SGTF / NRC Meeting

Virtual Meeting
September 7, 2023

Agenda

Time	Topic	Speaker
1:00 pm	Welcome and Introductions	All Participants
1:10 pm	Opening Remarks	NRC and Industry
1:15 pm	Industry Presentation: 1. Recently Published Reports 2. Status of Industry Guidelines 3. Interim Guidance 4. Nuclear Energy Institute 03-08 Deviations 5. Recent Operating Experience – None to Report 6. Re-characterization of PWSCC Low Row U-Bend Indications 7. Status Update on Transfer Function	Industry H. Cothron J. Mayo B. Cullen B. Cullen
2:45 pm	Break	All Participants
3:00 pm	1. Initial License Renewal and Subsequent License Renewal Guidance for Divider Plate and Tube-to-tubesheet Weld Cracking 2. Proposed Changes to Subsequent License Renewal Aging Management Program XI.M19, “Steam Generators”	NRC
3:20 pm	Address Public Questions/Comments	NRC
3:30 pm	Adjourn	

Secondary Side Filming Product Application General Corrosion Testing, 3002026279, March 2023

- Documents material compatibility testing completed to characterize the general corrosion behavior of commonly used plant metallic materials with applied films
- Two filming products, an amine-based product and a non-amine-based product, were tested by applying the filming products to specimens and then exposing the specimens to the prototypical secondary water chemistry.
- A combination of fully filmed, partially filmed (with a film/no-film boundary), and unfilmed specimens were tested to understand the impact of partial filming.
- The impact of a magnetite corrosion product deposit layer (distinct from the protective grown-in-place oxide layer) was also investigated.
- The test program did not identify any significant technical risks associated with the exposure of plant materials to either of the two tested products. Accordingly, the results support the safe implementation of a demonstration with either product.

Secondary Side Filming Product Application: Effect of Filming Products on General Corrosion Under Simulated Secondary Side Lay-Up Conditions, 3002026095, April 2023

- This work studied the effect of three filming products on the general corrosion of secondary-side systems and components under simulated lay-up conditions.
- Objectives: 1) assess any effect of pre-existing oxides on the application and the corrosion protection imparted by the film and 2) assess any effect of non-uniform or partial filming on the component surfaces as it is not feasible to ensure complete coverage on all surfaces throughout the secondary-side systems and components in the field.
- This testing supports further understanding of general corrosion behavior of several materials that can aid in valuing the application of filming products.

NDE Data Compatibility and Exclusion Criteria: Methodology for Evaluating Two NDE Data Sets Regarding Performance Similarity, 3002023853, June 2023

- Laboratory generated stress corrosion cracks are a more economical option for developing the supporting specimens and data for eddy current examination techniques compared to harvesting of steam generator (SG) tubes from operating SGs with subsequent destructive examination.
- Experience has shown that laboratory generated SCC may not always exhibit eddy current signal parameters consistent with available pulled tube data or other accepted SCC databases.
- This report describes a methodology for evaluating laboratory generated SCC against pulled tube data or other accepted SCC databases to determine if the data set in question is compatible with the reference data set.
- This report describes a method to determine whether a limited subset of flaws from the laboratory generated SCC data set can be utilized to supplement the data set of existing eddy current techniques.

Status of Industry Guidelines
Jeremy Mayo, TVA, Chair SGTF

Guideline Title	Current Rev #	Report #	Last Pub Date	Implementation Date(s)	Interim Guidance	Review Date	Comment
SG Integrity Assessment Guidelines	5	3002020909	Dec 2021	1/31/22	None	2025	
EPRI SG In Situ Pressure Test Guidelines	5	3002007856	Nov 2016	8/31/17	None	2023	Data will be checked in 2023 to determine if revision is needed
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	12/22/2021	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		Review meeting planned for 2025	Decided not to start a revision in 2024
Secondary Water Chemistry Guidelines	8	3002010645	Sept 2017	6/27/2018	Published 2019, 2020, 2023	Review meeting planned for 2024	Decided not to start a revision in 2023

- No NEI 03-08 deviations

Interim Guidance in Letter SGMP-23-02

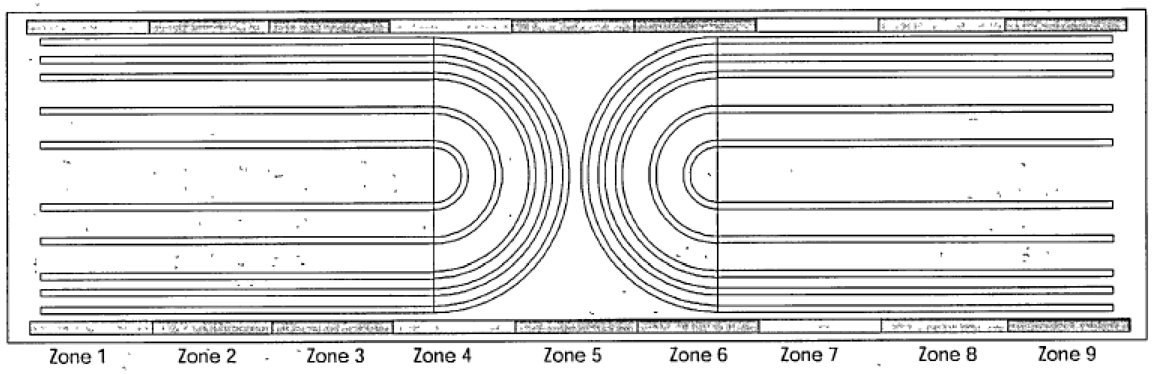
- Guidelines affected: Secondary Water Chemistry Guidelines, Rev 8
- Status: Endorsed, published, implementation by May 2024
- What Changed in the Guidance:
  - Allowed plants that were at operating above the Mid Point Value (MPV) with a decreased hydrazine-to-oxygen ratio to be able to continue to operate with that same ratio if they down-power below MPV
- Reason for Change:
  - If a plant was previously operating with reduced hydrazine-to-oxygen ratio but had to down-power to below MPV, they would be in action level (AL) condition and would need to respond which could result further plant power reductions
  - Wording does *not* allow low hydrazine-to-oxygen during start-up to prevent corrosion due to presence of reducible metal oxides

Recharacterization of PWSCC Low Row U-Bend Indications

Bill Cullen, EPRI

A600TT SCC Susceptibility

- A600TT has enhanced PWSCC resistance compared to A600MA
  - Thermal treatment provides carbide decoration along the grain boundaries
  - Validated by original material qualification and empirical performance
- The first 8 to 10 rows of U-bends (and some of straight length) received a post-bend stress relief at thermal treatment temperatures designed to reduce residual stresses to near straight leg levels (2 to 4 ksi)
- This residual stress level does not support SCC initiation

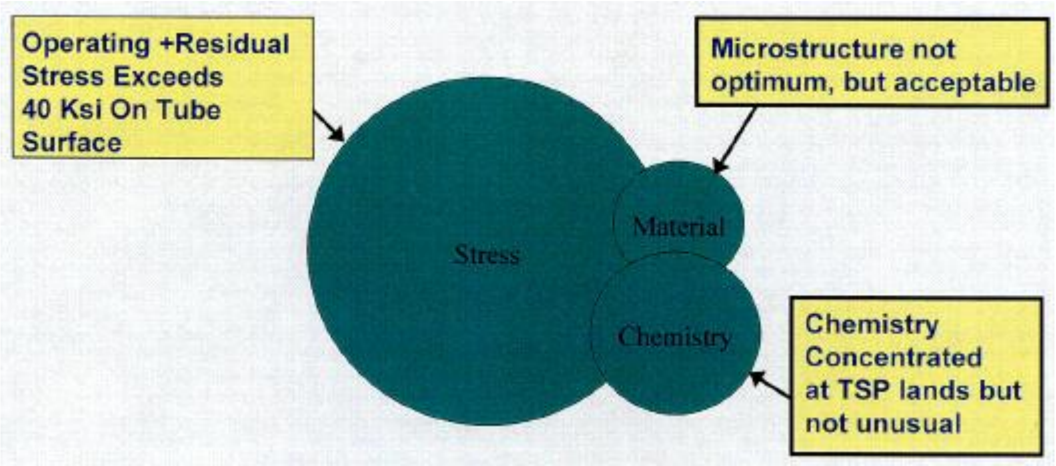


Zones 1 through 9 are heating zones in the furnace. Only zones 4, 5 and 6 were activated for stress relief of the u-bends.

SCC of a stress relieved U-bend without an additional stress riser is not a likely event

SCC Susceptibility Venn Diagram

- Taken from November 14, 2002 post outage presentation materials (NRC website)
- Since the ding results in plastic deformation, localized residual stresses can approach/exceed yield
- Remove one of the elements and SCC potential becomes negligible



Without a ding, the residual stress component is removed

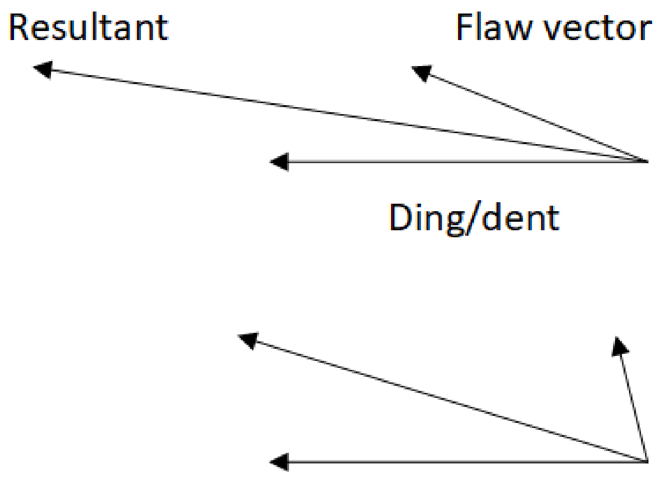
How can SCC form in Stress Relieved U-bends?

- A stress riser must be introduced post stress relief
- Less than optimal microstructure may also play a part
- Row 1 and 2 tube insertion was problematic;
  - Often tubes were over-inserted resulting in interaction with the top TSP and tube causing a ding on the intrados
- Without the ding, SCC is not supported
- First generation plant experience showed additional bending stresses may be introduced from severe denting causing PWSCC at the apex; not relevant for SS TSPs with quatrefoil tube holes

As-produced A600TT U-bends are not susceptible to PWSCC

Axial ODSCC on Dings and Dents Can Mimic PWSCC

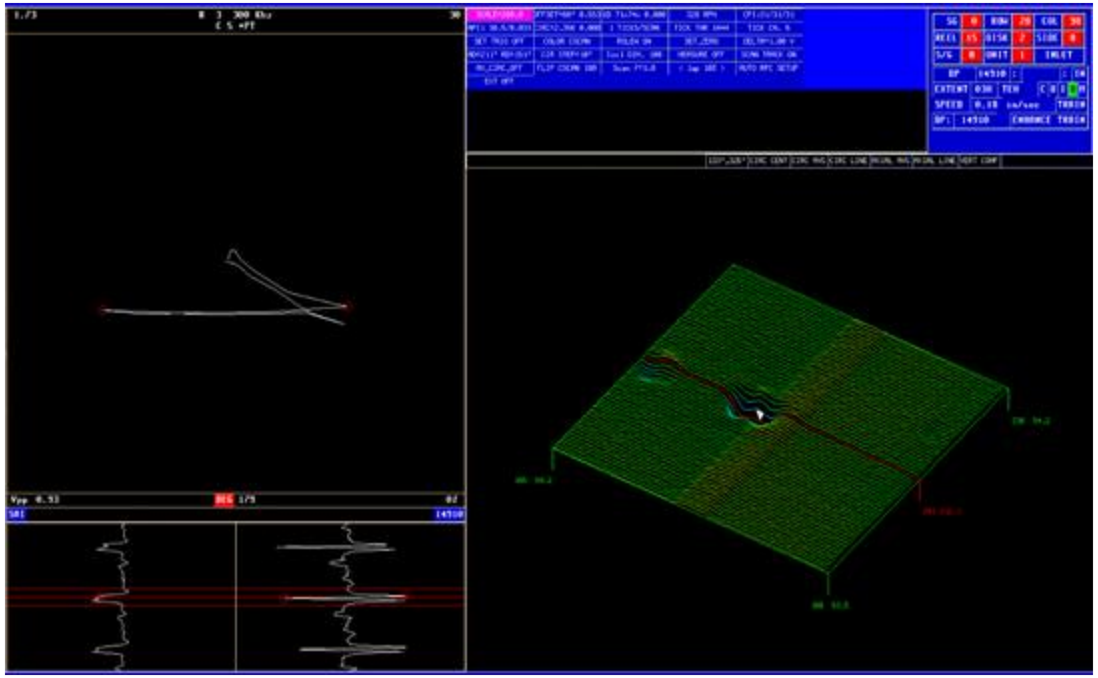
- +Pt does not completely eliminate the ding residual signal
- The +Pt residual signal resides at approximately 0 degrees phase
- Simple vector addition can be used to illustrate how an ODSCC signal when combined with the ding/dent residual can produce resultant signals in the ID plane
- For equal depth ODSCC, the larger the ding, more phase suppression and the smaller the ding, less phase suppression
- If modest depth ODSCC (60 to 80%TW) is present, the resultant amplitude should be similar to the residual
- If PWSCC is present, the resultant amplitude should be significantly larger than the non-flawed residual; this is not observed on in situ dings with SCC
  - PWSCC flaw amplitudes are about 3x larger than ODSCC for equal depths
- Through hysteresis, tube OD will have tensile stresses, ID compressive, thus PWSCC at a ding is not relevant

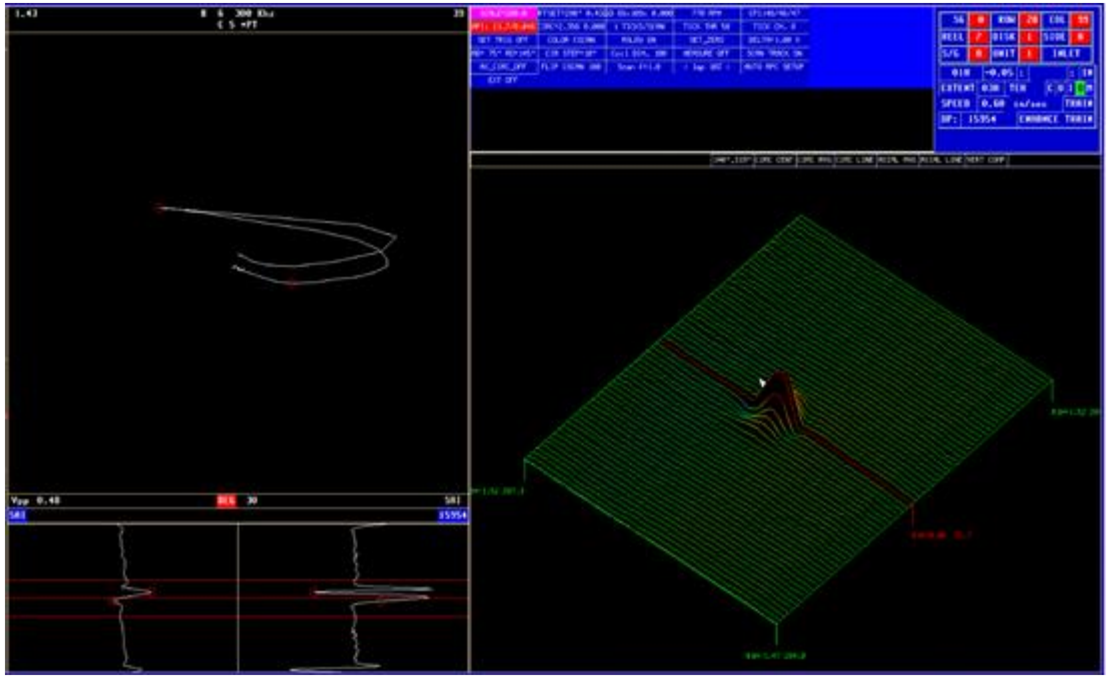


Note these are approximations, real ECT signals are rarely characterized by a linear vector

Doped Steam Axial ODSCC at Freespan Ding (ETSS 24013)

- Lab sample BOQ-28-02: 4.6V ding, 78%TW (DE), 0.23 inch long
- Pre-crack and post-crack +Pt graphics

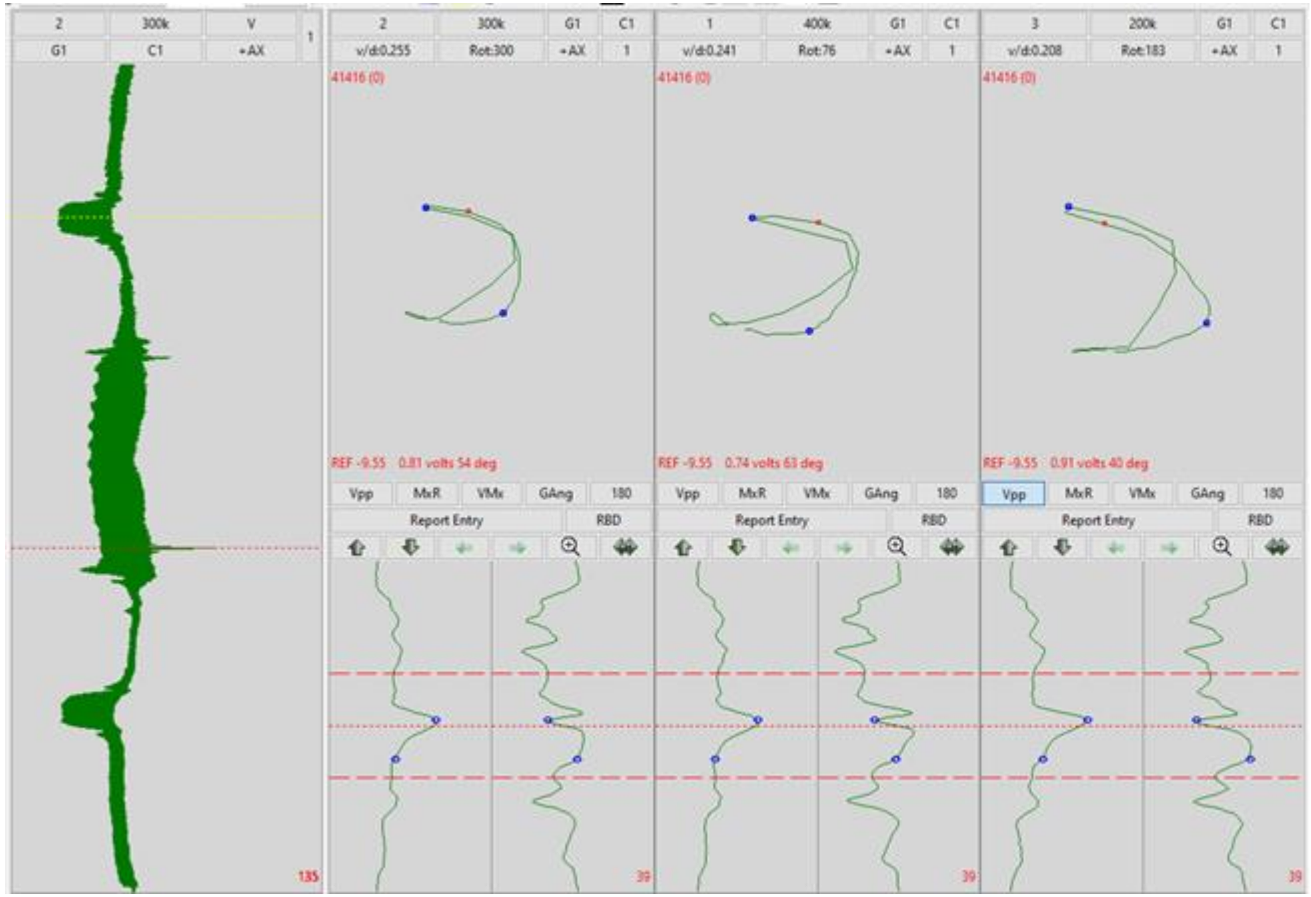




Post crack condition more resembles PWSCC than ODSCC due to phase suppression by the residual. The larger the ding, the greater the phase suppression of flaw signal

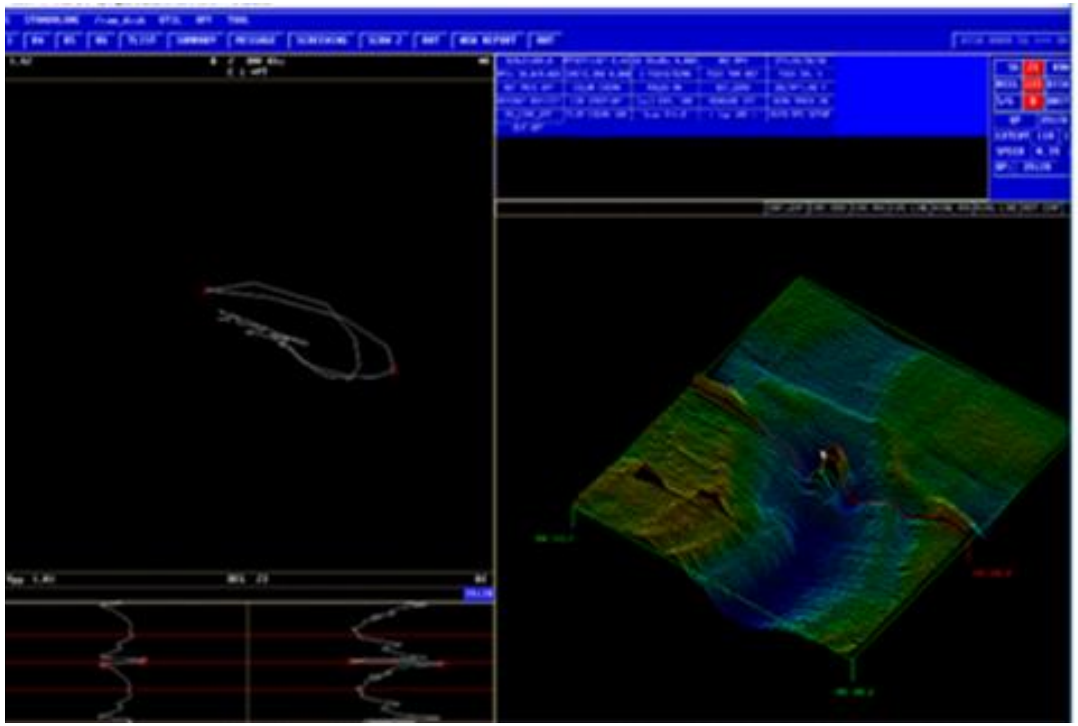
Recent U-bend SCC Experience (2021)

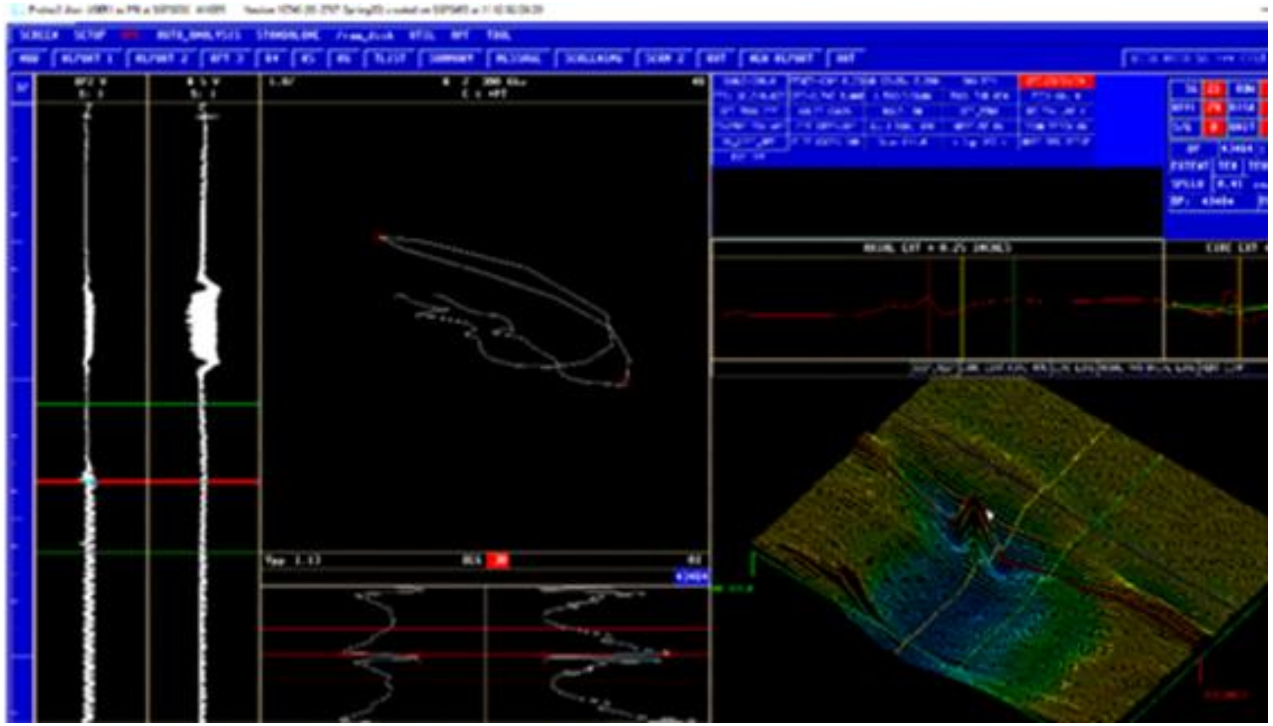
- Model 44F SG, Row 1 U-bend, axial ODSCC at ~4V ding, on intrados, about 1 inch above bend tangent, in-line with TSP contact land
- Smaller ding, lesser phase suppression
- Called ODSCC in the field



Recent U-bend SCC Experience (2021)

- Model D5 plant, Row 1 U-bend, axial ODSCC at ~6V ding, on intrados, about 1 inch above bend tangent, in-line with TSP quatrefoil contact land
- Initially called PWSCC in the field, concluded to be axial ODSCC based on EPRI flaw injection study
- Data Union simulation on left, plant signal on right





Historic U-bend “PWSCC” Experience (2009)

- Axial PWSCC reported on a Row 1 U-bend with large +Pt voltage (3V), and minor leakage during ISPT at SLB pressure differential
- Reported at “Blairsville Bump”; ⇨ NOT CORRECT
- Bump is located on intrados at the bend tangent
  - Presence of the bump with regard to SCC potential is irrelevant due to post bend stress relief
- Internal ball mandrel may not have been used on Model F SGs
- 2009 indication reported ~1 inch above tangent, possibly on the flank (EPRI and Westinghouse confirmation) but aligned with the TSP contact land
- Given the 2021 experiences, EPRI investigated this signal to determine the true nature of the degradation; it has long been reported that a bobbin “geometry” signal was present in prior bobbin data, possibly suggesting a ding was present
- Flaw injection and engineering studies were performed

2009 R1 C20 Signal Parameters

- +Pt data available from 1997 (NDD), 2003, and 2009
- Based on the 1997 residual measurement (1.2 to 1.4V), estimated ding voltage is approximately 6 to 7 volts
- A 1.83V, 19 degree phase precursor signal is observed in 2003
- A 3.11V, 28 degree phase signal is observed in 2009
- Small amplitude change from 1997 to 2003; classic performance of ODSCC/ding interaction
- PWSCC does not fit the 2003 signal parameters assuming 60%TW (1.25V, 21 degrees phase) donor signal

Injection Signals

- 65%TW ODSCC and PWSCC signals were injected into the 1997 data at the residual
  - Phase angle consistent with depth/direction
  - ODSCC: 0.5V injected signal
  - PWSCC: 1.25V injected signal
- 100%TW ODSCC: 3V, 32 degrees phase
- 100%TW PWSCC: 4V, 32 degrees phase
- Results:
  - ODSCC injections closely match the observed flaw parameters
  - PWSCC injections do not match the observed flaw parameters

Inspection Year	Actual (volts and phase)	OD Injection (volts and phase)	ID Injection (volts and phase)
2003	1.83V, 19 degrees	1.88V, 25 degrees	2.76V, 17 degrees
2009	3.11V, 28 degrees	3.37V, 26 degrees	~5V

Engineering Analysis

- EPRI Ding/Dent Crack Sizing Procedure used to develop depth profiles of the 2003 and 2009 +Pt data
- In situ pressure test performed in 2009:
  - Estimated leak rate from in situ pressure test = 0.002 gpm at 3200 psi
  - Using EPRI leak rate equations, a 0.08 inch 100%TW length is required to achieve 0.002 gpm at 3200 psi
- From the 2009 depth profile the 100%TW length is ~0.06 inch and length >95%TW is 0.10 inch, thus the estimated depths which could contribute to leakage match well with the observed leak rate
- If assumed to be PWSCC, a 3.11V signal does not associate with 100%TW degradation, thus in situ pressure test leakage is not credible for PWSCC

Conclusions

- Stress relieved U-bends without the presence of an additional stress riser do not represent an SCC potential
- Any observed SCC must be associated with tube damage following stress relief
- The three U-bend SCC events to date in low row stress relieved tubes have been associated with geometric anomalies (dings) which are aligned with the TSP contact land
- Injection studies validate the assumption of axial ODSCC at a ding and discount the presence of PWSCC

PWSCC of small radius U-bends can be considered as non-relevant

Conclusions

- This research eliminates the need for plants with Alloy 600TT tubed steam generators to consider U-Bend PWSCC as a potential mechanism
- These research results should not result in any changes to reporting
  - No change to inspection scope or frequency
  - No change to structural or leakage integrity calculations

Status Update of Transfer Function from Plus Point Voltage to Array Probe Voltage

Bill Cullen, EPRI

Background

- New array ETSSs or array ETSS updates for SCC are still several years out
- Most A600TT plants are using or plan to use array probes
- Transfer function was developed to provide a tool for developing or strengthening PODs for cracking by estimating array probe amplitude from prior +Pt signals (destructively examined) and including these signals in the A-hat function
  - Necessary for Operational Assessments
- Benchmarking validates the validity of the Transfer Function

+Point to Array Probe Transfer Function

The transfer function is a *generalized assessment* of amplitude performance of two probe types using known flaws (axial and circ EDM notches)

- +Point and array probe data was acquired from several A600TT plants (Model F, Model D5, Model 44F) during 2019 and used for the initial evaluation of the eventual EPRI transfer function (2019/2020)
- True SCC flaws are not required; benchmarking proves validity of the concept
- In 2021, EPRI recollected +Pt and array probe data however the transfer function is based on the 2019 data, which shows slightly conservative array probe amplitudes versus the EPRI collected data
    - Pulled tubes now dominate the array probe A-hat functions provided in the Transfer Function report
    - POD curves are more logical than prior versions
- Benchmarking of predicted vs measured array probe amplitudes for those flaws with both +Pt and array inspection data is excellent

Benchmarking is the key comparison point and validates the transfer function

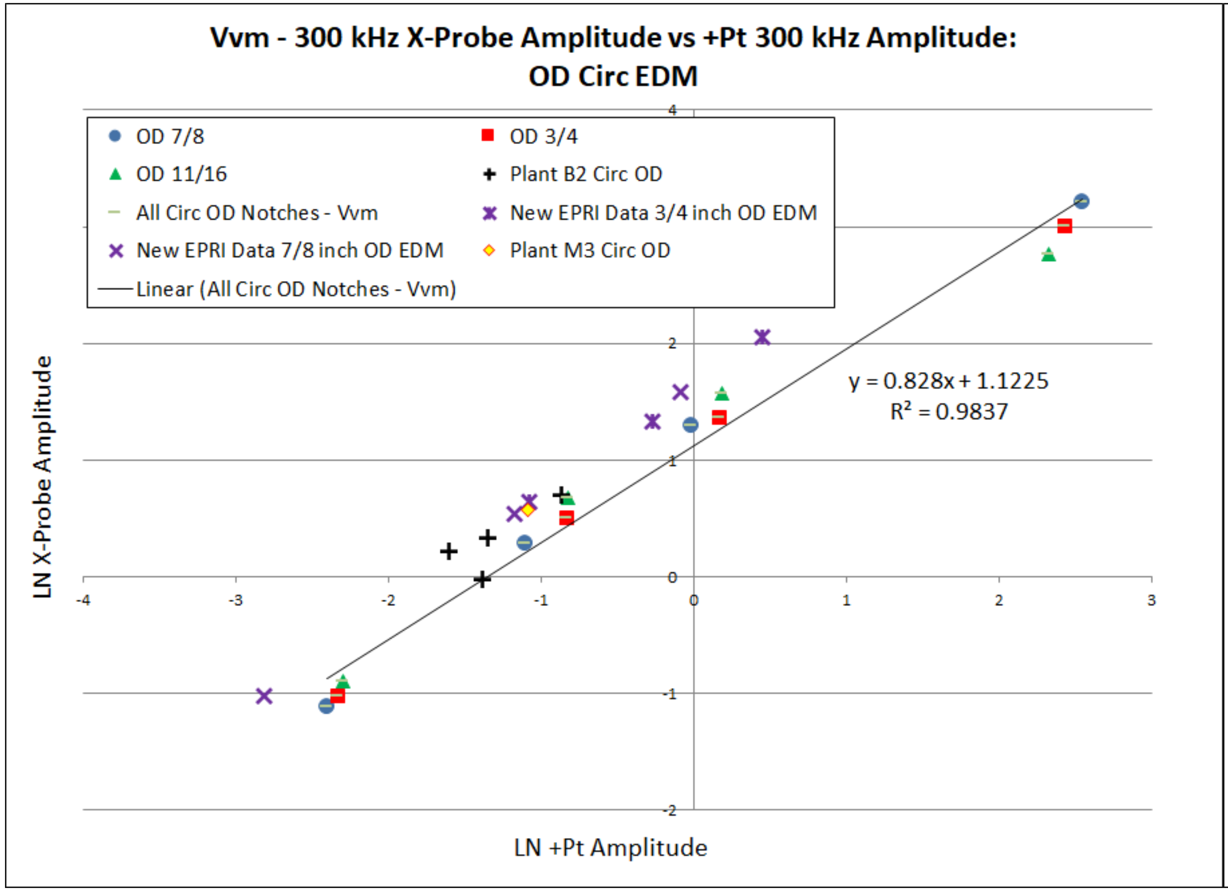
+Point to Array Probe Transfer Function

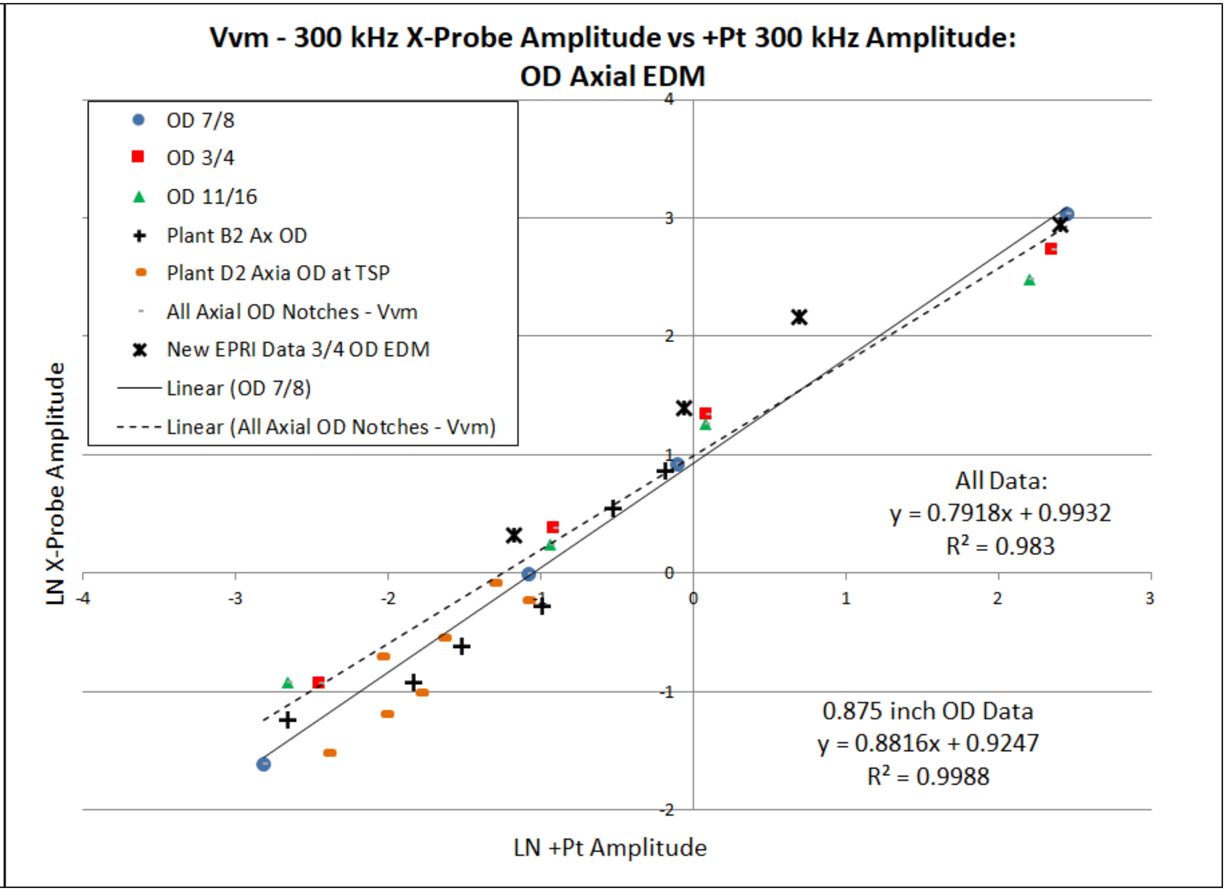
The methodology and its validation are extremely simple

1. Develop a linear regression of array probe signal amplitude on +Point Signal amplitude for generalized probe performance; this is the transfer function
2. Test (benchmark) the transfer function against empirical plant data and evaluate the results
3. Assesses compatibility of lab-produced flaws not for development of the transfer function but for inclusion in A-hat data set based on amplitude versus depth comparison of pulled tube and lab-produced flaws
4. Generate new array probe A-hat functions for axial and circumferential ODSCC
5. Develop example POD curves using example noise data sets and assess the reasonability of these curves

- PWSCC mechanism transfer function to be developed in 2024

+Point to Array Probe Transfer Functions

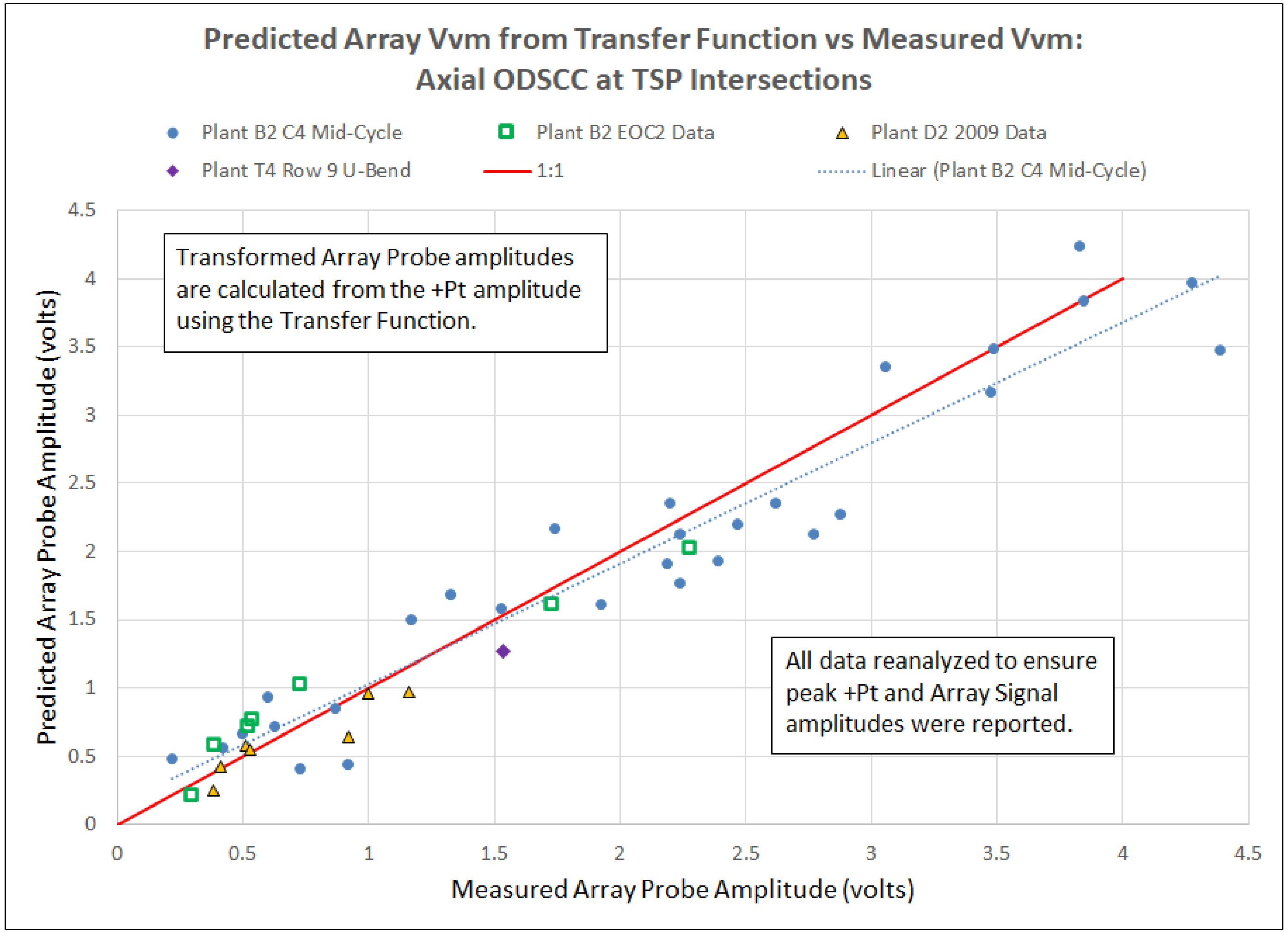




Vpp performance is similar, Vvm shown here since Vvm is used for A-hat development. Volumetric degradation follows the axial ODSCC trending.

Axial ODSCC Benchmarking

- Empirical +Pt/Array data was reanalyzed to ensure the peak amplitude response was measured
- Array probe response can be sensitive to the selected coil pair
- Data from 3 plants (1 A600MA, 2 A600TT) and two tube diameters are included
- In general, measured Array Probe amplitude exceeds predicted; this is conservative
- Excellent benchmarking results



Conclusions

- Axial ODSCC benchmarking results show excellent agreement between predicted and measured Array probe voltages
- PWSCC Transfer Functions will be developed in early 2024
- EPRI will continue to benchmark with available data, including the data for developing Array probe ETSSs
- Tube integrity engineers will be able to use the transfer function to develop POD curves until ETSSs are available
  - These ETSSs are planned to be completed 2025 if there are no issues


Together...Shaping the Future of Energy®