NRC'S HANDOUT

FOR THE MEETING ON JULY 11, 2007, WITH

WOLF CREEK NUCLEAR OPERATING CORPORATION

ON WOLF CREEK GENERATING STATION

REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATION AMENDMENT
STEAM GENERATOR TUBE INSPECTIONS WITHIN TUBESHEET
TAC NO. MD0197

WOLF CREEK GENERATING STATION
DOCKET NO. 50-482

REFERENCES

1. Wolf Creek Nuclear Operating Corporation (WCNOC) letter dated February 21, 2006. (NRC ADAMS Accession No. ML060600454)

2. WCNOC letter dated May 3, 2007. (NRC ADAMS Accession No. ML071290101)

REQUESTED INFORMATION

1. Reference 1, Enclosure I, Table 6-4 - Are the listed F/L, force per length, values correct? If so, please describe in detail how they were calculated. If not correct, please provide all necessary revisions to the H* analysis results. [For Byron 2, Braidwood 2, and Seabrook, F/L is calculated as follows:

F/L = (Pull Force/specimen length) x (net contact pressure/total contact pressure)

A consistent approach for Wolf Creek (based on allowing 0.25 inch slip) would yield F/L values on the order of 200 pounds per inch (lb/inch) rather than 563 lb/inch as shown in the Table.]

2. Reference 2, Enclosure I, Response to RAI questions 1 and 2 - provides the sensitivity of contact pressure to many of the material and geometric parameters used in the analyses. The response provides only a qualitative assessment of these sensitivities to support the conclusion that the values assumed in the H* analyses support a conservative calculation of H*. For example, the sensitivity study showed that contact pressure is sensitive to the yield strength of the tubing. The response states that the yield strength of the tubing used in the pullout test specimens was higher than the documented mean yield strength for prototypical tubing material, but did not indicate to what extent the yield strength of the test material bounds the range of prototypic yield strength variability. Thus, the staff has no basis to agree or disagree with the conclusion that test specimen contact pressures are conservatively low. The steam generators contain up to 5620 tubes, and it needs to be demonstrated that the computed H* distances are conservative for all the tubes, not simply the average tubes or 95% of the tubes. Please provide a quantitative assessment demonstrating that the assumed values of the material and geometric parameters support a conservative H* analysis for all tubes. This assessment should consider thermal expansion coefficient (TEC) for the tube and tubesheet in addition to the parameters included in the Reference 2 response.

[Note: Reference 2, Enclosure I, Response to RAI question 3, states, "A flaw that is measured at the condition monitoring structural limit or the operational assessment repair limit must have a probability of 95% at a confidence level of 50% of satisfying the structural requirements in the acceptance standard used in EPRI [Electric Power Research Institute] Report TR-107621." This guideline is not entirely consistent for the technical specification performance criteria for tube integrity. If there are ten tubes which are each determined to have a 95% probability of satisfying the acceptance standard, then there is only a 60% probability that all ten tubes satisfy acceptance standard. The technical specifications require that all tubes have adequate margin against burst (or pullout).]

3. The H* analyses in References 1 and 2 are based, in part, on pullout resistance associated directly with hydraulic expansion process. This pullout resistance was determined by subtracting out the effects of differential thermal expansion between the tube and tubesheet test collar from the measured pullout load. The calculated differential thermal expansion effect was based, in part, on an assumed TEC value of 7.42E-06 in/in/°F for the 1018 steel tubesheet test collar. What is the impact of considering an alternative TEC value of 7E-06 in/in/°F (from Matweb.com for 1018 steel interpolated at 600 degrees Fahrenheit) on the computed pullout force determined from the pullout test and on the computed H* distances?

4. Reference 2, Enclosure I, Response to RAI question 7 - The Model D5 steam generator (SG) pullout data in Table 2 indicate that pullout force increases with temperature for the 3-inch long specimens and decreases with temperature for the 6-inch long specimens. For the 4-inch specimens, pullout force increases with temperature to 400 °F and decreases with temperature beyond that point. Discuss the reasons for this apparent discrepancy in trends among the data. Discuss whether the reduction in tube yield strength with temperature might be sufficient for some specimens to limit any increase in contact pressure associated with differential thermal expansion between the tube and tubesheet.

5. Following up on question 4 above, is there a possibility that any tubes could be stressed beyond the compressive yield strength (at temperature) of the tube material due to differential thermal expansion, internal pressure, and tubesheet hole dilation for the range of yield strengths in the field? Describe the basis for either yes or no to this question. If yes, how has this been factored into the contact pressures, accumulated pullout resistance load as a function of elevation, and H* in Tables 7-6 through 7-10 and 7-6a through 7-10a of Reference 2, Enclosure I?

6. Reference 2, Enclosure I, Response to RAI question 17 - The response states near the bottom of page 30 of 84 that Case 1 results shown in Table 3.0 are for the limiting cold leg analysis and reflect the following assumption: "Although the pullout test data indicated positive residual mechanical joint strength, the residual joint strength is ignored for SLB [steam line break] accident condition[s] to conservatively account for postulated variability of the coefficient of thermal expansion." The NRC staff notes, however, that the limiting H* value shown in Table 3.0 for Case 1 is that necessary to resist three times the normal operating pressure end cap load, not that needed to resist 1.4 times SLB. It is the staff's understanding based on review of Tables 7-6 through 7-10 and 7-6a through 7-10a that the residual mechanical joint strength (522 lb/inch) was reflected in the H* computations for normal operating and accident conditions, including SLB. Discuss and clarify these apparent discrepancies.

7. Reference 2, Enclosure I, Table 7-6 - This table states that the required pullout force is 1680 lb. Table 7-6 indicates that for a tubesheet radius of 12 inches the needed depth of engagement is less than 10.52 (about 10.2 using linear interpolation). However, the table states that an engagement depth slightly greater than 10.52 (i.e., 10.54) is needed. Discuss and explain this apparent (minor) discrepancy.

8. Reference 1, Enclosure I, Table 6-4 - The listed F/L values are based on allowing 0.25 inch slippage. Reference 1 does not address the potential for limited, but progressive incremental slippage under heatup/cooldown and other operational load cycles. Nor does Reference 1 address the effects of slippage on normal operating leakage and on accident-induced leakage or the ratio of normal operating and accident induced leakage. The response to RAI question 5 in Reference 2, Enclosure I, does not provide any further insight into this issue. That response specifically addressed test results for tubes with a hard roll expansion, and the staff believes that the slippage versus axial load characteristics for such an expansion may be entirely different than for a hydraulic expansion. Discuss and address the potential for progressive incremental slippage under heatup/cooldown and other operational load cycles. In addition, address the potential for slippage under operational and accident conditions to affect the ratio of accident-induced leakage to operational leakage.

9. Discuss your plans for revising the proposed technical specification (TS) amendment to monitor the tube expansion transition locations relative to the top of the tubesheet to ensure that the tubes are not undergoing progressive, incremental slippage between inspections.

10. Reference 1, Enclosure I, Section 7.1.4.2 - This section provides a brief discussion of the SLB, feed line break (FLB), and loss-of-coolant accident (LOCA) in terms of which is the most limiting accident in terms of tube pullout potential. Expand this discussion to indicate whether SLB and FLB are the most limiting accidents among the universe of design basis accidents (DBAs) (or other faulted conditions in the design basis) in terms of both tube pullout and the margin between the calculated accident-induced tube leakage for each DBA and the assumed accident-induced tube leakage in the safety analyses for that DBA.

11. Figure 11 of Reference 2, Enclosure I contains loss coefficient data for Model F SG tubing that was not included in Figure 6-6 of Reference 1, Enclosure 1. This data was for contact pressures ranging from about 1200 psi to about 2000 psi. Why was this data not included in Figure 6-6? Discuss if this is this because of low expansion pressures and if the data that is not included in Figure 6-6 room temperature data. [If yes, then the NRC staff observes that the room temperature loss coefficients for the Model F specimens are relatively invariant with contact pressure above a contact pressure threshold of around 700 psi. The 600 degree F data is also invariant with contact pressure. Thus, loss coefficient may not be a direct function of contact pressure once a threshold degree of contact pressure is established. The difference in loss coefficient data between the 600 °F data and the room temperature may be due to parameter(s) other than contact pressure. This other parameter(s) may not be directly considered in the B* analysis.]

12. Figure 13 of Reference 2, Enclosure I contains additional loss coefficient data taken from the crevice pressure study in the white paper. Provide a figure showing all individual data points from which Figure 13 was developed. Describe the specific applied pressure differentials from the crevice pressure study used to calculate the contact pressure for each data point.

13. Although the means of the regression fits of the loss coefficient data for the Model F and Model D SGs are shown in Figure 13 of Reference 2, Enclosure I, to be within a factor of three of each other, the slope and intercept properties remain highly divergent, seeming to cast further doubt that loss coefficient varies with contact pressure (above some threshold value of contact pressure). Discuss this and describe any statistical test that have been performed to establish the significance of correlation between loss coefficient and contact pressure. In addition, describe any statistical tests that have been performed to confirm that it is appropriate to combine the data sets to establish the slope and intercept properties of loss coefficient versus contact pressure.

14. Reference 2, Enclosure I, page 25 of 84 - For the case of assumed zero slope of loss coefficient versus contact pressure, two constant loss coefficient values were compared. Does the first assumed value come from Figure 14? If not, provide additional information on where this assumption comes from. If yes, explain the relationship between the assumed value and Figure 14. Does the second assumed value come from Figure 12? If not, provide additional information on where this assumption comes from. If yes, explain the relationship between the assumed value and Figure 12.

15. Reference 2, Enclosure I, Figure 15 - clarify the title of Figure 15 in terms of whether it reflects consideration of residual mechanical strength in the joint during an SLB. Is Figure 15 for the hot or cold leg? Explain the following: (1) why the B* values at small tubesheet radii are less than those listed in Reference 1, Enclosure I, Table 11-1 and (2) why the contact pressures shown in Reference 1, Enclosure I, Figures 9-6 and 9-7 are different from those shown in Tables 7-6 and 7-8 of Reference 1, Enclosure I.

16. Reference 2, Enclosure I - Provide a description of the revised finite element model used to support the revised H* calculations in Tables 6-7 through 6-10 and Tables 6-7a through 6-10a. Compare this revised model to the original model which supported the Reference 1 analysis. Explain why the revised model is more realistic than the original model.

17. Reference 2, Enclosure 1, Attachment 1 (The Westinghouse Letter Summary of Changes to B* and H*), page 14 - address the status of the divider plate evaluation being performed under EPRI sponsorship, and the schedule for completion of the various topics being addressed in the evaluation. Describe any inspections that have been performed domestically that provide insight on whether the extent and severity of divider plate cracks is bounded by the foreign experience. Discuss the available options for inspecting the divider plates.

18. Discuss how the ability of the divider plates at Wolf Creek to resist tubesheet deflection (without failure) under operating and accident loads is assured in the short term, pending completion of the EPRI evaluation. Include in this discussion the actions that are planned in the near term to ensure that the divider plates are capable of resisting tubesheet deflection.

19. Reference 2, Enclosure 1, Attachment 1 - Provide a description of the Crevice Pressure Test. This description should address, but not necessarily be limited to the following:

a. Description of test specimens, including sketches.
b. Description of "pre-treatments" of test specimens (hydraulic expansion pressure, heat relief, etc.).

c. Description of test setup, including sketches.
d. Description of test procedure.
e. What were the secondary side temperatures in Tables 1 and 2 corresponding to the listed secondary side pressures and how were the secondary side pressure and temperatures controlled and monitored?
f. How long did each test run and how stable were the pressure readings at each of the pressure taps during the course of each test?
g. What was the temperature of (1) the coolant in the crevice and (2) the tube and tubesheet collar as a function of elevation?
h. How were the temperature distributions for item g determined? Were direct temperature measurements of the tubesheet collar performed as a function of elevation?

20. Reference 2, Enclosure 1, Attachment 1 - The pressure tap locations in Figure 2 are different from those shown in Figure 3. Discuss and explain this difference or provide corrected figures.

21. Reference 2, Enclosure 1, Attachment 1 - Figures 2 and 3 assume crevice pressure at the top of tubesheet is at the saturation pressure for the primary system. Discuss and explain the basis for this assumption. Why wouldn't the crevice pressure trend to the secondary side pressure near the top of the tubesheet?

22. Reference 2, Enclosure 1, Attachment 1 - Figure 3 refers to tests labeled SLB 9 and SLB 10 which are not listed in Table 2. Discuss and explain this, or provide a revised Table 2 and Figure 3 showing all test results.

23. Reference 2, Enclosure 1, Attachment 1 - Page 6 states in part that the following change should be made to the H*/B* analyses: "The driving head of the leaked fluid has been reduced." Discuss and clarify this sentence. The staff notes that resistance to leakage occurs from two sources: resistance from the flaw and resistance from the crevice. Because the crevice pressure was assumed to be equal to the secondary pressure, the original analysis assumed the entire pressure drop (the driving head) was across the flaw. The tests described in the white paper eliminate any pressure across the flaw (by using holes rather than cracks) and force the entire pressure drop to occur along the crevice. Thus, there is no net change in the total driving head between the primary and secondary sides. In fact, the driving head from the bottom to the top of the crevice would seem to have been increased.

24. Reference 2, Enclosure 1, Attachment 1 - The top paragraph on page 10 states, in part, "the median value of the crevice pressure ratios provides a conservative value that is an average representation of the behavior at the top of the tubesheet. The median is typically a better statistical representation of the data than the mean because the median is not influenced by a smaller data set but by the total range in values in the sample set." The staff has the following questions regarding these sentences:

a. Discuss and clarify what data set "median value" applies to. For example, does the "median value" for the NOP data set in Table 1 mean the median value of the 15 pressure tap data points obtained during three tests, or does it mean a median value of a subset of these 15 data points? If a subset, what subset and

why? Alternatively, does it mean the median value at each pressure tap location?

b. Discuss why this median value is a conservative representation of the behavior at the top of the tubesheet.

c. Discuss what is meant by "top of the tubesheet." For 17-inch inspection zone amendments, shouldn't this mean the upper 17-inches to ensure a conservative analysis? If not, why not? To ensure a conservative analysis for H* and B*, should not the objective be to establish crevice pressure as a function of elevation that can be directly applied into the H* and B* computations.

d. Discuss why the median is not influenced by a smaller data set and how the median is influenced by the total range of values in the sample set.

25. Reference 2, Enclosure 1, Attachment 1 - Provide a copy of Reference 3. The cited web page appears to be no longer available. Also, provide copy of Reference 4.

26. Reference 2, Enclosure 1, Attachment 1 - What were the specific data sets used to compute the Dixon Ratio values at the top of page 11?

27. Reference 2, Enclosure 1, Attachment 1 - In Table 5 under the heading of outliers, rows 1 and 2 refer to "total set," whereas lines 3 and 4 refer to "included." Does "included" mean the same thing as "total set." If not, how does it differ from "total set," and how does it differ from "excluded?"

28. Reference 2, Enclosure 1, Attachment 1 - Provide a step-by-step description (including an example) of how the values in Table 5 were obtained.

29. Reference 2, Enclosure 1, Attachment 1 - Confirm that the "unaltered" case in Table 5 reflects the use of the improved tubesheet/divider plate model with a "divider plate factor" of 0.399.

30. Reference 2, Attachment II - Proposed TS 5.5.9.c states that, "The following alternate tube repair criteria may be applied as an alternative to the 40% depth-based criteria." This appears to mean that you are proposing that the implementation of the alternate tube repair criterion is optional. It is the NRC staff's position that the word "may" should not be "shall." Discuss and explain your proposed use of the word "may." Alternatively, the proposed inspection exclusion zone in TS 5.5.9.d could be revised to make the exclusion conditional on implementation of the alternate repair criterion in TS 5.5.9.c.1.

31. Reference 2, Attachment II - The first sentence of proposed TS 5.5.9.c.1 states, "For tubes fully expanded into the tubesheet, degradation found in the portion of the tube below the depth identified in the below tables from the top of the tubesheet does not require plugging." Discuss your plans for revising this sentence to clarify what constitutes a fully expanded tube (e.g., through the use of a footnote) and for clarifying the rest of the sentence. For example, the word "degradation" should be replaced with "tubes with flaws." This is consistent with the rest of TS 5.5.9 which uses the word "flaws" rather than the word "degradation." In addition, it is tubes

which are plugged, not flaws. As another example, it is believed that clarity can be gained by revising the sentence to state, "..., tubes with flaws located below the depths identified in the following tables ..."

32. Reference 2, Attachment II - The second sentence of proposed TS 5.5.9.c.1 states, "All tubes with degradation identified in the portion of tube within the region from the top of the tubesheet to the depth identified in the below tables shall be removed from service. Discuss and explain the proposed use of the word "degradation" instead of the word "flaws." The use of the word "flaws" is consistent with the rest of TS 5.5.9 which uses the word "flaws" rather than the word "degradation." In addition, the NRC staff suggests the licensee may wish to consider replacing the words "below tables" with "following tables."

33. Reference 2, Attachment II - The proposed revision to TS 5.5.9.d includes the following sentence, "For tubes fully expanded into the tubesheet, the portion of the tube below the top of the tubesheet identified in C.1 above is excluded." This sentence is confusing as to what is intended by the sentence. Discuss and clarify this sentence is intended to mean. For example, the sentence could be clarified by stating, "...the portion of the tube below the inspection depths from the top of the tubesheet identified in C.1 above is excluded."

34. Reference 2, Attachment II - Proposed specification TS 5.6.10.h - Discuss and clarify the words "for each ... indication" in the phrase "for each service-induced indication within the thickness of the tubesheet."

35. Reference 2, Attachment II - Proposed specification TS 5.6.10.j - Discuss and clarify the used of the words "is determined" in the second sentence. The NRC staff suggests that the words "is determined" in the second sentence should be replaced to read "was determined."

36. The proposed technical specification amendment would apply to both the hot and cold leg side; however, the NRC staff notes there have been no reported instances of cracks in the tubesheet region for plants with Alloy 600 thermally treated tubing and, thus, there seems to be little compelling reason to extend the applicability of the requested amendment to the cold leg side. Discuss and explain why the amendment request should apply to both the hot leg side and the cold leg side. It is the NRC staff's position that the amendment request should not apply to cold leg side.

LICENSEE'S HANDOUT

FOR THE MEETING ON JULY 11, 2007, WITH

WOLF CREEK NUCLEAR OPERATING CORPORATION

ON WOLF CREEK GENERATING STATION

Revision to TS 5.5.9, "Steam Generator (SG) Program"

WCNOC

Westinghouse

Westinghouse

Agenda

- Introductions/Purpose of Meeting
- WCGS SG Management Program
- Industry Operating Experience
- WCGS SG Tube Inspection License Applications
- Success Path for Approval of WCNOC LAR
- NRC Staff Presentation
- Review of New RAIs (6/22/07 electronic mail)
- Questions/Conclusions
- Public Comments

WCGS SG Management Program

- Ensure SG tube integrity and reliability over licensed life of plant
- Maintain current SG longevity as long as technically and economically feasible
- Avoiding non-relevant inspections and unnecessary tube plugging can achieve these goals by minimizing inspection costs and maximizing power production while ensuring the integrity of the tubes
- The current LAR to exclude portions of the tube below the top of the tubesheet from periodic inspections is technically justified and programmatically prudent
  - Similar alternate repair criteria for inspection depths within the tubesheet have been previously approved for mil-annealed plants (W*, F*, C*)

Industry Operating Experience

- Generic Letter 2004-01 (Aug 2004)
  - Required per TSs in conjunction with 10 CFR Appendix B to employ inspection techniques capable of detecting all flaw types which may be present at location required to be inspected
  - Disputed the industry practice of inspecting a limited distance below the top of the tubesheet (typically 3"), with rotating probe when there is a potential for cracking to exist in the expanded length below the portion inspected
- Catawba Unit 2 –A600TT (Fall 2004)
  - Indications reported approximately 7" from top of hot leg tube sheet in one tube
  - Indications in several tubes in the tack expansion region
  - Indications reported in tube-to-tubesheet weld

Industry Operating Experience
(continued)

- Vogtle Unit 1 – A600TT (Spring 2005)
  - Indications in two tubes in areas with bulges and/or overexpansions
- To date – no other instances of cracking within bulges and/or overexpansions below the top of the tubesheet have been reported in A600TT SGs
  - Additional indications in tubes in the tack expansion region have been reported

WCGS SG Tube Inspection License Applications

- Communication with NRC in April 2005 indicated a firm position to inspect the entire length of the tubesheet expansion region using a qualified probe to detect axial and circumferential cracks
- Refueling Outage 14 (April 2005) – exigent LAR submitted and Amendment No. 162 issued
  - Approved a one-time allowance for Refueling Outage 14 and subsequent operating cycle to exclude the lower 4 inches of the tubesheet from the required inspection (conservative 17" inspection depth chosen for convenience)
  - H* (structural requirements) and B* (leakage requirements) analysis performed by Westinghouse

WCGS SG Tube Inspection License Applications

(continued)

- A study documented in the Degradation Assessment identified the pre-cursor signals in the tubesheet expansion region, primarily bulges (BLG) and overexpansions (OXP)
- 20% sample of the BLG/OXP population in the upper 19 inches inspected with +Pt probe in SGs B and C
- Inspection sample concentrated in upper 10” to focus on most critical region (from a leakage perspective)
- No indications or degradation found

Westinghouse

WCGS SG Tube Inspection License Applications

(continued)

- LAR Requesting Permanent Change to TS 5.5.9 (Feb. 2006)
  - Requested optimized inspection depths (<17" from top of tubesheet)
    - Maximum inspection depth of approximately 8" from top to tubesheet near centerline of bundle, decreasing in a stepwise pattern, to less than 3" near the edge of the bundle
  - 26 RAIs issued June 2006
  - Sufficient time not available to respond to RAIs and NRC review of RAIs to support approval for Refueling Outage 15 (Oct. 2006)

WCGS SG Tube Inspection License Applications
(continued)

- Refueling Outage 15 (Oct 2006) – LAR submitted (6/30/06) and Amendment No. 169 issued
  - Approved a one-time allowance for Refueling Outage 15 and subsequent operating cycle to exclude the lower 4 inches of the tubesheet from the required inspection (conservative 17" inspection depth chosen for convenience)
  - Sampling program in SGs A and D included greater than 50% of the combined BLGs and OXPs
  - Inspection sample concentrated in upper 10" to focus on most critical region (from a leakage perspective)
  - No indications or degradation found

WCGS SG Tube Inspection License Applications

(continued)

- Permanent Change to TS 5.5.9 (cont.)
  - PWR Owner's Group project established to evaluate and respond to all RAI's associated with H* and B* license amendment requests
  - WCNOC Responses to RAIs provided (May 2007)
  - Second set of RAIs (36) provided to WCNOC electronically on 6/22/07

Success Path for Approval of WCNOC LAR

- Significant resources spent pursuing change
- WCNOC is concerned that the success path for approval of the amendment request to support Refueling Outage 16 (Spring 08) has not been defined
  - WCNOC is concerned that the most recent set of RAIs may not be the last

Success Path for Approval of WCNOC LAR

(continued)

- Refueling Outage 16 begins in March 08 – plans and schedule for responding to all remaining concerns
  - Prefer not to pursue third one-time change
- Expect some of the RAIs may be resolved today as a result of the information provided
- Expect responses to RAIs, as currently understood, to be submitted by 9/14/07
- License Amendment issued by 2/08?

Westinghouse

NRC Staff Presentation

NRC presentation

Wolf Creek H*/B* NRC RAI Responses

RESTATEMENT OF RAI

1. Reference 1, Enclosure I, Table 6-4 - Are the listed F/L, force per length, values correct? If so, please describe in detail how they were calculated. If not correct, please provide all necessary revisions to the H* analysis results. [For Byron 2, Braidwood 2, and Seabrook, F/L is calculated as follows:

   F/L = (Pull Force/specimen length) x (net contact pressure/total contact pressure)

   A consistent approach for Wolf Creek (based on allowing 0.25 inch slip) would yield F/L values on the order of 200 pounds per inch (lb/inch) rather than 563 lb/inch as shown in the Table.]

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The listed value of 522.3 lbf/in is correct.
- The values are based on 0.25 inch slip pullout test data and contact pressures that are calculated using the theory of elasticity:

$$F = p_0 \frac{E_t A \Delta f}{\nu b}\left(1 - e^{-\mu \alpha L}\right)$$

$$\alpha = \frac{2b^2}{b^2 - a^2}\frac{\nu}{E_t \Delta f}$$

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- Where:

  F = Measured pullout force resulting in 0.25 inch slip (lbf)
  Po = contact pressure (psi)
  Et = Elastic modulus of the tube material
  a = inside radius of the tube
  b = outside radius of the tube
  Δf = flexibility of tube minus the flexibility of the collar
  ν = Poisson's ratio
  μ = coefficient of friction (0.2 inch)

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The value for *Po* is calculated for each test using a coefficient of friction of 0.3.
- Next a value for $Pc - \sigma$ is calculated.
- The average *F/L* value is then calculated using the equation:

  $$F/L = 2\pi R_o (P_c - \sigma)\mu$$

  Where:

  R_o = expanded tube outside radius (0.352 inch)
  μ = coefficient of friction (0.2)

Westinghouse

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

2. Reference 2, Enclosure I, Response to RAI questions 1 and 2 - provides the sensitivity of contact pressure to many of the material and geometric parameters used in the analyses. The response provides only a qualitative assessment of these sensitivities to support the conclusion that the values assumed in the H* analyses support a conservative calculation of H*. For example, the sensitivity study showed that contact pressure is sensitive to the yield strength of the tubing. The response states that the yield strength of the tubing used in the pullout test specimens was higher than the documented mean yield strength for prototypical tubing material, but did not indicate to what extent the yield strength of the test material bounds the range of prototypic yield strength variability. Thus, the staff has no basis to agree or disagree with the conclusion that test specimen contact pressures are conservatively low.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI (Cont.)

The steam generators contain up to 5620 tubes, and it needs to be demonstrated that the computed H* distances are conservative for all the tubes, not simply the average tubes or 95% of the tubes. Please provide a quantitative assessment demonstrating that the assumed values of the material and geometric parameters support a conservative H* analysis for all tubes. This assessment should consider thermal expansion coefficient (TEC) for the tube and tubesheet in addition to the parameters included in the Reference 2 response.

[Note: Reference 2, Enclosure I, Response to RAI question 3, states, "A flaw that is measured at the condition monitoring structural limit or the operational assessment repair limit must

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI (Cont.)

have a probability of 95% at a confidence level of 50% of satisfying the structural requirements in the acceptance standard used in EPRI [Electric Power Research Institute] Report TR-107621." This guideline is not entirely consistent for the technical specification performance criteria for tube integrity. If there are ten tubes which are each determined to have a 95% probability of satisfying the acceptance standard, then there is only a 60% probability that all ten tubes satisfy acceptance standard. The technical specifications require that **all** tubes have adequate margin against burst (or pullout).]

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The impact of varying the following parameters on H*/B* distances will be quantified:
  - yield strength of the tubing
  - coefficient of thermal expansion (TEC) of the tubing and tubesheet
  - tubesheet hole diameter
  - tube outer diameter
- The values for TEC will vary by +/- 10% (ASME Code Accuracy).
- The uncertainty on yield strength will be based on WCAP-12522.
- Manufacturing drawings will be reviewed to determine maximum reasonable tolerances on tube and tubesheet geometry.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

3. The H* analyses in References 1 and 2 are based, in part, on pullout resistance associated directly with hydraulic expansion process. This pullout resistance was determined by subtracting out the effects of differential thermal expansion between the tube and tubesheet test collar from the measured pullout load. The calculated differential thermal expansion effect was based, in part, on an assumed TEC value of 7.42E-06 in/in/ºF for the 1018 steel tubesheet test collar. What is the impact of considering an alternative TEC value of 7E-06 in/in/ºF (from Matweb.com for 1018 steel interpolated at 600 degrees Fahrenheit) on the computed pullout force determined from the pullout test and on the computed H* distances?

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

The impact of reducing the value for TEC to 7E-06 in/in/°F on the tubesheet on the H*/B* distances will be evaluated for Wolf Creek.

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

4. Reference 2, Enclosure I, Response to RAI question 7 - The Model D5 steam generator (SG) pullout data in Table 2 indicate that pullout force increases with temperature for the 3-inch long specimens and decreases with temperature for the 6-inch long specimens. For the 4-inch specimens, pullout force increases with temperature to 400 °F and decreases with temperature beyond that point. Discuss the reasons for this apparent discrepancy in trends among the data. Discuss whether the reduction in tube yield strength with temperature might be sufficient for some specimens to limit any increase in contact pressure associated with differential thermal expansion between the tube and tubesheet.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

- The specimen number for test number 1 in table 2.0 is D5H-R3-1 not D5H-R5-1.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE

- There is no apparent discrepancy in the pullout force data; a trendline cannot be drawn through different specimens.
- As stated in the response to NRC RAI 8 in Enclosure 1 to WCNOC letter WO 07-0012, the data in Table 2.0 was intended to show that for an expansion length as short as 2.95 inches, a significant increase in pullout force occurs at elevated temperatures (e.g., for example, pullout force increases from 878 LBF to 3745 LBF when temperature increases from 70°F to 600°F, respectively).
- The impact of any reduction in tube yield strength due to temperature increase does not adversely affect pullout strength.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE NRC RAI

5. Following up on question 4 above, is there a possibility that any tubes could be stressed beyond the compressive yield strength (at temperature) of the tube material due to differential thermal expansion, internal pressure, and tubesheet hole dilation for the range of yield strengths in the field? Describe the basis for either yes or no to this question. If yes, how has this been factored into the contact pressures, accumulated pullout resistance load as a function of elevation, and H* in Tables 7-6 through 7-10 and 7-6a through 7-10a of Reference 2, Enclosure I?

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- It is anticipated that no tubes will be stressed beyond the compressive yield strength of the tubing.
- A simplified stress analysis will be completed.
  - The Tresca criterion (Maximum Shear Stress) will be used to predict compressive yielding
  - Preliminary results indicate that a tube with the largest applied contact pressures plus the end cap load has a factor of safety of <u>**1.3**</u> with respect to compressive yield.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

6. Reference 2, Enclosure I, Response to RAI question 17 - The response states near the bottom of page 30 of 84 that Case 1 results shown in Table 3.0 are for the limiting cold leg analysis and reflect the following assumption: "Although the pullout test data indicated positive residual mechanical joint strength, the residual joint strength is ignored for SLB [steam line break] accident condition[s] to conservatively account for postulated variability of the coefficient of thermal expansion." The NRC staff notes, however, that the limiting H* value shown in Table 3.0 for Case 1 is that necessary to resist three times the normal operating pressure end cap load, not that needed to resist 1.4 times SLB. It is the staff's understanding based on review of Tables 7-6 through 7-10 and 7-6a through 7-10a that the residual mechanical joint

Westinghouse

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI (Cont.)

strength (522 lb/inch) was reflected in the H* computations for normal operating and accident conditions, including SLB. Discuss and clarify these apparent discrepancies.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The NRC Staff's understanding is not correct. The residual mechanical joint strength was not included in the H* computations for both normal operating and accident conditions.
- The result of the analysis shows that the NOP case is limiting despite the elimination of the residual joint strength for the SLB case.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

7. Reference 2, Enclosure I, Table 7-6 - This table states that the required pullout force is 1680 lb. Table 7-6 indicates that for a tubesheet radius of 12 inches the needed depth of engagement is less than 10.52 (about 10.2 using linear interpolation). However, the table states that an engagement depth slightly greater than 10.52 (i.e., 10.54) is needed. Discuss and explain this apparent (minor) discrepancy.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- A visual basic routine is used in a spreadsheet to calculate the H* distances provided.
- The visual basic routine determines the H* value by summing the forces until the external load is equilibrated.
- The visual basic routine solves for the H* distance incrementally.
- The H* distance is found by interpolating the axial force to its zero location.
- The minor difference in H* distance from the simple interpolation of the data provided in Table 7.~~0~~6 is more likely than not due to increment size.
- The increment size is reduced when the solution is near.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

8. Reference 1, Enclosure I, Table 6-4 - The listed F/L values are based on allowing 0.25 inch slippage. Reference 1 does not address the potential for limited, but progressive incremental slippage under heatup/cooldown and other operational load cycles. Nor does Reference 1 address the effects of slippage on normal operating leakage and on accident-induced leakage or the ratio of normal operating and accident induced leakage. The response to RAI question 5 in Reference 2, Enclosure I, does not provide any further insight into this issue. That response specifically addressed test results for tubes with a hard roll expansion, and the staff believes that the slippage versus axial load characteristics for such an expansion may be entirely different than for a hydraulic expansion. Discuss and address the potential for progressive incremental slippage under

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI (Cont.)

heatup/cooldown and other operational load cycles. In addition, address the potential for slippage under operational and accident conditions to affect the ratio of accident-induced leakage to operational leakage.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- Based on previous testing, Westinghouse has concluded that there is no need for cyclic testing of all types of full depth expansion processes which close the gap between the tube and the tubesheet to virtually zero.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The potential for incremental slippage under heatup/cooldown and operational load cycles will be reviewed.

- The potential for incremental slippage under operational and accident conditions and the impact on the ratio of accident induced leakage to operational leakage will be reviewed.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF NRC RAI

9. Discuss your plans for revising the proposed technical specification (TS) amendment to monitor the tube expansion transition locations relative to the top of the tubesheet to ensure that the tubes are not undergoing progressive, incremental slippage between inspections.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- Based on the expected response to RAI 8, no changes to the TSs are proposed.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE NRC RAI

10. Reference 1, Enclosure I, Section 7.1.4.2 - This section provides a brief discussion of SLB, feed line break (FLB), and loss-of-coolant accident (LOCA) in terms of which is the most limiting accident in terms of tube pullout potential. Expand this discussion to indicate whether SLB and FLB are the most limiting accidents among the universe of design basis accidents (or other faulted conditions in the design basis) in terms of tube pullout and accident-induced tube leakage.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The following accidents model primary to secondary leakage in the Wolf Creek B*:
  - Steam generator tube rupture
  - Locked rotor
  - Control rod ejection
  - Steam line break
- An evaluation of these transients will be conducted to determine the duration of time that the primary-to-secondary pressure differential exceeds the normal operating condition primary-to-secondary pressure differential.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- Using the primary-to-secondary pressure differential information, a comparison to tube pullout requirements and accident analysis primary-to-secondary leakage assumptions will be completed for each transient.

- A similar evaluation completed for another plant showed that the duration of time that the primary-to-secondary pressure differential exceeds the normal operating pressure differential for a locked rotor or control rod ejection event is about 10 seconds and that the SLB event remains the limiting accident.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF THE NRC RAI

11. Figure 11 of Reference 2, Enclosure I contains loss coefficient data for Model F SG tubing that was not included in Figure 6-6 of Reference 1, Enclosure 1. This data was for contact pressures ranging from about 1200 psi to about 2000 psi. Why was this data not included in Figure 6-6? Discuss if this is this because of low expansion pressures and if the data that is not included in Figure 6-6 room temperature data. [If yes, then the NRC staff observes that the room temperature loss coefficients for the Model F specimens are relatively invariant with contact pressure above a contact pressure threshold of around 700 psi. The 600 degree F data is also invariant with contact pressure. Thus, loss coefficient may not be a direct function of contact pressure once a threshold degree of contact pressure is established. The difference in loss coefficient data between the 600°F data and the room temperature may be due to parameter(s) other than contact pressure. This other parameter(s) may not be directly considered in the B* analysis.]

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The reasons for not including the data are discussed in the response to NRC RAI 11 from Enclosure I to WCNOC letter WO 07-0012.

- These new data include:

  - Test results from the Model F specimens that were not prepared in accordance with criteria of the test specifications (i.e., low expansion pressures).

  - Test results from Model D5 specimens that resulted in no leakage.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The data that was added includes both room temperature data and elevated temperature data.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF THE RAI

12. Figure 13 of Reference 2, Enclosure I contains additional loss coefficient data from previous leak test results not from the crevice pressure study in the white paper. Provide a figure showing all individual data points from which Figure 13 was developed. Describe the specific applied pressure differentials from the crevice pressure study used to calculate the contact pressure for each data point.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

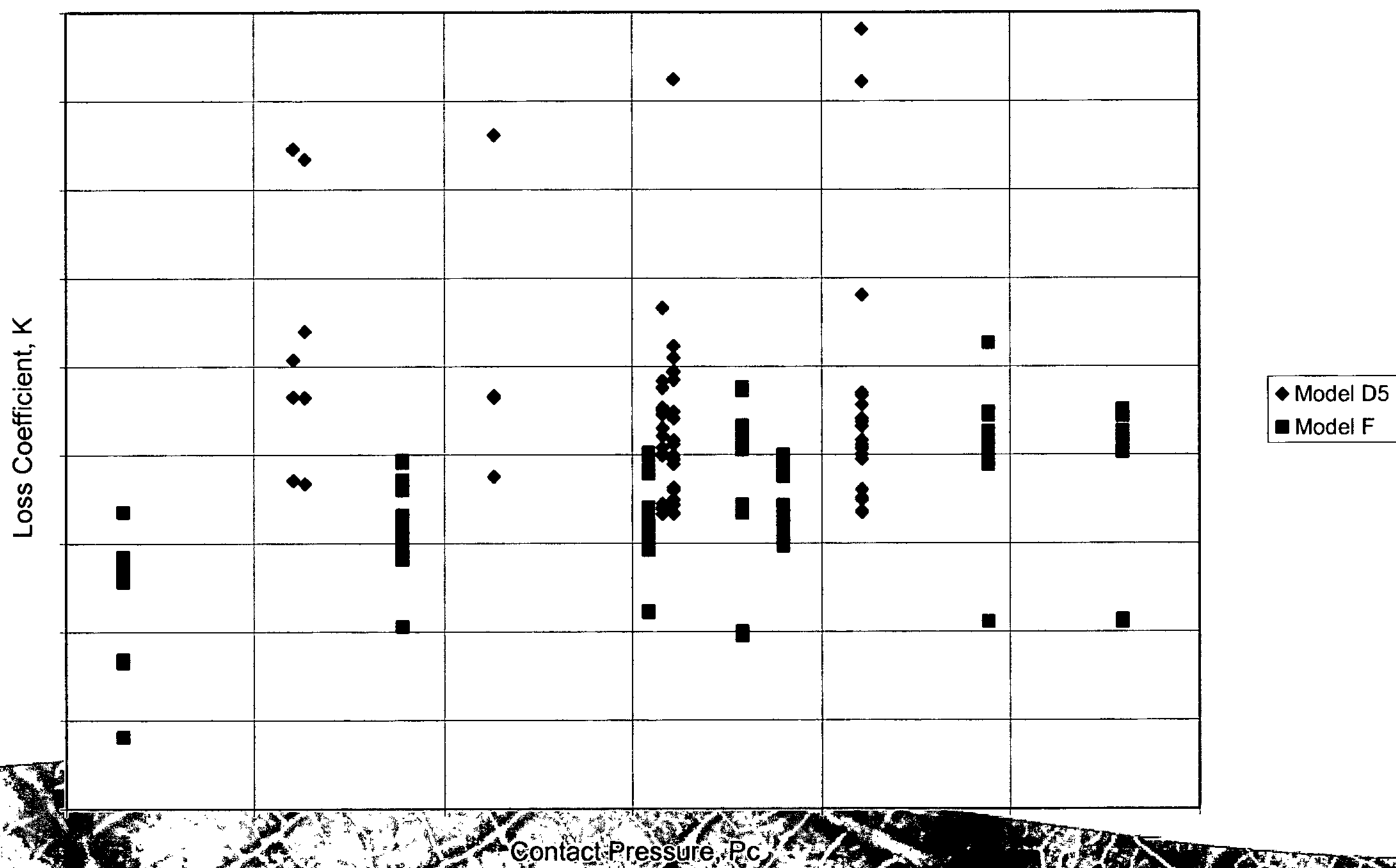
None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The data supporting Figure 13 is provided below:

Loss Coefficient versus Contact Pressure (Combined Model F and Model D5)



Westinghouse

Wolf Creek H*/B* NRC RAI Responses (Cont.)

- The pressure differentials used to calculate the contact pressures for each data point are listed in the following table:

TYPE OF SG	PRIMARY SIDE TEST PRESSURE (PSI)	TEST TEMPERATURE (°F)	contact PRESSURE (PSI)	CREVICE PRESSURE DIFFERENTIAL (PSI)
MODEL D	1450	70	634	1123
MODEL D	1885	70	603	1535
MODEL D	2835	70	1130	2641
MODEL D	1450	600	1610	1123
MODEL D	1885	600	1580	1535
MODEL D	2835	600	2110	2641
MODEL F	1000	70	153	503
MODEL F	1900	70	889	1556
MODEL F	2650	70	1544	2469
MODEL F	3100	70	1899	2985
MODEL F	1900	600	1792	1556
MODEL F	2650	600	2444	2469
MODEL F	3110	600	2799	2985

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

13. Although the means of the regression fits of the loss coefficient data for the Model F and Model D SGs are shown in Figure 13 of Reference 2, Enclosure I, to be within a factor of three of each other, the slope and intercept properties remain highly divergent, seeming to cast further doubt that loss coefficient varies with contact pressure (above some threshold value of contact pressure). Discuss this and describe any statistical test that have been performed to establish the significance of correlation between loss coefficient and contact pressure. In addition, describe any statistical tests that have been performed to confirm that it is appropriate to combine the data sets to establish the slope and intercept properties of loss coefficient versus contact pressure.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF
NONE

PLANNED RESPONSE

- No statistical tests were performed to see if the two data sets could be combined.
- The data for the Model F tests results in a reasonable correlation; the Model D data does not.
- The two data sets were combined; the combined linear regression model is more conservative than interpolating between the regression fits of either the Model D or Model F data.
- The high variability of the combined data set produces a 95% confidence interval fit that closely resembles the lower bounding limit of the entire data population.
- If no correlation is assumed to exist, the intercept for the log linear equation is the average value of the population and the slope of the log linear correlation is 0 (per EPRI Report TR-107621-R1).

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

14. Reference 2, Enclosure I, page 25 of 84 - For the case of assumed zero slope of loss coefficient versus contact pressure, two constant loss coefficient values were compared. Does the first assumed value come from Figure 14? If not, provide additional information on where this assumption comes from. If yes, explain the relationship between the assumed value and Figure 14. Does the second assumed value come from Figure 12? If not, provide additional information on where this assumption comes from. If yes, explain the relationship between the assumed value and Figure 12.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The first assumed value for zero slope loss coefficient comes from the lowest value from the Model D curve from Figure 14.
- The second assumed value for zero slope loss coefficient does not come from Figure 12.
- The second assumed value for zero slope represents the mean of all of the data points included in Figure 11 of Enclosure I to WCNOC letter WO 07-0012.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

15. Reference 2, Enclosure I, Figure 15 - clarify the title of Figure 15 in terms of whether it reflects consideration of residual mechanical strength in the joint during an SLB. Is Figure 15 for the hot or cold leg? Explain the following: (1) why the B* values at small tubesheet radii are less than those listed in Reference 1, Enclosure I, Table 11-1 and (2) why the contact pressures shown in Reference 1, Enclosure I, Figures 9-6 and 9-7 are different from those shown in Tables 7-6 and 7-8 of Reference 1, Enclosure I.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The results shown in Figure 15 **do include** the consideration of mechanical strength in the joint during SLB
- The results shown in Figure 16 **do not include** the residual strength of the joint during SLB
- The results shown in both Figure 15 and Figure 16 are for the cold leg
- The results shown in Figure 15 **are not used** in the current determination of B* and H* inspection distances and were provided only as a means of comparison to the results shown in Figure 16.
- The results shown in Figure 15 in Reference 2 and Figure 11-2 do not reflect the current level of technology nor the changes required to address recent RAI *(circa 2006-2007)*
- The B* and H* values at small tubesheet radii in Figure 15 are only slightly less than those listed in Table 11-1 for the cold leg. This is due to the correction of minor errors in the spreadsheet used to calculate the B* values.
- The contact pressures shown in Tables 7-6 and 7-8 of Enclosure I to WCNOC letter WO 07-0012 do not include the residual contact pressure due to hydraulic expansion

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

16. Reference 2, Enclosure I - Provide a description of the revised finite element model used to support the revised H* calculations in Tables 6-7 through 6-10 and Tables 6-7a through 6-10a. Compare this revised model to the original model which supported the Reference 1 analysis. Explain why the revised model is more realistic than the original model.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

The tables with the revised contact pressure in Reference 2, Enclosure I are 7-6 through 7-10 and 7-6a through 7-10a.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE

- There are two finite element models used to justify the contact pressure calculations for H* and B*.
  - The first, original, finite element analysis is an axisymmetric model, as shown in Enclosure I to ET 06-0004, and calculates the radial deflection of the tubesheet under unit load conditions as a function of the tubesheet elevation and radius.
  - The second finite element model is a three-dimensional solid model that calculates the vertical deflection of the tubesheet as a function of tubesheet radius for various load cases assuming different stiffnesses and/or cracking in the divider plate. The output from the second finite element model was used to check the results from the first and also defines the divider plate factor.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The original finite element model used to calculate the tubesheet deflection was not revised as it does not model the divider plate in the lower SG complex.

- The second finite element model used to determine the divider plate factor used in the H*/B* analysis was revised.

- The divider plate factor was conservatively chosen as 1.00 for the development of Tables 7-6 through 7-10 and 7-6a through 7-10a.

  - A divider plate factor of 1.00 means that no structural credit is taken for the presence of the divider plate.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

17. Reference 2, Enclosure 1, Attachment 1 (The Westinghouse Letter Summary of Changes to B* and H*), page 14 - address the status of the divider plate evaluation being performed under EPRI sponsorship, and the schedule for completion of the various topics being addressed in the evaluation. Describe any inspections that have been performed domestically that provide insight on whether the extent and severity of divider plate cracks is bounded by the foreign experience. Discuss the available options for inspecting the divider plates.

18. Discuss how the ability of the divider plates at Wolf Creek to resist tubesheet deflection (without failure) under operating and accident loads is assured in the short term, pending completion of the EPRI evaluation. Include in this discussion the actions that are planned in the near term to ensure that the divider plates are capable of resisting tubesheet deflection.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The B* and H* inspection depths reported in WCNOC letter WO 07-0012 **do not take any credit for the presence of a divider plate**. This is reflected in the analysis via the divider plate factor which is set to 1.00 such that no displacements are scaled in the calculation of the contact pressure. The divider plate is not required to restrict any deflections of the tubesheet in the Wolf Creek steam generators to support the B*/H* alternate repair criteria. Please see the response to RAI 17 and RAI 25 in Enclosure I to WCNOC letter WO 07-0012.

Westinghouse

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The status of the EPRI program is not related to the current B*/H* analysis and any results from the EPRI program will have no impact on future B*/H* analyses that do not take credit for the presence of a divider plate. In the event that a divider plate inspection revealed that the divider plate was 100% degraded, the result would be to use a divider plate factor of 1.00. The analysis provided to the Staff in Enclosure I of WCNOC letter WO 07-0012 already uses a divider plate factor of 1.00 in the final results. **Therefore, divider plate inspections are not necessary to support a B*/H* criteria for the Wolf Creek steam generators.**

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

19. Reference 2, Enclosure 1, Attachment 1 - Provide a description of the Crevice Pressure Test. This description should address, but not necessarily be limited to the following:

    a. Description of test specimens, including sketches.
    b. Description of "pre-treatments" of test specimens (hydraulic expansion pressure, heat relief, etc.).
    c. Description of test setup, including sketches.
    d. Description of test procedure.
    e. What were the secondary side temperatures in Tables 1 and 2 corresponding to the listed secondary side pressures and how were the secondary side pressure and temperatures controlled and monitored?

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI (Cont.)

f. How long did each test run and how stable were the pressure readings at each of the pressure taps during the course of each test?
g. What was the temperature of (1) the coolant in the crevice and (2) the tube and tubesheet collar as a function of elevation?
h. How were the temperature distributions for item g determined? Were direct temperature measurements of the tubesheet collar performed as a function of elevation?

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

A copy of the test report will be made available for viewing by the NRC Staff in the Westinghouse offices or in the RAI response.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

20. Reference 2, Enclosure 1, Attachment 1 - The pressure tap locations in Figure 2 are different from those shown in Figure 3. Discuss and explain this difference or provide corrected figures.

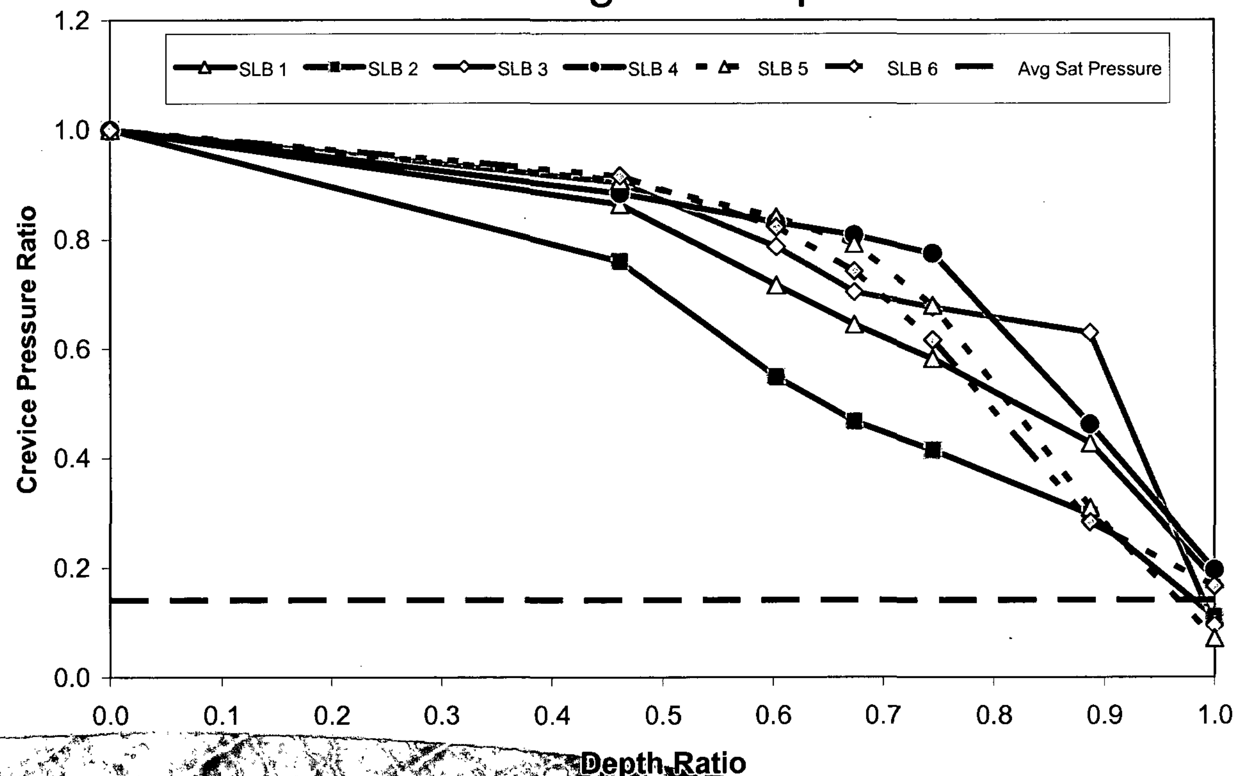
REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The ordinate values, the horizontal axis, in Figure 2 of the White Paper are correct. The ordinate values used in the original Figure 3 were incorrect. The revised version of Figure 3 is provided below.



Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

21. Reference 2, Enclosure 1, Attachment 1 - Figures 2 and 3 assume crevice pressure at the top of tubesheet is at the saturation pressure for the primary system. Discuss and explain the basis for this assumption. Why wouldn't the crevice pressure trend to the secondary side pressure near the top of the tubesheet?

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- Figures 2 and 3 show only the average, or mean, saturation pressure for all of the test results plotted.
- The saturation pressures come from measured test data and are not assumptions. The results are presented in Tables 1 and 2.
- The pressure does approach the secondary side pressure near the very top of the specimen (within less than 1 inch from the top) in both the SLB and NOP cases, as shown in Tables 1 and 2 in the White Paper.
- The reasons why the crevice pressures at the upper elevations in the specimen are not equal to the secondary side pressure will be discussed and clarified.

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

22. Reference 2, Enclosure 1, Attachment 1 - Figure 3 refers to tests labeled SLB 9 and SLB 10 which are not listed in Table 2. Discuss and explain this, or provide a revised Table 2 and Figure 3 showing all test results.

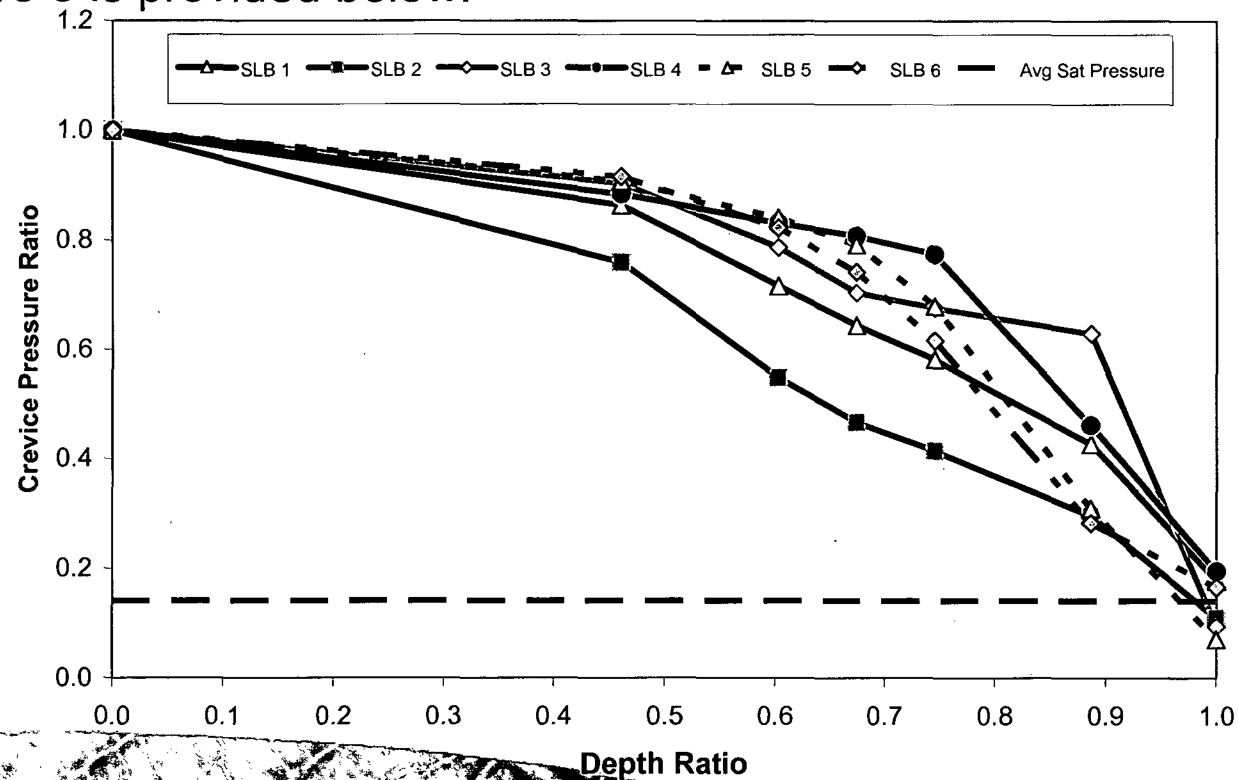
REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- The White Paper will be revised to correct any typos in the text or figures.
- The data in Table 2 is correct.
- A revised Figure 3 is provided below.



Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

23. Reference 2, Enclosure 1, Attachment 1 - Page 6 states in part that the following change should be made to the H*/B* analyses: "The driving head of the leaked fluid has been reduced." Discuss and clarify this sentence. The staff notes that resistance to leakage occurs from two sources: resistance from the flaw and resistance from the crevice. Because the crevice pressure was assumed to be equal to the secondary pressure, the original analysis assumed the entire pressure drop (the driving head) was across the flaw. The tests described in the white paper eliminate any pressure across the flaw (by using holes rather than cracks) and force the entire pressure drop to occur along the crevice. Thus, there is no net change in the total driving head between the primary and secondary sides. In fact, the driving head from the bottom to the top of the crevice would seem to have been increased.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The statements in the White Paper will be clarified and further explained.
- The test results indicate the crevice pressure distribution is distinct and different from the primary or secondary side pressures.
  - The driving potential on the fluid from the primary side to the crevice has been reduced.
  - The driving potential from the crevice to the secondary side is increased at the lower tubesheet elevations and decreased at the upper tubesheet elevations.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The limiting crevice pressure ratio determined using the approach described in the White Paper conservatively accounts for any changes in driving potential and limits the leakage resistance in the crevice too.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

24. Reference 2, Enclosure 1, Attachment 1 - The top paragraph on page 10 states, in part, "the median value of the crevice pressure ratios provides a conservative value that is an average representation of the behavior at the top of the tubesheet. The median is typically a better statistical representation of the data than the mean because the median is not influenced by a smaller data set but by the total range in values in the sample set." The staff has the following questions regarding these sentences:

    a. Discuss and clarify what data set "median value" applies to. For example, does the "median value" for the NOP data set in Table 1 mean the median value of the 15 pressure tap data points obtained during three tests, or does it mean a median value of a subset of these 15 data points? If a subset, what subset and why? Alternatively, does it mean the median value at each pressure tap location?

Westinghouse

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI (Cont.)

b. Discuss why this median value is a conservative representation of the behavior at the top of the tubesheet.

c. Discuss what is meant by "top of the tubesheet." For 17-inch inspection zone amendments, shouldn't this mean the upper 17-inches to ensure a conservative analysis? If not, why not? To ensure a conservative analysis for H* and B*, should not the objective be to establish crevice pressure as a function of elevation that can be directly applied into the H* and B* computations.

d. Discuss why the median is not influenced by a smaller data set and how the median is influenced by the total range of values in the sample set.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE

- ***The objective for incorporating the crevice pressure results into the B* and H* models was to obtain the largest penalty for both the leakage resistance (maximize the B* depth) and the resistance to pullout (maximize the H* depth) assuming a 360° sever in a tube and 100% degradation of the tube material below the sever.***

- The choice of crevice pressure model affects the structural calculations for H*.

- The median crevice pressure approach is ***more conservative*** than modeling the crevice pressure as a function of tubesheet depth because it ***reduces the contact pressure between the tube and the tubesheet along the entire length of the crevice***.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The "median value" with respect to the limiting crevice pressure ratio reported in the White Paper is the median value of the sorted data set of all test specimens including only the last two pressure readings after the outliers identified by the Dixon ratio test have been removed from the set. A detailed explanation of how this data set is created will be provided.

- The median value approach described in the White Paper is a conservative representation of the behavior at the top of the tubesheet because it captures the significant difference between the NOP and SLB conditions and it provides the **maximum penalty on the H*/B* distances throughout the tubesheet**.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The term “top of the tubesheet” refers to the top of the expanded portion of the test specimen. The test data was applied to a full depth tubesheet crevice using the three model approaches described in the White Paper. The most conservative model was chosen.
- As discussed in the response to RAI 10, in Enclosure I to WCNOC letter WO 07-0012, it is not as conservative to consider the entire crevice pressure distribution as opposed to the median value of the crevice pressures calculated at the top of the tubesheet.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The following example describes the calculation of the mean and the median using representative SLB data assuming the first crevice pressure model described in the White Paper.

x1	0.6297	0.6297	0.6297
x2	0.4617	0.4617	0.4617
x3	0.4278	0.4278	0.4278
x4	0.3095	0.3095	0.3095
x5	0.2969	0.2969	0.2969
x6	0.2828	0.2828	0.2828
x7	0.1957	0.1957	**0.1957**
x8	0.1786	0.1786	**0.1786**
x9	0.1663	0.1663	**0.1663**
x10	0.1103	**0.1103**	**0.1103**
x11	0.0945	**0.0945**	**0.0945**
x12	0.0711	**0.0711**	**0.0711**
MEDIAN	0.2393	0.2969	0.3687
MEAN	0.2687	0.3277	0.4014

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- Repeating the procedure gives the results shown in the White Paper as Table 5.

		Model 1		Model 2		Model 3	
Outliers?	Statistic	NOP	SLB	NOP	SLB	NOP	SLB
Total Set	Average	0.7093	0.6206	0.7093	0.5605	0.6804	0.5442
Total Set	Median	0.7112	0.6918	0.7112	0.6371	0.7112	0.6371
Included	Average	0.6327	0.2687	0.6327	0.1379	0.5169	0.0725
Included	Median	0.6977	0.2392	0.6977	0.1383	0.4955	0.0410
Excluded	Average	0.6327	0.4014	0.6327	0.1379	0.5999	0.0725
Excluded	Median	0.6977	0.3686	0.6977	0.1383	0.5994	0.0410

•This approach results in the most limiting case for both B* and H* by using the crevice pressure ratios determined by Model 1 excluding the outliers for both NOP and SLB conditions.

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

25. Reference 2, Enclosure 1, Attachment 1 - Provide a copy of Reference 3. The cited web page appears to be no longer available. Also, provide copy of Reference 4.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The academic web link given in the White Paper was moved. A PDF version of the current website, with the same material, will be provided to the Staff for their review.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The bibliographic information provided in the references listing of the White Paper is sufficient for purchase of the paper from any of the academic journal archives. WCNOC will provide the copyrighted information.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

26. Reference 2, Enclosure 1, Attachment 1 - What were the specific data sets used to compute the Dixon Ratio values at the top of page 11?

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- A sample data set will be analyzed, step-by-step, to illustrate how the Dixon Ratio values were obtained.
- The data sets used to calculate the Dixon Ratio values at the top of page 11 will be highlighted.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

27. Reference 2, Enclosure 1, Attachment 1 - In Table 5 under the heading of outliers, rows 1 and 2 refer to “total set,” whereas lines 3 and 4 refer to “included.” Does “included” mean the same thing as “total set.” If not, how does it differ from ”total set,” and how does it differ from “excluded?”

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The terms used to describe the results in Table 5 are noted on Page 16 of the White Paper.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- These are: 1) the mean of the entire data set, 2) the median of the entire data set, 3) a skewed mean and median, and 4) a skewed mean and median with potential data outliers removed.
- The description "total set" refers to calculating the limiting crevice pressure ratio using the entire set of crevice pressure ratio data (from the bottom of the tubesheet to the top of the tubesheet). This title refers to items 1 and 2 above.
  - The description "included" refers to calculating the limiting crevice pressure ratio using the entire set of data from the last two data points nearest the top of the tubesheet. None of the outliers that could potentially skew the limiting crevice pressure result to a lower, and less conservative value, are eliminated from consideration. This title refers to item 3 above.

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The description "excluded" refers to calculating the limiting crevice pressure ratio using the set of data from the top of the tubesheet, in the same fashion as the "included" data set, but with any potential outliers removed to obtain the most conservative result. The outliers are determined using Dixon's ratio test. This title refers to item 4 above.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

28. Reference 2, Enclosure 1, Attachment 1 - Provide a step-by-step description (including an example) of how the values in Table 5 were obtained.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The method for calculating the results in Table 5 is contained in Appendix A of Enclosure I to WCNOC letter WO 07-0012.
- A more detailed example of how the values in Table 5 were calculated will be provided.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

RESTATEMENT OF RAI

29. Reference 2, Enclosure 1, Attachment 1 - Confirm that the "unaltered" case in Table 5 reflects the use of the improved tubesheet/divider plate model with a "divider plate factor" of 0.399.

REQUEST FOR CLARIFICATION NEEDED FROM NRC STAFF

None

PLANNED RESPONSE

- The unaltered case is listed in Table 6, which compares the various B* and H* depths.
- The results in Table 6 reflect the crevice pressure results in Table 5.

Wolf Creek H*/B* NRC RAI Responses (Cont.)

PLANNED RESPONSE (Cont.)

- The divider plate factor, and the divider plate, does not influence the results given in Table 5.

- As stated on Page 16 of the White Paper (Appendix A of Enclosure I to WCNOC letter WO 07-0012 the "Unaltered" case listed in Table 6 uses a divider plate factor of 0.399.

Wolf Creek H*/B*
NRC RAI Responses (Cont)

RESTATEMENT OF RAI

30. Reference 2, Attachment II - Proposed TS 5.5.9.c states that, "The following alternate tube repair criteria may be applied as an alternative to the 40% depth-based criteria." This appears to mean that you are proposing that the implementation of the alternate tube repair criterion is optional. It is the NRC staff's position that the word "may" should not be "shall." Discuss and explain your proposed use of the word "may." Alternatively, the proposed inspection exclusion zone in TS 5.5.9.d could be revised to make the exclusion conditional on implementation of the alternate repair criterion in TS 5.5.9.c.1.

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

Wolf Creek H*/B*
NRC RAI Responses (Cont)

PLANNED RESPONSE

- No changes were proposed to the sentence specified in the RAI
- Wording is consistent with wording in NUREG-1431, Rev. 3.1, Westinghouse Standard TSs
- Wording is based on NRC approved TSTF-449, Rev. 4
- TS 5.5.9d. acceptable as is based on wording for satisfying the applicable tube repair criteria
- No changes proposed

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont)

c. Provisions for SG tube repair criteria. Tubes found by inservice inspection to contain flaws with a depth equal to or exceeding 40% of the nominal tube wall thickness shall be plugged.

The following alternate tube repair criteria may be applied as an alternative to the 40% depth-based criteria: the depth identified in the below tables

1. For Refueling Outage 15 and the subsequent operating cycle, degradation found in the portion of the tube below 17 inches from the top of the hot leg tubesheet does not require plugging. All tubes with degradation identified in the portion of tube within the region from the top of the hot leg tubesheet to 17 inches below the top of the tubesheet shall be removed from service.

INSERT 5.0-12

For tubes fully expanded into the tubesheet,

d. Provisions for SG tube inspections. Periodic SG tube inspections shall be performed. The number and portions of the tubes inspected and methods of inspection shall be performed with the objective of detecting flaws of any type (e.g., volumetric flaws, axial and circumferential cracks) that may be present along the length of the tube, from the tube-to-tubesheet weld at the tube inlet to the tube-to-tubesheet weld at the tube outlet, and that may satisfy the applicable tube repair criteria. For Refueling Outage 15 and the subsequent operating cycle the portion of the tube below 17 inches from the top of the hot leg tubesheet is excluded. The tube-to-tubesheet weld is not part of the tube. In addition to meeting the requirements of d.1, d.2, and d.3 below, the inspection scope, inspection methods, and inspection intervals shall be such as to ensure that SG tube integrity is maintained until the next SG inspection. An assessment of degradation shall be performed to determine the type and location of flaws to which the tubes may be susceptible and, based on this assessment, to determine which inspection methods need to be employed and at what locations.

identified in c.1 above

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont)

RESTATEMENT OF RAI

31. Reference 2, Attachment II - The first sentence of proposed TS 5.5.9.c.1 states, "For tubes fully expanded into the tubesheet, degradation found in the portion of the tube below the depth identified in the below tables from the top of the tubesheet does not require plugging." Discuss your plans for revising this sentence to clarify what constitutes a fully expanded tube (e.g., through the use of a footnote) and for clarifying the rest of the sentence. For example, the word "degradation" should be replaced with "tubes with flaws." This is consistent with the rest of TS 5.5.9 which uses the word "flaws" rather than the word "degradation." In addition, it is tubes which are plugged, not flaws. As another example, it is believed that clarity can be gained by revising the sentence to state, "..., tubes with flaws located below the depths identified in the following tables ..."

Wolf Creek H*/B*
NRC RAI Responses (Cont)

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

PLANNED RESPONSE

- The use of "tubes fully expanded" was based on one tube in SG B (R11, C121) not being expanded into the hot leg tubesheet. This tube will be plugged in Refueling Outage 16. The wording in TS 5.5.9c.1 will be revised to: "Tubes with crack-like indications located below the depths identified in the following tables do not require plugging."

Wolf Creek H*/B* NRC RAI Responses (Cont)

PLANNED RESPONSE (cont)

- Degradation vs Flaw
  - Utilized wording that was previously approved in 2 “one-time” amendments
  - WCNOC proposes to use “crack-like indications” in lieu of “degradation” or “flaw” in TS 5.5.9c.1. Proposed wording:

    “Tubes with crack-like indications located below the depths identified in the following tables do not require plugging. All tubes with crack-like indications located within the region from the top of the tubesheet to the depth identified in the following tables shall be removed from service.”
- “below tables” vs “following tables” – preference of writer, will use “following tables”

Wolf Creek H*/B*
NRC RAI Responses (Cont)

RESTATEMENT OF RAI

32. Reference 2, Attachment II - The second sentence of proposed TS 5.5.9.c.1 states, "All tubes with degradation identified in the portion of tube within the region from the top of the tubesheet to the depth identified in the below tables shall be removed from service. Discuss and explain the proposed use of the word "degradation" instead of the word "flaws." The use of the word "flaws" is consistent with the rest of TS 5.5.9 which uses the word "flaws" rather than the word "degradation." In addition, the NRC staff suggests the licensee may wish to consider replacing the words "below tables" with "following tables."

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont)

PLANNED RESPONSE

- RAI is essentially the same as RAI 31
  - "flaw" vs "degradation" is discussed in RAI 31
  - "below tables" vs "following tables" is discussed in RAI 31

Wolf Creek H*/B* NRC RAI Responses (Cont)

RESTATEMENT OF RAI

33. Reference 2, Attachment II - The proposed revision to TS 5.5.9.d includes the following sentence, "For tubes fully expanded into the tubesheet, the portion of the tube below the top of the tubesheet identified in C.1 above is excluded." This sentence is confusing as to what is intended by the sentence. Discuss and clarify this sentence is intended to mean. For example, the sentence could be clarified by stating, "...the portion of the tube below the inspection depths from the top of the tubesheet identified in C.1 above is excluded."

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

Wolf Creek H*/B*
NRC RAI Responses (Cont)

PLANNED RESPONSE

- TS 5.5.9d. provides the requirements for SG tube inspections. This Specification requires that the entire length of the tube in the tubesheet be inspected using a qualified probe to detect axial and circumferential cracks. The intent of the subject sentence is to specify that a portion of the tube below the top of the tubesheet is not required to be inspected.
- Changes are proposed to the wording in 5.5.9.d
  - "The portion of the tube below the inspection depths from the top of the tubesheet identified in c.1 above is excluded."

Wolf Creek H*/B* NRC RAI Responses (Cont)

RESTATEMENT OF RAI

34. Reference 2, Attachment II - Proposed specification TS 5.6.10.h - Discuss and clarify the words “for each indication” in the phrase “for each service-induced indication within the thickness of the tubesheet.”

REQUEST FOR CLARIFICATION FROM NRC STAFF

- WCNOC proposed the following wording for TS 5.6.10h.:
  - “h. The number of indications and location, size, orientation, and whether initiated on primary or secondary side for each indication detected in the portion of the tube above the depths identified in the Tables in TS 5.5.9 c.1.;”
  - The phrase “for each service-induced indication within the thickness of the tubesheet.” was not proposed.

Wolf Creek H*/B*
NRC RAI Responses (Cont)

RESTATEMENT OF RAI

35. Reference 2, Attachment II - Proposed specification TS 5.6.10.j - Discuss and clarify the used of the words “is determined” in the second sentence. The NRC staff suggests that the words “is determined” in the second sentence should be replaced to read “was determined.”

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

Westinghouse

Wolf Creek H*/B*
NRC RAI Responses (Cont)

PLANNED RESPONSE

- The verb tense is incorrect
- Changes are proposed in the wording for TS 5.6.10j.
  - j. The calculated accident leakage rate from the portion of the tubes below the depths identified in the Tables in TS 5.5.9 c.1. for the most limiting accident in the most limiting SG. In addition, if the calculated accident leakage rate from the most limiting accident is less than 2 times the maximum primary to secondary LEAKAGE rate, the report should describe how it **was** determined."

Wolf Creek H*/B*
NRC RAI Responses (Cont)

RESTATEMENT OF RAI

36. (Revised) The proposed technical specification amendment would apply to both the hot and cold leg side; however, the NRC staff notes there have been no reported instances of cracks in the tubesheet region for plants with Alloy 600 thermally treated tubing and, thus, there seems to be little compelling reason to extend the applicability of the requested amendment to the cold leg side. Discuss and explain why the amendment request should apply to both the hot leg side and the cold leg side. It is the NRC staff's position that the amendment request should not apply to cold leg side.

REQUEST FOR CLARIFICATION FROM NRC STAFF

None

Wolf Creek H*/B* NRC RAI Responses (Cont)

PLANNED RESPONSE

- The analysis and justification was performed for both the hot leg and cold leg
- Since the technical basis exists for both the hot leg and cold leg, inclusion of the inspection depths would encompass any unforeseen future degradation in the cold leg
- Limits the inspection depth in the cold legs needed in the future

Questions/Conclusions

- Agreement on course of action
  - WCNOC expects responses to RAIs, as currently understood, to be submitted by 9/14/07
  - Based on information provided, is issuance of a license amendment by 2/08 achievable

Public Comments