Westinghouse Electric Company LLC LTR-CDME-08-2, Rev. 1 NP-Attachment, "Meeting Handouts from the December 13, 2007 Meeting with Wolf Creek and NRR on H*/B*"
NON-PROPRIETARY

LTR-CDME-08-2, Rev. 1 NP-Attachment

Wolf Creek Nuclear Operating Corporation

Meeting Handouts from the December 13, 2007 Meeting with Wolf Creek and NRR on H*/B*

January 11, 2008

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H* Calculation Process

Wolf Creek/NRC/Westinghouse Working Meeting
12/13/2007

H* Calculation Flow Chart

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Details of Analysis Models

- Review Westinghouse Analysis Tools
- NRC Present Review Analysis

Crevice Pressure Models

Depth Dependent Model
Compared to
Limiting Median Crevice Pressure

Discussion on Depth Dependent Crevice Pressure

- RAI questioned use of "limiting median" crevice pressure
  - This was debated at length by W and chosen as the most conservative approach in 2006
  - RAI recommended use of "depth dependent" crevice pressure as more conservative based on use of WCAP equations and crevice pressure test data
    - Crevice length based on H* (assumed)
    - Pullout forces based on results of tubesheet FEA analysis in WCAP
- H* WCAP FEA results were based on NOP conditions (pressure and temperature)

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- Consistent use of SLB condition yields significantly shorter H*

H* vs. Crevice Pressure Models

(circa January 2007-White Paper, Rev 0)

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Current Status- December 2007

- After review of NRC analysis
  - Resulted in 2-pass H* calculation using depth based crevice pressure
- Questioning attitude on all of our methods and inputs
- Recognition of different approach to crevice pressure application

H* vs. Crevice Pressure Models

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H* vs. Crevice Pressure Models

(September 2007)

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Discussion on Depth Dependent Crevice Pressure

- W performed calculations based on depth-based crevice pressure
  - First pass to calibrate H* is based on full tubesheet depth
  - Second pass is based on the H* from the first pass
- Depth Dependent Crevice Pressure is not the most conservative application for the entire tubesheet
  - Limiting median crevice pressure is more conservative for R_{ts}>30"
  - H* based on limiting median crevice pressure is expected to be the most conservative
    - Conservatisms identified in current review

Conservatisms

- Application of Crevice Pressure
  - Current analysis assumes total crevice pressure applied to both tube and tubesheet
  - Entire pressure is not transmitted to the tubesheet
    - Published paper (Goodier)
  - If pressure on TS is reduced, H* decreases significantly
- Poisson effects are ignored
  - Pressure on tube ID causes local Poisson expansion and increased resistance to pullout when axial force is applied
  - Axial differential thermal expansion between tube and tubesheet causes Poisson expansion of tube due to friction resistance between the tube and tubesheet and increases the axial resistance

Effect of Reduced Pressure and Poisson Effect on Tubesheet Hole

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Effect of Consistent Application of SLB Conditions on FEA TS Displacement

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H* Conclusion

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B* Discussion

- H* may not be limiting for all cases near center of TS
  - Due to consistent application of SLB conditions to FEA model
- No significant effect of contact pressure
  - Absence of correlation between loss coefficient and contact pressure has no effect
  - Analysis uses an essentially bounding correlation of loss coefficient to contact pressure (Ref. RAI 2 Response & July Meeting)

B* vs. H*

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Conclusion

- Recommended inspection profile (September 2007) is bounding
  - B* is limiting at TS center but not greater than maximum H* shown in Appendix C of RAI 2 response
  - H* is limiting at all other radii
  - Recommended H* (2007 –RAI 2 response) is most conservative
    - Bounds analysis using depth dependent crevice pressure assuming no tube below H*

H* Uncertainties

Example Monte Carlo

H* Calculation Flow Chart

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Integrated MC is not Possible

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Simulation for H*

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What is "H^*_{mean}"?

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Variability of H* in Individual Parameters

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H* - MC Results

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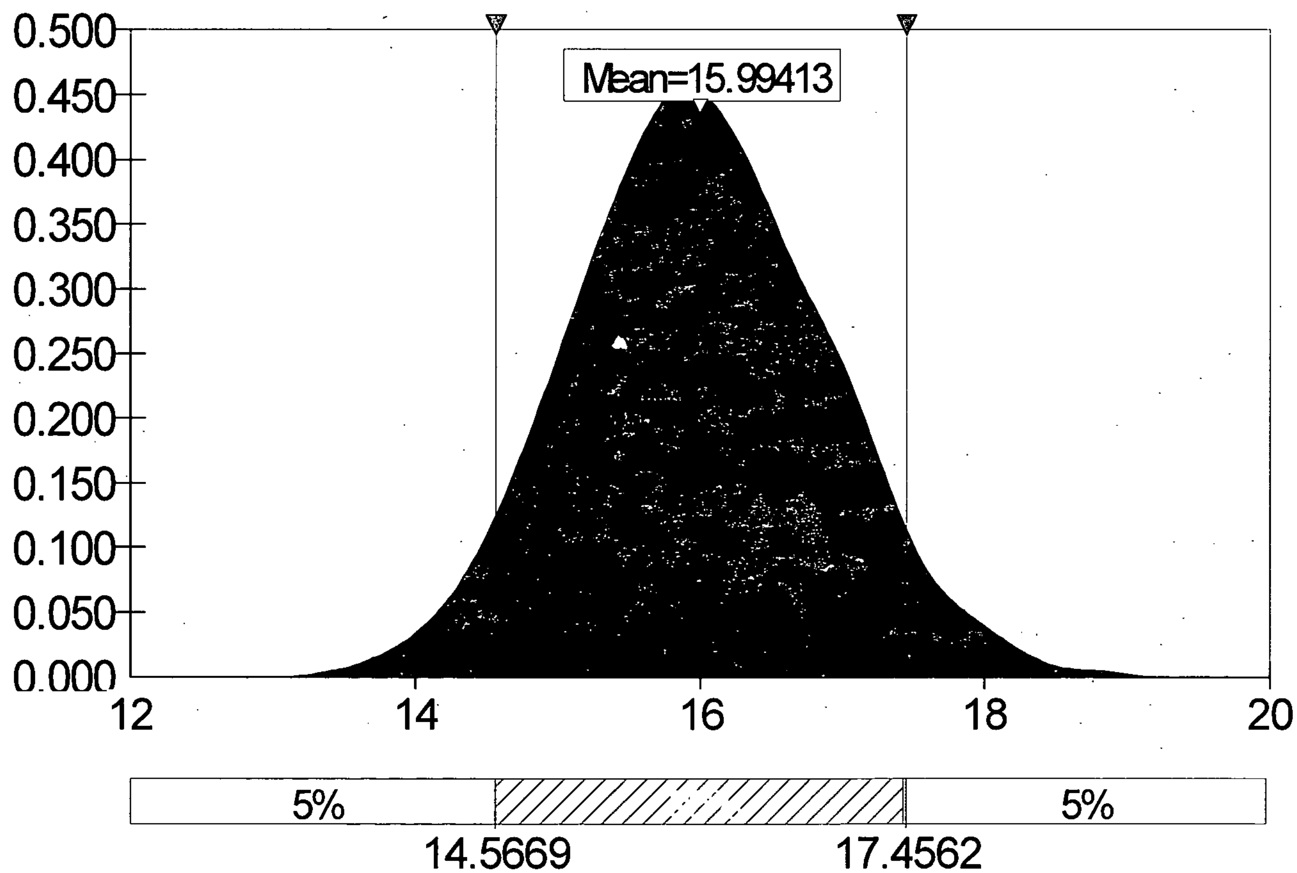
MC Results Based on Over-Conservative Crevice Pressure Model –

(Demonstration Purposes Only)



Discussion on Alpha

(a significant variable for H*)

- Issue
  - The Code provides values of alpha for different materials for design which are required for use for certified design
  - Other data indicates that alpha may vary from the Code value depending on specific tests (i.e. ANTER data)
- Conundrum
  - There are many design circumstances which would be more or less conservative if a non-Code value of alpha were used, e.g.,
    - Bolting loads
    - Tube loads in once-through SG
  - Does that mean all designs are potentially non-conservative?
- Conclusion for MC Analysis
  - Have to settle on a mean value of alpha but recognize that the value may vary
    - The code provides little guidance on variability
    - Individual test may provide basis of variability but may have questionable pedigree
  - Use the mean value with the greatest pedigree (ASME Code Value)
  - Use the variability defined by individual test (ANTER) data

Discussion on Residual Pullout Force

- Hydraulic Expansion process is controlled to achieve minimum expansion pressure
  - Tolerance is one-sided in greater expansion pressure direction
  - If minimum expansion pressure is not achieved, the tube is re-expanded to meet the required minimum pressure
  - It is possible for an entire expansion to be missed, but all tubes that were expanded achieved at least the minimum expansion pressure
- All tests that have been performed have demonstrated positive pullout force
  - Several different test programs
  - Tube "locks up" after very small translation in ideal test
  - Real SG conditions cause tube and tubesheet bending "that lock" up tube even at cold conditions (e.g., tube hole runout, misalignment)
    - Temperature and pressure multiply the lockup forces
  - Imperfections that cause tube cracking lock the tube in place (BLG/OXP)

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- Room temperature data is used to avoid correction for temperature effects
  - Uncertainty of α
- Variability depends on values of E_{TS}, E_t and Sy_t
  - This requires the dependent input calculations using the pullout test data

Other Conservatisms

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Detection of Tube Separation at H*

- The prerequisite for tube pullout is complete tube separation at, or below, H*
  - H* is defined as the point where the pullout forces are equilibrated
  - Independent confirmation that forces are not transmitted below H*
- Non-prototypic (but highly conservative with respect to H) test suggests that under ideal conditions a very small "slip" may occur
  - Extremely unlikely
- Assume 360 degree TW crack at H* or below
  - Preliminary mockup of two tubes butted together in a collar look like a tube-end signal to bobbin
  - ½ in. long 40%TW x0.005" wide EDM notch is clearly visible to bobbin in straight tube