

SGTF / NRC Technical Meeting



February 22, 2024

Agenda

1:00	Welcome and Introductions	NRC/Industry Rep
1:10	Opening Remarks	NRC/Industry Rep
1:15	Recently Published Reports	EPRI
	Status of Industry Guidelines	K. Thompson
	Interim Guidance	K. Thompson
	NEI 03-08 Deviations	K. Thompson
	Recent Operating Experience	S. Brown
	Update on International OE regarding wear due to secondary side deposits	J. Benson
	Circumferential PDA Calculations	B. Cullen
2:15	Address Public Questions/Comments	NRC
3:00	Adjourn	NRC



Recently Published Reports EPRI Staff

Primary-to-Secondary Leak Determinations Using Tritium During Operational Modes, 3002026374, September 2023

- This report reviews the use of tritium for PSL detection both during power and non-power operations presenting the relevant equations that can be used to calculate leakage as well as a better understanding of the limits involved with the use of tritium for leak detection.

Evaluation of Leak Rate Estimation Methodology with Partial Through-Wall Depth Circumferential Cracking, 3002026376, September 2023

- Current assumptions in the Integrity Assessment Guidelines for assessing circumferential degradation:
 - Calculated leak rates after pop-through are based on a leaking degradation length equal to the total degradation length.
 - Calculations are performed assuming a uniformly deep flaw profile with a uniform depth equivalent to the actual flaw profile.
 - A simplified approach to calculate crack tip opening area was developed and verified using tubing materials and simulated flaws.

Secondary Side Filming Product Application: Elastomer Compatibility Testing, 3002020947, September 2023

- This work studied the effect of three filming products.
- Objectives were to identify any gross chemical incompatibility issues and to gain insight into expected end-of-life condition of materials.

Hydrazine Alternative: Impact on Electrochemical Potential, 3002026561, October 2023

- Documents testing to better quantify the effect of DEHA on electrochemical potential in conditions consistent with the PWR/PHWR condensate/feedwater train.

Hydrazine Alternative: Evaluation of Hydrogen Injection, 3002022024, November 2023

- This study evaluates the reductive effect of hydrogen as compared to hydrazine, by electrochemical potential (ECP) measurement in a well-controlled laboratory loop facility, in both the plant start-up and normal operation conditions over a range of oxygen concentrations.

Investigation of Single-Phase and Two-Phase FAC with Dispersant Application, 3002020960, November 2023

- This investigation quantified the effect of the dispersant on FAC of carbon steel under single-phase and two-phase flow conditions.
- The behavior of the dispersant, including its change in concentration in the test loop at various temperatures is described.
- The results also confirmed that the dispersant has little to no volatility at 150°C and stays mainly in the liquid-phase in the two-phase system.
- The results will help utilities that are interested in implementing (or are currently implementing) dispersants to design or optimize their chemistry control program.

Foreign Object Wear Estimation Tool V 1.0, 3002026371, December 2023

- Software product that steam generator engineers can use to estimate potential tube wear work-rates from foreign objects located near the Top-of-Tubesheet in a steam generator tube bundle.

Steam Generator Eddy Current Simulation Model V6.0, 3002026370, December 2023

- The software can generate simulated eddy current signatures representing SG degradation of various dimensions (i.e., length, width, depth).
- A user-friendly interface allows the user to input desired test parameters (e.g., flaw dimensions, tube dimensions, tube material, probe type, test frequencies, etc.) and then run the model to produce the corresponding eddy current signals.

Status of Industry Guidelines, Interim Guidance and NEI 03-08 Deviations Kester Thompson

Guideline Title	Current Rev #	Report #	Last Pub Date	Implementation Date(s)	Interim Guidance	Review Date	Comment
SG Integrity Assessment Guidelines	5	3002020909	Dec 2021	1/20/23	None	2025	
EPRI SG In Situ Pressure Test Guidelines	5	3002007856	Nov 2016	8/31/17	None	2023	Data is being reviewed
PWR SG Examination Guidelines	8	3002007572	June 2016	8/31/17	Published 2019 and 2021		Revision in progress
PWR SG Primary-to-Secondary Leakage Guidelines	5	3002018267	Dec 2020	12/22/21	None	2024	

Guideline Title	Current Rev #	Report #	Last Pub Date	Implementation Date(s)	Interim Guidance	Review Date	Comments
Primary Water Chemistry Guidelines	7	3002000505	April 2014	1/28/2015		2025	
Secondary Water Chemistry Guidelines	8	3002010645	Sept 2017	6/27/2018	Published 2019, 2020, 2023	2024	

- No NEI 03-08 deviations

Guidance for Channel Head Inspections

- Current guidance in the Integrity Assessment Guidelines for SG Channel Head Inspections

Plants with materials susceptible to PWSCC shall perform SG channel head visual inspections of the primary side cladding, divider plate, stub runner, if applicable and associated welds using a visual scan by remote video camera or naked eye each time the SG primary manway is removed for tube inspections.

- This is based on results of SGMP research and industry's understanding of the Staff Interim Guidance that stated "For units with divider plate assemblies fabricated with Alloy 690 and Alloy 690 weld materials, a plant-specific Aging Management Plan (AMP) is not necessary given their low susceptibility to PWSCC"
- Some plants' aging management plans do not require inspection of the channel head assembly, and with 690 material, are not required by license renewal or SGMP guidelines to perform inspections
- SGMP considered the need to change our guidance and decided this wasn't necessary
 - Technically, components that are not susceptible to PWSCC do not require inspections
 - Plants may have requirements outside of SGMP guidance to perform inspections

Recent Operating Experience

Steve Brown

Recent US Operating Experience

- During a 100% inspection of the tubing and subsequent analysis of results, four tubes were identified with wear indications that were calculated to fail performance criteria from Technical Specifications.
- In-situ pressure testing completed on all four tubes
- All tubes satisfied Accident Induced Leakage Performance Criteria (AILPC)
- Of the four tubes pressure tested, 2 passed Technical Specifications required 3 X normal operating pressure differential (5500psi) limit, 2 failed structural integrity
- Eight-hour notification made to NRC
- SGMP was also notified and has provided assistance
- Apparent cause investigation still ongoing

Update to OE from International Member Regarding Wear Caused by Secondary Side Deposits

Jim Benson

International SG Operating Experience - SG Tube Wear

(Reported to EPRI in 2021)

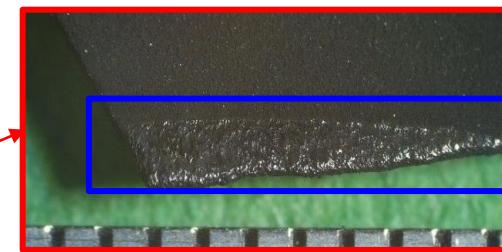
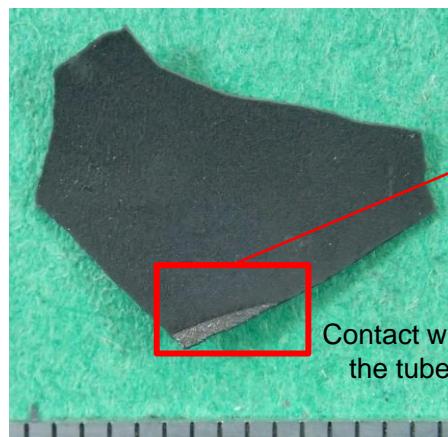
- Eddy current testing (ECT) at one unit identified indications on 4 SG tubes
 - One tube in SG-A and three tubes in SG-C, suspected to be wear initiating on the tube OD
 - All 4 indications were adjacent to 3rd TSP
 - SG-A tube flaw depth by ECT: 33%TW
 - SG-C tube flaw depth by ECT: 25%TW, 32%TW, 36%TW

Investigation of the Cause of Tube Wear

- The affected SG tubes were visually inspected using a compact camera applied from the secondary side
 - In SG-A, an object was identified between the bottom of the 3rd TSP and the tube
 - In SG-C, no objects were identified near the wear location in any of the 3 tubes
- The object from the SG-A tube wear location was removed
 - Wear was visually observed on the tube OD surface where the object had contacted the tube
- The lengths of the four identified wear scars ranged from 2 to 7 mm (0.08" to 0.28") as measured by ECT

Analytical Results of the Retrieved Object

- The retrieved object from the tube wear location in SG-A exhibited a shiny area at the object-to-tube contact location
- Radius measurement of the object revealed that the object had a curved shape closely matching the curvature of the tube OD.
- All four cases of SG tube wear are suspected to have been caused by OD deposit tube scale that spalled off the tube



Size: approx. 15mm×9mm
Thickness: approx. 0.2~0.3mm
Weight: approx. 0.1g

Corrective Action Considered by the Utility

- Application of Chemical Cleaning
 - The scale that resulted in tube wear mainly consisted of dense layers having a 5% or less porosity
 - Chemical cleaning is being studied as a means to prevent the recurrence of the event by making dense scales more porous
- For the purpose of monitoring scale buildup, it is planned to retrieve scales during every periodic outage to verify the thickness of scale dense layers and perform wear tests
- Chemical cleaning will be considered if the thickness of dense scale layers exceed a predetermined limit (e.g., 0.1mm)

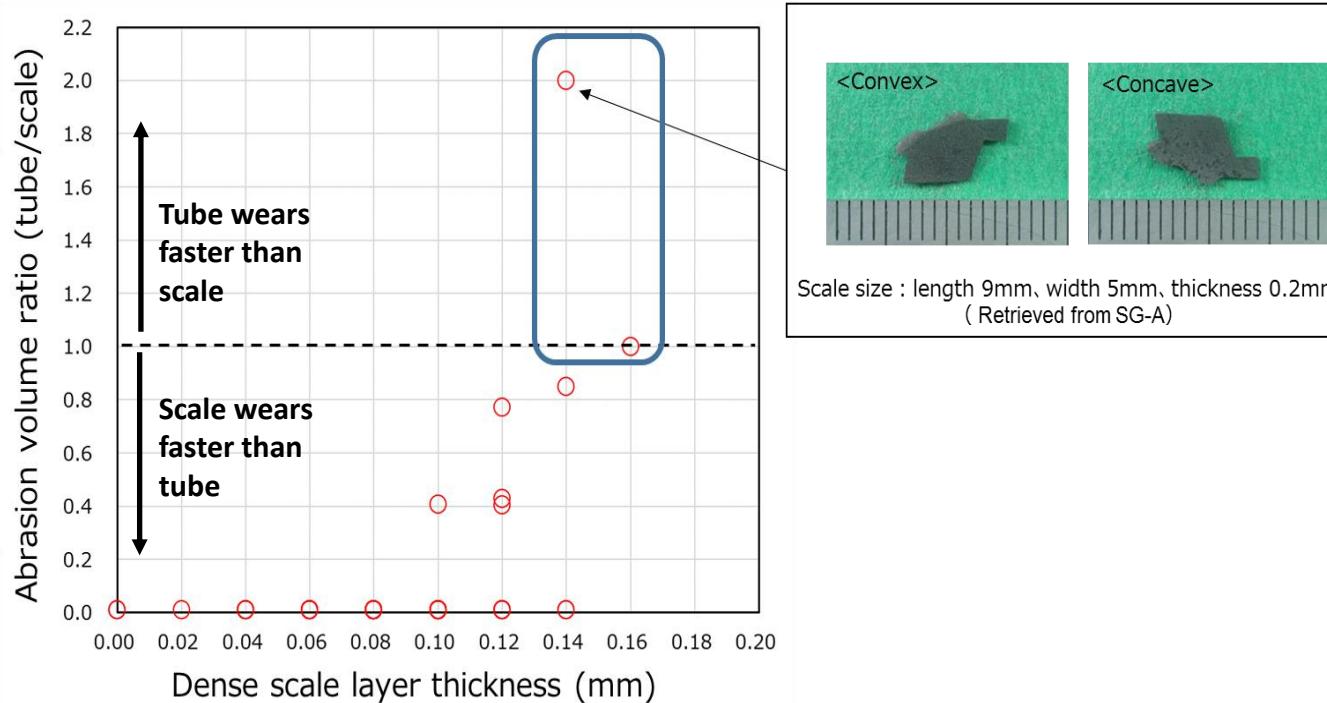
International SG Operating Experience - SG Tube Wear

(Reported to EPRI in 2023)

- ECT at two units identified indications on 15 SG tubes
 - The results for one unit represented a subsequent SG inspection outage to the inspection reported to EPRI in 2021. (12 indications)
 - The results for the other unit represented this unit's first-time observance of this type of indication (3 indications)
- The indications are believed to be wear caused by tube scale
 - 6 of the 15 indications were estimated to be $\geq 40\%$ TW by ECT
 - 14 of the 15 indications were located on the cold leg side of the SG
 - All 15 indications were adjacent to either the 2nd TSP (1), 3rd TSP (7), or the 4th TSP (7).

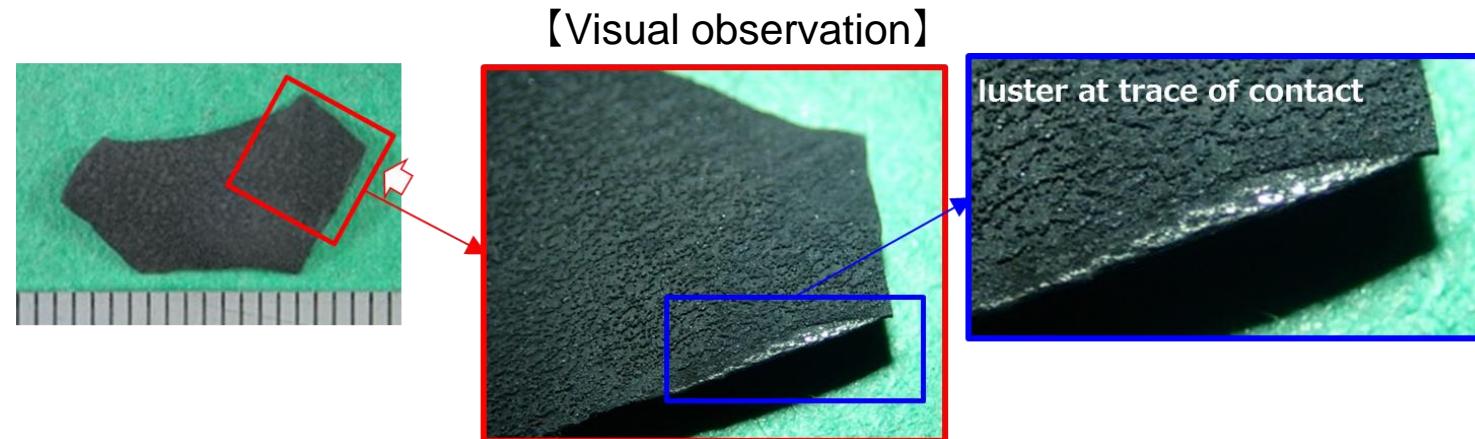
Utility Investigation

- Since no foreign objects were found, it was assumed that the scale caused the wear.
- Samples of scale were retrieved from inside the SGs to confirm its capacity to wear the tubes.
- Microscopic observations and wear tests confirmed that scale with high wear capacity [dense scale (i.e., 5% porosity) layer and thickness >0.1mm, abrasion volume ratio (tube/scale): 1.0] was present in both units.

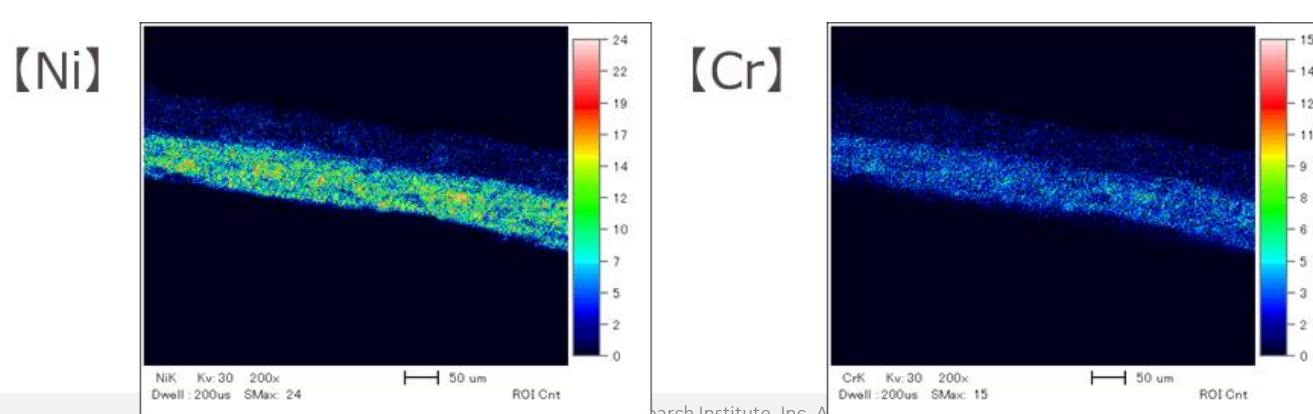


Utility Investigation

- Scale, presumed to have caused wear, has been identified. Figure shows a retrieved piece of scale.
 - Trace of contact on the tube
 - Components constitute the tube material (Nickel and Chromium)

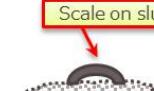
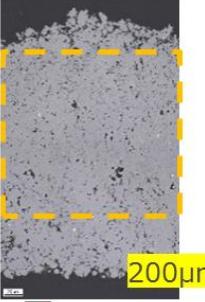
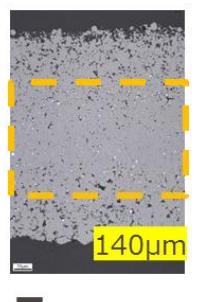
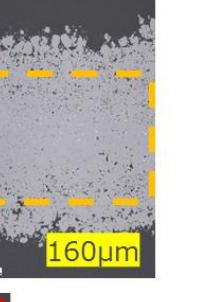
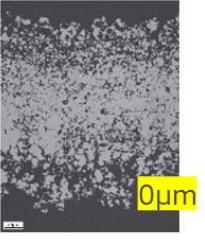
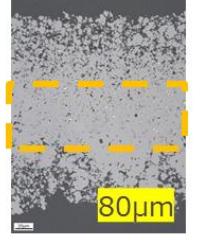
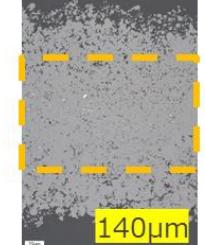
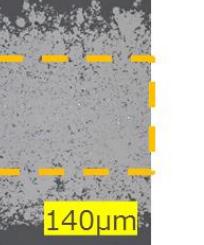


【Analysis of chemical composition】



Utility Investigation

- The effectiveness of the ASCA application was verified.
- In the lab, ASCA tests were conducted under simulated iron conditions in the SG to confirm the reduction of the dense scale layer thickness due to ASCA.
 - The influence of sludge pile height was also evaluated and showed that some of the scale was not made sufficiently more porous due to the presence of sludge.

	Previous test result	Test①	Test②	Test③
Status of sludge		 Amount of sludge : 0.8 g	 Amount of sludge : 2 g	 Amount of sludge : 4 g
Before ASCA	 dens scale layer thickness 200µm	 140µm	 160µm	 160µm
After ASCA	 dens scale layer thickness 0µm	 80µm	 20 µm reduction 20µm	 140µm

Corrective Actions Performed by the Utility

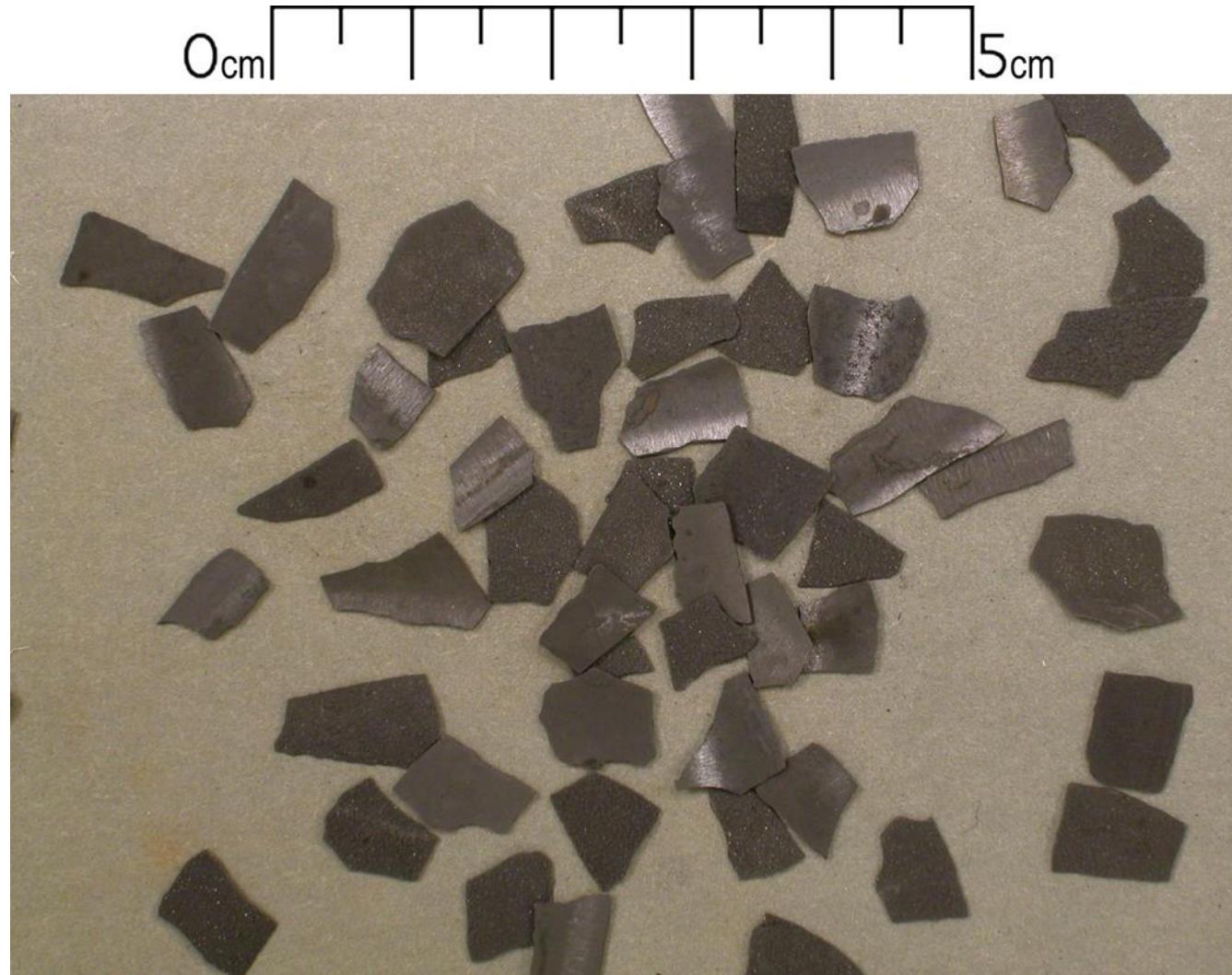
- Mechanical cleaning at the top of tubesheet and tube support plate regions was performed prior to ASCA
 - Starting from upper support plate (TSP 7), scale and sludge was removed by high pressure water and collected by lancing
- Enhanced ASCA was performed
 - EDTA concentrations and cleaning scopes were modified

SGMP Steam Generator Deposit Studies (Characterization of SG Deposits)

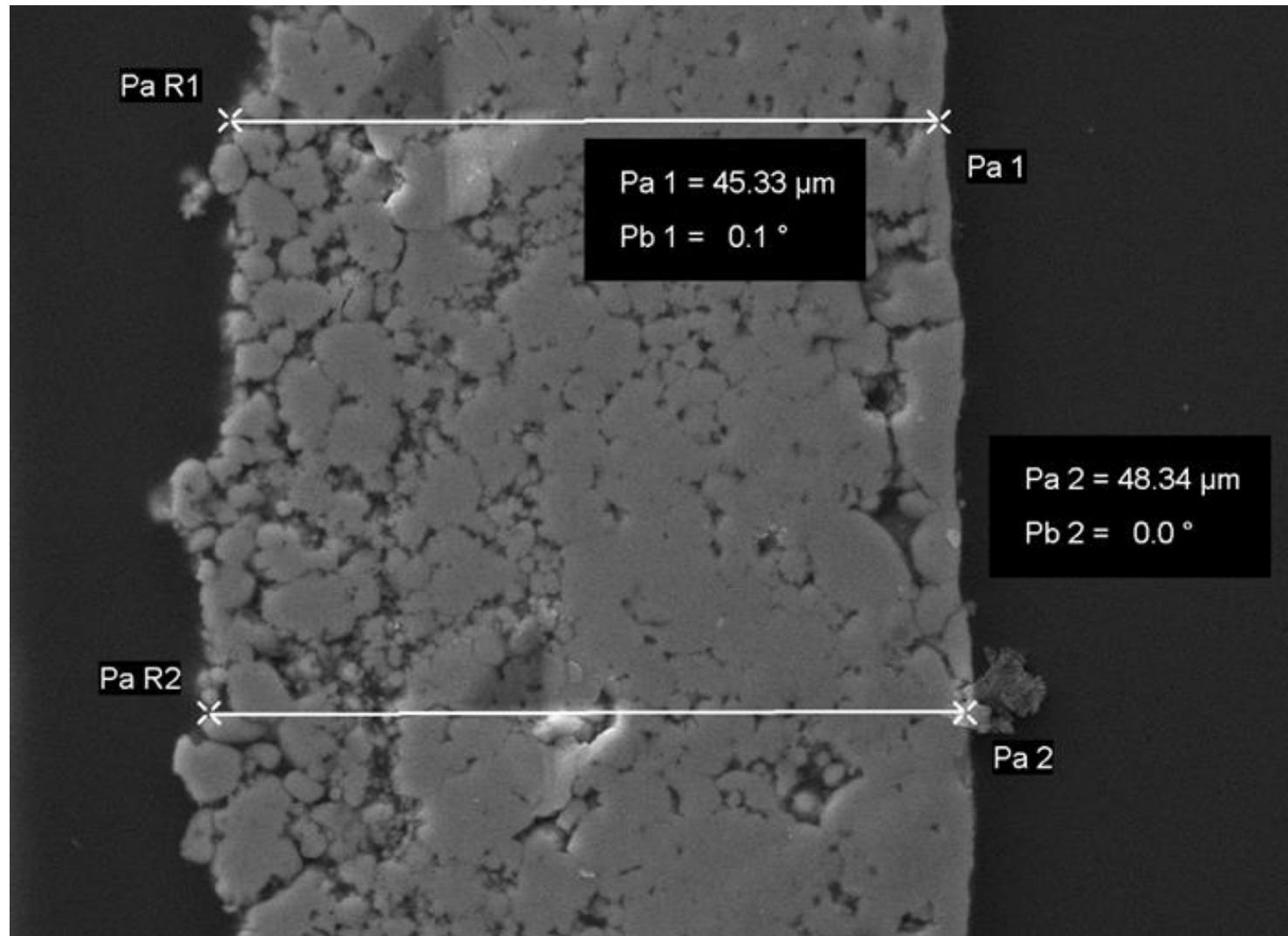
Deposit Characterization

- **Characterize removed spalled-off SG tube OD deposit flakes**
 - Numerous Units
 - Provide diversity of designs, locations, operating chemistry, materials of construction, etc.
 - Multiple sludge lancing campaigns
 - Allows tracking of parameters over time
 - Different SG operating ages (EFPY)
 - Pre- and post- ASCA and EPRI/SGOG
 - Allows evaluation of the effects of SG chemical cleaning
- **Deposit characterization focused on wear issue:**
 - Hardness
 - Composition
 - Porosity
 - Thickness

Examples of SG Flakes Identified as Tube Scale



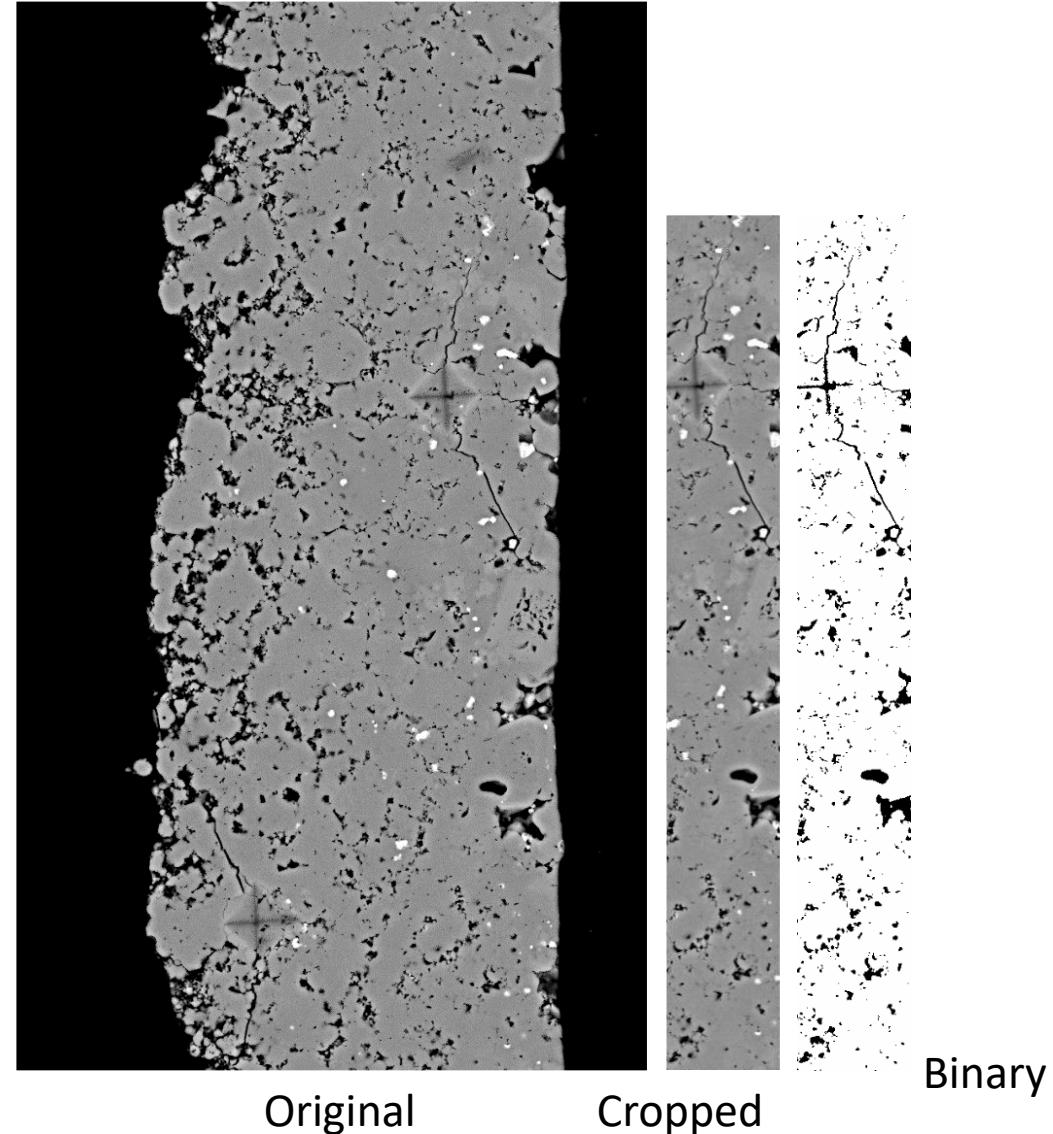
Example Deposit Flake Thickness Measurement



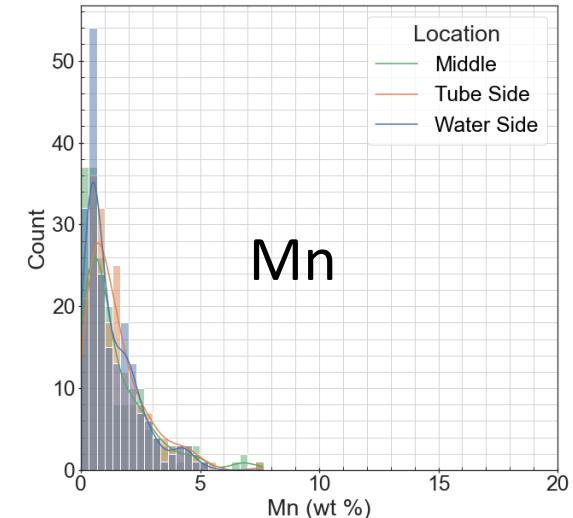
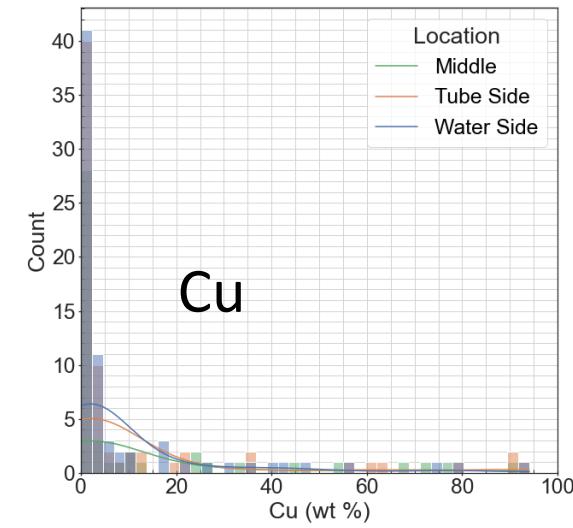
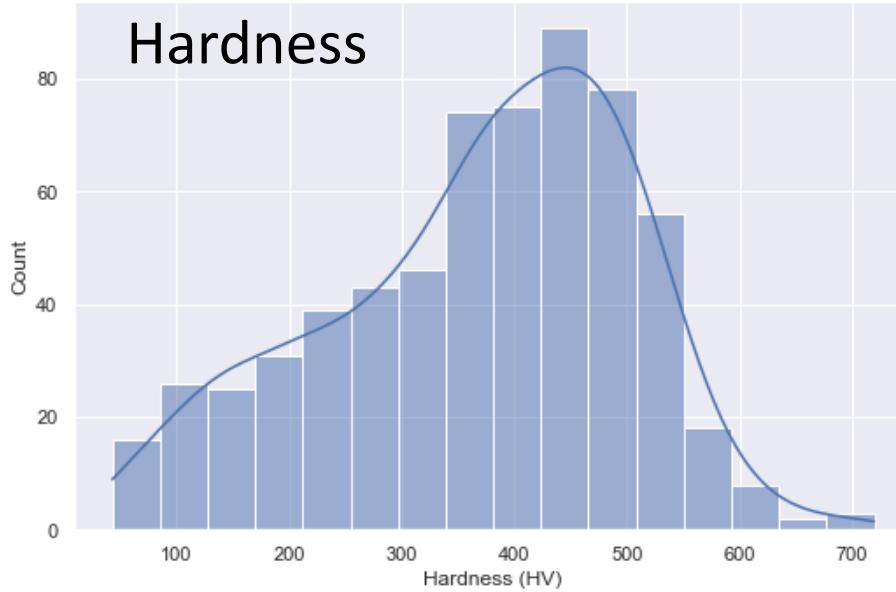
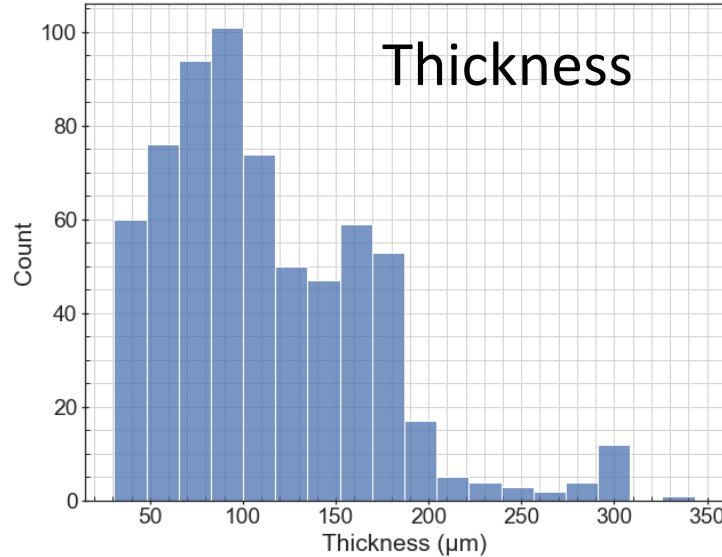
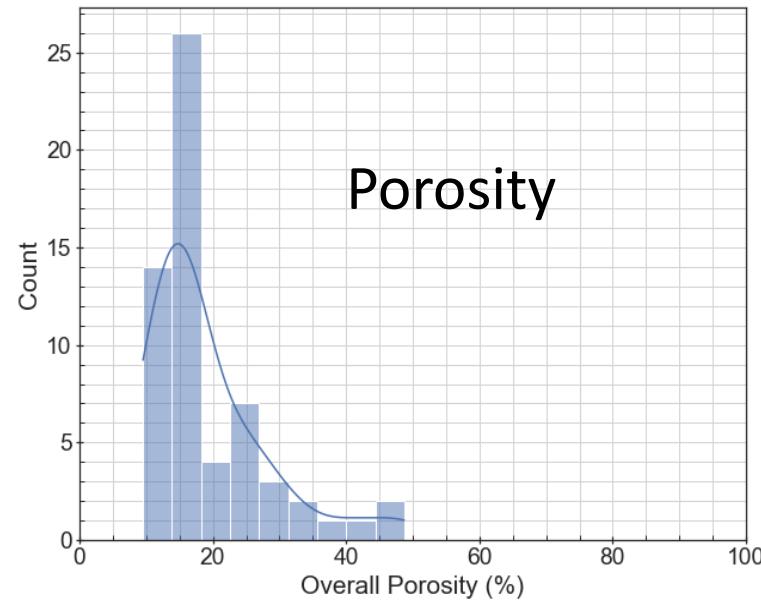
Example Porosity Analysis

In this study, three areas were selected for analysis in each flake:

1. a region near the tube side,
2. a region near the water side,
3. a region spanning the tube side to the water side



Distribution of Deposit Characteristics



Ongoing Research to Evaluate SG Deposit Flakes

- Task 1 - Perform additional assessments of removed flakes
 - Evaluate scale thickness and porosity as a function of operating time since a clean tube condition (i.e., plant startup, SG replacement, or hard SG chemical cleaning)
- Task 2 - Assess the affects of soft chemical cleaning on SG tube deposit flakes
 - Obtain removed SG deposit flakes from 3 sludge lancing campaigns
 - From each campaign, analyze one set of flakes in their “as found” condition
 - Analyze another set of flakes after undergoing a laboratory soft chemical cleaning application
- Task 3 - Issue a technical report on SG deposit flake studies

Circumferential PDA Calculation Examples

Bill Cullen

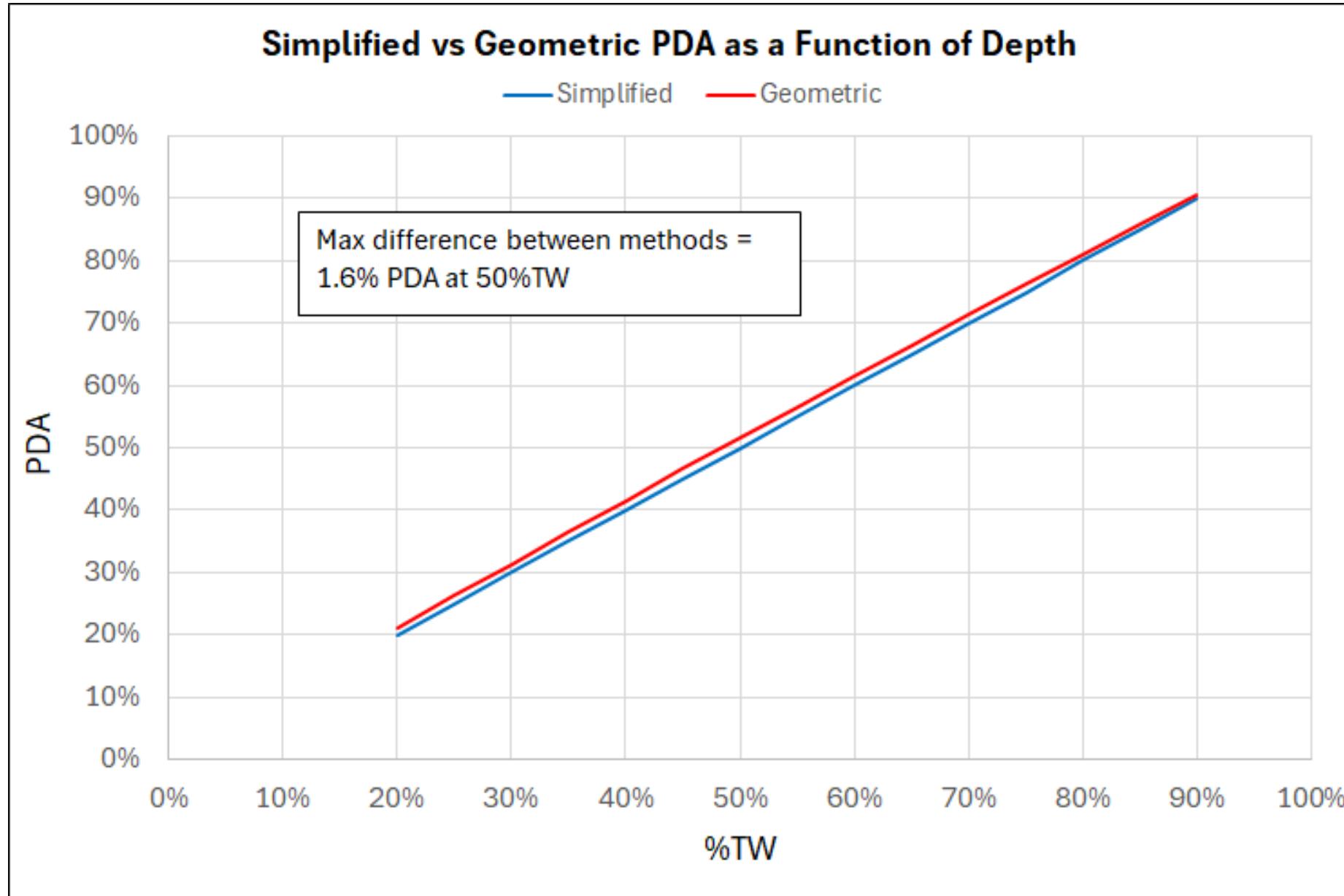
Simplified Method vs Geometric Formula for Calculating PDA

- Simplified method
 - $PDA = (\text{Depth} * \text{Length})/360$
- Geometric formula
 - $PDA = \frac{\pi \times (\text{Rout}^2 - \text{Rin}^2) - \pi \times (\text{Rout}^2 - \text{Rmid}^2)}{[\pi \times (\text{Rout}^2 - \text{Rin}^2)]}$
- EPRI guidelines do not prescribe how to calculate cross-sectional area of circ degradation
- The Flaw Handbook Calculator doesn't calculate PDA; it is an input
- The underlying spreadsheet used by the FHC were validated by manual calculation to be correct

NRC Observation - 360 degree, 75% through-wall crack

75% TW crack 360 degrees			
Shortcut PDA Calculation Method			
$(75)(360)/(360) =$		75.0	PDA
Actual Surface Area Calculation			
$\text{Pi}^*(\text{Rod}^{\text{A2}}-\text{Rid}^{\text{A2}})$	0.070	sq. inches	Cross sectional area of entire tube
$\text{Pi}^*(\text{Rod}^{\text{A2}}-\text{Rmid}^{\text{A2}})$	0.053	sq. inches	Cross sectional area of 75% through-wall crack
$\text{Pi}^*(\text{Rod}^{\text{A2}}-\text{Rid}^{\text{A2}})-\text{Pi}^*(\text{Rod}^{\text{A2}}-\text{Rmid}^{\text{A2}})$	0.017	sq. inches	Cross sectional area of remaining 25% tube wall
$0.053/0.070 =$	76.2	PDA	
Radius			
Tube OD	0.625	0.3125	
Tube ID	0.549	0.2745	
Wall Thickness	0.038		
75%	0.75		
75% of wall	0.0285		
OD - 75% of wall	0.284		
180 deg	180		

Industry's Comparison of Different Ways to Calculate



Conclusions

- If burst pressure is calculated as a function of PDA when determining CM, **there is no impact**
- If burst pressure is calculated as a function of PDA when performing an OA, **there is no impact**
- If you are comparing the calculated PDA for a detected flaw against the CM limit curve (deterministic), then there could be a small difference
- When burst is controlled by tensile failure mode, the difference in PDA between the geometric and approximate methods is a maximum of 1.6% PDA

Address Public Questions and Comments NRC Staff

The background of the slide is a dense collage of numerous small, square portraits of diverse individuals, primarily professionals, arranged in a grid pattern. The overall color tone of the background is a gradient of blue and purple.

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