flaws
Temp=600F