NEI Steam Generator Task Force

Industry Update for NRC

February 25th, 2010

NUCLEAR
ENERGY
INSTITUTE

Agenda

8:30 am	Introductions	NRC
	Opening Remarks	NRC/Industry
	NEI Steam Generator Task Force Update	Industry
12:00 pm	Lunch	
1:00 pm	NEI Steam Generator Task Force Update (continued)	Industry
3:30 pm	NRC feedback on various issues (e.g., TSTF-510)	NRC
3:45 pm	Address Public Questions/ Comments	NRC/Industry
4:00 pm	Adjourn	

NEI Steam Generator Task Force Update on Technical Issues

1. Survey results for -2 sigma 600TT tubes with cracks
2. Interim Guidance or Information Letter to address/clarify certain issues
   - Condition Monitoring of tubes that cannot be inspected
   - Comparison of Condition Monitoring results with prior Operational Assessment
   - SG Program Updates
   - Validation of repair limits
   - Large leaks (e.g., due to a wear scar) vs. tube burst
   - Guidance for tubes with potentially elevated stress
3. Deposit Modeling Results (Cruas)
4. Vogtle Tube Pull Evaluation
5. Insights from Bugey 3 Operating Experience
6. Project Plans for Foreign Object (FO) Detection & FO Wear Detection/Sizing
7. NEI 97-06 Revision
8. Update/Closure of Divider Plate Cracking
9. Upcoming Changes to Industry Documents
10. Recent SG Operating Experience

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Survey results for -2 sigma 600TT tubes with cracks

Herm Lagally, Westinghouse

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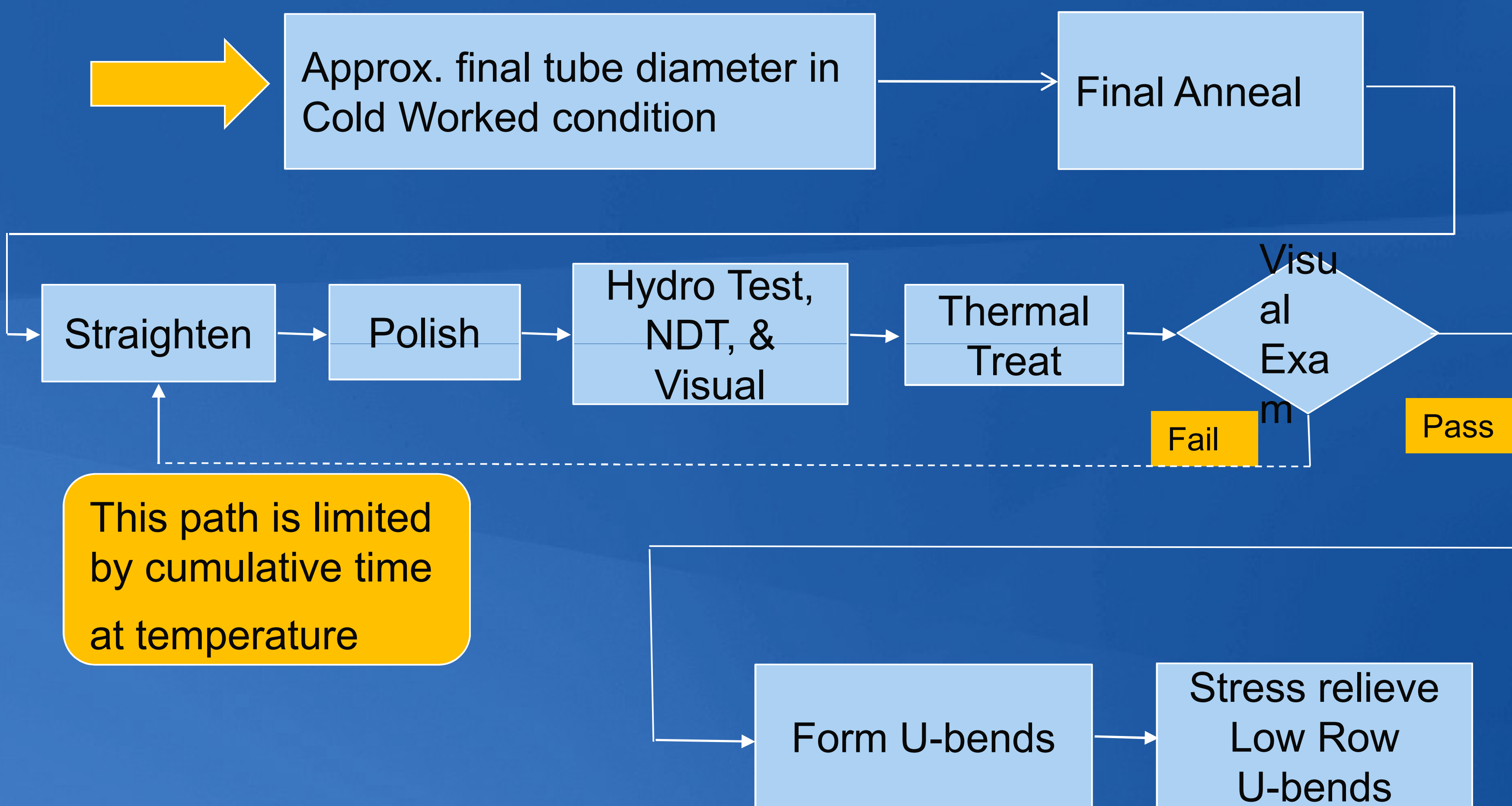
Blairsville Partial Manufacturing Flow Diagram



Background on Low Row

- **In Spring 2002, ODSCC at HL and CL TSP intersections identified**
  - Limited to a small number of tubes in short row tubes
  - All tubes with ODSCC exhibited a unique eddy current offset signal
  - Destructive examination of pulled tubes indicated an unexpected level of residual stress in the straight leg of the tubes
  - Root Cause Analysis suggested that the EC signal was related to variation in material condition most likely related to manufacturing sequence
    - Possible inadequate final stress relief or cold working after stress relief prior to bending

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Low Row Screen

- If final thermal treat is inadequate or tube is cold worked after final thermal treatment the entire length of the tube may exhibit residual stress
- After forming, the short-row u-bends are thermally treated
  - Thermal treatment includes a short section of the straight legs
  - The U-bends are essentially stress free
  - The straight legs still exhibit the residual stress (cold worked material condition)
- Results in a characteristic bobbin signal
  - Eddy current probe does NOT measure stress
  - Eddy current responds to a change in the material condition (strained vs. non-strained)

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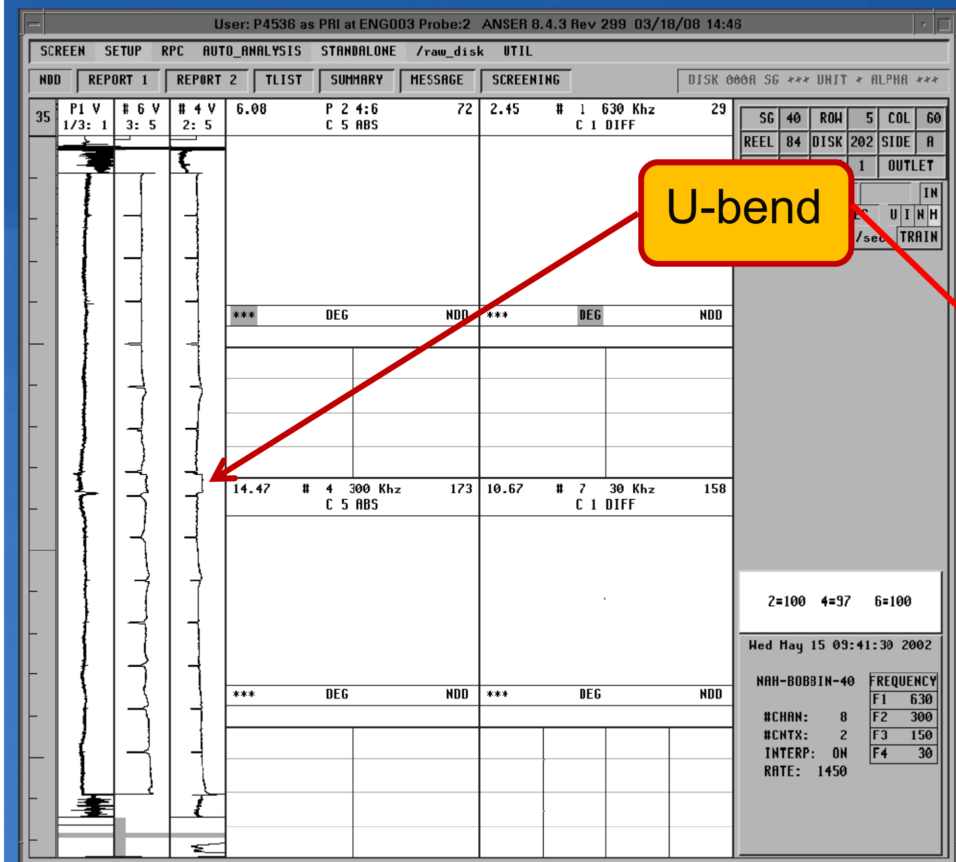
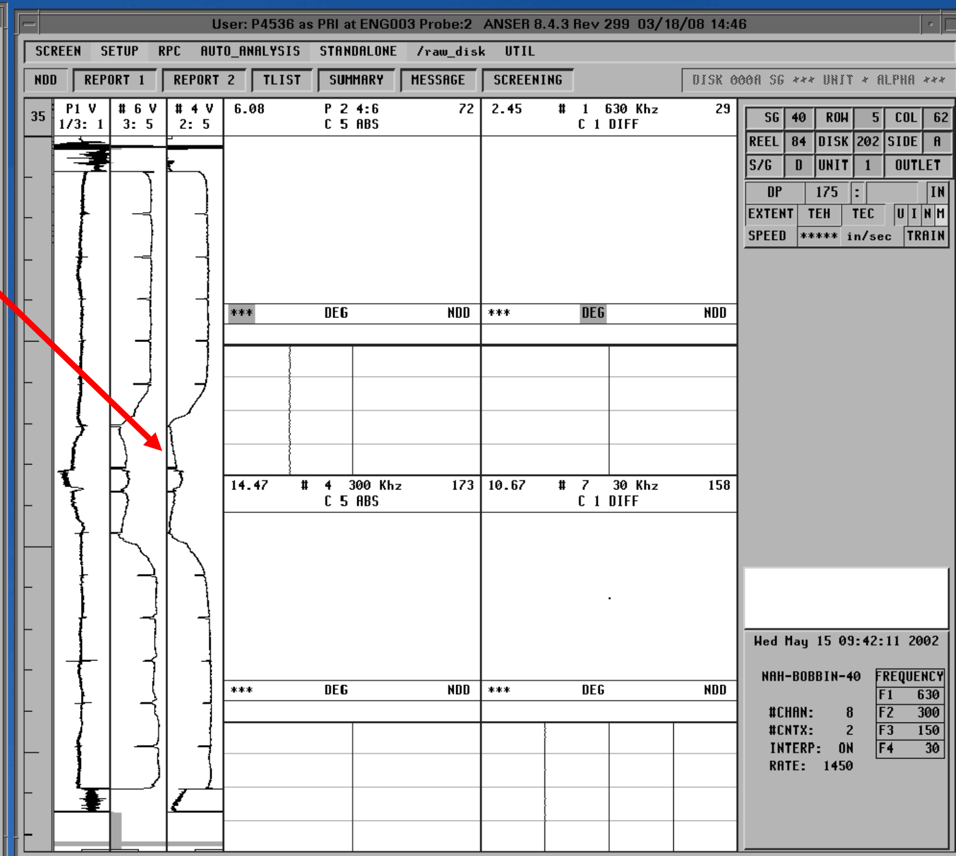
Eddy Current Signature of Low Row Tube

Normal Tube



Abnormal Tube



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Background for -2 Sigma Tubes

- **The same suspected manufacturing variance could exist in the longer-row tubes**
  - Difficult to detect in long rows because the U-bends are not stress relieved after forming
  - Forming the U-bends strains the material
  - The tube will exhibit a bobbin voltage difference between the straight leg and the U-bend
  - A normally processed tube exhibits a larger voltage difference - straight leg to U-bend - than a tube assumed to have residual stress
    - Established by comparing EC voltage for TT tubes to MA tubes
  - Lower -2 sigma of population selected as a conservative basis
  - ODSCC indications at TSPs in "-2 sigma" tubes have been identified

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High Row Screening

- **Normal Process** – entire length of tubing is essentially stress free
  - Forming the U-bend by cold working changes the material condition in the U-bends compared to the straight legs
    - Opposite condition of the stressed relieved short-row U-bends.
    - The bobbin probe provides a similar signal change between the straight leg and U-bend, but in the opposite direction.
    - Similarly, other manufacturing cold working such as tube expansion will leave higher residual stresses than in the straight sections of tubing.

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High Row Screening

- **Off-Normal Process** – entire length of tubing initially has residual stresses
  - Forming the U-bend increases the residual stress (material condition) in the U-bends compared to the straight legs
  - The bobbin voltage difference between the u-bend and straight legs would be smaller compared to normally processed tubes because the straight leg and U-bend both contain residual stresses

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High Row Screening

- Bobbin voltage difference between the straight legs and the U-bend is less than the population - 2 sigma lower voltage difference
  - Population is all of the tubes in the bundle on both HL and CL
    - Both HL and CL must be involved because the tube processing includes the entire length of the tube
  - Local buffing/polishing can cause local regions of residual stress
    - Does not impact a -2 sigma tube unless it simultaneously occurred at the same location on the HL and CL at location of voltage measurement

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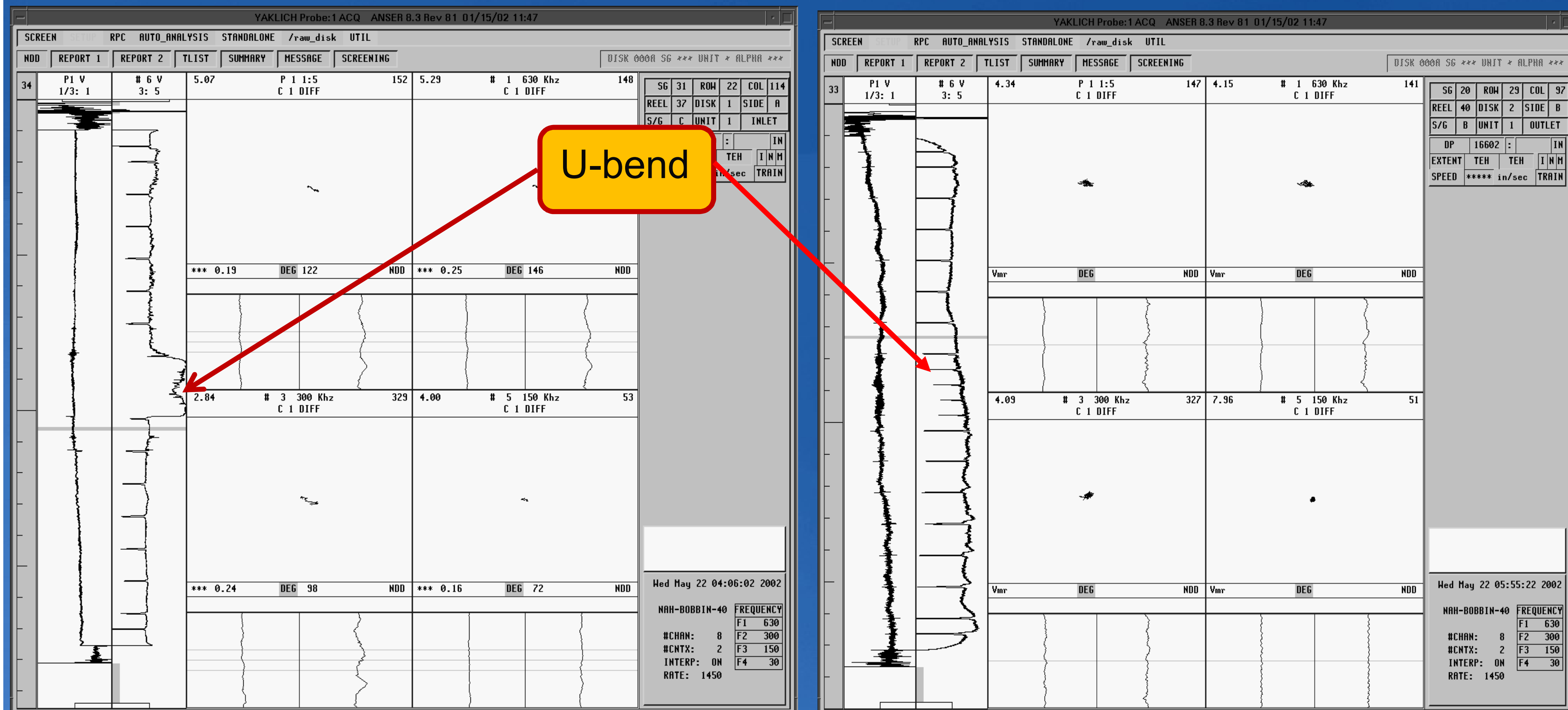
High Row Screening

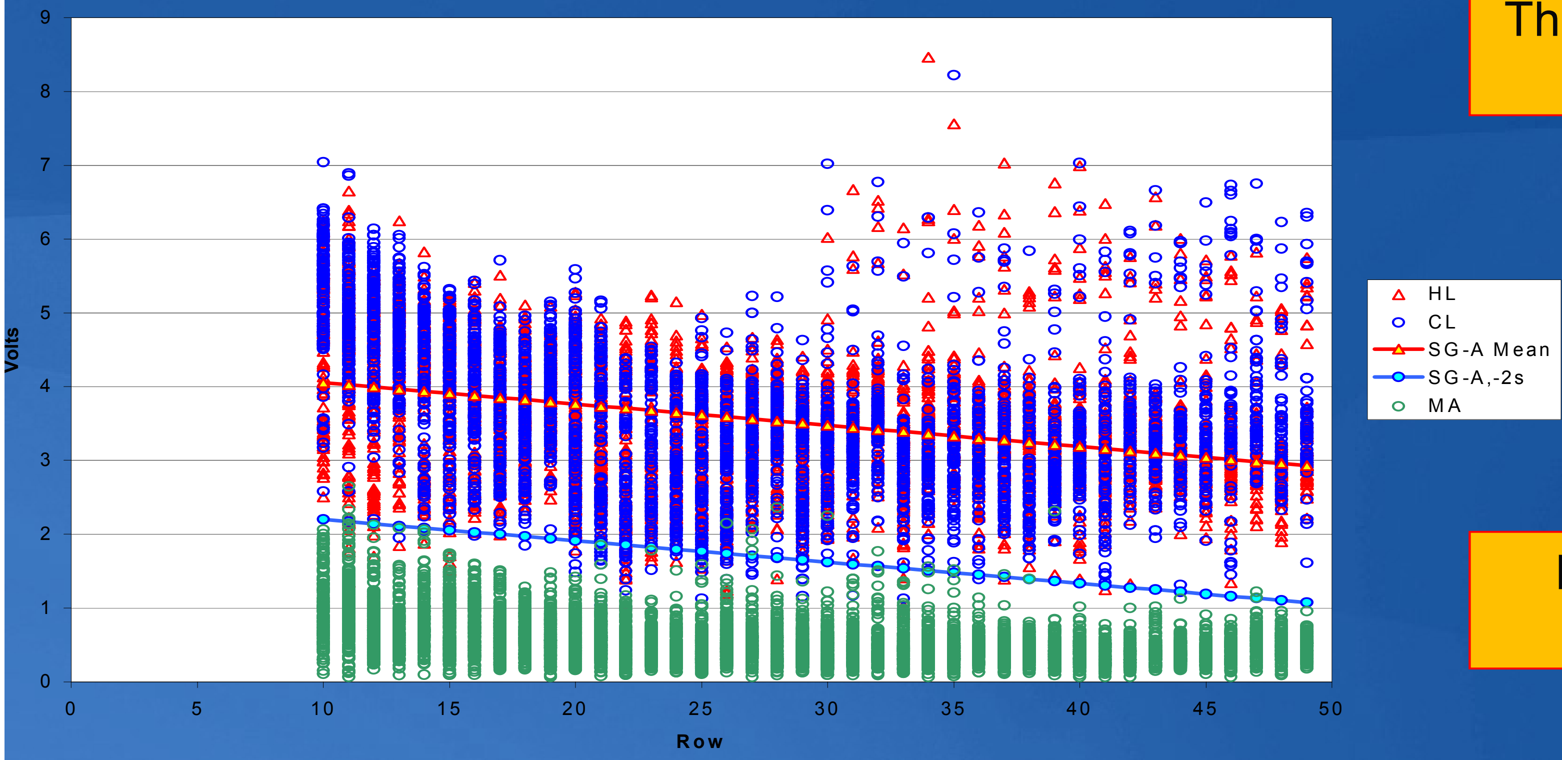
- -2 Sigma chosen to provide 95th percentile of the tube bundle offset population (H/L and C/L).
  - It has no physical significance.
  - It provides only a relative scale of the U-bend condition compared to the straight leg as a "standard".
  - Definition of -2 sigma is statistical based which means all steam generators will have -2 sigma tubes

Eddy Current Signature of High Stressed Higher Row Tube

Normal Tube	Abnormal Tube



Typical Bobbin Voltage U-bend Offset Distributions



Thermally Treated Tubes

Mill Annealed Tubes

ODSCC vs PWSCC

- Pulled tube destructive examination indicated bulk residual stress; primarily OD tensile hoop stress
- Final polish affects OD only; increases surface stress
- A600TT is resistant to PWSCC
- No corrosive concentration mechanism on primary side

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Application of “High Stress” and “-2 Sigma”

- Knowledge of the manufacturing sequence is critical to the application of the screening process results
  - The likely manufacturing deviation results in a primarily OD tensile residual stress
- SG manufacturing processes override potential tube manufacturing residual stresses
  - Forming the U-bends
  - Tube in tubesheet expansions
- Applicability of screening intended only for ODSCC at tube support plates
  - No technical basis considered or provided to address SCC at other locations on the tube.

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SGMP Survey Results

- All plants have completed the screening as recommended in SGMP Information Letter 9/14/2004
- SGMP requested screening results from Alloy 600TT fleet January 2010
  - All plants responded
  - Investigate the continued applicability of the screening methodology
- Only 2 plants have identified tube support plate ODSCC in higher row tubes

Summary Results for Cracks at Tube Support Plates

Plant	Unit	SG	Row	Column	Outage	Year	Location	HL Offset	CL Offset	-2 Sigma	Orientation
Braidwood	2	A	25	42	A2R10	2003	TSP	0.81	1.3	3.10	SAI/OD
Braidwood	2	C	38	20	A2R10	2003	TSP	0.52	2.18	2.40	SAI/OD
Braidwood	2	C	21	50	A2R10	2003	TSP	1.75	2.21	3.98	SAI/OD
Braidwood	2	C	21	50	A2R10	2003	TSP				SAI/OD
Catawba	2	B	24	62	EOC16	2009	TSP	2.42	1.9	3.03	SAI/OD
Catawba	2	D	41	55	EOC16	2009	TSP	3.66	1.07	1.95	SAI/OD
Catawba	2	D	41	55	EOC 16	2009	TSP				SAI/OD
Catawba	2	D	41	55	EOC 16	2009	TSP				SAI/OD
Catawba	2	D	41	55	EOC 16	2009	TSP				SAI/OD
Catawba	2	D	41	59	EOC 16	2009	TSP	1.89	1.58	1.95	SAI/OD
Catawba	2	D	41	59	EOC 16	2009	TSP				SAI/OD
Catawba	2	D	41	59	EOC 16	2009	TSP				SAI/OD

Conclusion

- To date -2 sigma tubes correlate reasonably well with ODSCC reported at TSPs
  - Application of the screening for -2 sigma tubes provides a broad indication of relative tube straight leg material condition compared to the U-bend material condition
  - Application of the screening for -2 sigma tubes does NOT provide the residual stress level in the tube
- Screening results are applicable only to straight length of tubes above the TTS
- -2 sigma tubes are NOT good predictor of potential for ODSCC at the tubesheet
- -2 sigma tubes are NOT intended to address PWSCC
- The survey results will be reviewed by SGMP to determine appropriate action

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Interim Guidance to address/clarify certain issues

Helen Cothron, EPRI

NRC Technical Issues with Industry Guidance

- Definitions in NEI 97-06 and the Integrity Assessment Guidelines
  - Appendix A of the Integrity Assessment Guidelines, Revision 3 defines accident induced leakage as:

"The primary-to-secondary leakage occurring during postulated accidents other than a steam generator tube rupture when tube structural integrity is assumed."

  - The phrase "when tube structural integrity is assumed" is deleted by this interim guidance
  - The definition will be incorporated into the next revision of NEI 97-06

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NRC Technical Issues with Industry Guidance

- Implementation Issues with the Integrity Assessment Guidelines
  - Section 7.6 of the Integrity Assessment Guidelines, Revision 3 states that "a comparison of the CM results to the previous cycle OA predictions shall be performed."
  - This requirement is not being implemented consistently
  - The following requirement is being added to the Integrity Assessment Guidelines with this interim guidance:

"A comparison table or discussion shall be documented in the OA report, with conclusions regarding validity of the prior cycle OA methodology or needed changes implemented in the current cycle OA methodology."

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NRC Technical Issues with Industry Guidance

- Implementation Issues with the Integrity Assessment Guidelines
  - The Integrity Assessment Guidelines do not address performing CM on tubes that are scheduled for inspection but are unable to be inspected and, as a result, may be plugged (e.g., obstructed tube, permeability variations).
  - Tech Specs require that CM be performed on all tubes inspected or plugged.
  - The following statements are being added to the Integrity Assessment Guidelines with this interim guidance:

"When meeting the performance criteria cannot be demonstrated based on the results of qualified inspection techniques, an engineering analysis, augmented inspection method(s) (e.g., ET diagnostic techniques, UT, PT, video probe), or in situ pressure testing are acceptable alternatives. CM by engineering analysis or augmented inspections <u>shall</u> include a rational basis for concluding the performance criteria have been met."

Additional Information in Interim Guidance

- Definitions in NEI 97-06 and the Integrity Assessment Guidelines
  - Appendix A and Section 2.6 of the Integrity Assessment Guidelines, Revision 3, define normal steady state full power operation as:

"The conditions existing during MODE 1 operation at the maximum steady state reactor power as defined in the design or equipment specification. Changes in design parameters such as plugging or sleeving levels, primary or secondary modifications, or Thot should be assessed and their effects on differential pressure included if significant."

  - The definition will be simplified and consistent with other terminology in the document

"The conditions existing during Mode 1 operation at normal steady state full power operation."

  - The definition will be incorporated into the next revision of NEI 97-06

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Additional Information in Interim Guidance

- Revision 3 of the Integrity Assessment Guidelines includes a requirement to use the Appendix I ETSSs
  - Implementation date is Sept. 1, 2010
- Primary goal of the Appendix I ETSSs was to provide generic, system performance indices
- This interim guidance makes the requirement to use the ETSSs immediate

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Issues Addressed in Current Guidance

- Validation of Repair Limits
  - Integrity Assessment, R2 requires repair limit to be determined as part of the DA process
    - No requirement to revisit after inspection results confirm growth rates
  - Revision 3 deleted the requirement, made it a recommendation and added guidance throughout the document
    - Chapter 3 states that “the repair limit and OA limit are obtained by further modification to consider degradation growth, and require that flaws on tubes remaining in service at the BOC satisfy the SIPC over the next inspection interval.

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Issues Addressed in Current Guidance

– Revision 3 deleted the requirement, made it a recommendation and added guidance throughout the document
  - Chapter 6 explains that “preventive repair may be required based on OA considerations. Depending on the growth rate of the degradation mechanism that is identified from the inspection, and the length of time between planned inspections (multi-cycle inspection intervals), it may be necessary to establish a lower through-wall limit for plugging to ensure tube integrity at the time of the next inspection.
  - Chapter 7 and 8 includes statements that plugging at lower limits may be necessary due to growth rates and cycle lengths

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Issues Addressed in Current Guidance

- SG Program Updates
  - NEI 03-08 requires utilities to implement the industry Guidelines and requires INPO to evaluate plant activities against the guidelines
  - NEI 97-06 requires all licensees to meet the applicable sections of the six EPRI guidelines
  - Technical Specifications establish NEI 97-06 and its associated guidelines as “the steam generator program

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Issues Addressed in Current Guidance

- Large leaks
  - Revision 3 of the Integrity Assessment Guidelines includes the following requirement:

    "In some SG designs wear scars do not have a sufficient length to cause a true tube burst. However, a large leakage event is possible. In these cases, if the possibility of a tube burst is discounted, then the probability of a large leakage event shall be calculated and the significance of this probability evaluated."

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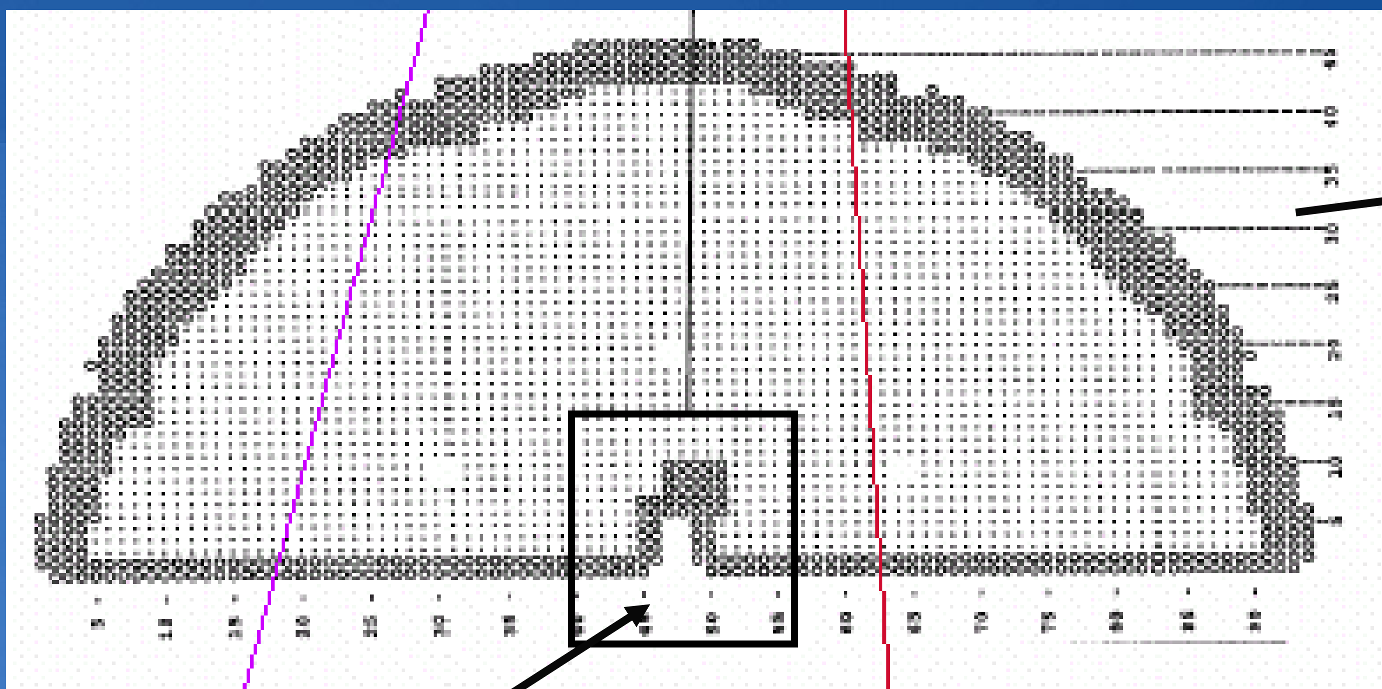
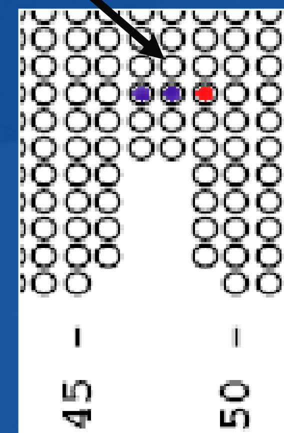
Deposit Modeling Results (Cruas)

Heather Feldman, EPRI

Specifics of Model 51B Design

Tubes R8[C47/C48/C49]

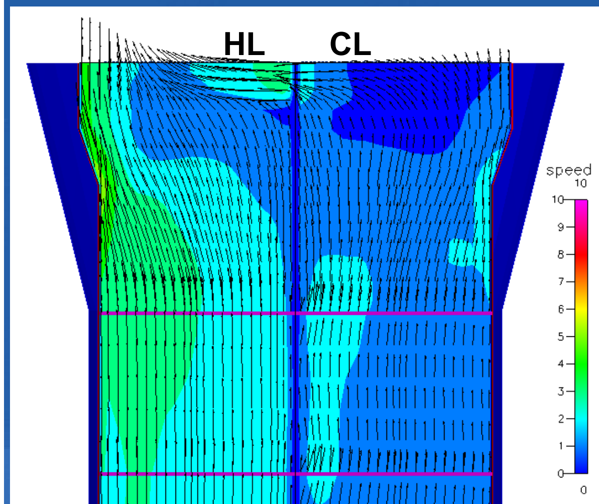




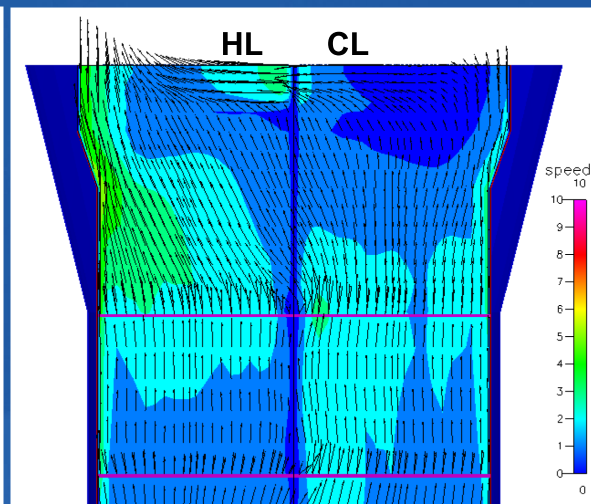
Tube Locations

Chimney (12 quatrefoil holes without tubes)

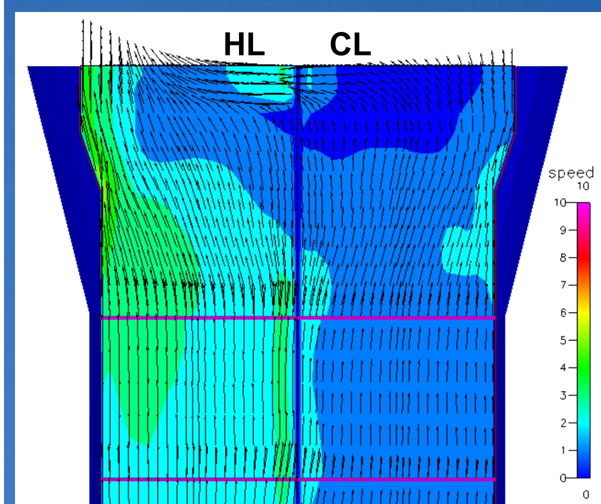
Thermal-Hydraulic Analysis



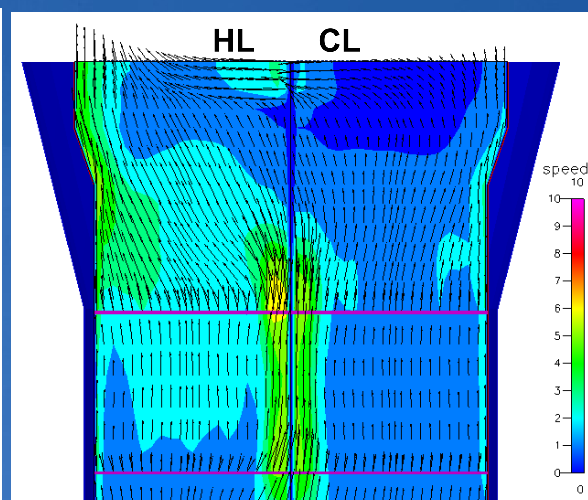
No Chimney, No Deposit Build Up



No Chimney, With Deposit Build Up



With Chimney, No Deposit Build Up



With Chimney, With Deposit Build Up

No Chimney

- Velocity does not increase preferentially near generator centerline with TSP deposit build up

With Chimney

- Velocity increases significantly near generator centerline & impinges on small-radius tubes in U-bend

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Flow Induced Vibration Analysis

- Fluid-elastic instability is considered the predominant mechanism
- Characterized by Critical Velocity Ratio (CVR)

$$\text{Critical Velocity Ratio (CVR)} \equiv \frac{V_e}{V_c}$$

V_e = Equivalent uniform crossflow gap velocity (average over tube length)

V_c = Critical velocity for onset of fluid-elastic instability (for each mode of vibration)

- CVR characterizes a margin for onset of fluid-elastic instability
  - Values ≥1 imply a tube may be unstable
  - Values < 1 imply a tube may be stable at the given conditions

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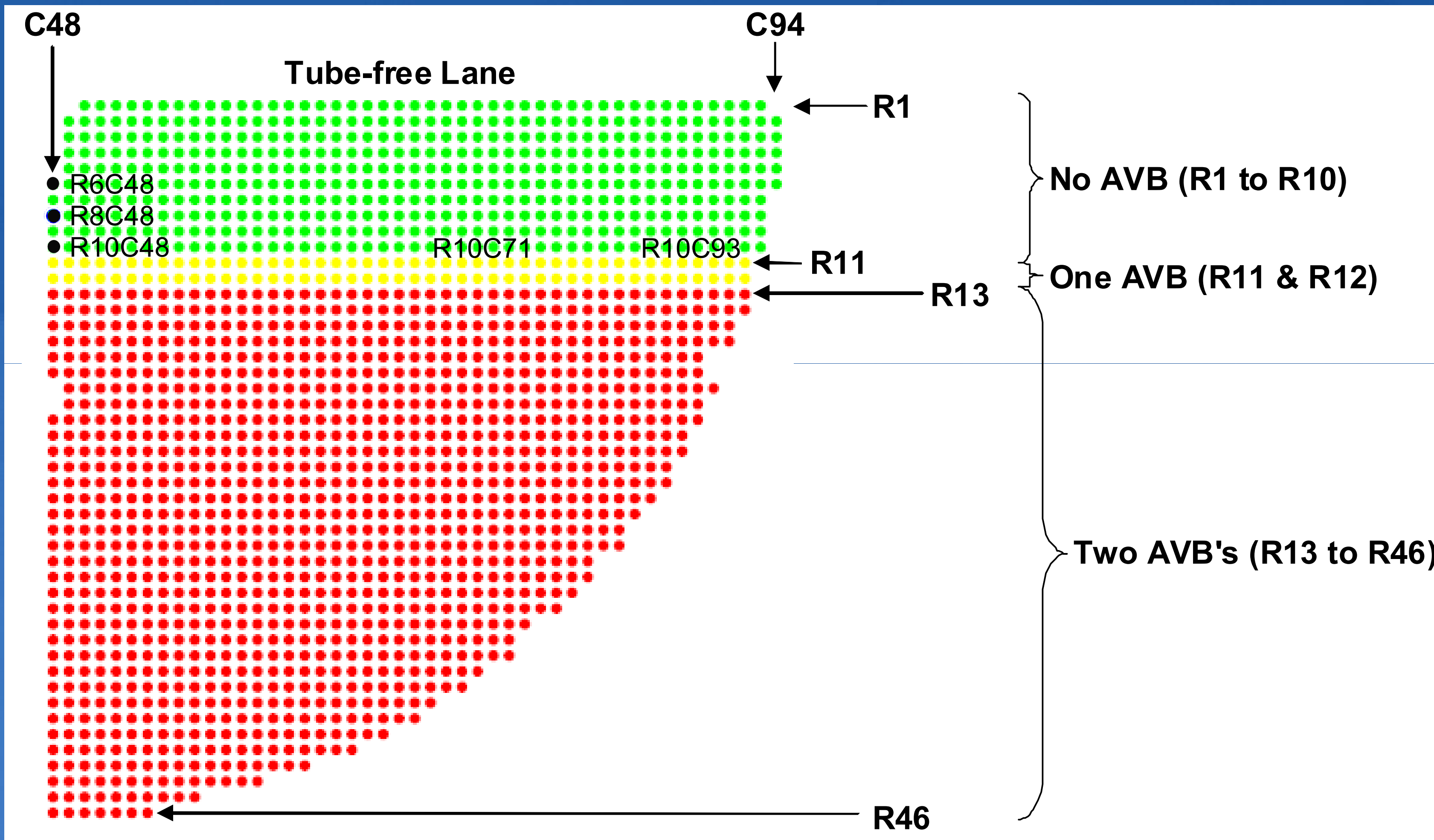
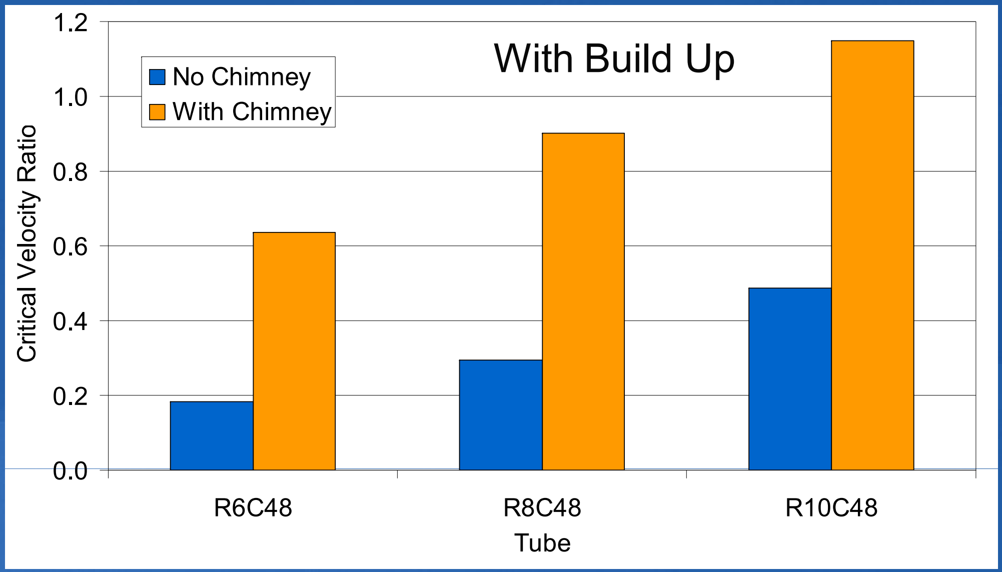
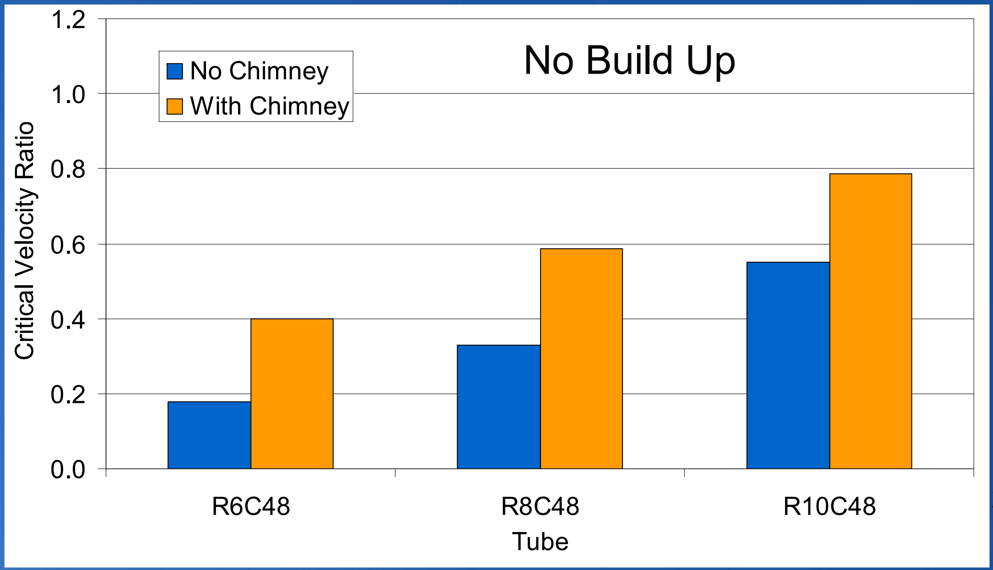
Tube Locations and Anti-Vibration Bars



Critical Velocity Ratio





Conclusions

- TSP build up has a detrimental effect on the FIV response of SG's with a chimney
  - High velocities near the small radius tubes in the U-bend region
  - Therefore, tendencies for fluid-elastic instability in this region are higher than for neighboring tubes
  - Velocity magnitude in this region is higher when there is TSP build up
- A SG with no chimney and with design and conditions analyzed in this study will not have FIV issues

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SGMP Project
Prediction of Steam Generator TSP Blockage

- Objective
  - To develop a model to predict average blockage as a function of time for the top broached hole TSP
- Approach
  - Model will be based on analysis of reported plant data supplemented by theoretical considerations
    - Broached-hole design, TSP and tubing material, total operating time, secondary chemistry, rate of transport of secondary impurities, iron transport rate to the SGs, deposit characterization, blockage estimates from visual inspections and eddy current
  - Statistical distributions, Monte Carlo approach

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Vogtle 1 Tube Pull Evaluation

Rick Mullins, Southern Company

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Background – Tube removal

- Two tubes exhibiting TTS ODSCC indications were selected for removal during 1R14
  - Tube R11C62 contained axial indications.
    - Damaged during the removal process.
    - Loaded beyond the elastic limit during the removal and some test result data has been compromised.
  - Tube R12C98 contained circumferential indications.

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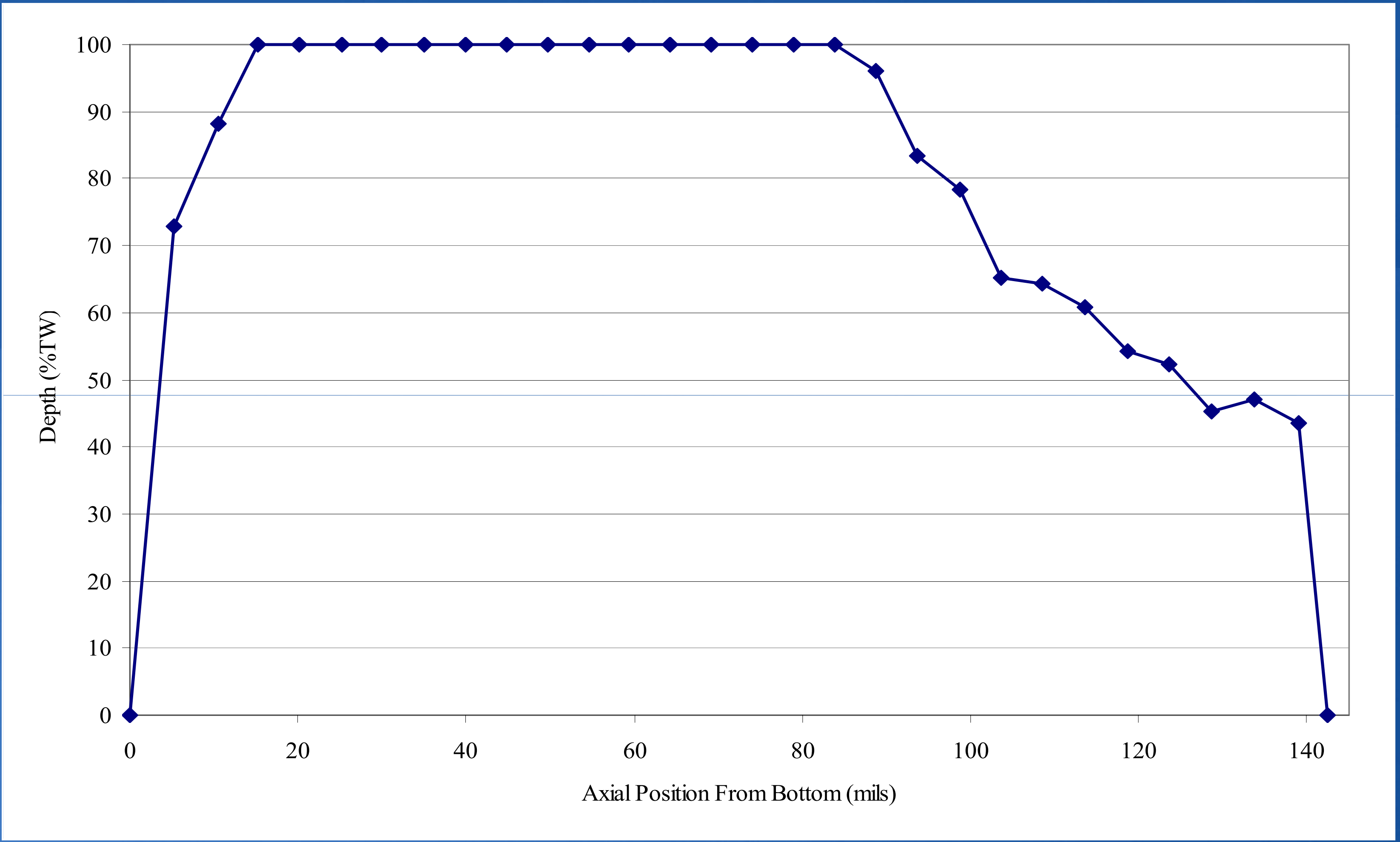
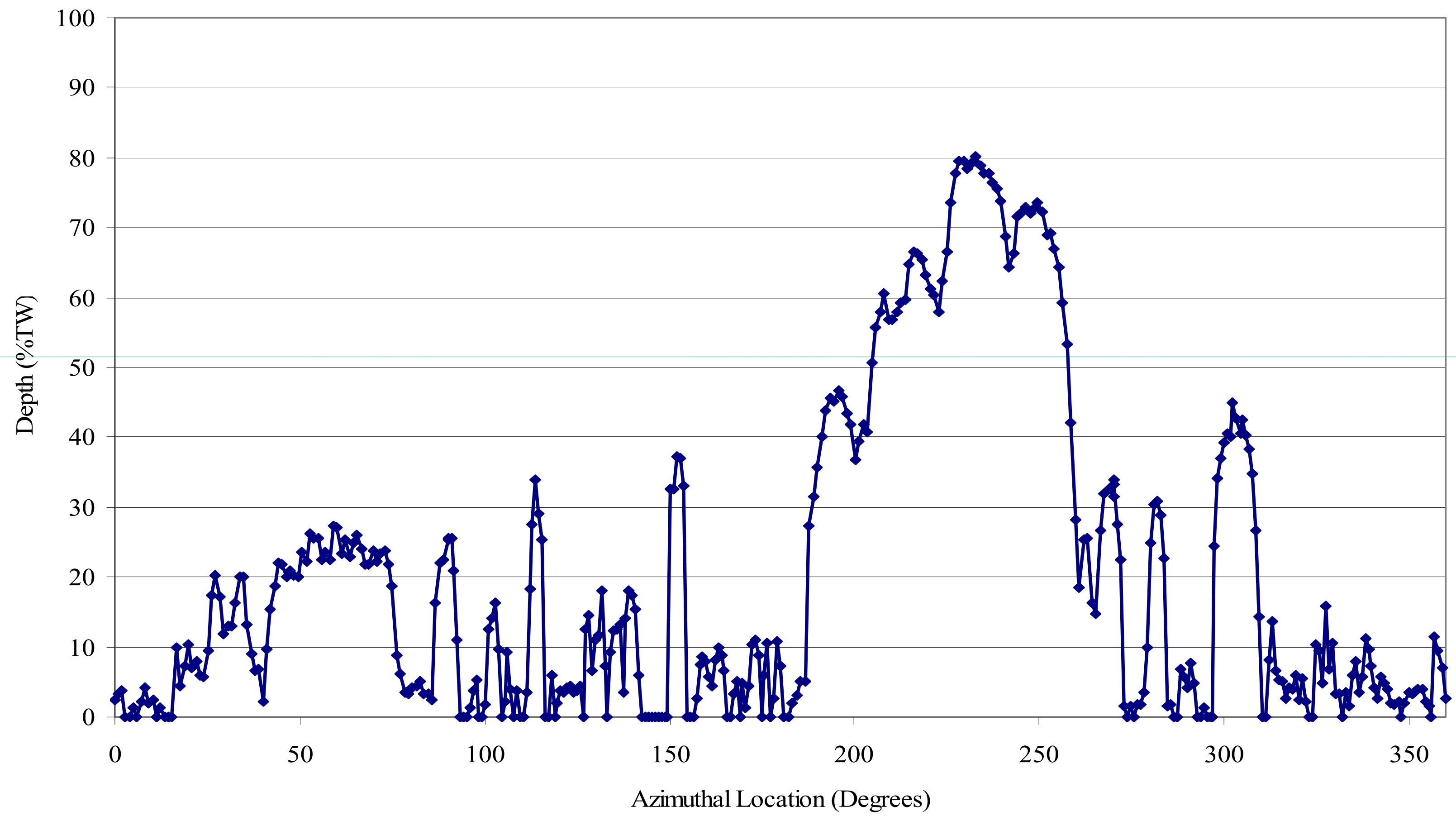
Lab Exam – Characterization of Cracks

- Both Tubes
  - OD initiated stress corrosion cracks
  - Within expansion transition (expansion transition and tube diameter typical)
- R11C62
  - Three distinct axial cracks, one small IGA patch
  - All three ODSCC cracks were through wall
- R12C98
  - Numerous circ cracks around circumference
  - Not through wall

Met Depth Profile – R11C62 (160° axial crack)



Met Depth Profile - R12C98 (circumferential crack)



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In Situ Pressure Test Screening Data

Field +Point	Field Data Review	Lab +Point	Met Data	Plant-Specific In Situ Parameters
R12C98				
SCI 0.44 v 54% TW OD 7.3% PDA 51° extent	SCI 0.39 v 40% TW OD 0.16 in long 38 ° extent	MCI (138°) 3.09 v 70% TW OD 0.25 in long 69° extent 0.39 v 40% TW OD 0.32 in long 27° extent	MCI 31 cracks 80% TW 21% PDA Longest crack 92°	**Proof Test** CA > 201° (OD) **Leak Test** V_{CRIT} = 3.9 v V_{THR-L} = 1.33 v MD_{THR-L} = 75%
R11C62		Damaged in pull		
SAI 0.71 v 88% TW OD 0.18 in long	Unresolved MAI 0.71 v 92% TW OD 0.29 in long	Unresolved MAI 6.14 v 96% TW OD 0.19 in long	MAI 100% TW (0.073 in) 0.142 in long 100% TW (0.093 in) 0.123 in long 100% TW (0.035 in) 0.124 in long	**Proof Test** VM > 0.4 v **and** Length > 0.6 in **Leak Test** V_{CRIT} = 2.4 v V_{THR-L} = 1.0 v MD_{THR-L} = 75%

Burst Test

Purpose: Confirm burst pressure exceeds 3xNODP
>4597 psig, includes factors for temperature, gage uncertainty

Tube	R11C62 axial	R11C62 axial	R12C98 circ	R12C98 circ
Region	TTS	freespan	TTS	freespan
Burst Pressure (psig)	9700	12525	10725	11250
Burst Orientation	axial	axial	circ	axial
Calculated Burst Pressure (psig – from field ECT data)	6448	10926	10004	10926
Calculated Burst Pressure (psig – from lab data)	9139	11347	9472	11347

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Microstructure

- No significant difference in the microstructure was observed between regions near the cracks and remote from the cracks
- The microstructure is characterized as having a fine grain size, in the range ASTM E112 size 9-10. The fine grain size suggests a lower temperature mill anneal.
- Note: Smaller Number=Larger Grain Size
- The microstructure exhibited some variety of grain sizes but did not exhibit any banding of small grains, which would be typical of low temperature mill annealed Alloy 600 (A600MA) with grains in the ASTM E112 size 10-12 range.

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Microstructure (cont.)

- The archive tubing has larger grains, ASTM size 8, which is more representative of A600TT tubing in Model F steam generators. The pulled Vogtle-2 tubes had grain sizes of 8 and 9
- Both pulled tubes exhibit relatively low density of grain boundary carbides for 600TT and a relatively high density of intragranular carbides
  - The low density of intergranular carbide precipitation suggests that the mill annealed treatment was ineffective in dissolving sufficient carbon and carbides
  - The fine grain size also suggests lower temperature mill anneal
  - Without sufficient carbon in solution, intergranular carbides cannot precipitate during the thermal treatment
  - Precipitation occurred on undissolved, intragranular carbides

Sensitization Test

- Sensitization tests performed and still under review
- Preliminary results suggest tubes were not sensitized
- The Vogtle 1 pulled tubes showed weight losses of 121-195 $mg/dm^2/day$.
- In contrast,
  - Generic archived tubing showed a weight loss of 27 $mg/dm^2/day$,
  - The Vogtle 2 pulled tube ranged from 31-40 $mg/dm^2/day$
  - The Seabrook tube ranged from 32-87 $mg/dm^2/day$.

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Thermal Treatment Investigation

- A review of specific Vogtle-1 manufacturing records has been initiated.
- The records are generally not detailed enough to assign actual point specific heat treatment, furnace location, and other processing characteristics to a specific tube from a SG.

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Comparison with Seabrook Pulled Tubes

- Orientation: Vogtle-1 mostly circ, Seabrook axial
- Location: Vogtle-1 at TTS, Seabrook at supports
- Freespan residual Stress: Vogtle-1 1 ksi, Seabrook 17-22 ksi
- Microhardness: Both low and even (~180 VHN)
- Microstructure: Non-optimal microstructure in pulled tubes from Vogtle-1 and Seabrook.

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Conclusions

- Vogtle-1 indications are ODSCC cracks within the expansion transition
- Cracks did not violate burst pressure criteria or exceed the in situ pressure test criteria
- Microstructure indicates material did not respond as predicted to thermal treatment
- Vogtle-1 ODSCC dissimilar to Seabrook ODSCC
- Additional investigation is required
- No parameters identified outside manufacturing tolerances
- No method to identify susceptible tubes

Bugey 3 Operating Experience

Steve Swilley, EPRI

Bugey 3 Operating Experience

Operating Experience on 600-MA SG tubes

- The BUG3 plant is operating since 1979 with original SG : 600-MA tubes SG - carbon steel drilled holes TSP
- During the plant's outage in June :
  ECT controls (bobbin coil + rotating probe) performed on the L12C32 tube SG1-HL
  - Signal corresponding to a circumferential crack located at the **2nd TSP level**
- It is the first time that such a type of defect is detected on a French SG :
  - Extended controls with the rotating probe
    - another circ. crack is detected (L45C44 – PE1)
  - Decision to pull out L12C32 tube (L45C44 not possible)
- During the pull-out operations, tubeL12C32 broke at the **1rst TSP level**
- In the EPRI Database, circumferential cracks under TSP are associated with denting :
  - EPRI analysis confirms that no significant deformation is measurable on the tube

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Bugey 3 Operating Experience

Operating Experience on 600-MA SG tubes

- The metallurgical examination of the fractured part at TSP1 of the BUG3 tube shows a multidirectional damage on the secondary side including a combination of IGA and IGSCC :
  - structural integrity analysis performed on the broken part of the tube shows significant margin against burst under design-basis accidental conditions
  - EC performed indicates that SG n°1 of BUG3 has an atypic behaviour
- Complementary examination on SG's are still ongoing, including :
  - met. exams on other pulled tubes
  - data analysis on different ECT exams

EDF

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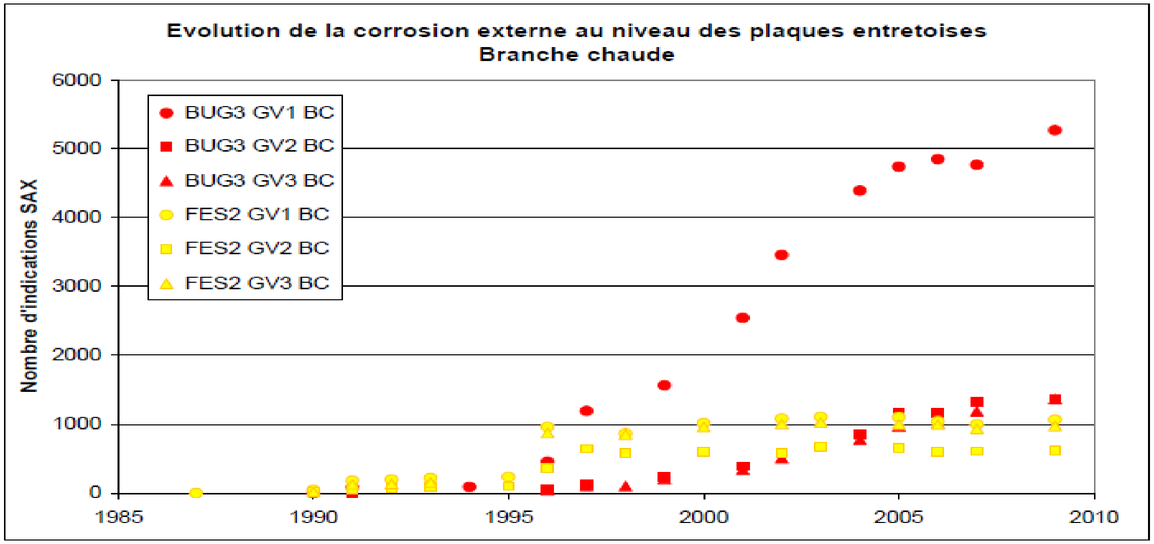
Bugey 3 Operating Experience

BUG3 : TSP secondary side corrosion through years

- NDE results for Bugey 3 SG / FES2



Bugey 3 Operating Experience

Operating Experience on 600-MA SG tubes

- Fessenheim 2, another plant with 600 MA – drilled TSP SG, in outage this summer ,
- Specific investigation were performed in order to ensure that :
  - the tube integrity is maintained untill the next SG inspection

These investigations included :

- complementary ECT programm
  - 100% screening with bobbin coil + rotating probe
- Metallurgical exams on 3 pulled tubes
- Preventive pluggings of 58 tubes

Project Plans for Foreign Object (FO) Detection & FO Wear Detection/Sizing

Steve Swilley, EPRI

Detection of Foreign Objects
Detection & Sizing of Foreign Object Wear

- Project update
  - Report 1020631 Published January 2010
    - Ability to detect foreign objects at varying distances from structures and tube surface researched for all three probe types
    - Effects of Foreign Objects on wear sizing shows little impact in many cases (typically conservative)

Detection of Foreign Objects
Detection & Sizing of Foreign Object Wear

- Project update (cont')
  - Continuing research on effects of structure/transition on volumetric wear detection
    - Sample fabrication
      - Machine shop work on flaws in progress
    - Should lead to ETSS development for detection and sizing of loose part wear at TTS expansion transition
    - 3 frequency bobbin mix will also be evaluated
  - Developing detection and sizing ETSSs for array probes (Intelligent Probe and X Probe)
    - Based upon existing EPRI loose part wear scar samples

NEI 97-06 Revision 3

Jim Riley, NEI

Overview

- NEI 97-06 revision 2 issued in 2005
- Changes in SG program guidance and the SG tech specs have created inconsistencies
- Additional input requested today
- Revision process
  - NRC review of draft?
- Revision 3 will be issued this year

NEI 97-06 Revision 3 Team

- Gary Boyers, FPL
- Rick Mullins, SNC
- Dan Mayes, Duke
- Russ Lieder, NextEra Energy
- Scott Redner, Xcel Energy
- Helen Cothron, EPRI
- Jim Riley, NEI

Specific Revision Topics

- Definitions
  - Accident induced leakage
  - Normal steady state full power operation
  - Operational assessment
  - SG tubing
- Performance of condition monitoring
- Accident leakage performance criteria

Additional Revision Topics

- Input requested…

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Revision Process

- Revision team develops draft
- SGTF review
- SGMP review
- NRC review?
- PMMP approval
- No NSIAC approval required
  - NSIAC will be informed of changes
- Implementation to be determined

NEI

Update/Closure of Divider Plate Cracking

Chris Casino, Westinghouse
Helen Cothron, EPRI

Divider Plate Project Summary

- Phase I Results
  - Cracks observed in divider plate (DP) welds, stub runner (SR) and heat affected zone (HAZ) in foreign fleet.
  - Westinghouse Model 51 SG limiting case for US plants.
  - Model 51 is limiting case due to thinnest DP and greatest structural effect of degraded DP.
  - Compares well with foreign OE.

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Divider Plate Project Summary

- Phase I Results
  - Degraded DP increases vertical tubesheet displacement.
  - Observed cracks in foreign SGs not capable of causing the DP to fail suddenly.
    - Long, shallow cracks cannot rapidly propagate through the ductile weld material at high temperatures.
    - Remaining weld ligaments in DP connections capable of bearing load.

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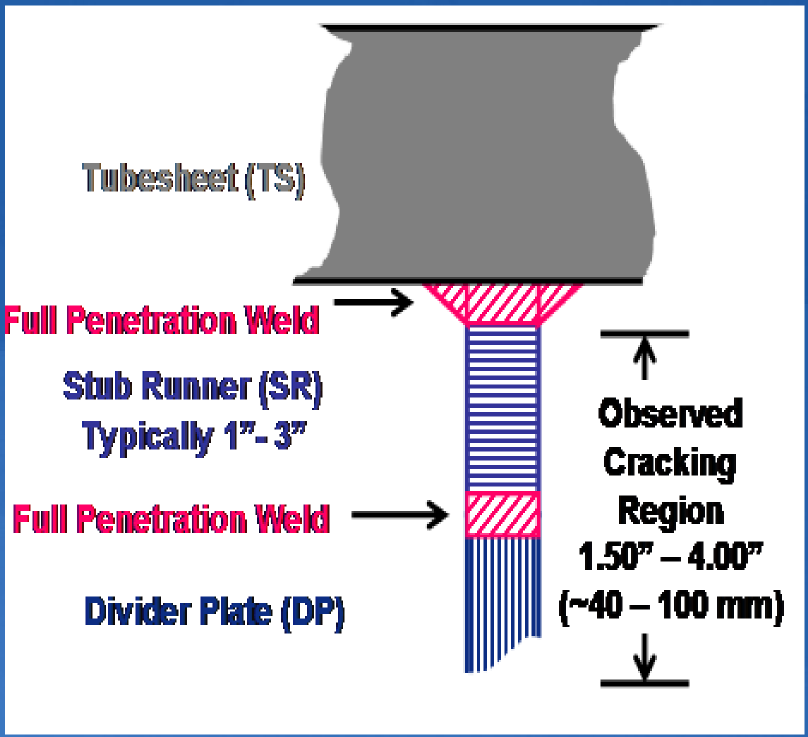
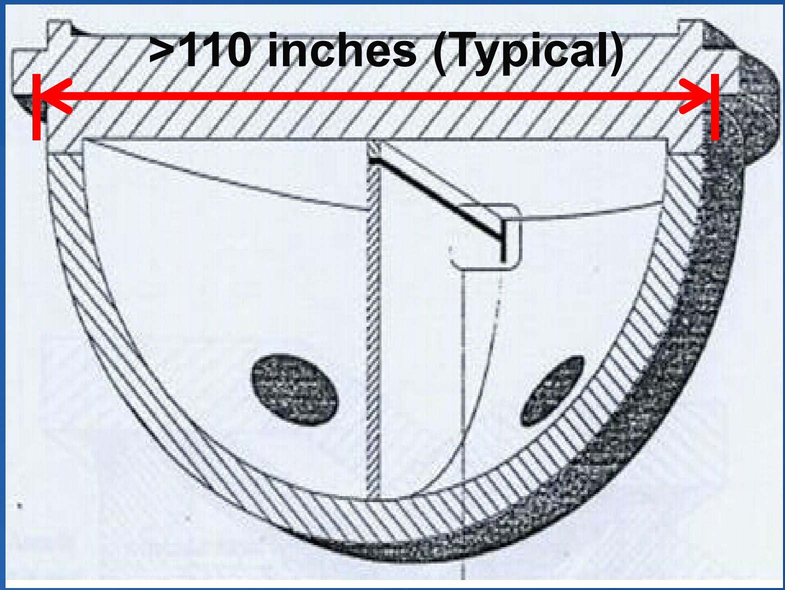
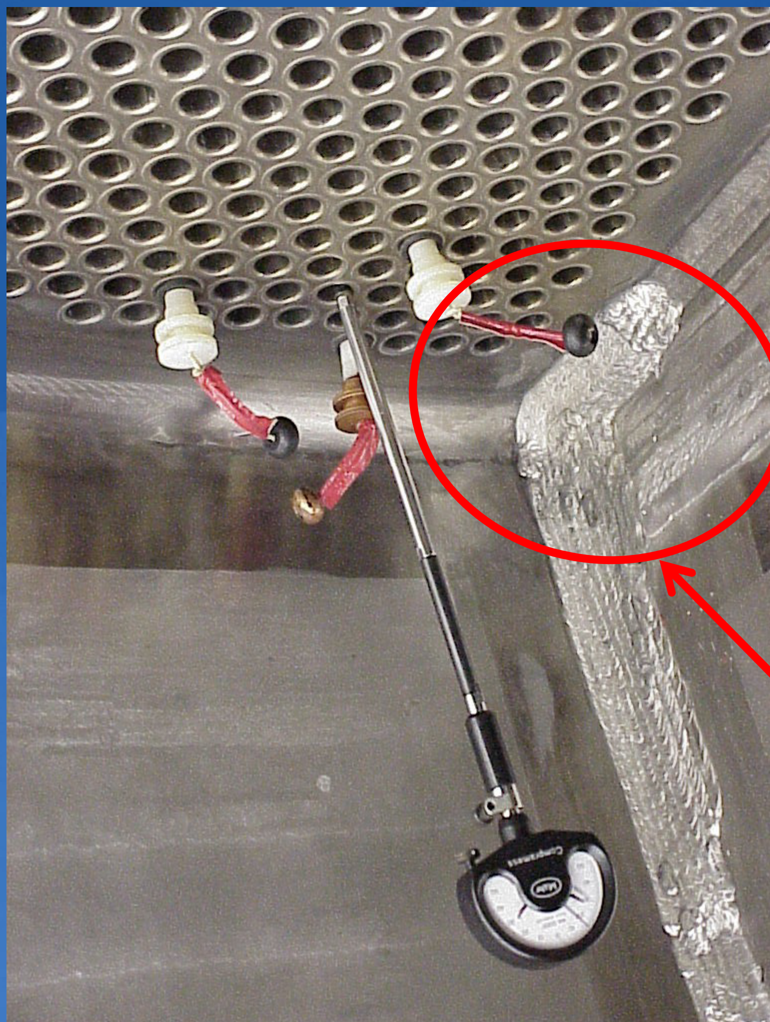
Divider Plate Geometry Reference

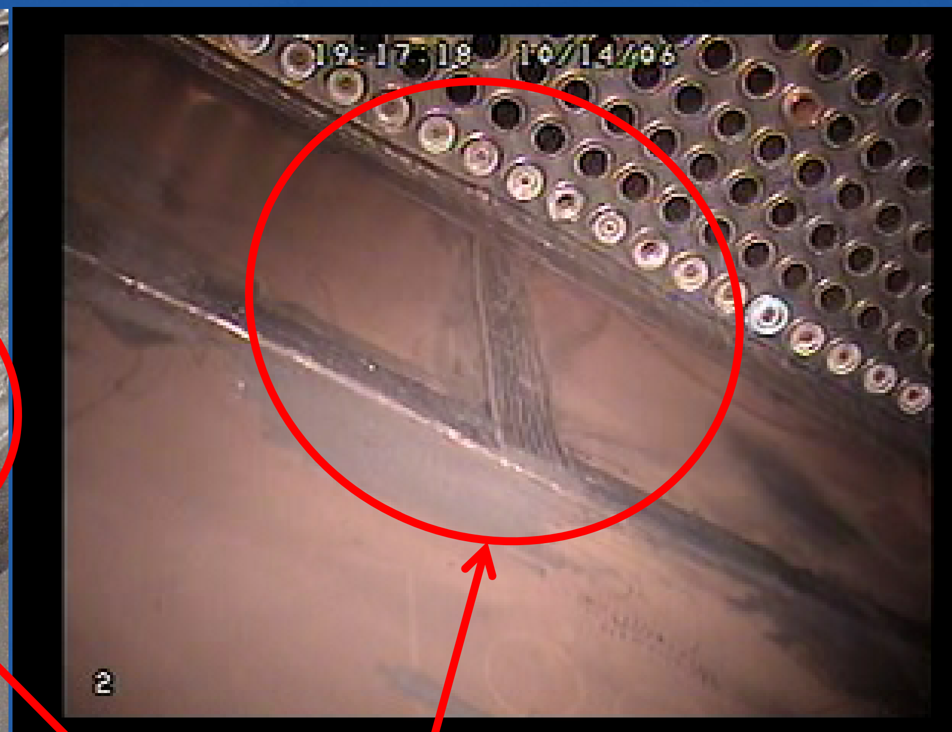




DP cracking limited to HAZ region of plate, SR and weld.

Divider Plate Geometry Reference





Regions of Interest in Foreign OE

Divider Plate Project Update

- Foreign plants continue to inspect DP.
- Cracks in the DP can increase in both length and depth during normal operations after initiation.
- Domestic concerns led to proposing additional work.
- Phase II of the program began 2007.

Divider Plate Project Update

Key Issues in Phase II:

- Analysis of Transients (LOCA and Non-LOCA).
- Analysis of Multiple Crack Geometries.
  - Multiple and Combined origin sites.
- Review if ASME Code Stress Reports are affected by degraded DP condition.
- **Are DP Cracks a safety concern?**

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Divider Plate Project Update

- Phase II Analysis Details:
  - Focused on “fully degraded” and “more realistic” conditions.
  - A “fully degraded” divider plate has a crack that is 100% through wall and 100% of the length of the plate.
  - “More realistic” conditions describes detailed 2D crack growth modeling in a 3D structure.

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Divider Plate Project Update

- Phase II Scope completed in 2008:
  - LOCA Transient Analysis
  - Non-LOCA Transient Analysis
- Conclusions
  - Worst case crack opening area (COA): **16** in^2
  - The bounding COA equals ~20 tubes.
  - A fully degraded divider plate does **NOT** adversely affect SG performance during LOCA or non-LOCA events.
  - A fully degraded divider plate is **NOT** a safety concern during plant operations.

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Divider Plate Project Update

- Phase II Scope completed in 2009:
  - ARC Impact.
  - SG Tube Plug and Sleeve Impact.
  - Review if ASME Code Stress Reports are affected by degraded DP condition.
- Conclusions:
  - No changes in current analyses would result from a degraded DP.

Divider Plate Program Documents

- Phase I Results:
  - EPRI Final Report 1014982.
- Phase II Results
  - EPRI Technical Update 1016552.
  - EPRI Technical Update 1019040.
  - Final summary of Phase II scope to be published this year.

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Divider Plate Project Update

- The following components were evaluated and are not affected by a degraded divider plate:
  - Tubesheet
  - Channel head
  - The lower shell
  - Tubesheet to channel head junctions
  - Tubesheet to lower shell junctions
  - Tube-to-tubesheet welds

Divider Plate Project Update

- The following analyses are ***not affected*** by a degraded divider plate:
  - Supporting analysis and boundary conditions for lower SG complex.
  - The performance or safety function of the SG and the affected loop during a postulated accident condition.
  - The supporting analysis basis for tube plugs installed prior to 1989.
  - C* Alternate Repair Criteria.
  - H* Alternate Repair Criteria.

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Divider Plate Project Update

- The following analyses were evaluated and determined to be ***sensitive*** to a degraded DP:
  - SG mechanical tube plugs used after 1989.
  - Laser welded and TIG welded sleeves.
  - F* Alternate Repair Criteria.
  - W* Alternate Repair Criteria.
- DP factor of 0.76 was used in the analyses.
- Conservative because 0.76 is **less than the level of support in the case of a fully degraded divider plate.**

Divider Plate Project Update

- The analyses for Leak Limiting Alloy 800 sleeves do not include a divider plate:
  - It is unlikely that additional consideration of tubesheet deformation would invalidate the current design.
  - The limiting cases for bending in the Alloy 800 sleeve design are in the free span and exceed any potential deformation that could be experienced by the tube to tubesheet portion of the tube.

Recent Manufacturing OE

- SONGS replacement steam generator DP cracking.
  - Manufacturing issue, not service induced.
  - Significantly different design than existing fleet.
  - DP in existing fleet are not intended to be structural components in lower SG complex.

Phase II Results

- Improved Crack Modeling
- Kinematic Modeling
  - Based on Operating Experience
  - Varying crack initiation sites
  - Calculates Time to Failure
- Detailed FEA Studies
  - 2-D Crack Geometries
  - Cold Leg or Hot Leg
  - Varying crack initiation sites

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Phase II Results

- Kinematic Modeling:
  - Applies worst case observed crack growth rates.
  - Uses vibration models to estimate displacement amplitudes per load cycle.
  - Not a stress based analysis.
  - Useful for estimating the effect of multiple cracks and multiple crack lengths at different locations.

Phase II Crack Analysis

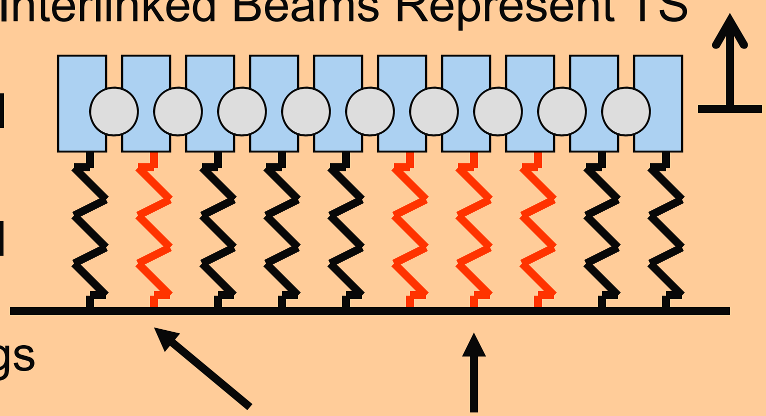
INPUT

<u>DP Crack Indications</u>
1. Number of Crack Sites
2. Estimated Crack Length
3. Estimated Crack Depth

OUTPUT

<u>Crack Analysis Results</u>
- TS Displacement
- TS Mode Shape
- Estimated Time to Failure

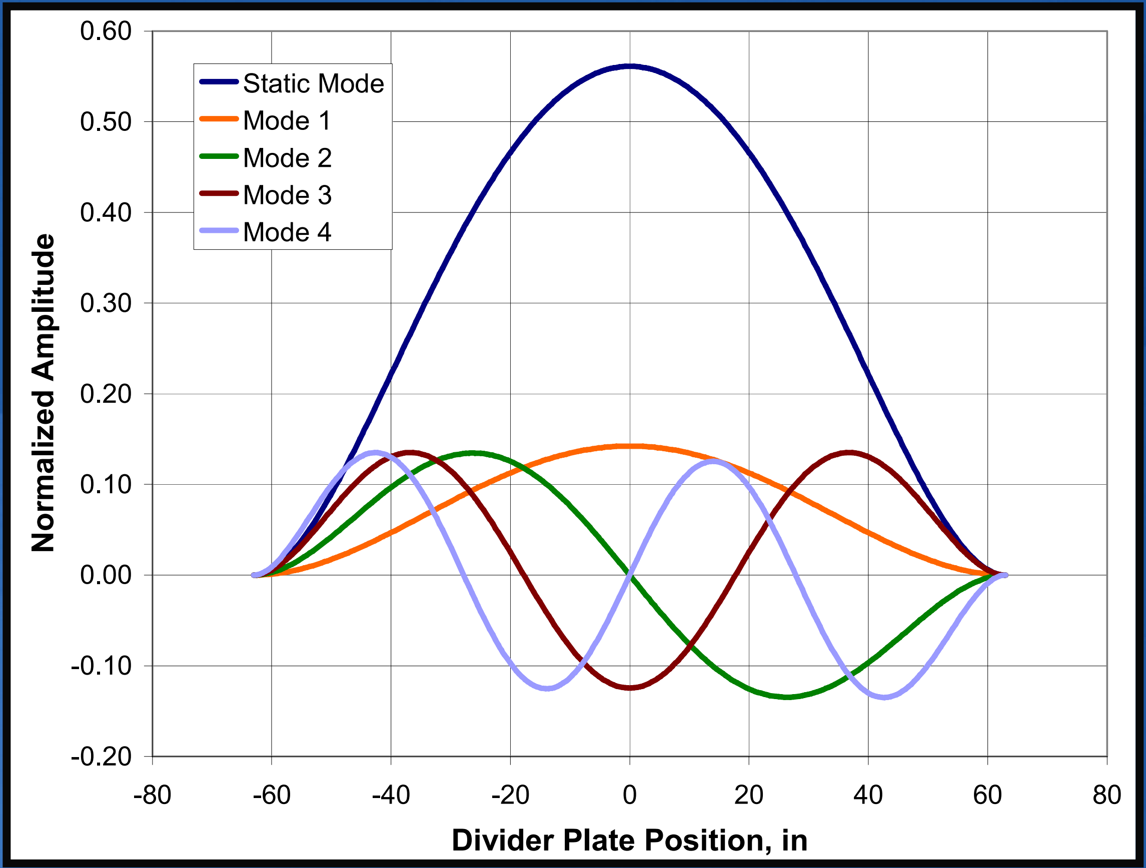
MODEL



Phase II Results

- Several crack initiation patterns studied.
  - Center of plate.
  - Edges of plate.
  - Center and edges of plate.
  - Different lengths and depths.
- Analysis predicts an increase in the time to propagate through-wall from 6 years to 60 years based on OE.

Phase II Results



Static Mode = 0 Hz
Mode 1 = 28 Hz
Mode 2 = 48 Hz
Mode 3 = 85 Hz
Mode 4 = 136 Hz

- Maximum Static Displacement at centerline ~ 0.35 inch.
- Frequencies above 7 Hz are very unlikely.

Phase II Results

- Detailed FEA Studies
  - 3-D Divider Plate
  - 2-D Crack Growth
    - Varying Length and Depth
  - 10 Different Crack Patterns Analyzed
  - Cold Leg and Hot Leg Cracks Studied
  - Cracks can cross DP faces (e.g., hot leg face to cold leg face)

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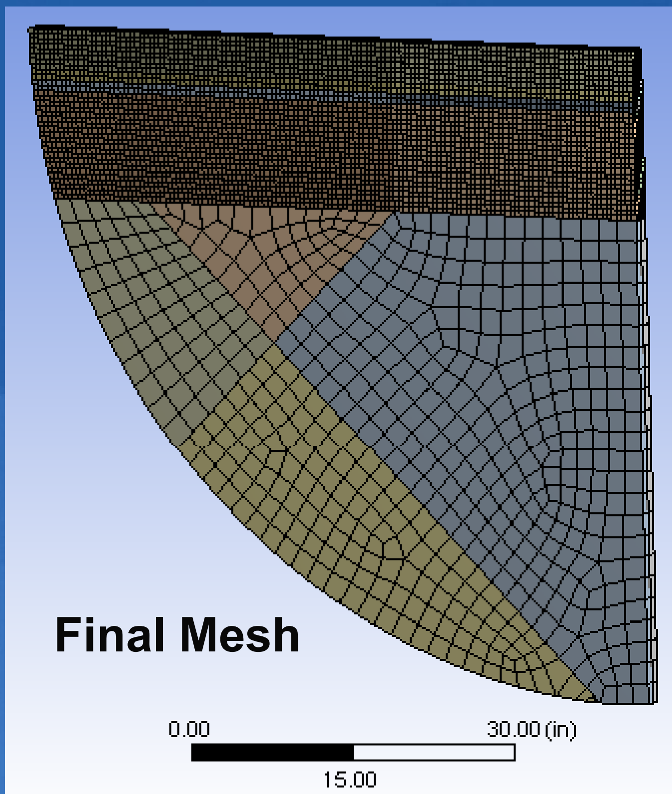
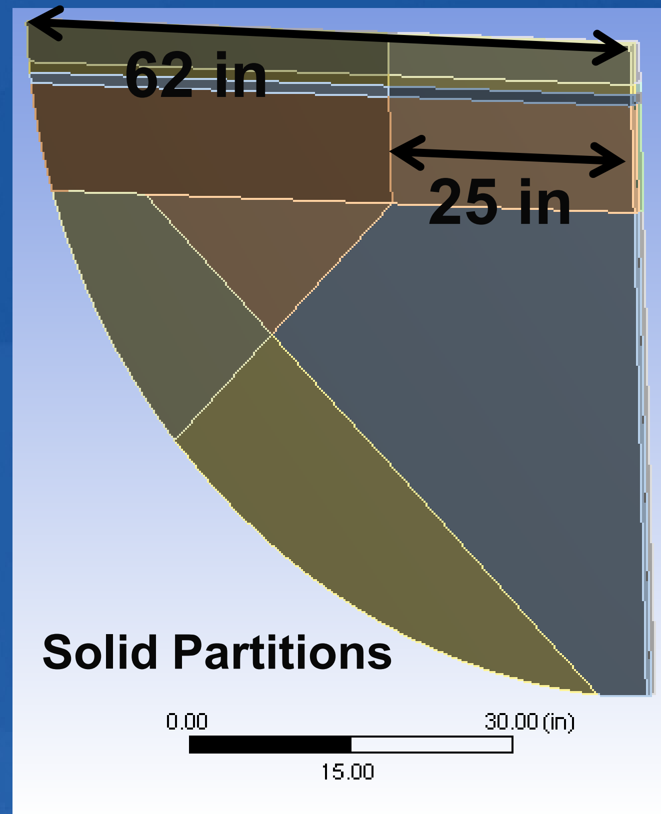
Phase II Results





- Divider plate has a ~62 inch radius, 2 inches thick.
- 3-D Solid Finite Element Model.

Phase II Results

- Sub-Model Boundary Conditions
- Conservatively Applied to Maximize Crack Growth and Vertical Stresses
- Drawn from Bounding Normal and Upset Operational Conditions
- Limiting case in Original Design Basis for Model 51
  - Hot Leg to Cold Leg Difference: 50 psi
  - Primary to Secondary Difference: 1815 psi
  - Temperature = 600 °F

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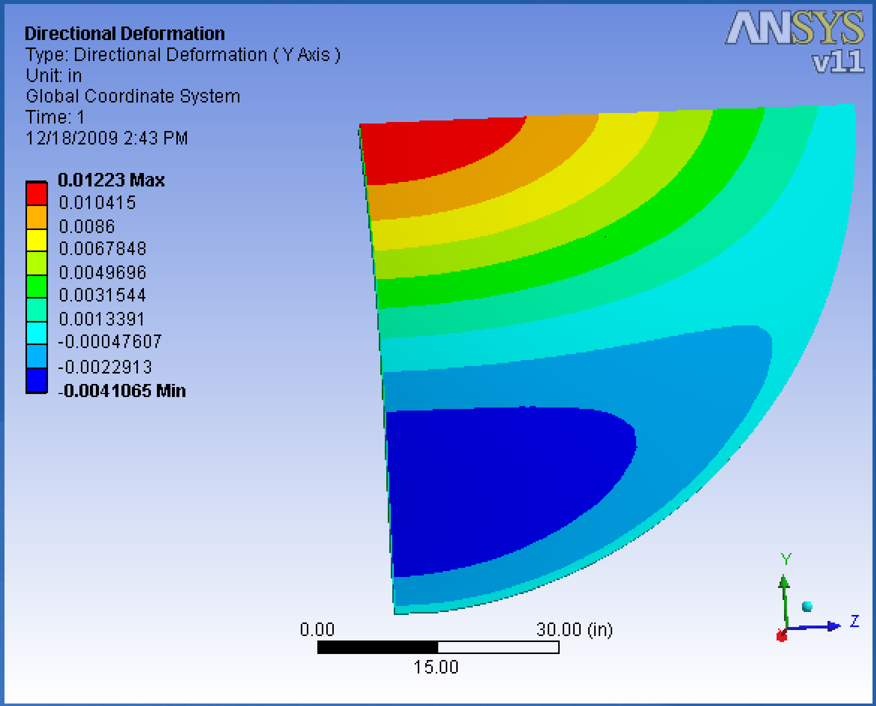
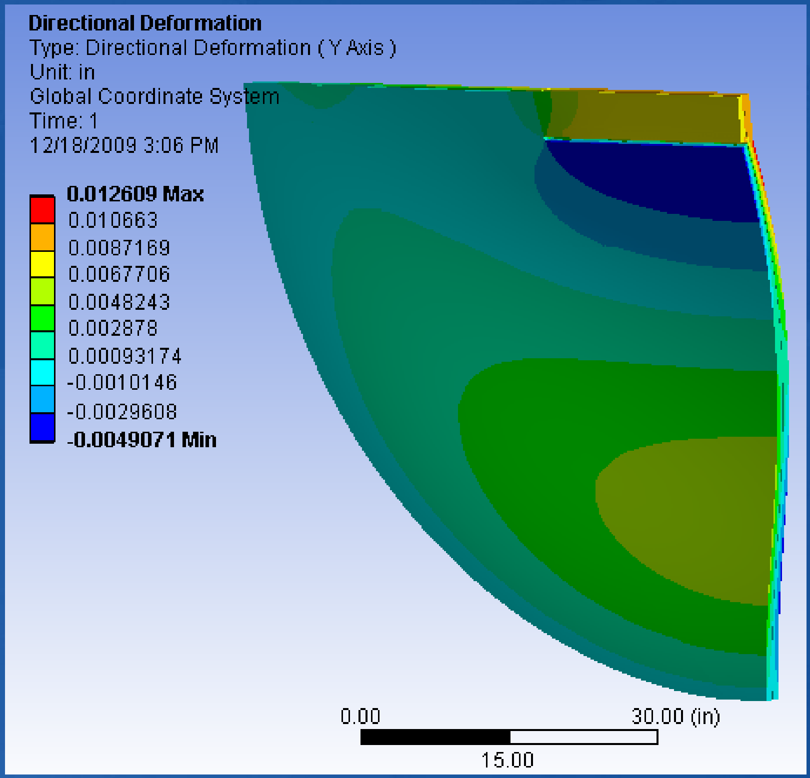
Phase II Results



Relative Vertical Displacement:
Uncracked
35x Magnification



Relative Vertical Displacement:
HL Face Crack, 50% Depth
35x Magnification

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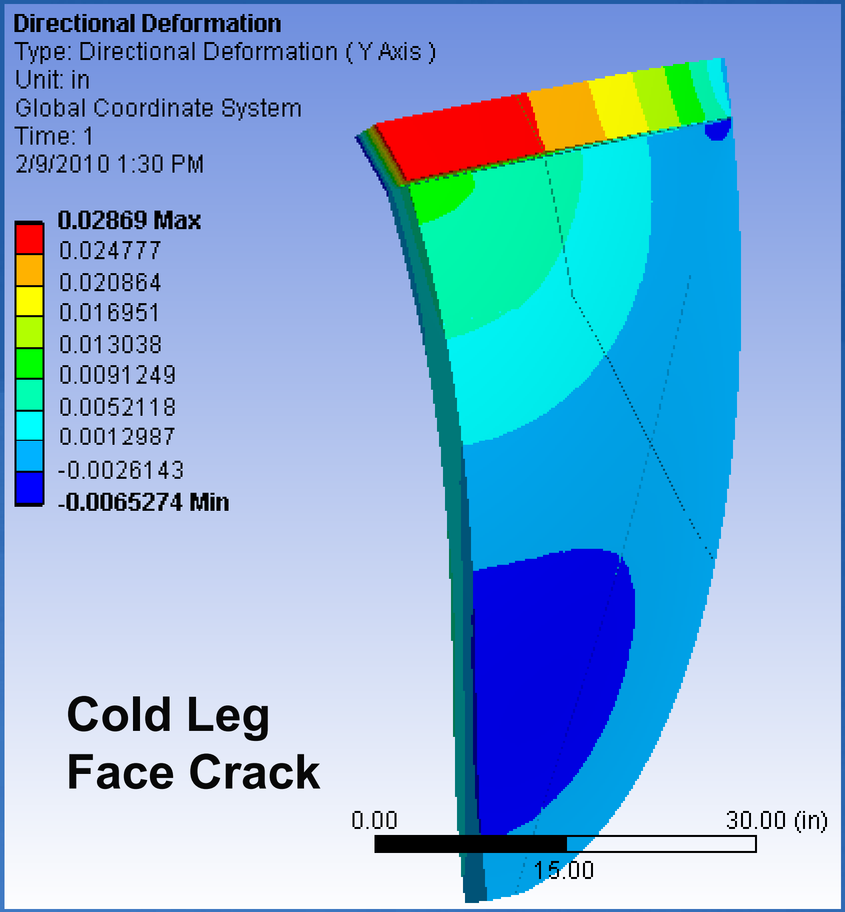
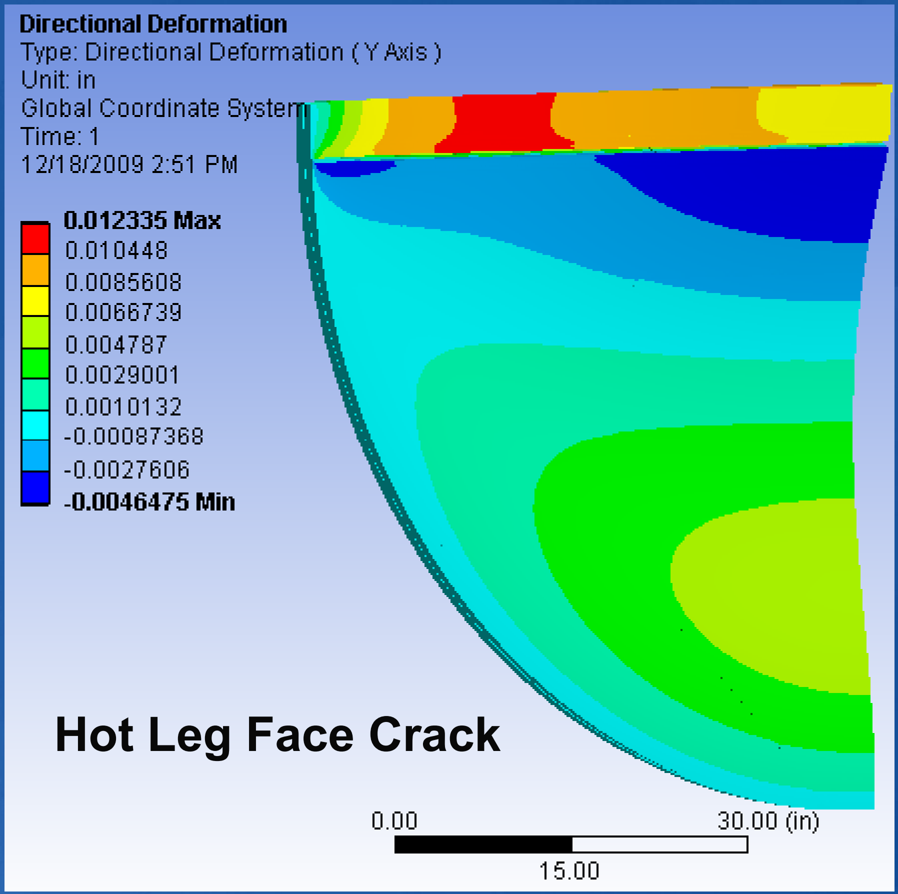
Phase II Results





Relative Vertical Displacement Results
(35x Magnification)

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Phase II Results

- Stress Analysis Results
  - Large Compressive Stresses develop ahead of crack edge.
  - Magnitudes range from 3 ksi - 93 ksi.
  - It is not possible to grow a crack through the compressive stress field.
  - In the worst case crack geometry, the compressive stresses range from 3 ksi to 60 ksi.

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Phase II Results

- Divider Plate is not considered a part of the primary pressure boundary nor is it considered a significant part of the steam generator structure in the existing fleet.
- Not classified as an ASME Structure.
- WNEP 9106 Vol. 5, Page 6-1 (33/245): "A rigid Section III analysis is therefore not required of the divider plate..."

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Phase II Results

- No identified need for US plants to inspect based on program results.
  - Degraded DP is not a safety concern during operations.
  - Degraded DP is not a structural concern during operations.
  - Degraded DP does not affect existing repair criteria or repair tools.
  - DP Inspection not mandated by ASME Code.
- No identified need to repair degraded DP.

Conclusion

- Cracks can grow in DP during normal operations, but, they are:
  - Not a safety concern.
  - Not a structural concern.
  - Do not need to be inspected.
  - Do not need to be repaired.
- A Degraded DP is not considered to be a safety issue.
- SGTF considers this issue closed

Upcoming Changes to Industry Documents

Jim Benson, EPRI

SGMP Industry Document Status and Revision Schedule

Title	Current Rev #	Report #	Last Pub Date	Implementation Date(s)	Interim Guidance	Review Date	Comments
Steam Generator Integrity Assessment Guidelines	3	1019038	Nov-09	9/1/2010	SGMP-IG-09-03	2012	
EPRI Steam Generator In Situ Pressure Test Guidelines	3	1014983	Aug-07	3/14/2008 6/14/2008	none		Rev 4 process to begin in 2010
PWR Steam Generator Examination Guidelines	7	1013706	Oct-07	9/1/2008	SGMP-IG-08-04	2010	
PWR Steam Generator Primary-to-Secondary Leakage Guidelines	3	1008219	Dec-04	7/17/2006 10/17/2006	none		Rev 4 expected in 2011
PWR Primary Water Chemistry Guidelines	6	1014986	Dec-07	6/17/2008 9/17/2008	SGMP-IG-09-01	2010	
PWR Secondary Water Chemistry Guidelines	7	1016555	Feb-09	8/20/2009 11/20/2009	none	2011	
Steam Generator Management Program Administrative Procedures	2	1015482	Sep-07	01/03/2008 04/03/2008	SGMP-IG-08-01 SGMP-IG-08-02 SGMP-IG-08-03		Draft Rev 3 to be sent out for Broad Based Review by 5-31-10
Steam Generator Degradation Specific Flaw Handbook	1	1019037	Dec-09			n/a	

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SGMP Guidance Update

- **Guideline revisions recently published**
  - Revision 3 to SG Integrity Assessment Guidelines
    - Implementation required by **September 1, 2010**
- **Guidelines currently in revision**
  - Revision 4 to SG Primary-to-Secondary Leak Guidelines
  - Revision 3 to SGMP Administrative Procedures
  - Revision 4 to In Situ Pressure Test Guidelines

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SGMP Guidance Update

- **Guidelines recently reviewed**
  – Primary Chemistry – No revision required (June 2009). Next annual review scheduled for June 2010.
  – SG Exam Guidelines – Re-evaluate need for revision June 2010
  – PWR Secondary Water Chemistry Guidelines, Rev 7 – Review in late 2010
- **Interim Guidance Letters**
  – Draft IG Letter is in review to require the use of the new ETSSs developed under Appendix I of the SG Examination Guidelines
- **Information Letters**
  – None

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Recent SG Operating Experience

June-December 2009

Russ Lieder, Nextera Energy Seabrook, LLC

2009 Industry Operating Experience (June-December)

- In situ pressure tests required at 2 stations in Fall 2009 to demonstrate tube performance criteria
  - Vogtle 1 in-situ pressure tested a tube with a U-Bend axial indication
    - Primary-to-Secondary leak identified during drain down (0.15 gpd)
    - Negligible leakage during in-situ pressure test at normal operating differential pressure
    - 0.002 gpm at accident differential pressure
  - Waterford 3 in-situ tested a eggcrate axial indication
    - No leakage or burst at $3\Delta P$ + 500 psi

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2009 Industry Operating Experience (June-December)

- Siemens SGs with Alloy 800 tubing reporting denting and OD circumferential crack-like indications at the top of the tubesheet
  - Doel 3 increase in deposits at top of tubesheet and denting
  - Asco 1 denting and OD circumferential cracking
  - Asco 2 denting
  - Almaraz 1 denting
  - Almaraz 2 denting and OD circumferential cracking
- Belleville 2, Framatome SGs with Alloy 600TT tubing also reporting "denting" and OD circumferential cracking at the top of the tubesheet in the "kiss roll" area.

2009 Industry Operating Experience (June-December)

- EDF continues to chemically clean all the SGs in their fleet to address the potentially adverse thermal/hydraulic effects of broach hole fouling. EdF will also employ the use of scale conditioning agents such as ASCA and DMT.
- Entergy incorrectly plugged a tube during the ANO Unit 2 outage in 2005. This missed plugged tube was identified during the 2009 outage.
  - Incorrect measurement lengths from the robotic system which produced a slightly different location within the SG.
  - Verification method determined to be inadequate

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2009 Industry Operating Experience (June-December)

- Salem Unit 2
  - First ISI of replacement steam generators resulted in large population of AVB wear indications.
  - 1556 AVB wear indications in 584 tubes
  - Quantity of wear impacts ability to skip the next cycle. Operational Assessment could only justify one cycle of operation.

NEI

2009 Industry Operating Experience (June-December)

- Sequoyah 2 (Alloy 600 MA)
  - CL Freespan crack indications detected by bobbin
    - +point characterized the indication as 8 separate axial outer diameter crack like indications
  - PWSCC detected in cold leg tubesheets
    - 3 tubes with indications below top of tubesheet
  - In-situ testing not required
  - No tubes pulled

NEI

2009 Industry Operating Experience (June-December)

- Seabrook
  - Axial ODSCC at top of tubesheet hot leg
    - Single indication in one steam generator
    - Located 0.26" below top of tube sheet at bottom of expansion transition
    - Length 0.12"
    - In-situ not required

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NRC feedback on various issues (e.g., TSTF-510)

Address Public Questions/Comments

Adjourn