H*- NRC/Expert Panel Update Review

NRC / Industry Meeting

July 17, 2008

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Progress Since May 14th Meeting

- In-depth EP meeting at Waltz Mill; 7/10/08
  - Focus on probabilistic approach
  - Begin review of analysis models and methods
- CTE tests in progress; partial data received
- 3-D TS deflection analysis is in progress
  - Validate 2-D FEA analysis used in H*
- Input variables interaction study started
- TS stiffness analysis started to validate TS stiffness with pressurized tubes

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NRC Technical Issues Considered in Preliminary Analysis (May 14, 2008)

- Material properties and their variability
  - Conservative values from EP for CTE
  - ANTER and PMIC data points resolution
- Independent structural analysis of tubesheet complex for each operating condition – NOP, SLB, FLB
- Residual contact pressure not resolved but addressed by parametric analyses (Interaction pressure assumed to be 311 psi or zero)

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NRC Technical Issues Not Addressed in Preliminary Analysis (May 14, 2008)

- Generally, those issues not addressed in the preliminary analysis are expected to decrease the value of H*
  - Refined analysis for tubesheet hole dilation
    - Addressed at 7/11/08 EP meeting
  - Residual contact pressure; new test program expected to validate RCP; value greater than zero reduces H* length.
- Probabilistic criteria resolution
  - Expert Panel review of full bundle probabilistic analysis
    - Addressed at 7/11/08 EP meeting
- Incremental slippage
  - Expert Panel review of need for monitoring program

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NRC Technical Issues Not Addressed in Preliminary Analysis (May 14, 2008)

- Crevice pressure distribution model
  - Distributed crevice pressure model adopted
- Leakage Analysis
  - Not a constraint on H*
  - Utilize IARC approach for permanent H* ARC
    - D'Arcy model for leakage through a porous medium
  - Request NRC feedback regarding source/method of 2.5 ratio of SLB/NOP leakage used in IARC

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Conclusions (May 14, 2008)

- Monte Carlo results show with high degree of confidence that H* exists for all tubes
  - 95/50 based on H* at worst-case tubesheet radius
  - All other radii have lesser H* values and are bounded by the worst case
- Structural model refinement expected to decrease H*
- Expect to demonstrate non-zero residual contact pressure; H* will decrease compared to RCP=0 analysis

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CTE Test Matrix

Material	Heats	Specimens per Heat	Tests per Specimen	Total Tests
SA508 Expected to be complete week of 7/21/2008	3	3	3	27
A600TT as delivered	3	3	3	27
A600 TT after hydraulic expansion in collar	3	3	3	27
All data expected to be complete mid-August; expanded tube tests are the limiting item All other materials at ANTER; expedited service provided				

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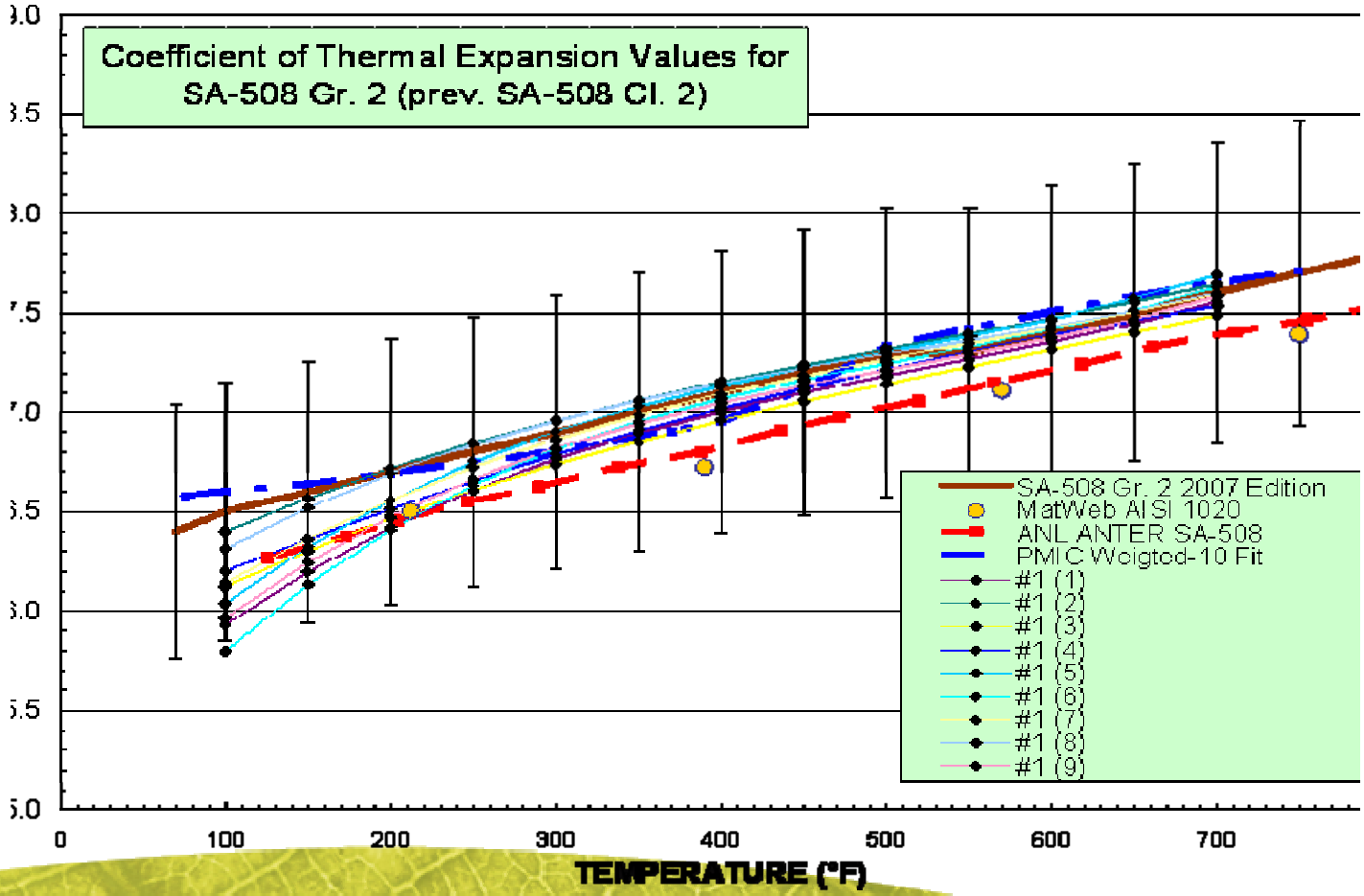
New CTE Data



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W/EP/NEI Meeting: 7/10,11/08 Agenda

- Input Variability
  - ANTER results
  - Are there other inputs that can be questioned?
- Probabilistic Analysis
  - Resolve position on burst-equivalence of H*
  - Resolve position on whole bundle criteria
  - Develop position on whole bundle probabilistic analysis
  - Approach/status/results on variables interaction study
- Structural Analysis
  - Tubesheet deflection analysis
  - Beta factor analysis
- Calculation Model for Residual Contact Pressure
  - How is test data converted to RCP
- Integration for H*-Spreadsheets
  - Details of how H* is determined (equations and spreadsheet implementation)
  - Basis for coefficient of friction

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Expert Panel Discussions on Criteria for Establishing H*

- Implementation of H* effectively redefines pressure boundary from tube-end weld to another location within the tubesheet.
  - Is this a burst problem?
  - Any Code precedent?
- EP proposed 2 options for probabilistic evaluation of H*: (Option A, Option B)

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Expert Panel Discussions on Criteria for Establishing H*

Option A: H* Based on Tube Integrity Performance Criteria

- Inner Row Tubes – Accident Leakage
  - Probability for Slippage of one or more tubes at Limiting Accident Condition is ≤ 5% (leakage requirement).
  - Pullout (burst) is not possible

- Periphery Tubes – Tube Pullout and Accident Leakage
  - Probability for Pullout of one or more tubes at SIPC Loadings ≤ 5% (burst requirement).
  - Probability for Slippage of one or more tubes at Limiting Accident Condition is ≤ 5% (leakage requirement).
- Note that if “no slip” requirement is applied for pullout, then leakage criterion is also satisfied.

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Expert Panel Discussions on Criteria for Establishing H*

- Consideration of Bundle Geometry for Option A
  - Inner Row Tubes (approximately inner 40 rows) – tube pullout distance will be limited (burst condition is prevented)
  - Periphery Tubes (outer 10-20 rows) – tube pull-out is unlikely but arguable as a bounding possibility

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Expert Panel Discussions on Criteria for Establishing H*

Option B: Alternate Criteria Based on DG-1074 ,GL 95-05 and EPRI 1012984*

- For inner and periphery tubes
  - Probability of pullout of one or more tubes under limiting accident conditions not to exceed 1×10^{-2}
  - Probability for accident induced leakage exceeding the leakage limit not to exceed 5%

- Note that if “no slip” requirement is applied for pullout, then leakage criterion is also satisfied.

*Technical Basis for SG Tube Integrity Performance Acceptance Standards

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Expert Panel Discussions on Criteria for Establishing H*

- Structural Integrity Performance Criteria (SIPC)
  - 3 NOPD
  - 1.4 LAPD
  - 1.2 Pm + 1.0 Axial Secondary Loads
- Leakage Integrity Performance Criteria (AILPC)
  - Accident Induced leakage not exceeding 1 gpm

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Performance Acceptance Criteria

- Fully probabilistic analysis of whole bundle used to define the “worst-case” degraded tube
  - IAGL Chapters 2 and 8 definition of “worst-case degraded tube”
- If the “worst-case” degraded tube meets SIPC with at least 95% probability, the full bundle meets SIPC with 0.95 probability
- AILPC satisfied with at least 95% probability

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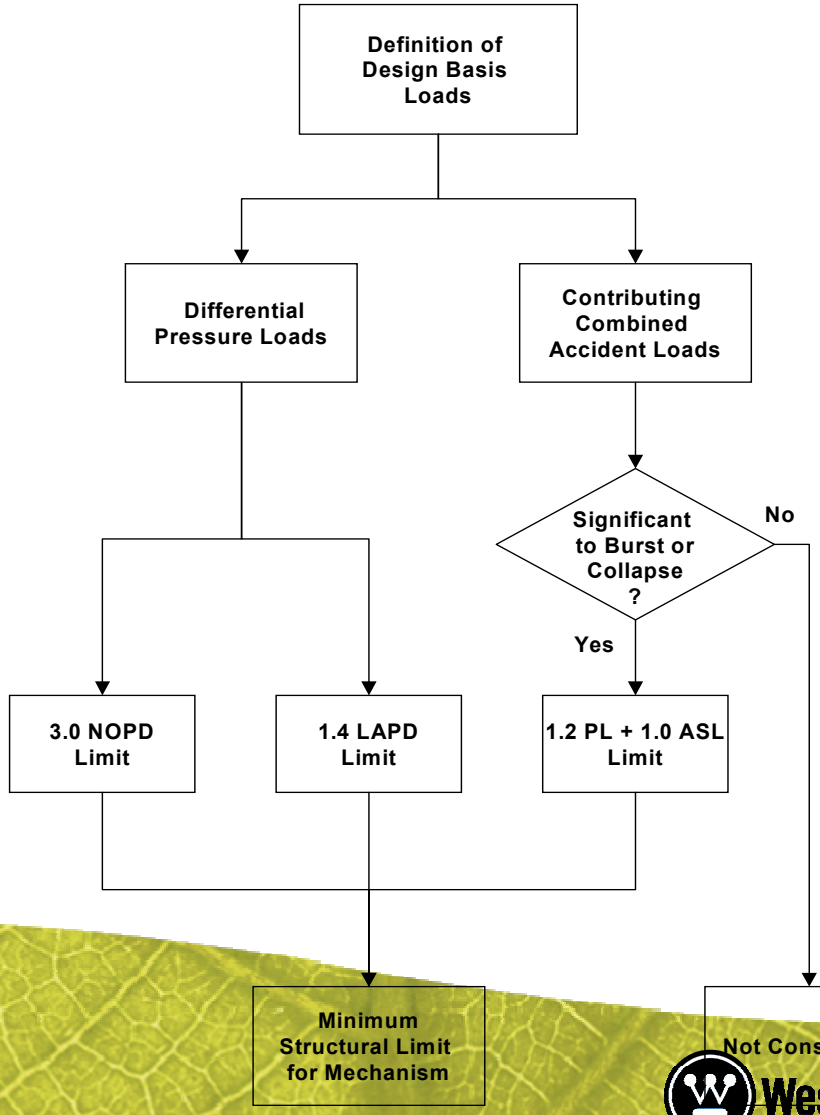
Expert Panel Discussions on Criteria for Establishing H*

Structural Limit to Satisfy SIPC Is Minimum Limit From Three Separate Assessments for Normal Operating and Accident Conditions



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Expert Panel Discussions on Criteria for Establishing H*

- Basis for No Burst at Inner Rows (Option A)
  - Travel distance before contact with adjacent neighboring tube is small
- High probability of tube integrity in outboard adjacent tube will be maintained by inspecting to a conservative H*.
  - Likelihood of significant circumferential degradation in uninspected length is low based on recent outage data
  - Preliminary analysis of full depth inspection data shows structurally significant crack is extremely unlikely
- Tube contact pressures with tubesheet in uninspected tube length are high and sufficient to carry tube axial force even absent tube end weld.
- Additional margin on H* can be included to account for tube contact loads.

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Refined Analysis of Tubesheet Hole Dilation

- Include effect of adjacent pressurized tubes directly in tubesheet FEA model
  - Validate TS stiffness using independent FEA model of TS sector
  - Consider TS edge and plugged tube effects
- No separate factor required to adjust crevice pressure

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Feedback Requested from NRC

- Position on CTE variability
  - P.J. King and P. Riccardella Analysis
- Viability of Option A
- Leakage Approach
  - IARC application of D'Arcy model
  - What is the technical basis of 2.5 factor?

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