February 18, 2004

Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION CONCERNING WCAP-16180NP, REVISION 0, "OPERABILITY ASSESSMENT FOR COMBUSTION ENGINEERING PLANTS WITH HYPOTHETICAL FLAW INDICATIONS IN PRESSURIZER HEATER SLEEVES" (TAC NO. MC1751)

Dear Mr. Bischoff:

By letter dated December 23, 2003, the Westinghouse Owners Group (WOG) submitted for NRC staff review Topical Report (TR) WCAP-16180NP, Revision 0, "Operability Assessment for Combustion Engineering Plants with Hypothetical Flaw Indications in Pressurizer Heater Sleeves." By letter dated January 30, 2004, the WOG provided updated inspection guidance that it will be sending to licensees that operate Combustion Engineering designed (CE-designed) pressurized water reactors (PWRs). The staff has completed its preliminary review of the TR and has identified a number of items for which additional information is needed to continue its review. The staff has recently discussed our intention to forward this request for additional information (RAI) to you and is now doing so. Please provide the requested information so that the review can be completed in a timely manner. Partial submittals would be welcomed to minimize delays.

In addition to the information in the enclosure, the staff notes that we have evaluated the proposed guidance provided in your January 30, 2004, letter regarding what would constitute an adequate degradation management program for CE-designed facilities' pressurizer heater sleeves. Based upon the information available at this time, the staff considers the detailed proposal in your January 30, 2004, letter to constitute an acceptable degradation management program as it adequately addresses initial bare metal visual examination of all pressurizer heater sleeves, followup nondestructive examination (NDE) if leakage is discovered, and potential NDE scope expansion if circumferential flaws are found in the pressure boundary at these locations. Responses to the enclosed RAI are, however, still necessary for the staff to complete its review of your operability assessment and to ensure that no additional modification of your proposed degradation management program is warranted.

If you have any questions, please call me at (301) 415-1436.

Sincerely,

***/RA by B. Benney for D .Holland/***

Drew Holland, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure: Request for Additional Information

cc w/encl:
Mr. James A. Gresham, Manager
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Pittsburgh, PA 15230-0355

Mr. Frederick P. Schiffley, II
Chairman, Westinghouse Owners Group
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<u>REQUEST FOR ADDITIONAL INFORMATION</u>

<u>WCAP-16180-NP, "OPERABILITY ASSESSMENT FOR COMBUSTION ENGINEERING PLANTS WITH HYPOTHETICAL CIRCUMFERENTIAL FLAW INDICATIONS IN PRESSURIZER HEATER SLEEVES"</u>

<u>WESTINGHOUSE OWNERS GROUP</u>

<u>PROJECT NO. 694</u>

1. Provide additional information regarding all pressurizer heater sleeve inspections which have been conducted at Combustion Engineering (CE) designed facilities in the U.S. using nondestructive examination (NDE) technology capable of detecting circumferential and/or axial primary water stress corrosion cracking (PWSCC).

   Your response should address what NDE inspections, if any, were conducted on leaking pressurizer heater sleeve penetrations at Arkansas Nuclear One Unit 2, Calvert Cliffs Units 1 and 2, Millstone Unit 2, Palo Verde Unit 3, and Waterford Unit 3 from 1987 through 2003. Your response should also address instances in which licensees performed similar NDE inspections on heater sleeves which had not shown visual evidence of leakage, for example as part of a planned activity to perform proactive ½ nozzle replacements (like Palo Verde Unit 2 in 2003) or other mitigative actions.

   For each inspection conducted:

   a. Provide the plant name and date (month, year) of the inspection.

   b. Identify the types of inspection methods that were used (e.g., ultrasonic, eddy current, etc.). Provide information about each inspection method to support your answer to c. below.

   c. Identify whether each inspection method used was capable of detecting circumferential cracking, axial cracking, or both, due to PWSCC. For each inspection method, distinguish between detection capability for part through-wall cracks that may have initiated from either the inside diameter or outside diameter of the pressurizer heater sleeve.

   d. Identify how many sleeves were inspected using each identified inspection method.

   e. Identify, as accurately as practical, the "inspection volume" for each inspection (i.e., what length of the pressure boundary and non-pressure boundary portion of each heater sleeve was inspected).

   f. Provide the results, including number and location, of flaw indications discovered during the inspection.

2. The risk assessment is based on the assumption that the small break loss-of-coolant accident (SBLOCA) frequency due to heater sleeve failure is 1/3 of the existing baseline SBLOCA frequency estimated in NUREG/CR-5750 for the period 1987-1995. Which NUREG/CR-5750 value was used: the "small pipe break" value (5E-4/critical year) or the "very small LOCA/leak" value (6.2E-3/critical-year)? Please explain the connection between the analysis provided for the sleeve degradation phenomena and the value used for the LOCA frequency due to those phenomena. It appears that the risk analysis assumes that the SBLOCA frequency cannot be increased by the sleeve degradation to a value that exceeds the SBLOCA frequency estimated in NUREG/CR-5750 for other phenomena during the period 1987-1995. If that is the assumption, please explain why the continuing degradation of heater sleeves cannot increase the SBLOCA frequency by much more than the assumed value.

3. What values of conditional core damage probability (CCDP) were used to quantify the core damage frequency (CDF) increase due to the assumed heater sleeve failure frequency? Which plants do these CCDP values represent?

4. On page 5-24 of WCAP-16180-NP it is stated that, “the welding residual stresses were applied as secondary stresses, which redistribute in the presence of the crack.” So far, the NRC accepted only an approach of applying residual stresses directly on crack faces (i.e., as primary stresses) for various applications related to reactor pressure vessels, control rod drive mechanism (CRDM) penetrations, and in-core instrument (ICI) nozzles.

    a. Explain how your proposed method of applying welding residual stresses in combination with operating stresses in WCAP-16180-NP is equivalent or conservative to the approach which has been accepted by the NRC to date. In this case, "conservatism" should be understood to result in faster PWSCC growth rates, shorter critical crack sizes, shorter time periods between when a flaw may be detectable by leakage and when it would reach the critical flaw size for failure, etc.

    b. If the method you proposed for applying welding residual stresses in combination with operating stresses in WCAP-16180-NP cannot be shown to be conservative relative to the approach that has been accepted by the NRC to date, provide revised results applying residual stresses consistent with the industry’s approach for CRDM and ICI nozzles to support your current operability assessment.

    c. If, after having provided the information requested in b., you wish the staff to review the method proposed in WCAP-16180-NP for applying welding residual stresses in combination with operating stresses, provide an adequate theoretical discussion, supported by finite element modeling and test data, of how welding residual stresses relax and redistribute with crack extension. The theoretical discussion should include a comparison of the proposed approach with the corresponding case for operating stresses caused by the applied loads.

5. Provide relative radial displacements (gaps) between the heater sleeve and the pressurizer bottom head bore surface for the limiting heater. Since the assembly of the sleeve and pressurizer bottom head connected by the J-groove weld has the geometry of a cylindrical crack, provide a quantitative assessment of the applied stress intensity factor, K, and the potential for fatigue crack initiation and growth.

6. In WCAP-16180-NP, the applied K values were calculated using the J-integral software developed by Dominion Engineering. Provide validation of the software by comparing results from it with those from widely used commercial Fracture Elastics Mechanics (FEM) codes. Discuss the effect of mixed modes, $K_I$, $K_{II}$, and $K_{III}$, and the choice of surface (or volume) of integration on the surface independence of your J-integral (note, the validation reported in Reference 14 in WCAP-16180-NP is too general and detailed information should be given if the validation there could be used to resolve this question).

7. Section 5.4 of WCAP-16180-NP states that, "[t]he fracture toughness for the Inconel alloy used in the heater sleeve tubes has been taken directly from work by Brown and Mills...." Provide this fracture toughness value and the fracture mechanics analysis equations which used this value. Provide the flow stress that was used in the limit load calculation and justify its use in this application. Clarify the modifications that you made to Appendix C of Section XI of the American Society for Mechanical Engineers (ASME) Code for the through-wall flaw application.

8. The operability assessment provided in WCAP-16810-NP is based upon the assumption of a initial circumferential flaw below the J-groove weld which is completely throughwall over some fraction of the heater sleeve circumference with no degradation present in the rest of the heater sleeve cross-section. This "idealized" flaw geometry is analytically convenient, but may not represent the most detrimental flaw geometry which could potentially develop in these heater sleeves.

   For each heater sleeve geometry which was evaluated, provide a complimentary operability assessment which assumes an initial circumferential flaw below the J-groove weld which extends 360 degrees around the circumference of the heater sleeve, on the inside surface, with a depth of 10 percent of the wall thickness. Consistent with the discussion in question (4) above regarding the evaluation of residual and operating stresses:

   a. Discuss how this flaw would grow in the radial direction, focusing on differences in PWSCC growth rates around the circumferential extent of the flaw.

   b. Determine the time period before this initial flaw would be detectable by reactor coolant pressure boundary leakage monitors or by visual examinations.

   c. Determine the time period before this initial flaw could lead to heater sleeve severance, consistent with the criteria for predicting severance postulated in WCAP-16180-NP.

9. A substantial part of the technical basis for the operability assessment in WCAP-16180-NP relies on the ability to accurately, or conservatively, predict leakage from tight PWSCC flaws. In general, leak rate predictions are very uncertain and highly sensitive to assumptions made about the morphology of the leaking flaw.

   Section 5.6, "Leak Rate Calculations" of WCAP-16180-NP states that, "[p]rocedures used in these calculations have been reviewed and approved by the NRC in prior work for Leak-before-Break (LBB) reports on reactor primary loop systems." It is not clear from this description whether this is in reference to only the methodology used by Westinghouse for the calculation for leakage due to two-phase flow, or also in reference to essential crack morphology parameters (flaw surface roughness, number of turns, etc.) used by Westinghouse in LBB evaluations. Essential crack morphology parameters used in LBB evaluations are usually based on corrosion-fatigue crack morphologies and would lead to very non-conservative leakage rate estimates for PWSCC flaws.

   Provide the following:

   a. The values for essential crack morphology parameters used in the evaluation.

   b. A technical basis for why the essential crack morphology parameters cited in response to part (a) are representative of PWSCC flaws

   c. A reassessment, if necessary, of the leakage rate vs. crack length plots given in Figures 5-19 and 5-20, if the essential crack morphology parameters used in the original analysis were not representative of PWSCC flaws.

   d. An extension of the original analysis or the reanalysis performed in response to part (c) which extends the information shown in Figures 5-19 and 5-20 out to the point of showing the flaw size which would give 10 gallons per minute of leakage.

   e. In addition, both the operability assessment and the inspection recommendations provided in the December 23, 2003, letter that forwarded WCAP-16180-NP are based on the ability to visually identify evidence of leakage. Provide, based on your crack growth and leak rate analyses, an assessment of the time required for evidence of leakage (i.e., boron deposits) to become visible at the exterior surface of the pressurizer shell after a flaw initially begins to leak. This question is particularly relevant given the experience with the reactor pressure vessel (RPV) bottom mounted instrumentation (BMI) nozzles (a penetration configuration which is similar to pressurizer heater penetrations) at South Texas Project Unit 1 (STP Unit 1). The STP Unit 1 experience suggested that, based on isotopic analysis of the deposits found on the RPV surface, that the STP Unit 1 nozzles may have been leaking for 3 to 4 years prior to boron deposits becoming visible.

10 . Discuss the consequence of loose part damage should a through-wall circumferential flaw exist above the J-groove weld of the heater sleeve.

11. Describe any and all fabrication rejection notices associated with each of the heater sleeves in Palo Verde 2 that were identified as exhibiting PWSCC during the 2003 inspections.

12. The report states that the crack growth rate projections are based on the "MRP curve," and that the materials reliability project (MRP) curve was not designed to be an upper bound to all available crack growth rate data. Figure 5-17 illustrates that individual data points for crack growth rates observed in the laboratory can exceed the MRP curve by factors as large as 6.6. While the NRC has accepted the use of the MRP curve in deterministic flaw evaluations (for flaws in base metal) for RPV head penetrations, uncertainty in the flaw growth rate data should be evaluated when evaluating the probability of pressurizer heater sleeve failure.

    Provide an assessment which demonstrates the effect of the uncertainty in PWSCC flaw growth rates on the probability of pressurizer heater sleeve failure and the estimated time required for flaw to grow from being detectable by leakage to the size where it could lead to failure of the penetration.

13. Stress analyses used to predict crack growth rates are based on simulation of the welding process and these simulations are typically "ideal" models of the welding process. Experience with leaking cracks in the nozzles located in the upper and lower reactor vessel heads indicates actions during fabrication (e.g., grinding, repair welds, straightening of nozzles, etc) and welding anomalies (e.g., weld lack of fusion, hot cracking, etc.) can produce "non-ideal" welds and/or residual stress fields which lead to cracks where none were predicted to occur based on similar “ideal” models of the welding process.

    Provide an assessment of how actions such as grinding, repair welding, and straightening or reaming of heater sleeves or the presence of welding anomalies could change the predictions of this report. In particular, what is the effect on the predicted crack growth rates and the probability that a crack would leak enough to assure detection before sleeve ejection could occur?