July 9, 2010

MEMORANDUM TO: Gloria J. Kulesa, Chief
Plant Licensing Branch II-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

FROM: Robert M. Taylor, Chief ***/RA/***
Steam Generator Tube Integrity and
Chemical Engineering Branch
Division of Component Integrity
Office of Nuclear Reactor Regulation

SUBJECT: VOGTLE ELECTRIC GENERATING PLANT – AUDIT OF STEAM GENERATOR H* AMENDMENT REFERENCE DOCUMENTS (TAC NUMBERS ME3003 AND ME3004)

On June 14 and 15, 2010, Kenneth Karwoski, Emmett Murphy, and Andrew Johnson performed an audit at the Waltz Mill Site of the Westinghouse Company. The purpose of the audit was to gain a better understanding of the H* analysis pertaining to eccentricity, to review the draft responses to the letter of unresolved issues regarding the Vogtle Electric Generating Plant H* amendment request, dated November 23, 2009 (Accession Number ML093030490), and to determine which documents would need to be provided on the docket to support any future amendment requests implementing the H* analysis.

As a result of the audit, the team determined that the issues related to the slice model have been resolved and that within the context of the slice model, eccentricity does not appear to be a significant variable affecting tube-to-tubesheet contact pressure or calculated H* distances. What was previously termed the “eccentricity issue” can now be more accurately described as a “post-processing issue” pertaining to tubesheet displacements calculated by 3-D finite element analysis (FEA) results. Westinghouse believes that the decrease in contact pressure exhibited by the Model D5 steam generators (SGs), when going from normal operating to main steam line break (MSLB) conditions, is an artifact of the post-processing on the 3-D FEA results, coupled with uniquely low temperatures in the Model D5 SGs during MSLB conditions. Westinghouse is continuing to develop a 2-D FEA model, called the square cell model, that will calculate the tubesheet bore displacements from the raw displacement data of the 3-D FEA analysis, and hopefully show MSLB contact pressures higher than normal operating contact pressures, for the Model D5 SGs.

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In addition, it is hoped that the square cell model will confirm the conservatism of the analyses performed with no eccentricity adjustment for Model F, 51F, and 44F SGs and that all tubes maintain contact with the tubesheet bore over the full tube circumference for all elevations, for all SG models, under normal and accident conditions.

The enclosed audit report should be placed on the docket and forwarded to the licensee per the Office of Nuclear Reactor Regulation's Instruction LIC-111, "Regulatory Audits."

If you have any comments or concerns, please let us know.

Docket Nos.: 50-424 and 50-425

Enclosure:
As stated

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Docket Nos.: 50-424 and 50-425

Enclosure:
As stated

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AUDIT REPORT
VOGTLE ELECTRIC GENERATING PLANT
STEAM GENERATOR H* ANALYSIS REFERENCE DOCUMENTS

On June 14 and 15, 2010, an audit was performed at the Waltz Mill Site of the Westinghouse Electric Company. The purpose of the audit was to gain a better understanding of the H* analysis pertaining to eccentricity, to review the draft responses to the letter of unresolved issues regarding the Vogtle Electric Generating Plant H* amendment request, dated November 23, 2009 (Accession Number ML093030490), and to determine which documents would need to be provided on the docket to support any future amendment requests implementing the H* analysis. The audit team members included Kenneth Karwoski, Emmett Murphy, and Andrew Johnson, all from the Division of Component Integrity.

As a result of the audit, the team determined that the issues related to the slice model have been resolved and that within the context of the slice model, eccentricity does not appear to be a significant variable affecting tube-to-tubesheet contact pressure or calculated H* distances. What was previously termed the "eccentricity issue" can now be more accurately described as a "post-processing issue" pertaining to tubesheet displacements calculated by 3-D finite element analysis (FEA) results. Westinghouse believes that the decrease in contact pressure exhibited by the Model D5 SGs, when going from normal operating to main steam line break (MSLB) conditions, is an artifact of the post-processing on the 3-D FEA results, coupled with uniquely low temperatures in the Model D5 steam generators (SGs) during MSLB conditions. Westinghouse is continuing to develop a 2-D FEA model, called the square cell model, that will calculate the tubesheet bore displacements from the raw displacement data of the 3-D FEA analysis, and hopefully show MSLB contact pressures higher than normal operating contact pressures, for the Model D5 SGs. In addition, it is hoped that the square model will confirm the conservatism of the analyses performed with no eccentricity adjustment for Model F, 51F, and 44F SGs and that all tubes maintain contact with the tubesheet bore over the full tube circumference for all elevations, for all SG models, under normal and accident conditions.

Background

In the fall of 2004, crack-like indications were found in tubes in the tubesheet region of Catawba Nuclear Station Unit 2, which has Alloy 600 thermally treated SG tubes. Since 2004, other nuclear plants with Alloy 600 thermally treated SG tubes have found crack-like indications in tubes within the tubesheet as well, including Braidwood Unit 2, Byron Unit 2, Comanche Peak Unit 2, Surry Unit 2, Vogtle Unit 1, and Wolf Creek. Most of the indications were found in the tack expansion region near the tube-end welds and were a mixture of axial and circumferential primary water stress corrosion cracking.

ENCLOSURE

On February 21, 2006, Wolf Creek Nuclear Operating Corporation (WCNOC), the licensee for Wolf Creek Generating Station, submitted a license amendment request (LAR) that would permanently limit the scope of inspections required for tubes within the tubesheet. The amendment request was based on the H* analysis performed by Westinghouse that provided a technical basis for permanently limiting the extent of inspections required for the portion of the tube within the tubesheet. After three requests for additional information and several meetings with WCNOC, the staff informed WCNOC during a phone call on January 3, 2008, that it had not provided sufficient information to allow the staff to review and approve the permanent LAR; therefore, WCNOC withdrew the LAR. VEGP had also submitted a permanent LAR that used the same technical basis as the WCNOC LAR and also withdrew the VEGP permanent LAR.

After withdrawing the permanent LAR, VEGP submitted, by letter dated February 13, 2008 (Accession Number ML080500223), one-cycle LARs that used a more conservative interim alternate repair criteria (IARC) approach. After VEGP responded to requests for additional information, the IARCs were approved by the U.S. Nuclear Regulatory Commission (NRC) on April 9, 2008 (Accession Number ML080950247), and September 16, 2008 (Accession Number ML082530044).

Since the withdrawal of the first permanent LARs in 2008, industry has addressed questions posed by the NRC about the H* technical analysis and improved the finite element modeling used in the analysis. The NRC and industry held public meetings (Accession Numbers ML083300422, ML090370945, and ML091210437) and phone calls to discuss resolution of issues that were raised by the NRC.

In the spring of 2009, VEGP submitted a second permanent LAR using the H* analysis (Accession Number ML091470701). This H* analysis referenced in this LAR had resolved the RAIs from the 2008 LAR, but raised the technical issue related to eccentricity as discussed previously.

Key Licensee Staff Interviewed

Hermann O. Lagally, Westinghouse Company
Gary W. Whiteman, Westinghouse Company
Chris D. Cassino, Westinghouse Company
Adam Roslund, Westinghouse Company
Tom Hess, Southern Nuclear Operating Company
Sarah LeBlanc, Southern Nuclear Operating Company

Documents Audited

1. Draft RAI response, “Effects of Tubesheet Bore Eccentricity and Dilation and Their Relative Importance to H*,” dated June 2, 2010.
2. Draft RAI response, “H* Square Cell Model – NRC Audit,” June 14, 2010.
3. Draft RAI response LTR-SGMP-10-33, “H*: Response to NRC Questions Regarding Tubesheet Bore Eccentricity,” May 6, 2010.
4. LTR-SGMP-09-111 rev. 1, “Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*,” dated June 7, 2010.

Other References

1. Letter of Unresolved Issues Regarding H* LAR dated November 23, 2009 (Accession Number ML093030490).
2. Request for Additional Information Regarding H* LAR dated July 10, 2009 (Accession Number ML091880384).
3. Vogtle H* License Amendment Request dated May 19, 2009 (Accession Number ML091470701).

Audit Activities

The audit consisted of an opening session, three distinct auditing sessions, and a closing session. During the opening session, the audit team summarized the key issues that it was hoping to resolve during the audit and Westinghouse reviewed the status of the responses to the November 23, 2009, NRC letter. The first audit session dealt with the slice model and how eccentricity was calculated within the model. The second session dealt with the square cell model and how eccentricity was calculated within that model. The third session dealt with the impact on H* distances of having the bottom of the expansion transition values being greater than the predicted 0.3 inches. During the closing session, the audit team provided their observations on which draft responses to the issues in the November 23, 2009, letter needed additional clarification, which had been sufficiently answered in the draft response, and which ones had been overcome by events and were no longer applicable.

Opening Session

During the opening session, the audit team expressed the following concerns to the Westinghouse and SNC staff:

1. There is a lack of clear descriptions of the models used to evaluate eccentricity effects, and their technical justification.

2. The models do not separate out the effects of change in average bore diameter from effects of eccentricity on contact pressure, leading to improper relationships between eccentricity and contact pressure (or other figure of merit, e.g., scale factor).
3. The limits of pressure/temperature applicability of the various eccentricity models are not clearly defined and justified.
4. The applicability of the different eccentricity approaches to the full range of diameters (delta Ds) and eccentricities predicted by the 3-D FEA analyses of the lower SG assembly needs clarification for all conditions.
5. The maintaining of positive contact between the tube and tubesheet bore around the full tube circumference for the delta Ds and eccentricities predicted by the 3-D FEA analyses of the lower SG assembly needs clarification for all loading conditions.
6. The conservatism of the ratios of contact pressures under accident conditions to those under normal operating conditions, as affected by the eccentricity adjustments, needs to be better justified. Of particular concern are the ratios for the Model D5 SGs, where a different model is used for the eccentricity adjustments for MSLB than for normal operating conditions.

Additionally, the audit team addressed the following issues that it felt would constitute success in resolving the eccentricity issue:

1. Development of a conservative relationship between eccentricity and contact pressure (or other figure of merit) as a function of the average change in diameter (delta D_{avg}) and any other variable affecting the relationship.
2. That the proposed H* distances reflect this conservative relationship.
3. Demonstrating that tube-to-tubesheet bore contact pressures increase during accidents relative to normal operating values at all tube locations and elevations.
4. Tube-to-tubesheet bore contact is maintained around the entire circumference of each tube under normal and accident conditions.

Audit Session One

The audit team reviewed a draft document dated June 2, 2010 (pertaining to the effect of tubesheet bore eccentricity and dilation), and then held a question and answer session with the Westinghouse staff about how the eccentricity and dilation were modeled for the many cases shown in Table 1 of the draft document. This document included an updated version of the "slice model" (2-D FEA model) to address staff concerns in the November 23, 2009, letter and staff concerns relating to earlier versions of the draft responses to the November 23, 2009 letter. This updated model eliminated the sleeve and utilized displacement boundary conditions to replicate the desired amount of eccentricity for a given delta D_{avg}. The staff observed that the contact pressures calculated with the thick shell model at the top of page 3 appeared incorrect, based on the staff's independent calculations. The staff also expressed a concern that the use

of displacement boundary conditions to replicate the desired eccentricity was over-constraining the 2-D FEA and leading to over-predictions of contact pressure. The staff's opinion is that use of force boundary conditions to produce the desired amount of eccentricity provides a more realistic approach. For cases 4, 5, and 6 in Table 1, for example, the staff believes that the discrepancy in normalized contact pressures calculated with the thick shell model, versus those calculated by the 2-D FEA model, is largely due to the use of displacement boundary conditions, and that the FEA results would more closely align with the thick shell results if force boundary conditions were used. These concerns notwithstanding, the results in Table 1 confirm the staff's opinion that average contact pressure is a function primarily of delta D_{avg} rather than eccentricity. The staff concluded that the available evidence supports the conclusion that no (scale factor) adjustment to tubesheet bore delta D_{avg} is needed to account for tubesheet bore eccentricity.

Westinghouse presented H* analysis results showing that elimination of the scale factor adjustment does not adversely impact previously calculated H* distances. In addition, Westinghouse presented charts demonstrating Model F, 44F, and 51F SGs continue to exhibit an increase in contact pressure when going from normal operating to MSLB conditions. (The staff noted that a more detailed version of these charts, which is representative of all tube locations, should be included with future LAR submittals for permanent H*.) This increase in contact pressure supports the conservatism of the model used to calculate the accident leak rate ratios. However, Model D5 SGs continue to exhibit a decrease in contact pressure when going from normal operating to MSLB conditions. Thus, the model used to calculate the accident leak rate ratios may not be conservative for this case. Westinghouse attributes the calculated decrease in contact pressure as an artifact of how the tubesheet bore displacements were determined from displacement results from the 3-D finite element model coupled with the uniquely low temperatures in the Model D5 SGs during MSLB conditions. Westinghouse stated that the 3-D FEA does not model the tube bore holes explicitly. Rather, the tubesheet is modeled as a solid object whose stiffness properties have been modified to reflect the presence of the holes. This means that the 3-D FEA model simulates the gross displacements of the overall tubesheet, where the calculated displacements in the interior of the tubesheet are representative of average displacements, but don't reflect actual local values such as at the tubesheet bore surfaces.

Audit Session Two

Westinghouse made a presentation of its square cell model, which is a 2-D FEA model of a single square cell of the tubesheet with a bore hole in the middle and each of the four sides of the cell measuring one tube pitch in length. Displacement boundary conditions are applied at the edges of the cell, based on the raw displacement data from the 3-D FEA model. The model also includes the tube cross-section inside the bore. Displacement compatibility between the tube outer surface and bore inner surface is enforced except at locations where a gap between the tube and bore tries to occur. Westinghouse states that the use of displacement boundary

conditions (from the 3-D FEA) in the manner described is appropriate since the contact pressure components due to primary pressure inside the tube, crevice pressure between the tube and bore surface, and thermal expansion of the tube would produce very small displacements at the edges of the cell compared to the applied displacements from the 3-D FEA.

The purpose of this model is to calculate the actual tubesheet bore displacements and, thus, more realistic estimates of the contact pressure component associated with the primary-to-secondary pressure acting across the thickness of the tubesheet and the thermal expansion of the tubesheet. This model will also be used to confirm that tube to tubesheet bore contact is maintained around the entire tube circumference under normal and accident conditions at all locations.

This model is a refinement of a model submitted to the staff in the summer of 2009, which was the subject of several of the staff's RAI questions. This revised model is still under development, and no draft documentation of the model was available for staff review. Although the objectives of the square cell model approach appear reasonable, the staff was unable to provide feedback on the details of the approach. The staff requested that the documentation of the approach include intermediate and combined results for all applied displacement, temperature, and pressure load components.

The staff noted that the square cell model approach also needs to be applied to the Model F, 44F, and 51F SGs to confirm that the analyses for these plants are conservative.

Audit Session Three

The Westinghouse staff presented a summary of LTR-SGMP-09-111 rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*," dated June 7, 2010. This document was developed by Westinghouse in response to a request from the licensees (including SNC) that were implementing the H* methodology, because the licensees had committed to survey their SG tubesheets and to notify the NRC of any tubes with BET distances that had significant deviations from the assumed BET value of 0.3 inches. In the summary, the Westinghouse staff stated that there was enough margin between the H* value proposed for use by the various licensees and the Westinghouse recommended H* values for the various SGs to allow for BET distances up to one inch. After discussion between the audit team and the Westinghouse staff about the contact pressure gradient within the tubesheet at various radial locations, the audit team asked the Westinghouse staff to verify the affect of increasing the assumed BET depth on H*, for all radial locations with an H* depth that was within one inch of the H* depth at the worst possible location, for each type of SG (Model F, D5, 44F, 51F).

Closing Session

In the closing session, the audit team reviewed the RAI questions that had been asked of VEGP in the November 23, 2009, letter, and provided feedback on which questions had been resolved by information included in the draft RAI responses, which questions would require additional information, and which questions had been overcome by changes and no longer required a response. The specific feedback provided was:

RAI Question Number:

1. Information provided in the draft RAIs to date is sufficient.
2. Information provided in the draft RAIs to date is sufficient; however, for part 2.d. ensure that the range of delta Ds presented in future permanent H* amendment requests captures the range of Ds used in the 3-D FEA.
3. Information provided in the draft RAIs to date is sufficient.
4. Information provided in the draft RAIs to date is sufficient; however, ensure that the range of delta Ds presented in future permanent H* amendment requests captures the range of Ds used in the 3-D FEA.
5. Ensure the description of the Square Cell model address the fundamental concerns contained within this RAI.
6. Information provided in the draft RAIs to date is sufficient; however, ensure that the range of delta Ds presented in future permanent H* amendment requests captures the range of Ds used in the 3-D FEA.
7. Information provided in the draft RAIs to date is sufficient.
8. No additional work on this question is required, but as the Westinghouse report is being prepared, be cognizant of providing the necessary details or a similar question may be asked in the future.
9. No additional work on this question is required, but as the Westinghouse report is being prepared, be cognizant of providing the necessary details or a similar question may be asked in the future.
10. Information provided in the draft RAIs to date is sufficient; however, ensure that the range of delta Ds presented in future permanent H* amendment requests captures the range of Ds used in the 3-D FEA.
11. Information provided in the draft RAIs to date is sufficient.
12. No additional work on this question is required, but as the Westinghouse report is being prepared, be cognizant of providing the necessary details or a similar question may be asked in the future.
13. Information provided in the draft RAIs to date is sufficient.

14. No additional work on this question is required, but as the Westinghouse report is being prepared, be cognizant of providing the necessary details or a similar question may be asked in the future.

The audit team also provided feedback that the following documents needed to be formally docketed with any future permanent H* amendment requests:

1. Draft document, "Effects of Tubesheet Bore Eccentricity and Dilation and Their Relative Importance to H*," dated June 2, 2010.
2. Draft RAI response, "H* Square Cell Model – NRC Audit," June 14, 2010.
3. Draft RAI response LTR-SGMP-10-33, "H*: Response to NRC Questions Regarding Tubesheet Bore Eccentricity," May 6, 2010.
4. LTR-SGMP-09-111 rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*," dated June 7, 2010.

The audit team also provided the following feedback:

1. The evidence presented by Westinghouse in Table 1 of the draft RAI response, confirms the staff's opinion that average contact pressure is a function primarily of delta D_{avg} rather than eccentricity. Based on this, the staff concluded that no scale factor adjustment to tubesheet bore delta D_{avg} is needed to account for tubesheet bore eccentricity.

2. While Westinghouse presented charts demonstrating Model F, 44F, and 51F SGs continue to exhibit an increase in contact pressure when going from normal operating to MSLB conditions, the staff noted that a more detailed version of these charts, which is representative of all tube locations, should be included with future LAR submittals for permanent H*.

3. Although the objectives of the square cell model approach appear reasonable, the staff was unable to provide feedback on the details of the approach. The staff requested that the documentation of the approach include intermediate and combined results for all applied displacement, temperature, and pressure load conditions.