February 4, 2003

Mr. Garry L. Randolph
Vice President and Chief Nuclear Officer
Union Electric Company
P.O. Box 620
Fulton, MO 65251

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION - TECHNICAL SPECIFICATION STEAM GENERATOR TUBE INSPECTION LICENSE AMENDMENT REQUEST FOR CALLAWAY PLANT, UNIT 1 (TAC NO. MB6478)

Dear Mr. Randolph:

In your application dated October 3, 2002 (ULNRC-04745), you proposed an amendment to the Technical Specifications (TSs) for the Callaway Plant. In the application, you proposed changes to TS 5.5.9, "Steam Generator (SG) Tube Surveillance Program," to add a requirement for using the rotating pancake coil (RPC) to the H* depth in the SG tubesheet. The proposed amendment is based on the proprietary Westinghouse Topical Report WCAP-15932-P, "Improved Justification of Partial-Length RPC Inspection of Tube Joints of Model F Steam Generators of Ameren-UE Callaway Plant," Revision 0, dated September 2002. In our letter of November 4, 2002, the NRC stated that it would withhold the proprietary information in that report in accordance with 10 CFR 2.790. A non-proprietary version of WCAP-15932 was also submitted with your application.

Since your application was submitted, there have been several teleconferences with your staff on the information contained in the application. This was done to expedite the NRC staff's review of the application so that it could understand the technical basis for the proposed H* distances for the four SG zones before the SG tube inspections were completed in the October 2002 refueling outage. This resulted in several e-mails being sent to your staff with questions on the application and several e-mail responses to the questions being sent by your staff to the NRC. This culminated in the calls on October 19, 2002, when a Westinghouse white paper on use of the RPC in SG tube inspections was given to NRC. The plant has since restarted from the refueling outage.

The enclosed request for additional information (RAI) is to docket the questions that were submitted to your staff. The enclosed information is needed for the NRC staff to complete its review of your application. Any differences between the enclosed questions and the e-mails is either editorial or the deletion of questions that duplicated other questions. In a telecon on the enclosed questions with your staff on January 28, 2003, they agreed to submit the responses within 120 days of the receipt of this letter. Your staff also stated that the enclosed questions contain no proprietary information. If the responses are submitted by that time, the NRC staff expects to complete its evaluation within its stated goal of completing licensing actions within one year of the date of the application.

If you have any questions, please contact me at 301-415-1307, or at jnd@nrc.gov through the Internet.

Sincerely,

/RA/

Jack Donohew, Senior Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-483

Enclosure: Request for Additional Information

cc w/encl: See next page

If you have any questions, please contact me at 301-415-1307, or at jnd@nrc.gov through the Internet.

Sincerely,

/RA/

Jack Donohew, Senior Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket No. 50-483

Enclosure: Request for Additional Information

cc w/encl: See next page

DISTRIBUTION:
PUBLIC
PDIV-2 Reading
RidsNrrPMJDonohew
RidsNrrLAEPeyton
RidsOgcRp
RidsAcrsAcnwMailCenter
RidsRgn4MailCenter (KBrockman)
LLund
JTsao
KKarwoski

ADAMS Accession No.: ML **NRR-088**

OFFICE	PDIV-2/PM	PDIV-2/LA	EMCB/SC	PDIV-2/SC
NAME	JDonohew:rkb	EPeyton	LLund	SDembek
DATE	1/30/2003	1/30/03	2/3/03	2/4/03

DOCUMENT NAME: C:\ORPCheckout\FileNET\ML030350719.wpd
OFFICIAL RECORD COPY

cc:
Professional Nuclear
Consulting, Inc.
19041 Raines Drive
Derwood, MD 20855

John O'Neill, Esq.
Shaw, Pittman, Potts & Trowbridge
2300 N. Street, N.W.
Washington, D.C. 20037

Mr. Mark A. Reidmeyer, Regional
Regulatory Affairs Supervisor
Regulatory Affairs
AmerenUE
Post Office Box 620
Fulton, MO 65251

U.S. Nuclear Regulatory Commission
Resident Inspector Office
8201 NRC Road
Steedman, MO 65077-1302

Mr. J. V. Laux, Manager
Quality Assurance
AmerenUE
Post Office Box 620
Fulton, MO 65251

Manager - Electric Department
Missouri Public Service Commission
301 W. High
Post Office Box 360
Jefferson City, MO 65102

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-4005

Mr. Ronald A. Kucera, Deputy Director
for Public Policy
Department of Natural Resources
205 Jefferson Street
Jefferson City, MO 65101

Mr. Rick A. Muench
President and Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
Post Office Box 411
Burlington, KA 66839

Mr. Dan I. Bolef, President
Kay Drey, Representative
Board of Directors Coalition
for the Environment
6267 Delmar Boulevard
University City, MO 63130

Mr. Lee Fritz
Presiding Commissioner
Callaway County Court House
10 East Fifth Street
Fulton, MO 65151

Mr. David E. Shafer
Superintendent Licensing
Regulatory Affairs
AmerenUE
Post Office Box 66149, MC 470
St. Louis, MO 63166-6149

Mr. John D. Blosser, Manager
Regulatory Affairs
AmerenUE
P.O. Box 620
Fulton, MO 65251

Mr. Scott Clardy, Director
Section for Environmental Public Health
P. O. Box 570
Jefferson City, Missouri 65102-0570

REQUEST FOR ADDITIONAL INFORMATION

RELATED TO STEAM GENERATOR TUBE INSPECTION LICENSE AMENDMENT

UNION ELECTRIC COMPANY

CALLAWAY PLANT, UNIT 1

DOCKET NO. 50-483

The information requested by the NRC staff is on the licensee's application dated October 3, 2002, in which the licensee proposed changes to TS 5.5.9, "Steam Generator (SG) Tube Surveillance Program," to add a requirement for using the rotating pancake coil (RPC) to the H* depth in the SG tubesheet. Of the following questions, questions 1 to 5 are on the Callaway Technical Specifications (TSs), and questions 6 to 73 are on the proprietary Westinghouse Topical Report (TR) WCAP-15932-P, "Improved Justification of Partial-Length RPC Inspection of Tube Joints of Model F Steam Generators of Ameren-UE Callaway Plant," Revision 0, dated September 2002, which was submitted with the application.

Questions on the TSs:

1. Discuss if the TSs should also specify that the H* depth inspection is applicable to hot leg tubes only so as to be consistent with the technical basis in the Westinghouse TR. The proposed TS wording implies that the H* depths can be applied to the cold leg tubes also.

2. Provide the following: (1) confirm that the primary-to-secondary leakage in the Callaway TSs is 150 gallons per day (gpd) per steam generator, and (2) describe the current plant administrative procedures regarding operator actions when a steam generator tube leakage occurs.

3. The proposed phrase to be added to TS 5.5.9.d.1.h, "Tube Inspection," states that the tube inspection includes "inspection with rotating pancake coil (or equivalent) from the tube expansion transition at the top of the tubesheet to the H* depth as specified in TS Table 5.5.9-4." Discuss what is the starting point (or reference point) of the H* depth measurement, including the following:

    a. The TR mentioned that the starting point for the H* depth is the top of tubesheet whereas the proposed TS wording implies that the starting point is the expansion transition. If the top of the tubesheet is the starting point, then consideration should be made in the TS wording for cases where the expansion transition is located above or below the top of tubesheet. If the starting point is the expansion joint point, then the TS requirement is not consistent with the TR. If the starting point is from the expansion joint, then is the H* depth measured from the top of the expansion transition joint or from the bottom of the expansion transition joint? The starting point of the H* depth should be clarified.

b. In general, when inspecting the top of tubesheet, licensees also inspect the tube above the top of tubesheet (e.g., three inches above the top of the tubesheet). How many inches above the top of the tubesheet is proposed to be inspected?

4. Address whether there should be a TS requirement for future inspection of H* tubes, including if each H* tube must be inspected during each steam generator tube inspection to assure that there are no indications in the H* distance.

5. The proposed TS wording describes the H* inspection distance and probe; however, the TS has no requirement stating that if any indication is found within the H* distance it must be repaired or plugged (i.e., plug on detection) and if any indication is found below the H* distance in the tube in the tubesheet it may remain in service. Discuss this issue.

<u>Questions on Westinghouse Report WCAP-15932-P</u>:

6. Page 2-2. One of the assumptions for the H* criterion is that tube cracking within the tubesheet is primary water stress corrosion cracking (PWSCC). This implies that the H* criterion will not be applicable to tubes with other degradation mechanisms such as outside diameter stress corrosion cracking (ODSCC). If this is the correct interpretation, then TS 5.5.9.h needs to limit the H* criterion to PWSCC only.

7. Page 2-2. One of the assumptions states that bobbin coil eddy current testing (ECT) is capable of detecting circumferential crack and deep axial indications within the tubesheet. It is not clear in the TR that the bobbin coil is qualified for these indications. Describe the qualification of the bobbin coil for these types of indications.

8. Page 2-1. It is stated that any indication in the tube region below the H* distance in the tubesheet may remain in service. It is not clear whether a severely degraded indication (e.g., 100 percent through-wall crack) may remain in service even if the indication is located below the H*distance. Address the disposition strategy for the through-wall indications below the H* distance.

9. Page 3-1, 4th paragraph. It is stated that the maximum practical primary-to-secondary leakage during normal operation is 75 gpd. On page 3-4, it is stated that the plant will shut down when the leak rate is above 75 gpd. Discuss if the 75 gpd leakage limit is an analytical condition of the H* depth criterion, and if the limit should be included in the proposed TS requirement for the H* criterion.

10. Page 3-3, 5th paragraph. It is stated that +point, Vpp > 3 volt, would be used within the tubesheet and below the RPC inspection depth. Address the following:

    a. Why the peak-to-peak voltage is specified to be greater than 3 volts for the +point probe.

    b. It is the staff's understanding that within the H* depth, the RPC (i.e., +point) would be used and below the H* depth, a bobbin coil would be used; however, the statement in the 5th paragraph implies that a +point would be used below the H* depth, not the bobbin coil. Explain the discrepancy.

11. Page 3-3, 6th paragraph. It is stated that all of the tubes in the 50 percent program of

the opened steam generators would be inspected to the H* depth. Describe the "50 percent program." It is not clear to the staff whether the inspection strategy is consistent with the inspection strategy on page 3-3 in the TR. Clarify and describe the inspection strategy.

12. Page 3-5, 4th paragraph. It is stated that the H* values do not contain any margin for non-destructive examination (NDE) uncertainty in elevation of the crack features. Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," recommends measurement uncertainties (i.e., measurement error and analyst variability) in the eddy current inspections. Provide justification for not including measurement uncertainties

13. Page 3-5, 5th paragraph. It is stated that the H* values are grouped in four zones based on the tubesheet upward bending during normal operation and during the limiting accident condition. It is not clear if the zones were calculated based on the limiting conditions and if the radii for each zone include any statistical/calculational errors. Address these issues.

14. Page 5-1. Provide the following: (1) how many test tubes were assembled in the leak test program, and (2) how many tests were performed at room temperature, normal operating temperature, or accident event temperature.

15. Page 6-1. It is stated that the tubesheet constraints the crack opening area and that the constraining effect for axial cracks is taken into account in the leakage calculation by using an effective crack length that is less than the actual length. However, during an accident, the tubesheet bows and the tubesheet bore expands, and the expansion of the tubesheet bore would reduce the constraint effect. Address how the tubesheet bore expansion was taken into consideration in the leakage or tube pull-out calculations, including the impact of the bore expansion on the leak rate and pull-out force (e.g., the percentage of the leak rate or pull-out force caused by the bore expansion).

16. Section 7.0. In its structural analysis, Westinghouse used carbon steel material properties for the tubesheet; however, there is a stainless steel (or nickel-based alloy) cladding on the top of the tubesheet. Address how the material properties of cladding were considered in the tubesheet structural analysis, including the effect of the cladding, if any, on the H* depth and on the leakage calculations.

17. Address how a leakage model with a through-wall circumferential crack having a 360 degree extent below the H* depth in the tubesheet has been considered, including what would be the leak rate of such a crack. Considering the worst scenario leakage from H* tubes, address how many tubes can be applied with the H* criterion without exceeding TS primary-to-secondary leakage limit.

18. In the proposed TS Table 5.5.9-4, the H* depth for inspection depth zone A is proposed to be 2.38 inches. This H* depth is smaller than the H* depth proposed for zones B, C, and D, and can be viewed as not as conservative in terms of tube structural and leakage integrity. In general practice, licensees inspect 3.0 to 6.0 inches below the top of the tubesheet using the RPC. Address the differences in the proposed H* depths by inspection depth zone, and include the following:

a. Describe the history of indications detected within 2.38 inches below the top of the tubesheet at Callaway.

b. Describe the structural and leakage integrity of a tube with an H* depth of 2.38 inches.

19. Discuss the length(s) of the test tube inside the tubesheet collar in the mock-up tests, including if the distance of 2.38 inches was modeled in the test. Discuss whether the test tube was severed at the 2.38 inch location inside the tubesheet. It should be pointed out that the TR discussed only perforated locations in the tube, not a severed tube.

20. In its review, the staff found that the description of the inspection depth zones A, B, C, and D in proposed TS Table 5.5.9-4, by listing the range of radii of the zone from the vertical centerline of the tube sheet, is not as descriptive as Figure 3-6 in the TR. Address whether Figure 3-6 in the TR should be included in the Callaway TSs (i.e., can the proprietary information in the figure be omitted to allow it to be placed in the TSs?).

21. In the conference call on October 17, 2002, a Westinghouse representative stated that all tubes with indications in the H* distance region would be plugged as shown by Figure 2-1 of the TR, because the RPC would not be able to size the indications. However, a Union Electric representative stated that tubes with some indications detected in the H* distance may not be plugged and thus would remain in service, and that tube plugging would be based on the TS 5.5.9 tube plugging criteria of 40 percent through-wall, because the RPC can size the indications in the H* region. Address the discrepancy between these statements.

22. Abstract:

a. Page vii, Abstract. Explain the engagement distances of 0.30 inch and 1.4 inches with respect to the P* distance.

b. Page vii, Abstract. It is stated that "...P* is to show the acceptability of a tube separation below the P* distance for about 95% of the operating tubes in the bundle..." Discuss whether tube separation would be acceptable in terms of structural and leakage integrity for the remaining 5 percent of the tubes in the bundle.

23. Section 1.0:

a. It is stated that PWSCC has been identified in the region between the bottom of the hydraulic expansion transition and the 3-inch depth in the Callaway steam generators. Provide the historical data of tube indications (circumferential and axial) found in the tubesheet. Specify the maximum distance measured from the top of the tubesheet into the tubesheet that PWSCC indications have been detected.

b. Discuss the disposition of an indication that is detected by a RPC probe that is not within the H* distance, but is within the expansion transition zone (e.g., above the top of the tubesheet) or below the H* distance. Include in the discussion if the disposition would be in terms of the requirements specified in TS 5.5.9.

24. Section 2.0:

Page 2-1, 4th paragraph. It is not clear why P* distance is not specified in the Callaway TSs as an inspection requirement because the P* distance is related to the H* distance. It is stated in the TR that, "... the initiation of inspection to H* depths also initiate the use of P*..." Discuss if this recommendation will be adopted at Callaway and included in the TSs.

25. Section 5.0:

a. Page 5-1, Section 5.1.1. Provide information on the test collars, i.e., the number of collars used in the test, the dimension of the collars (1.63 inches in outside diameter?), and the number of tube specimens in any one collar. Discuss whether the test program included testing of the tubesheet bowing effect.

b. The summary of the tests is addressed on page 5-4. In the summary, there is no mention of fatigue (mechanical or thermal) testing. The mechanical fatigue testing would include cyclic load testing, and the thermal fatigue testing would consider the thermal expansion and contraction (during heatup and cooldown) of the tube length between the top of the tubesheet and the tube support plate(s) where the tube may be constraint by either denting or deposits. Discuss why these tests were not considered.

c. Page 5-4. It is not clear in the TR whether the H* distances were modeled in the test mock-ups. Discuss if this was done, and provide the length of the tube in the tubesheet for the tube pull-out and leakage tests.

26. Section 6.0:

a. Page 6-2, 3rd paragraph. The report discussed the proprietary DENTFLO computer code in calculating leak rate of an axial crack and the effective crack length in the leak rate calculations; however, there is no discussion of a leak rate calculation for a circumferential crack. It is not clear how the effective crack length of a circumferential crack is modeled in the leak rate calculation. Provide a discussion on the leak rate calculation for a circumferential crack.

b. Page 6-3, 1st paragraph. It is stated in the TR that a through-wall circumferential crack of 180 degree extent was considered in the leak rate calculation. Discuss why a through-wall circumferential crack of 360 degree extent is not the worst scenario crack and was not considered in the leak rate calculation. See Question 17.

c. Page 6-3, 2nd paragraph. Provide leak rate results of a single axial and circumferential crack under steam line break conditions and normal operational conditions.

27. Section 7.0:

a. Page 7-1, 4th paragraph. The report discussed a previously developed finite element model for the model F steam generator. Discuss if this model was developed for Callaway and provide the reference for this model.

b. Page 7-2. It is not clear whether the tube bores were included in the finite element model. In addition, the tubesheet bores are not evident in the finite element model as shown in Figure 7-1. The TR stated that an equivalent ligament efficiency, modified modulus of elasticity, and modified Poisson's ratio were used to simulate the tubesheet bore. However, it is not clear how the ligament efficiency is input in the finite element model to simulate the tubesheet bore in the finite element model. Discuss how the ligament efficiency can simulate the tubesheet bore, including the previous sentences.

c. Pages 7-3 and 7-4. The TR cited References 9.21, 9.22, 9.23, 9.24 (e.g., on page 7-12, Reference 9.28 was cited); however, these references could not be found in the reference section of the report. Explain the discrepancy.

d. Page 7-3, 2nd paragraph. The TR discussed a previous calculation performed with a 3-D finite element model of a model D-4 steam generator. Provide the reference of this analysis.

e. Pages 7-8 and 7-9. Discuss whether the pressure and temperature parameters for the feedline break, steamline break, and loss-of-coolant accident (LOCA) events were specifically taken from the Callaway design basis accident analysis or from a generic accident analysis. On the basis of the references cited in the TR, it seems that the pressure and temperature parameters used in the Callaway analysis may be generic values. Discuss if this is correct, and confirm whether the generic pressure and temperature parameters used in the H* analysis bound the values in the accident analysis of the Callaway plant.

f. Pages 7-23 and 7-24; Tables 7.2-2a and 7.2-2b. Explain the significance of Psec = 893 psig and Psec = 955 psig, and why there is no Psec value in Table 7.2-3?

g. Page 7-26. Discuss whether the P* analysis in Section 7.3 was benchmarked with testing data. It is the staff's understanding that the purpose of the P* distance is to provide assurance that if a tube having a H* distance less than P* distance is pulled out from the tubesheet, that tube would be confined by the adjacent row tube without damaging other tubes. However, absence of a valid verification of the P* methodology, the shortest H* distance should be made to be greater than P* distance to assure that if a tube is pulled out, it would not impinge on any tubes. Discuss this.

h. Discuss how the tubesheet bowing is considered in the structural and leakage integrity calculations, providing the following: (1) the maximum and minimum values of the tubesheet bowing, (2) the locations of the maximum and minimum tubesheet bowing, and (3) the maximum and minimum values of tubesheet bore expansion.

i. Discuss whether the finite element model has been benchmarked with the actual test results to verify the accuracy of the analytical method of calculating tubesheet bowing.

28. In the proposed TSs, the inspection extent references the expansion transition. Given how the testing was performed, clarify whether the proposed TSs should be modified to reference from the bottom of the expansion transition or the top of the tubesheet, whichever is lower.

    There are several references in the TR indicating that H* is reckoned from the top of the tubesheet and assumes a conservative distance between the bottom of the hydraulic expansion transition and the top of the tubesheet. Discuss the reference point for the H* distances provided in the TSs.

29. Discuss the role of P* in determining the H*distances in the proposed amendment. If P* is relied upon in determining the proposed H* distances, address the following:

    a. Discuss why P* is limited to non-stayrod and non-patchplate area tubes, including if this is because there are no nearby neighbors or are there other reasons?

    b. The basis for assuming that tube separation below the P* distance for approximately 95 percent of the tubes in the bundle.

    c. How have the effects of degraded tubes been accounted for in the P* analysis?

    d. Describe the test data supporting the analytical calculations with respect to neighboring tubes limiting the extent of tube pull-out.

    e. Discuss how sliding of the tubes and distortion (bending) of the tubes were accounted for in the analysis.

    f. Discuss the effects of one tube impacting another tube assuming the tube "impacted" is degraded to the steam generator performance criteria by the most limiting damage mechanism.

30. Clarify the meaning of the statement on page 1-2 in the TR: "a similar approach has been demonstrated to be acceptable for use in cases of tube weld damage due to loose parts." Provide the data which demonstrates that leakage during normal operation can be related to leakage during postulated transients. Discuss the relationship, including how ligament tearing is accounted for in this relationship and how the scatter in the data is accounted for in the H* methodology.

31. Assumptions regarding the location of the bottom of the expansion transition were made in the TR. For Callaway, if the inspection distances are from the top of the tubesheet, provide the maximum distance from the top of the tubesheet to the bottom of the expansion transition (i.e., ones below the top of the tubesheet). Discuss how this distance is used in relation to the H* distances provided in the TS and how the NDE uncertainty in determining the top of the tubesheet, the bottom of the expansion transition, and the inspection distance is accounted for in the analysis. List the assumptions made and provide the basis for the assumptions.

32. Several assumptions were made in establishing the H* and P* distances in Section 2.2 of the TR. List the assumptions and provide the technical basis and data for each of the assumptions (with the exception of the assumption regarding the 1.0 gpm leakage limit during steam line break (SLB) and the primary side makeup capacity). Discuss whether the inspection techniques have been qualified in accordance with the Electric Power Research Institute (EPRI) guidelines and provide the qualification data. Discuss whether the EPRI guidelines are being followed with respect to the frequency of inspection for plants with mill annealed Alloy 600. If not, provide the technical justification for the deviation.

33. It was indicated that past experience with circumferential cracks inside the tubesheet for another type of tube joint indicated that leakage is low and that the same trend is expected for Callaway. Discuss the relationship between the contact pressures at Callaway to these other plants. Discuss the extent to which these indications were subjected to the full range of normal operating, transient, and accident conditions.

34. It was assumed in Section 3.1.2.2 of the TR that the pull-out distances associated with the normal operating pressure (NOP) values could be ignored since the plant will shut down because of leakage. Discuss the basis for this assumption. As indicated above, past experience indicates that leakage is low from circumferential cracks. Discuss the possibility that no leakage may be observed from a joint that is totally severed at some distance or has a through-wall crack. In determining the steam line break pull-out distance, discuss how the lower temperature during the break was accounted for in determining the inspection distance.

35. In determining the acceptance limits, the most limiting primary-to-secondary differential pressure during normal operation should be used (most limiting would equate to the maximum differential pressure that can be observed during normal operation for the life of the steam generator). In performing the testing, it would appear that the lowest differential pressure should be used, since it would result in a lower contact pressure. Discuss the basis for performing the tests at 1900 psi, which is considerably higher than normal operating differential pressure. Discuss how the lowest normal operating pressure was accounted for in determining the H* inspection distance, and provide the

data associated with the determination of the resistance to pull-out as a result of the hydraulic expansion.

36. Describe how the roughness of the collars used during the testing program compare to the roughness of the tubesheet bore. Describe any data confirming the as-built roughness of the tubesheet bore. Discuss if the lowest possible value of roughness was used, and, if not, how was this accounted for in determining the inspection distances.

37. In performing the leak rate tests, discuss why a 100 percent through-wall circumferential crack was not assumed at the H* distance. If based on some qualification data, discuss the potential for a partial through-wall flaw to "pop" through-wall during a steam line break or to grow from partial through-wall at one inspection to through-wall during the next inspection.

38. It was indicated in Section 5.1.4.1 of the TR that wall thinning calculations were performed to determine the effect of tack rolling. Discuss the reason for this section of the TR. Also, discuss if the tack rolling was at the tube end in the field, and, if so, if the test specimens also had this tack rolling and whether the tack roll performed on the test specimens had the lowest contact pressure that could be observed in the field. Provide the basis (including applicable data) for your answer.

39. With respect to the test specimens, it was indicated that segmented expansions were performed. Discuss the various configurations tested, including, for example, were all tests segmented or were some tests fully expanded for the entire region of the tubesheet? Discuss also the basis for concluding that the test specimens were representative of the expansions in the field, including, for the segmented samples, is it possible that the tack roll assumed a greater percentage of the load than the hydraulically expanded region and, if so, discuss the need to repeat the test to account for the fact that this area is below the H* distance. In addition, discuss the basis for assuming the pull out force is evenly distributed along the length of the tube in contact with the tubesheet.

40. In Section 5.3.2 of the TR it was indicated that: "in the 600°F pullout tests, the lowest value for 'first slip' or 'breakaway' force was 3000 lbs." This section then indicates that the results were conservative because of the lack of the additional resistance to pull-out due to the differential pressure tightening between the tube and the tube hole surface which would be present in the plant. Discuss at what pressure were these tests run and how was the tube/tubesheet heated.

41. Provide a comparison of the results of the leak tests provided in Section 5.3.1 of the TR to the predictions from the proprietary DENTFLO computer code.

42. Section 6.3, page 6-2. It is not clear why degradation of various depths was assumed in the leakage analysis. Given the potential for a tube to be circumferentially severed below the H* distance (or near severance at the time of inspection), it would appear

appropriate to assume every active tube is severed at the H* distance. Discuss this discrepancy.

43. A finite element model was used in determining tubesheet hole dilations. Discuss the basis for the assumptions in this model, or compare the differences between this model and that used for other plants with similar repair criteria which have been approved (e.g., Diablo Canyon W* criteria).

44. Discuss whether the H* distances in the TSs are based on a feedline break or an SLB. In the TR, the acceptance criteria is more restrictive than a feedline break; however, the transients are different. Discuss whether an analysis was performed to confirm that the more conservative inspection distance was determined.

45. With respect to the TSs, given that the test program was done on non-degraded tubing, discuss why the TSs should not specify that any tube with detected degradation below the expansion transition and within the H* distance should be plugged, including the technical basis for assuming pull-out is not affected by tube degradation.

46. Discuss how the dynamic effects associated with steam generator blowdown during a SLB or feedline break are modeled in the determination of the H* distance (e.g., are there increased loads placed on the tubes as a result of the blowdown of the steam generator?).

47. Discuss any test data supporting the magnitude of the pressure and temperature effects on contact pressure. Because the corrections in the TR appear to be analytical rather than experimental in nature, discuss whether mockup tests have been performed on specimens at room temperature and at operating temperature (or at ambient and operating pressure), and, if so, discuss whether the results of these tests support the contact forces for these effects used in the analysis. If testing of hydraulically expanded tubes is not available, discuss whether tests from other types of expansions (e.g., WEXTEX, hardroll) are applicable and the results of any testing on these specimens. The staff notes that resistance to pull-out in the peripheral tubes appears to be controlled mainly by the effects of pressures and temperature rather than by hydraulic expansion.

48. The first 10 rows of the Callaway steam generator tubes were fabricated with thermally treated Alloy 600 material and the rest were fabricated with mill-annealed Alloy 600 material. Discuss whether there is any difference in the pull-out capacity and leakage resistance between the thermally treated Alloy 600 tubes and mill-annealed Alloy 600 tubes, because it seems that the test specimens, leakage and pull-out calculations discussed in the TR were based on mill-annealed Alloy 600 material properties only.

49. Discuss whether in TS 5.5.9, there should be a requirement that limits the application of the proposed H* depths to the original steam generators, because this requirement is to assure that the H* depths will not be inadvertently applied to future replacement steam generators, such as a statement in the Bases for Surveillance Requirement 3.4.13.2.

50. Discuss the need to modify the pull-out length to account for differences in the thermal treatment process between the low row (less than row 10) and the high row tubes.

51. In several places, references are made to documents for which no references are listed (e.g., what is reference 9.21 cited in Section 7.1.2?). This needs to be clarified in the TR.

52. Tube flaws may remain in service at the end of the next operating cycle for the following reasons: (a) they were knowingly left in service at the beginning of cycle (since they were below the H* distance and sized with a qualified technique as being less than 40 percent through-wall), (b) a region of the tubesheet area was not inspected with a qualified probe so indications were not detected at the beginning of cycle (e.g., below the H* distance circumferential flaws would not be detected), (c) they initiated during the cycle, and (d) they were missed during the inspection and continued to grow. The methodology for predicting leakage from flaws in the tubesheet area was provided in the TR, based in part on the computer code DENTFLO. Describe the methodology to be used to determine the number, severity, and location (depth within the tubesheet) of flaws for purposes of determining the amount of leakage (using the DENTFLO code) during postulated accident conditions, including the following information for flaws that are found, in the steam generators, to extend below the bottom of the expansion transition:

    a. the outage in which the flaw was found,

    b. the orientation of the flaw (axial and circumferential indications),

    c. the location of the indication with respect to the bottom of the expansion transition and the top of the tubesheet,

    d. the size of the flaw to include the method of sizing (by plus-point, bobbin, or RPC), length (axial and/or circumferential), depth, and percent degraded area (for the circumferential indications), and

    e. the H* zone (A, B, C, or D) where the flaw is located.

53. Based on the discussion of "turbo mix" in the telecon held on October 19, 2002, with Union Electric staff, explain the use of the "turbo mix" with the bobbin coil indications in (1) the bobbin coil inspection of the steam generator tubes in the then current refueling outage, and (2) determining indications of circumferential cracks previously found by use of the pancake coil in the tube inspections in the same outage.

54. In a telecon on November 19, 2002, the licensee discussed several circumferential tube flaws that were detected in the tubesheet region of the Callaway steam generators during the Fall 2002 inspection. Provide the bobbin coil and rotating probe inspection data for the following tubes in the associated Callaway steam generators: SG A--R25C71; SG C--R18C77; SC C--R21C101; SC C--R29C69; and SG D--R42C57. Include with this data the appropriate calibration runs, a drawing of the standards, and

the setups from the various calibration groups. Also provide a copy of the eddy current data analysis guidelines.

55. On page 12 of the Westinghouse report, "RPC Inspection Lengths for Tube-To-Tubesheet Joints In the Callaway Steam Generators," SG-SGDA-02-47, the licensee indicated that the in-situ pressure test included a 360 degree, through-wall circumferential indication. The licensee stated that the circumferential indication did not leak under the SLB condition during the in-situ pressure test. The indication may not have leaked because (a) it was not as severe as eddy current data indicated, (b) the in-situ pressure test may be limited in its ability to provide results representative of an SLB, and/or (c) it does not represent the worst-case scenario. The staff notes that if a full-length tube pressure test is performed at a pressure of three times the normal operating pressure, it may result in simulating three times the axial loads; however, it also increases the interface pressure between the tube and the tubesheet as a result of pressure by 3 times. In addition, the in-situ pressure test does not include the effect of tubesheet bow. Ideally, the test should result in the more limiting of the following conditions: (a) imparting 3 times the axial loads on the tube at normal operating pressure and temperature with a hole dilation consistent with that observed during normal operation; or (b) imparting 1.4 times the axial loads on the tube at SLB differential pressures and temperature with a hole dilation consistent with that observed during an SLB.

    a. Discuss whether the appropriate end-cap loads and contact loads between the tube and the tubesheet, as a result of pressure, are simulated during the test (i.e., if the interface pressure due to the tube’s internal pressure is increased by a factor of three during the test, it would not appear that the test is providing useful information).

    b. Provide a description of the test apparatus (including whether it was a partial or full length tube test; if a partial test, address the location of the sealing bladders with respect to the top of the tubesheet).

    c. Provide an analysis demonstrating the in-situ test conditions bound the conditions observed during normal operation and an SLB as a result of tubesheet bow.

    d. Discuss whether the in-situ testing performed at Callaway can be used to assess the structural and leakage integrity of tubes with flaws in the tubesheet region. If the in-situ test does not provide information regarding the integrity of the indications in the tubesheet region, discuss the implications of these results.

56. The licensee investigated the location of the bottom of the expansion transition in relation to the top of the tubesheet. The licensee included a value of 0.30-inch in the H* distances based on an understanding of the expansion method and a review of data from other units. Based on an assessment of the eddy current data at Callaway, provide the maximum distance that the bottom of any of the expansion transitions is from the top of the tubesheet.

57. In evaluating the potential for leakage from reactor vessel head penetrations which have

an interference fit (similar to the steam generator tubes), the industry's Materials Reliability Program (MRP-75) analyses include the fact that a leak into the annulus region between the nozzle and the head results in application of pressure on the outside of the nozzle and inside of the hole in the vessel head. This change in boundary condition from the as-designed configuration increases the pressure dilation of the vessel head (pressure applied to a larger diameter than the inside of the nozzle) and eliminates the pressure deflection of the nozzle. The net effect of the leakage into the gap is therefore to increase the gap opening. Discuss whether the analyses performed in support of determining the pull-out distance and the leakage from a steam generator tube account for this phenomena. If the model doesn't account for this effect, please perform an analysis to determine the need to account for this effect.

58. Provide the "no-contact" length for each of the steam generator zones for both normal operating and postulated accident conditions (including the factors of safety for both conditions).

59. On page 9 of the Westinghouse report, SG-SGDA-02-47, Westinghouse stated that it made several modifications to the leakage analysis in the TR:

    a. It removed room temperature tests from the analysis data.

    b. It revised the crack opening area model to account for the fact that pressure acting on the flanks of the cracks is compressive relative to the material adjacent to the crack plane. This reduced the crack opening area by 50 percent.

    c. The revised leakage analysis considered the tube material below the crack whereas in the original analysis the tube material below the crack was not considered.

    Provide a more detailed description of the revised model and its basis, including:

    a. A description of the testing program used to develop the loss coefficient. Provide the data acquired and the data used in the correlation.

    b. A description of the testing program used to develop the flow through a crack. Provide the data acquired and the data used in the correlations.

60. It was noted in the Westinghouse report, SG-SGDA-02-47, that all of the test specimens in the test program exhibited leakage at both room and elevated temperature conditions with higher leak rates being measured at room temperature. Although this general trend is expected because of the lower contact pressures at room temperature, discuss whether the magnitude of the differences in leak rates is consistent with what would be expected given the models used for accounting for the effects of temperature on contact pressure. If the trends cannot be quantitatively explained, discuss the need to perform additional testing to ensure there is a fundamental understanding of all key parameters.

61. If the loss coefficients are lower at lower temperatures and an SLB results in temperatures less than 600°F, discuss the need to obtain a loss coefficient corresponding to the temperatures actually observed during an SLB. If no data is available from realistic SLB temperatures, discuss the need to use the room temperature test data to ensure the condition is bounded.

62. On page 7 of the Westinghouse report, SG-SGDA-02-47, the licensee postulated a theory regarding why the loss coefficient may increase with the initial introduction of primary water into the crevice. Regarding this theory, please address the following:

    a. Discuss whether the corrosion products or the primary water in the crevice would result in a loss of contact pressure above the joint and whether this effect was considered in the analysis. For example, suppose corrosion of the tubesheet resulted in the accumulation of corrosion products between the tube and the tubesheet, would the corrosion products result in a loss of contact pressure (due to a phenomenon such as denting)? In addition, suppose a tube was leaking from a crack in the tubesheet region, discuss the potential for loss of contact pressure as a result of the leakage. Provide the technical basis for the answers.

    b. During the leak rate testing program as discussed in Westinghouse report, SG-SGDA-02-47, it was noted that when repeat tests were performed on a specimen at elevated temperature, there was an increase in the loss coefficient (with few exceptions). Please describe these exceptions and assess the key parameters that may explain why these exceptions occur (e.g., specimens with lower contact pressures, more severe flaws, random, etc.). Given the results of this analysis, discuss whether similar conditions occur in the field.

    c. Discuss the extent to which the same phenomenon (increase in loss coefficient as a result of leakage) would occur in the field given that the water chemistry in the plant is different than the pressurizing medium used during the tests. Also discuss the handling of the specimens between these tests. Discuss whether the loss coefficient is increasing with time simply as a result of different environments and handling (the lab specimens are probably exposed to much more oxygen than would be present in a steam generator during operation).

    d. Given that the tubesheet collar used in the test is a different material than that used in the field and was primarily selected to simulate the rigidity of the tubesheet, discuss whether different results may be obtained if the actual tubesheet material was used.

63. On page 8 of the Westinghouse report, SG-SGDA-02-47, Westinghouse stated that the leak rate can be measured by the pressure drop during the in-situ pressure test and that if there is no detected drop in the pressure during a hold period, there has been zero leakage. Westinghouse also stated that the in-situ testing equipment is capable of measuring leak rates as small as 0.001 gpm.

a. The staff understands that the holding period for the maximum pressure is usually two minutes. If the holding period is extended to a longer period of time such as the duration of a steam line break event, the tube may leak because the crack opening area may enlarge. Discuss the potential for the tube to leak when the holding period is extended.

b. Describe how the leak rate was measured in the in-situ pressure tests.

c. Assuming the in-situ test can simulate the conditions of an SLB, please provide the basis for the statement that the in-situ testing equipment is capable of measuring leak rates as small as 0.001 gpm.

d. With respect to the statement that the detection capability is improved if pressure is monitored, discuss the sensitivity of this technique for the standard hold times used during in-situ tests. Provide the basis for this answer.

64. The licensee indicated that the flaws in the tubesheet may grow deeper without getting appreciably longer. The basis for this conclusion is not obvious. It may simply mean that the stresses at the deepest part of the flaw were the highest with somewhat lower stresses elsewhere. The profile could indicate a deep section with a shallower extent around the remaining portion of the circumference (below the detection threshold). If this were the case, all flaws could eventually grow to be 360 degrees in circumferential extent and 100 percent through-wall. Discuss the need to obtain field data to confirm the expectation.

65. Regarding Figure 14 in the Westinghouse report, SG-SGDA-02-47, and the determination of the distribution of indications below the inspected region, it is not apparent that the methodology presented supports the conclusion that the distribution of indications below the H* distance is uniform, for the following reasons:

a. If one were just interested in the most severe indications, it would appear that only the data from 3" to the H* distance should be included in the Figure since the first 3 inches of the tube were inspected during prior outages (since circumferential indications in the first 3-inches had been removed from the population during past inspections).

b. Given that eventually all indications below the H* distance will become severe since they will not be detected nor repaired, it would seem appropriate that all indications should be assessed (i.e., not just the most severe).

c. Given that each zone is potentially inspected to a different distance, it would appear appropriate to evaluate whether there is differences between the various zones.

Provide a list of all indications, the outage in which they were detected, their severity (circumferential extent, average depth, maximum depth, percent degraded area), their elevation with respect to the top of the tubesheet (e.g., TSH-2.5 inches), and the zone in which they were found.

Replot Figure 14 based on all indications (regardless of severity, zone, or outage in which they were detected) and also with all indications in specific zones to assess whether the uniform distribution assumption still holds.

66. Regarding the theory that the flaws are a result of local expansions of the tube material into manufacturing depressions within the drilled holes in the tubesheet:

    a. Discuss the basis for this theory.

    b. Are these manufacturing depressions evident from bobbin coil or rotating pancake coil inspections?

    c. Discuss whether the flaws observed were contained within the area "bounded" by the depression in all cases.

    d. Discuss why flaws have not been observed in Zone A given the postulated cause of cracking (presumably the frequency of these manufacturing depressions would be the same from one zone to the next).

    e. Given these observations, discuss the need to modify the leakage assessment for Refueling 12 and subsequent outages to address cracks that may be occurring in Zone A and other zones.

67. To evaluate the leakage through a 360 degree circumferential extent, 100 percent through-wall circumferential flaw, the maximum crack opening area was determined from an analysis which considers either (a) the primary pressure acting on the crack flanks with a tube material acting as a spring to resist parting of the crack faces, or (b) from extrapolating the areas obtained from analyzing a series of circumferential cracks up to about 270 degree in circumferential extent. Please provide a more detailed description of how this was done, its basis, and any data supporting the predictions from this model.

68. With respect to the assumption in the leakage model that the leak rate from a circumferential crack is the same as the leak rate from an axial crack if the crack opening areas of the two cracks are identical, the staff agrees to a first approximation that this is true when the ratio of wall thickness to crack opening displacement is not large (e.g., ratio <10). However, when this ratio is large, it is not clear whether this assumption would hold true. As a result, discuss the need to account for differences in leak rates when the wall thickness to crack opening displacement is large. Discuss whether the leakage model considered cases when the wall thickness to crack opening displacement is large (e.g., ratio > 10).

69. The staff notes that there are uncertainties associated with many aspects of the leakage evaluation. There are uncertainties in the number of flaws, the locations of the flaws, the size of the flaws and whether they grow in circumferential extent, the loss coefficient, and the constraining effect the tubesheet has on crack opening. Given the uncertainties in the evaluation, a leakage model similar to that developed for NRC Generic Letter 95-05, "Voltage-Based Repair Criteria for Westinghouse Steam Generator Tubes Affected by Outside Diameter Stress Corrosion Cracking," should be considered to

ensure the leakage estimates provided by the model represents a 95^{th} percentile value at a 95 percent confidence when accounting for all of the uncertainties. Discuss how uncertainties are treated in the leakage model.

70. The leak rates for various crack sizes are plotted in Figure 19 in the Westinghouse report, SG-SGDA-02-47. This figure represents the leak rate for indications at the boundary between Zones B and C. It would seem that similar data would need to be developed for all Zones unless there is no potential for circumferential cracks in those other zones such as Zones A and D.

71. The staff understands that tube inspections are frequently performed beyond the specified inspection extent (e.g., three inches). Without understanding more details of what indications were found, where they were found, and when they were found, the staff is unable to draw any conclusions regarding whether a conservative prediction of the number of flaws that could be present below the H* distance is being determined. Please clarify the data in Tables 1, 2, and 3 in the Westinghouse report SG-SGDA-02-47. Also, the information in Tables 1, 2, and 3 do not appear to match the description in the text. For example, the text indicated that the number of indications found for all of the steam generators was 46, but the corresponding table entry (based on staff's interpretation) indicates the number is 52.

72. The Callaway inspection results have shown that circumferential and axial cracks may develop within the H* distance during an operating cycle. At the time of plant startup, there will be no detected degradation within the H* distance. During the course of the cycle, a flaw could initiate within the H* distance of this tube. This flaw may affect the pull-out resistance of the joint. In addition, there is a potential that 360 degree, 100 percent through-wall flaws at or below the H* distance may occur.

    a. Discuss the need to expand the inspection distance of the rotating pancake coil probe to account for the initiation/growth of flaws within the H* distance during the course of the cycle.

    b. Provide data supporting the ability to assess the impact of degradation within the H* distance on the pull-out resistance of the joint.

73. On page 13 of the Westinghouse report, SG-SGDA-02-47, it states that, "...the stress from the pressure on the flanks is 0.214 of the stress that would result from an end cap pressure load for the same pressure..." Provide the technical basis for the 0.214.