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Three Mile Island, Unit 1 Summary of Tube-to-Tube Wear Identified During T1R19 (Fall 2011)

January 26, 2012

NRC Headquarters

Introduction

Introductions and Opening Remarks

Bill Carsky, TMI-1 Site Engineering Director

- Greg Ciraula, TMI-1 Engineering Programs Manager
- Mark Torborg, TMI-1 Steam Generator (SG) Program Engineer
- Steve Queen, Director Corporate Engineering Programs
- Jay Smith, Corporate SG Program Manager
- Wendi Croft, Senior Licensing Engineer

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Purpose

- ✓ Provide information on tube-to-tube (T-T) wear
  - Inspection results
  - How the indications were identified
  - Reporting Criteria
  - Primary and secondary analysis
  - How the indications were sized
  - Basis for sizing techniques
  - Future planned actions

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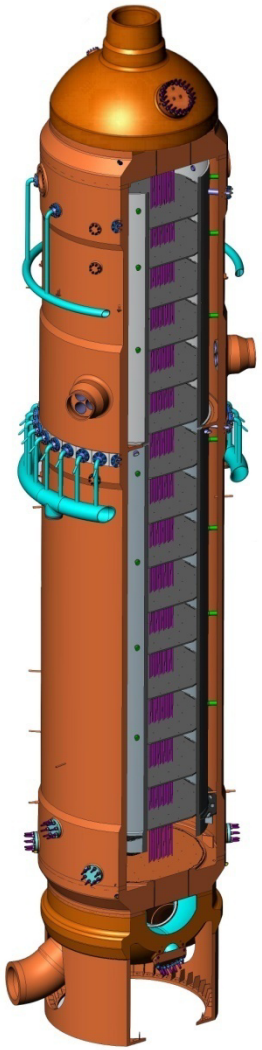
Background



- ✓ TMI-1 installed AREVA, Enhanced Once Through Steam Generators (EOTSGs) during T1R18
  - Operated January 2010 – October 2011
- ✓ General design features of EOTSGs
  - 15,597 tubes per EOTSG
  - Full depth hydraulic expansions in tubesheets
  - 15 stainless steel tube support plates (TSP)
    - Trefoil broached holes, 1.18” thick
    - Numbered 01S (bottom) – 15S (top)
    - 15S TSP has 1470 drill holes in peripheral tubes
    - Spacing between TSPs varies from 35” - 46.4”
    - Aspirating ports are in 10th span
  - Nominal gap between tubes is 0.25”
- ✓ First inservice inspection performed in October 2011
  - 24-month fuel cycles
  - 1.72 effective full power years (EFPY) on EOTSGs
  - Maintained hot conditions throughout operating cycle

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T1R19 Inspection Overview

- ✓ 100% full length bobbin coil inspections in each EOTSG
- ✓ X-Probe inspections of peripheral tubes (two tubes deep) in each EOTSG (Evaluated 1st span for loose parts)
- ✓ Tube damage mechanisms found in each EOTSG
  - Tube-to-tube support plate wear (T-TSP) (expected)
  - Tube-to-tube wear (T-T) (not expected)
- ✓ No evidence of tie rod bowing
- ✓ No tie rod to tube contact or proximity

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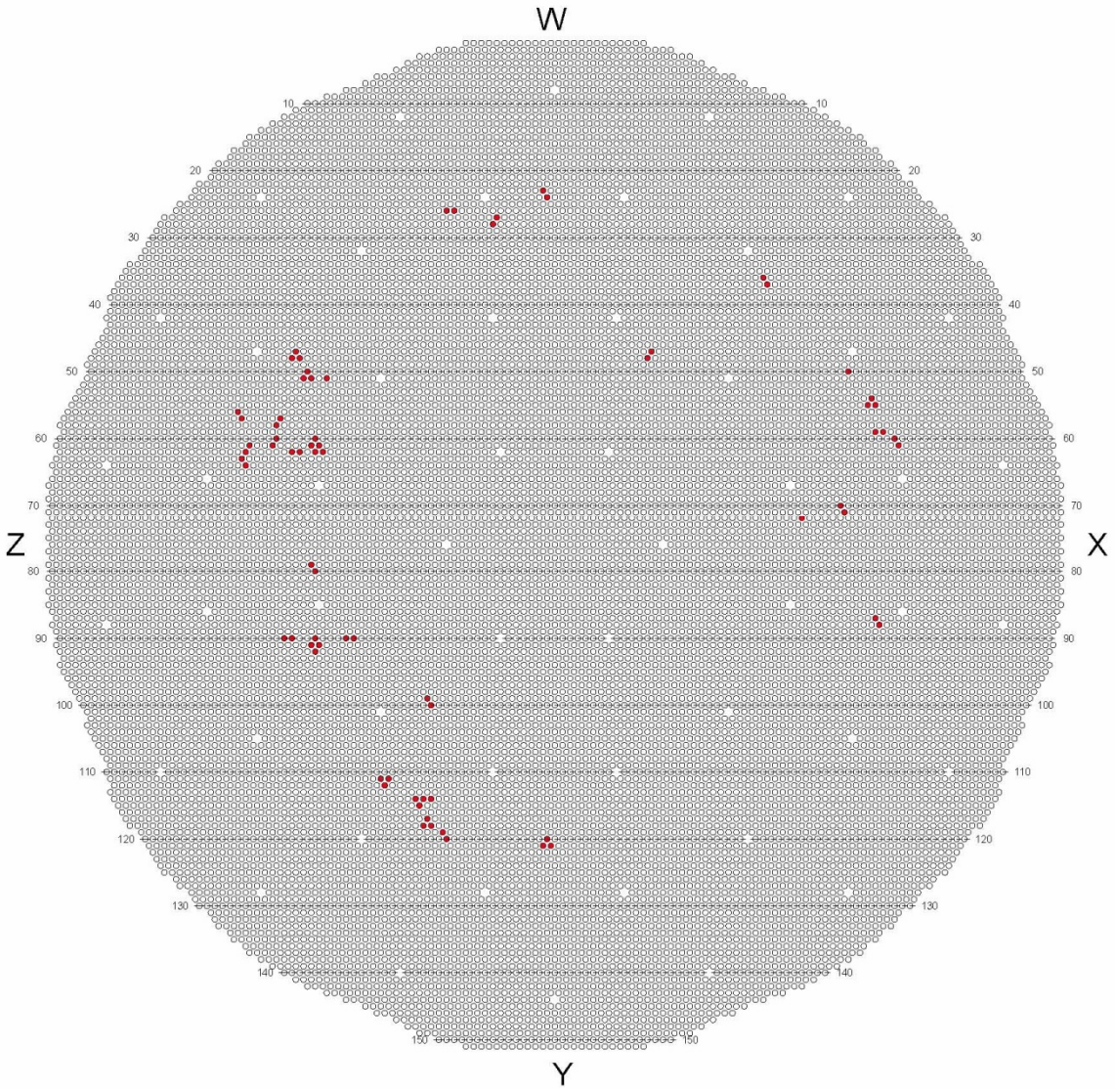
EOTSG A, T-T Wear Map



TMI Unit 1 Repl
1R19 - 10/11

Tube-to-Tube Contact

AREVA - FDMS map module Version 11.0

S/G A
PRIMARY FACE
INLET

TOTAL TUBES:	15597
TUBES SELECTED:	74
OUT OF SERVICE (#):	0

GROUP	TUBES
Tube-to-Tube Contact	74

SCALE: 0.068887 X
Thu Nov 10 08:28:21 2011

TMI Unit 1 Repl S/G A INLET AREVA

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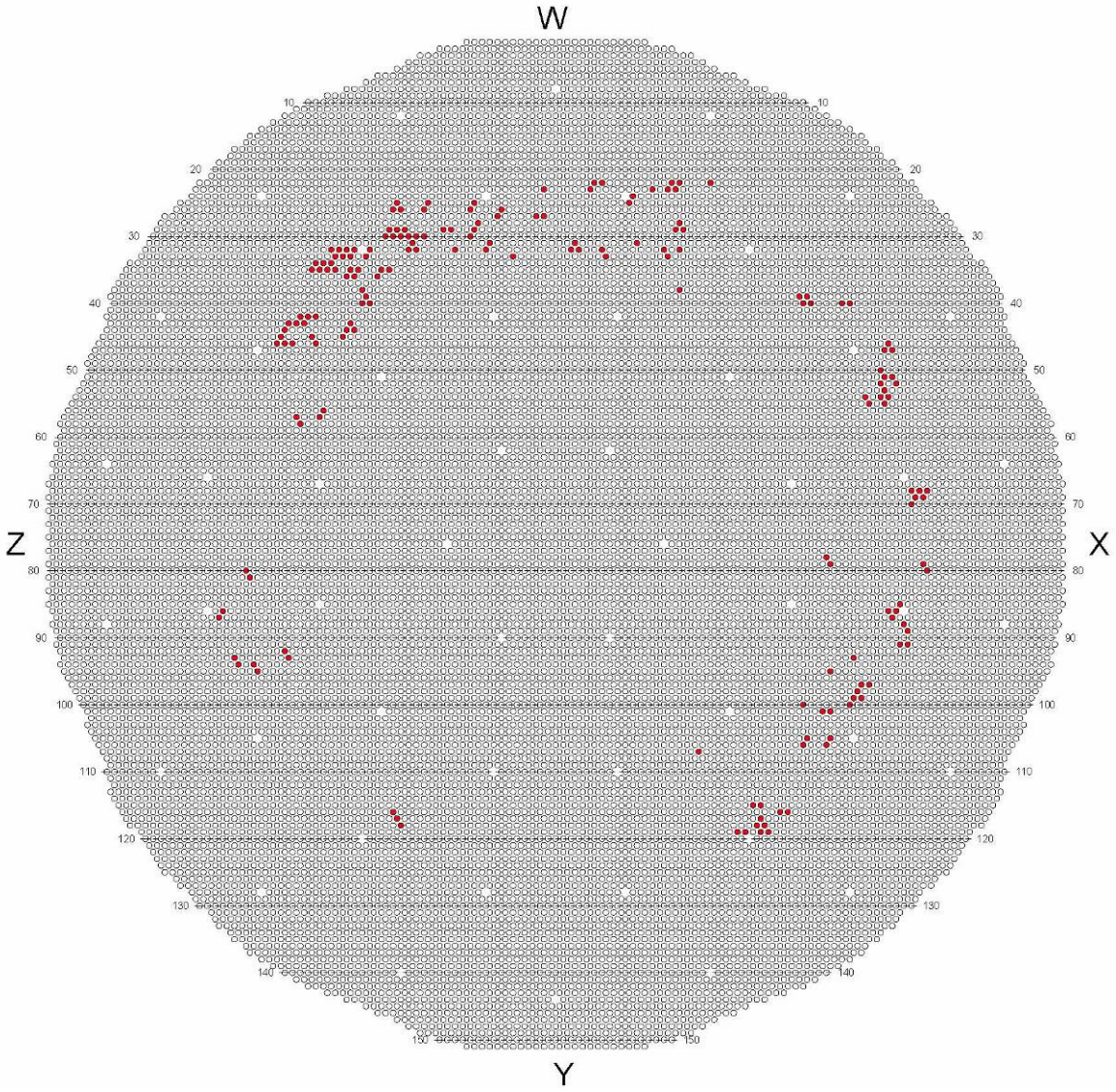
EOTSG B, T-T Wear Map



TMI Unit 1 Repl
1R19 - 10/11

Tube-to-Tube Contact

AREVA - FDMS map module Version 11.0

S/G B
PRIMARY FACE
INLET

TOTAL TUBES:	15597
TUBES SELECTED:	183
OUT OF SERVICE (#):	NA

GROUP	TUBES
Tube-to-Tube Contact	183

SCALE: 0.068887 X
Thu Nov 10 08:43:19 2011

TMI Unit 1 Repl S/G B INLET AREVA

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T1R19 T-T Wear Identification

- ✓ Reported as absolute drift indications (ADIs) during bobbin coil inspection with most indications located:
  - In mid-span
  - In the 9th span
  - In a radial pattern 30” – 45”
  - In adjacent tubes (two or three)
- ✓ Performed X-Probe and +Point on ADI signals
  - Verified indications in adjacent tubes face each other
  - Symmetrically tapered to maximum depth in center
  - In adjacent tubes the indications are at same elevation and are same length/depth
  - Length and depth have a correlation that is consistent with wear
  - Good correlation of phase angles and voltages between channels
- ✓ Analysts, Exelon Engineering, and AREVA Engineering consensus is that these indications are T-T wear
  - Notified Steam Generator Management Program (SGMP) per the requirements of Nuclear Energy Institute (NEI) 97-06
  - Notified NRC

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Process for Screening T-T Wear

- ✓ Indications reported as ADIs
  - Industry standard is to use I-Codes to identify (possible) flaw signals where no qualified sizing technique exists and supplemental testing is required.
  - Exelon guidelines require analysts to report all indications of suspected tube wall degradation.
- Primary Analysis (manual)
  - ≥ 0.5 volts & ≤ 90º channel 6 **or** %TW >0 on channels 4 & 6
- Secondary Analysis (auto)
  - ≥ 0.5 volts & 30º - 95º on channel 6
  - %TW >0 on channels 4 & 6 and ≥ 0.16 volts on channel 6
  - ≥ 0.25 volts & 60º - 120º on channel 6

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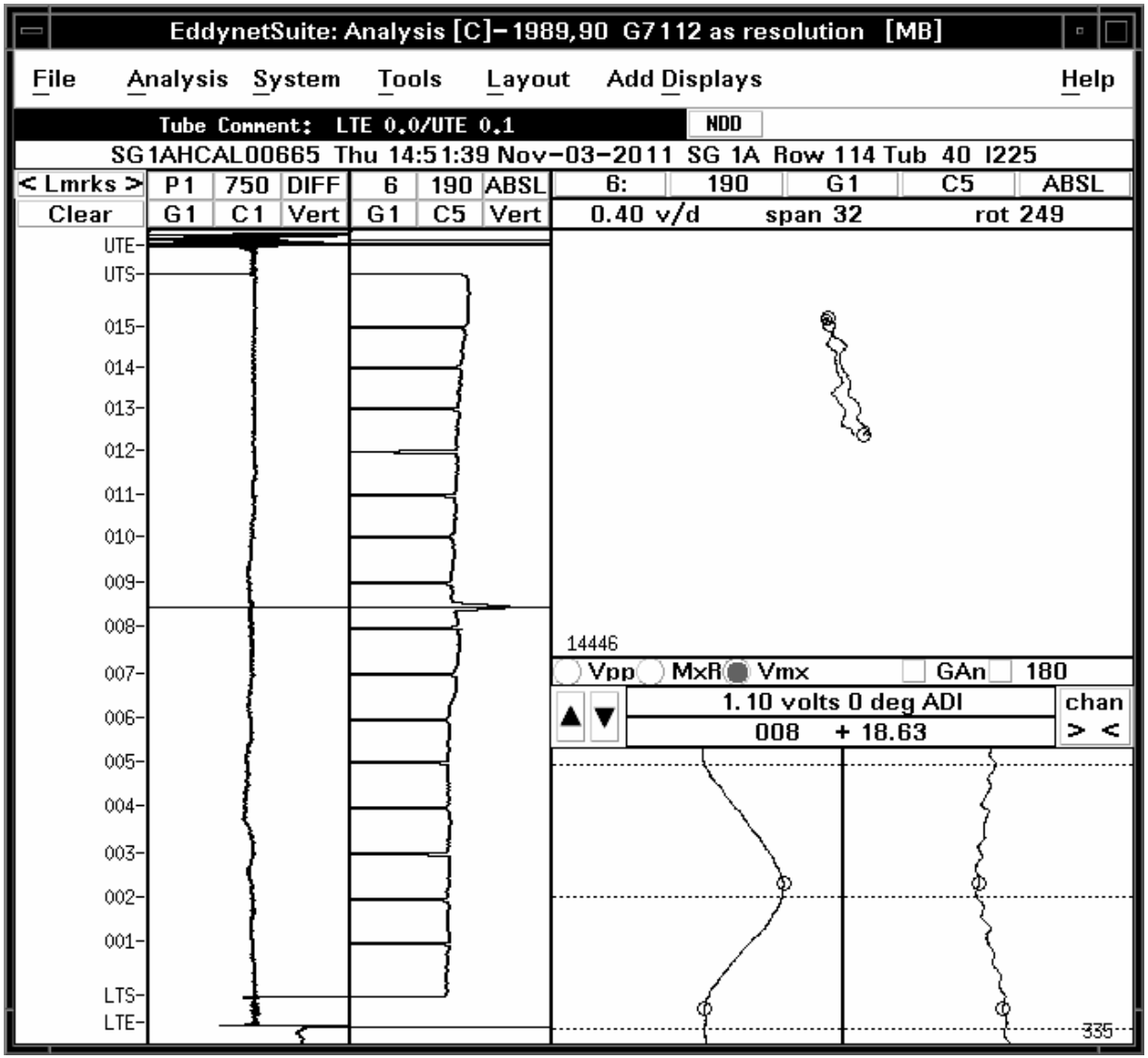
Example TMI-1 T-T Wear Bobbin Data



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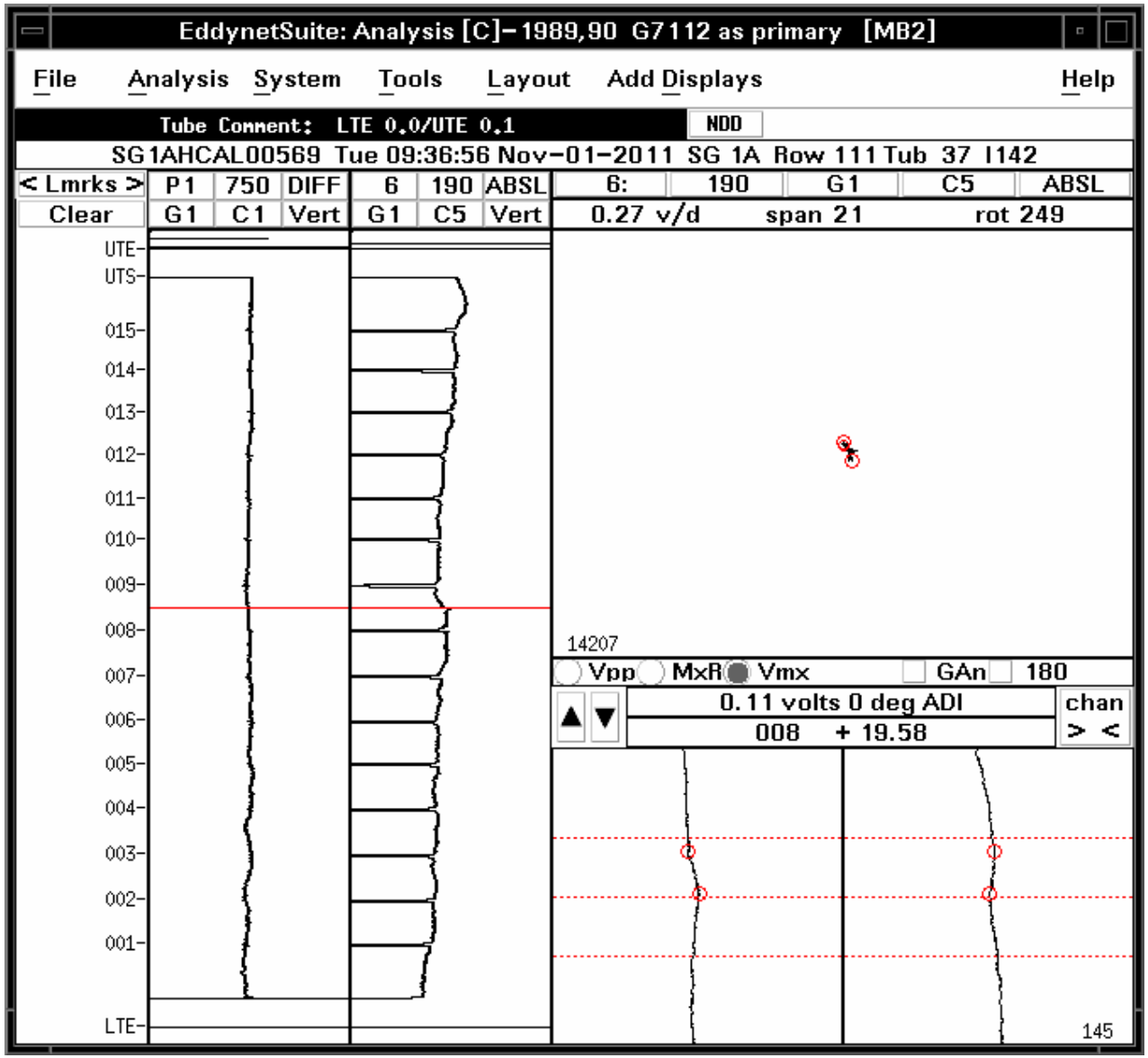
Example TMI-1 T-T Wear Bobbin Data



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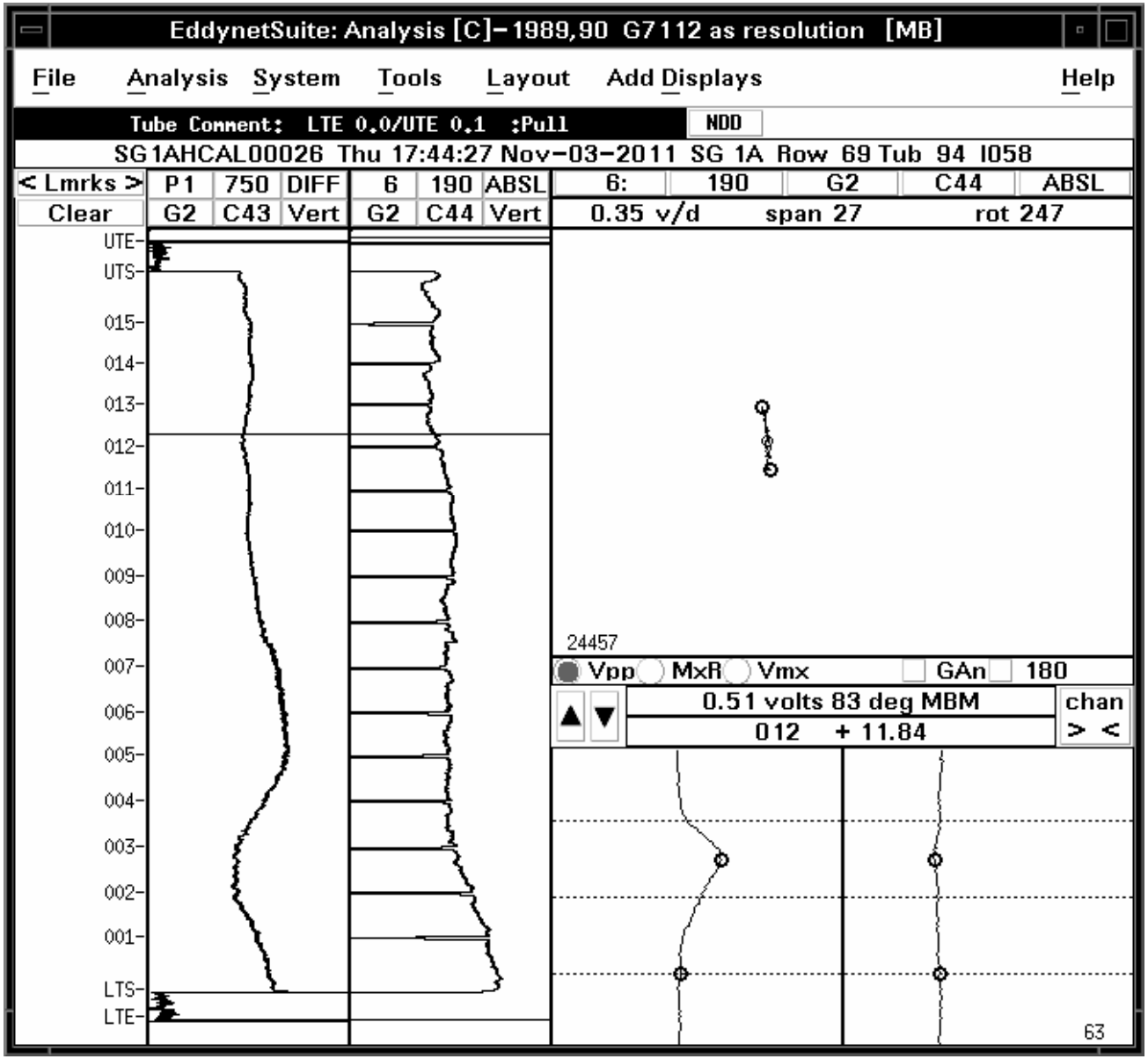
Example TMI-1 MBM Screened as ADI



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Summary of ADI Indications (T-T Wear)

- ✓ ADI Indications ≥ 0.5 volt
  - "A" - 9 Tubes
    - Primary = 9, Secondary = 7, Both = 7
  - "B" - 19 Tubes
    - Primary = 19, Secondary = 18, Both = 18
- ✓ All ADIs including review for paired tubes
  - "A" - 74 Tubes with ADIs (0.08 – 1.62 volts)
    - Primary = 20, Secondary = 34, Both = 13
      - Either Primary or Secondary = 41
      - 74 of 74 confirmed by +Point or X-Probe
  - "B" - 202* Tubes with ADIs (0.07 - 1.25 volts)
    - Primary = 145, Secondary = 95, Both = 71
      - Either Primary or Secondary = 169
      - *183 of 202 confirmed by X-Probe

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Process for Screening T-T Wear

- ✓ Per Exelon & SGMP PWR Steam Generator Examinations Guidelines, I-Code indications are "Category III: Supplemental Test Required"
  - Prior to T1R19, +Point and X-Probe identified as probes to be used for supplemental examinations
    - X-Probe qualified for sizing T–TSP wear (EPRI ETSS 11956.3)
    - +Point qualified for sizing T-TSP wear (EPRI ETSS 96910.1)
    - +Point qualified for sizing various shapes of wear (EPRI ETSS 27901 – 27907)
      - EPRI ETSS 27905.3 "Flat Wear" was determined to be the correct technique for T-T wear in EOTSGs

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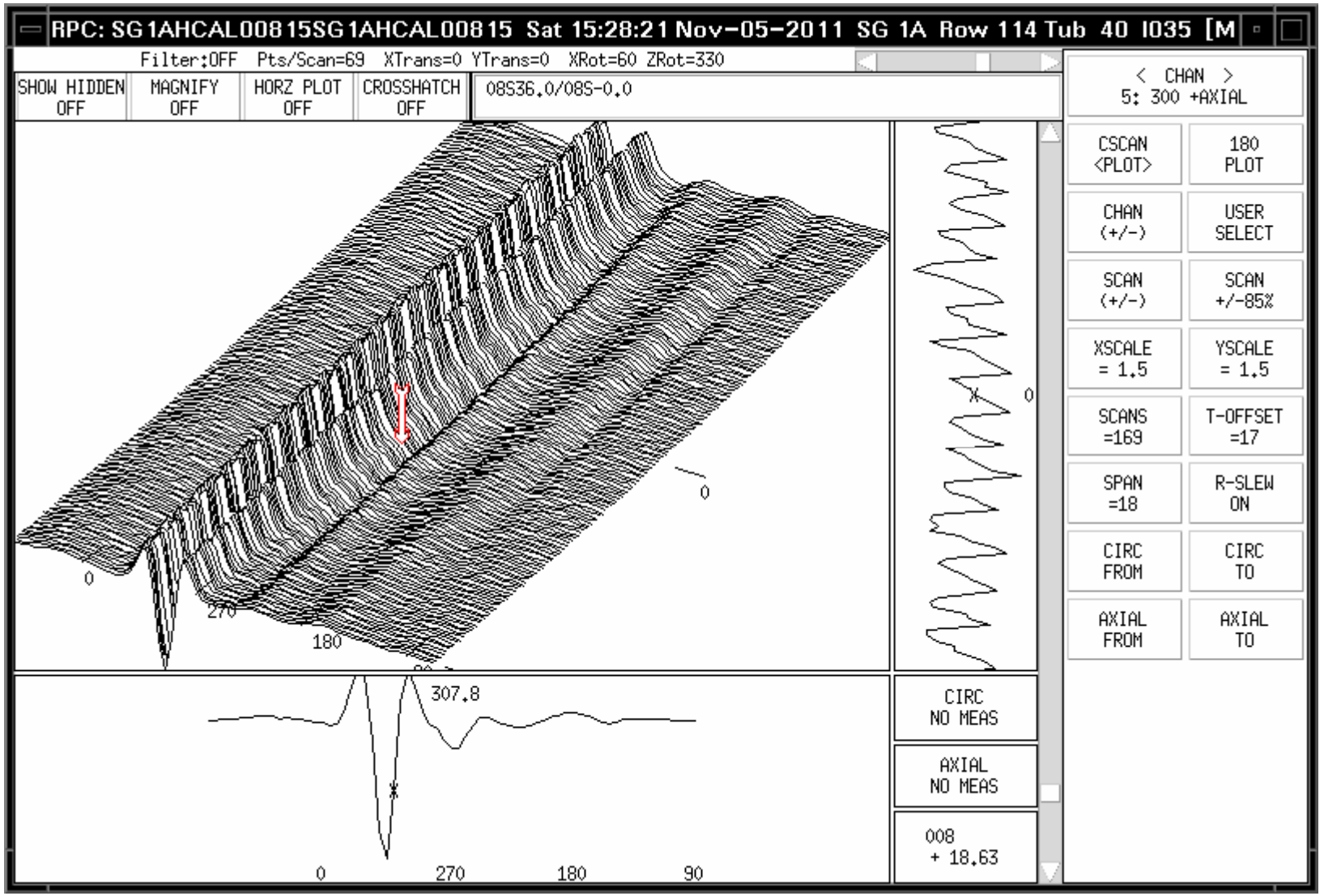
Example TMI-1 T-T Wear +Point Data



NOTE: Graphic shows partial indication

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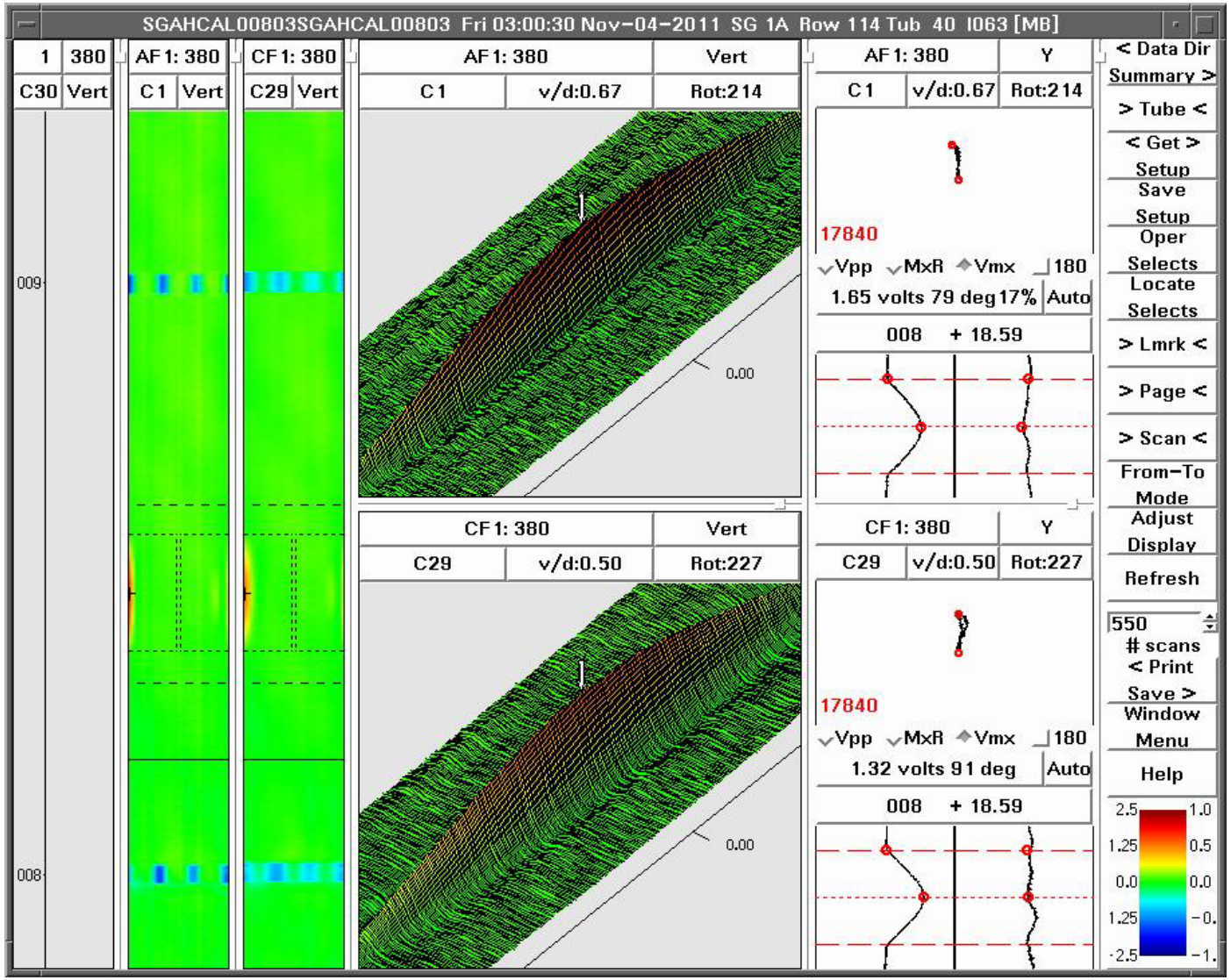
Example TMI-1 T-T Wear X-Probe Data



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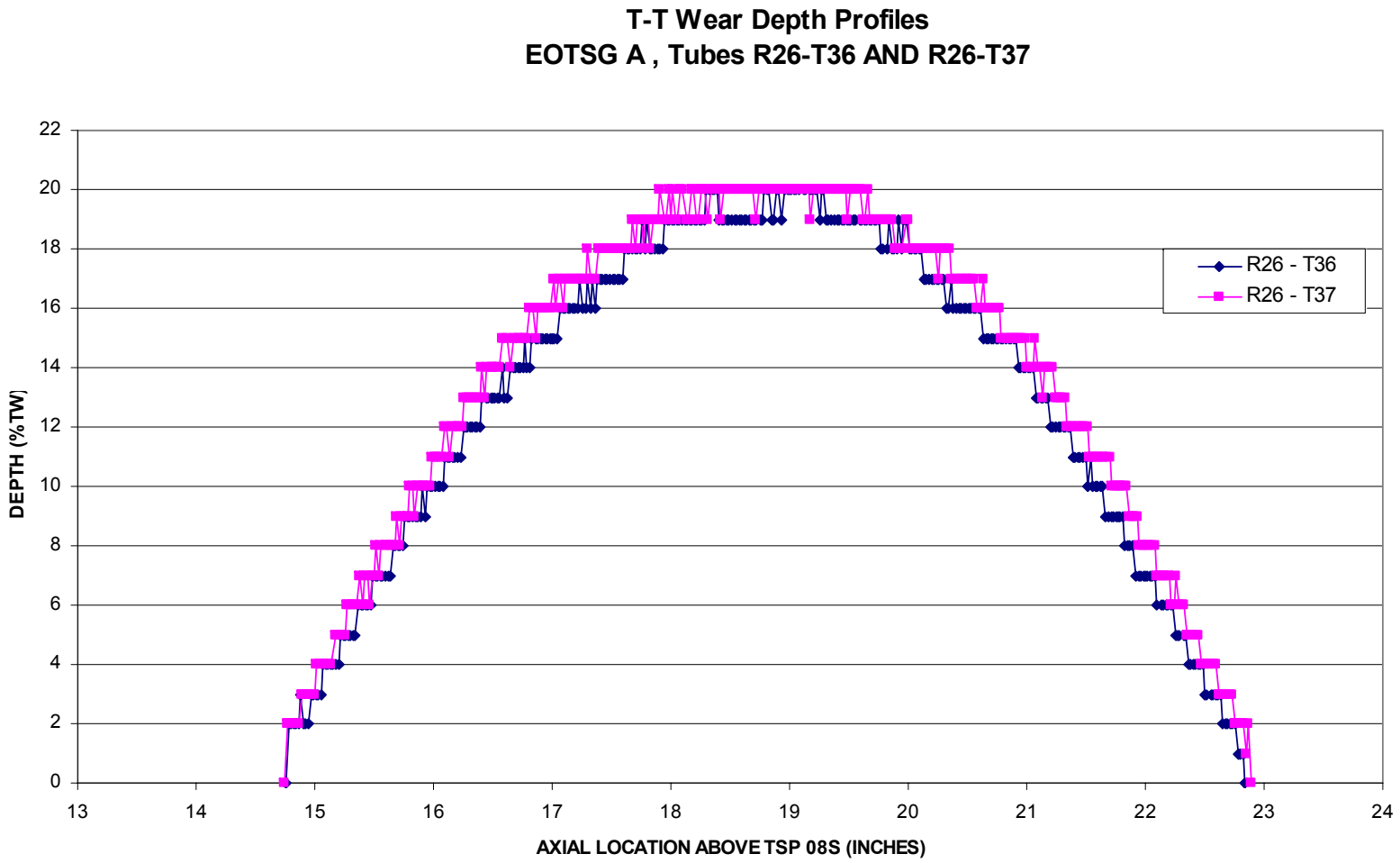
Example Depth Profiles in Paired Tubes



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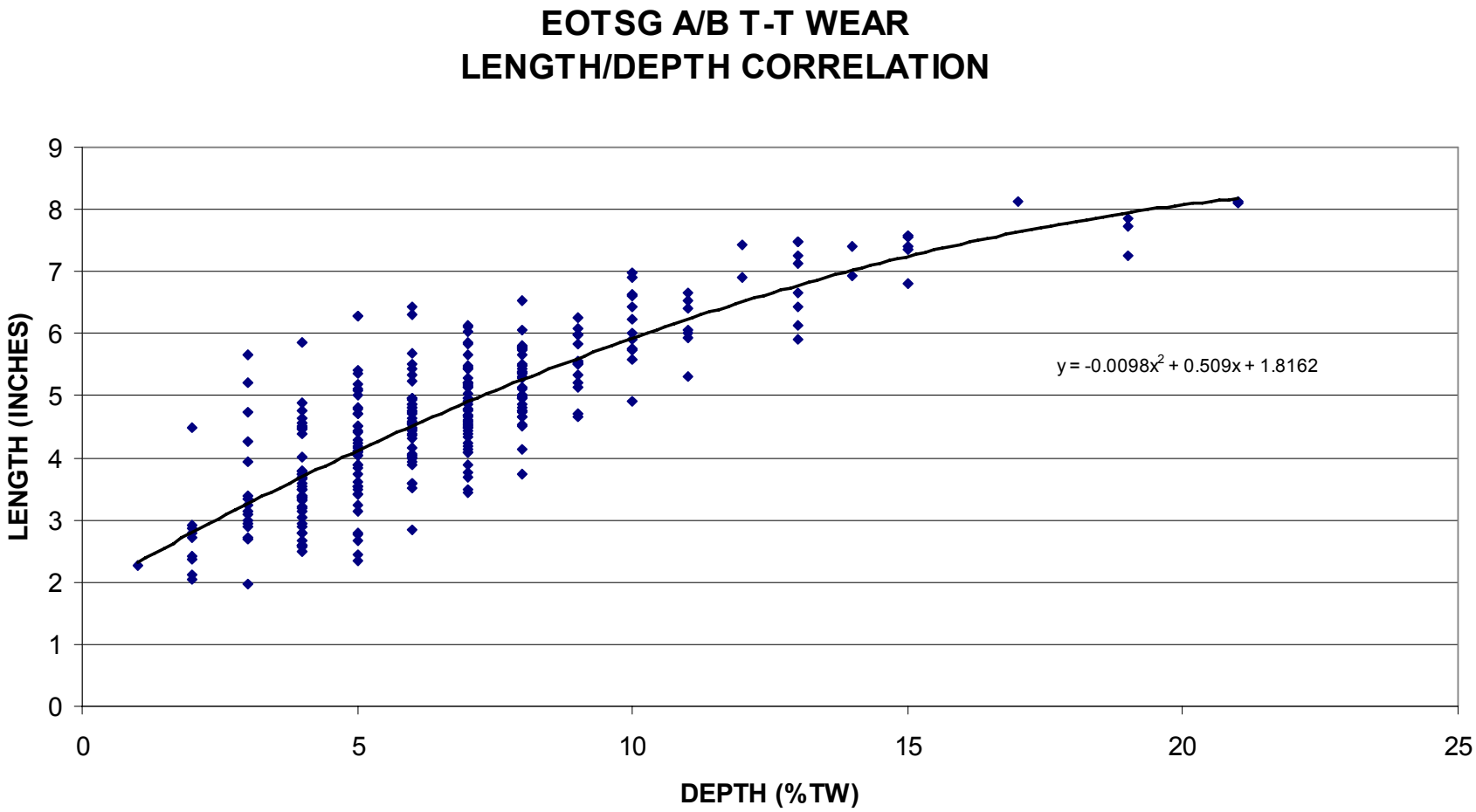
T-T Wear Length-Depth Correlation



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Site Qualified Sizing Technique for T-T Wear

- ✓ X-Probe T-T wear sizing technique developed in cooperation with EPRI
  - Used two of the same samples used to develop ETSS 27905.3 (+Point Flat Wear)
  - Developed “Power” trend line/regression curve using methodology used for other EPRI X-Probe techniques
    - ETSS 11956.1 – 11956.4, Broached TSP Wear
  - “Power” trend line/regression scatter plot based on multiple examinations of 16 wear scars
    - Wear scars ranged from 8% - 60% TW
  - Analysis of standards performed by multiple analysts from three different vendor organizations
  - Accuracy validated through comparison of +Point and X-Probe results for EOTSG A

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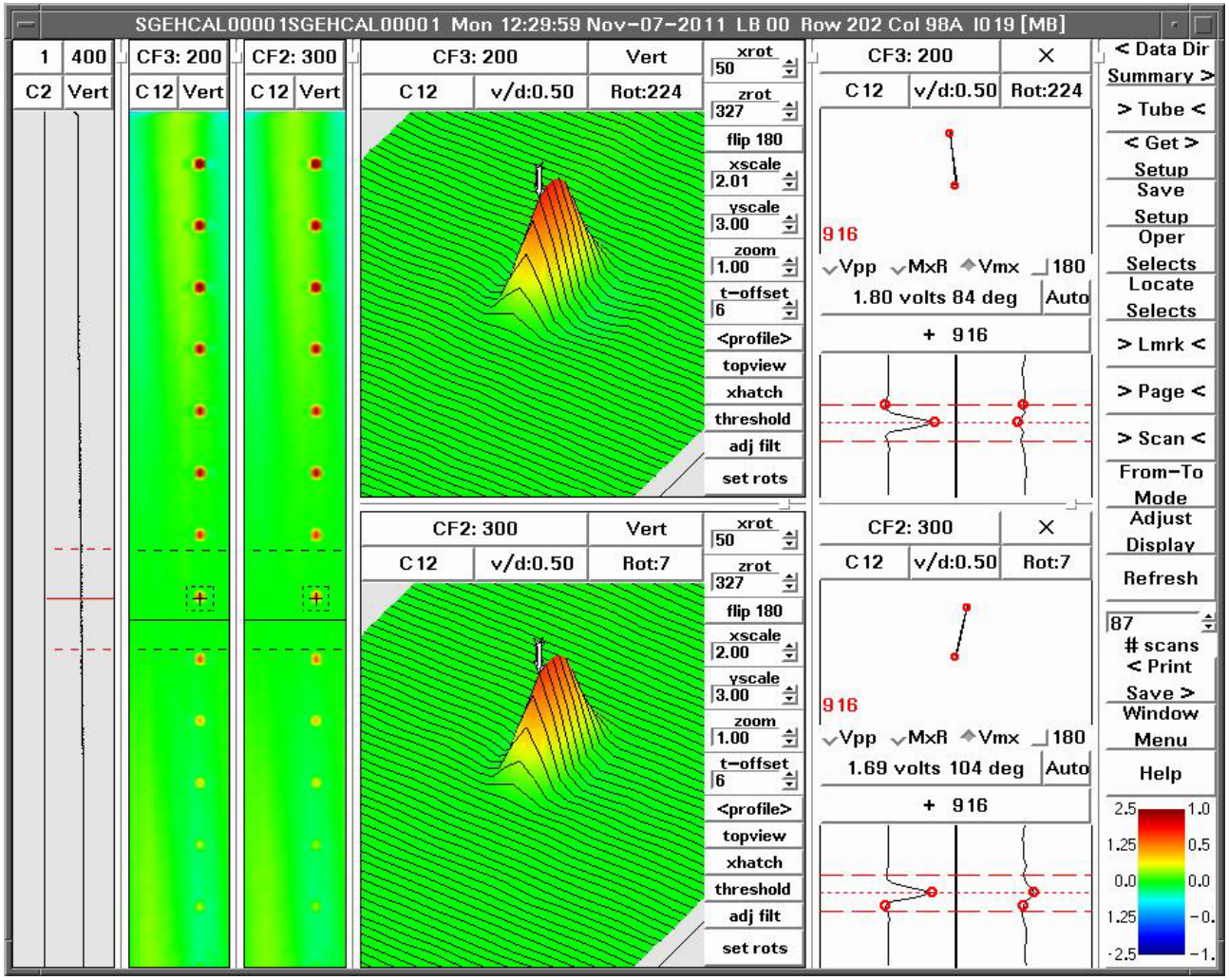
Graphic of Flat Wear Standard X-Probe



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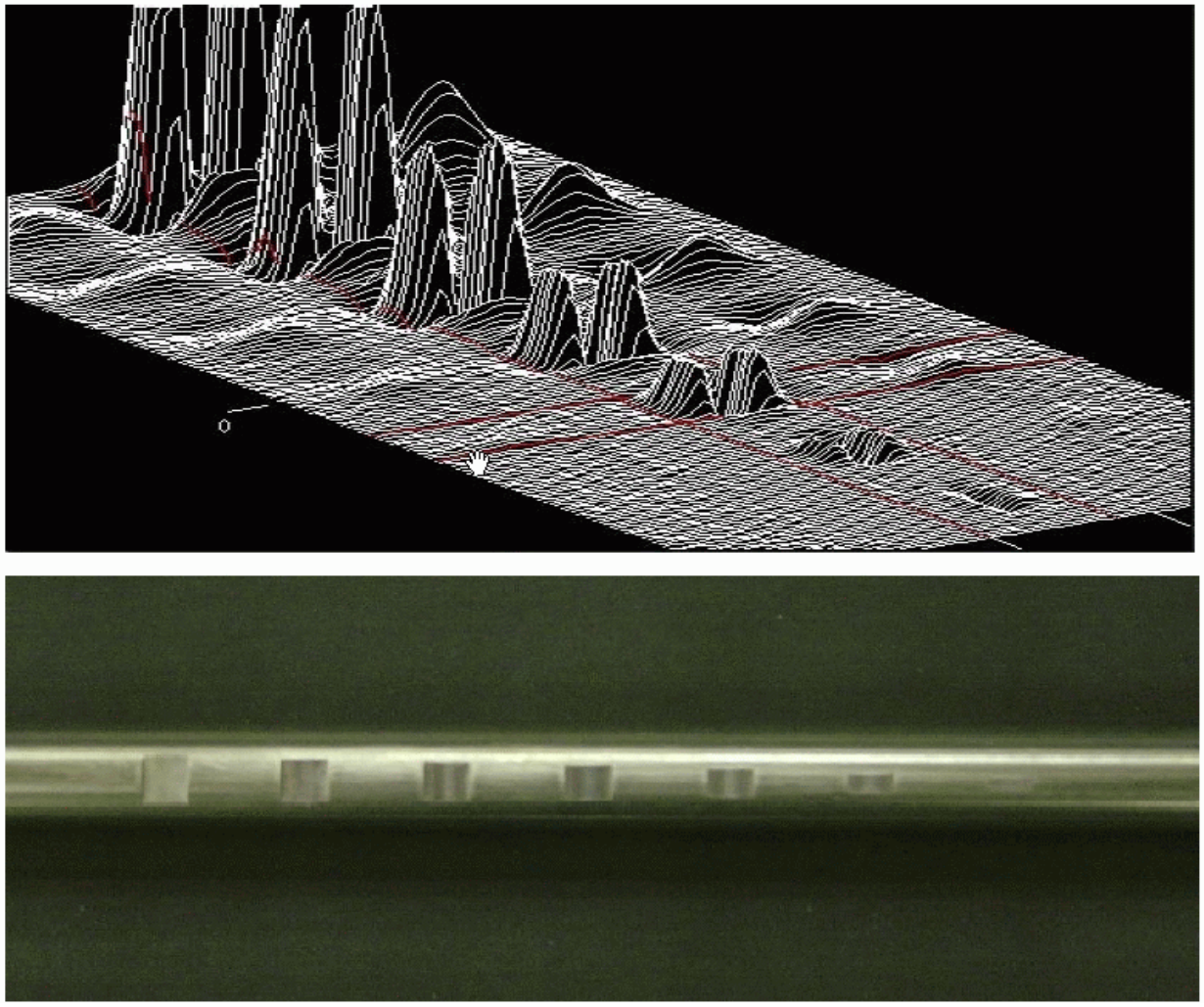
Graphic of Flat Wear Standard +Point



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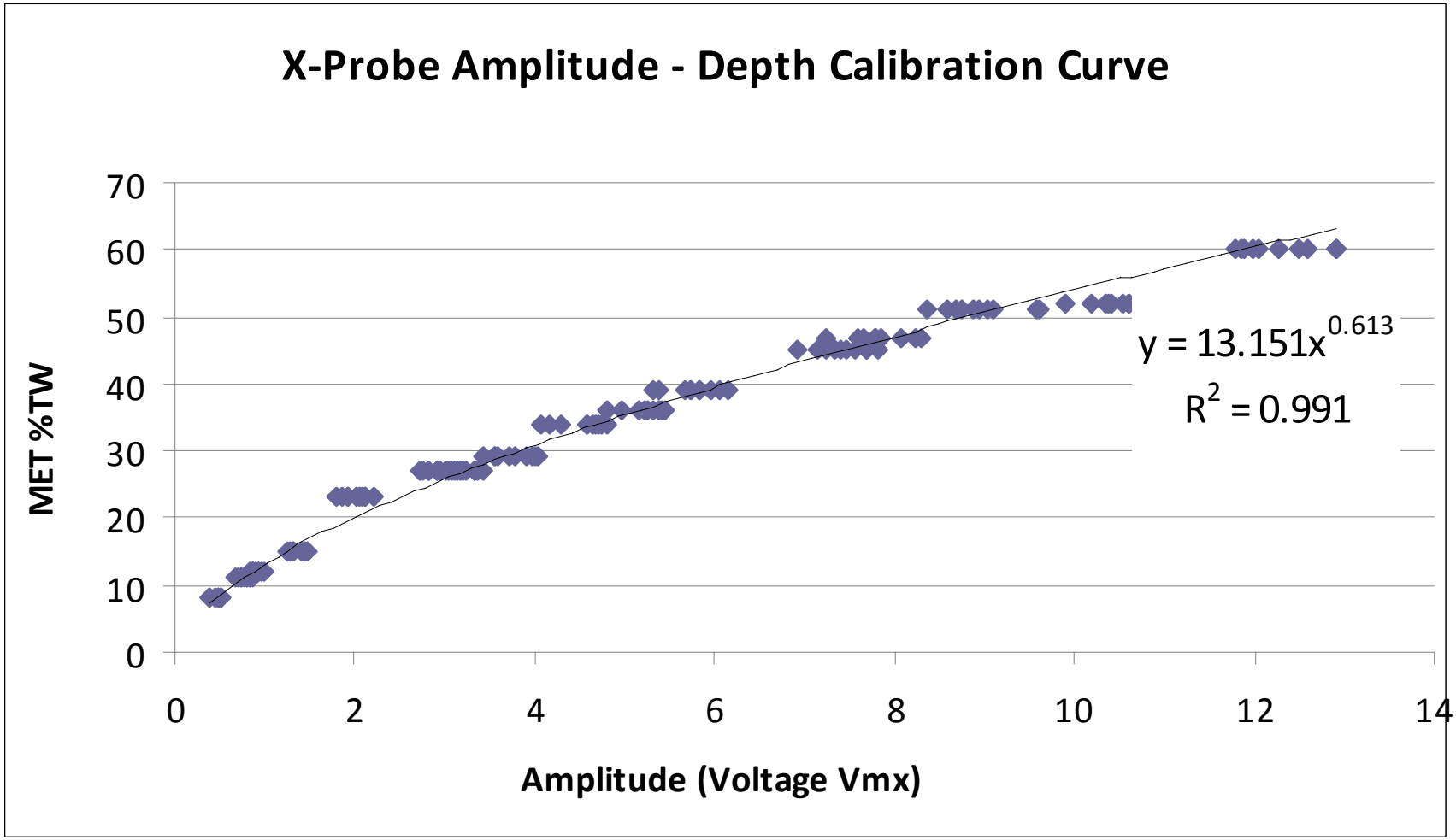
X-Probe Calibration Curve



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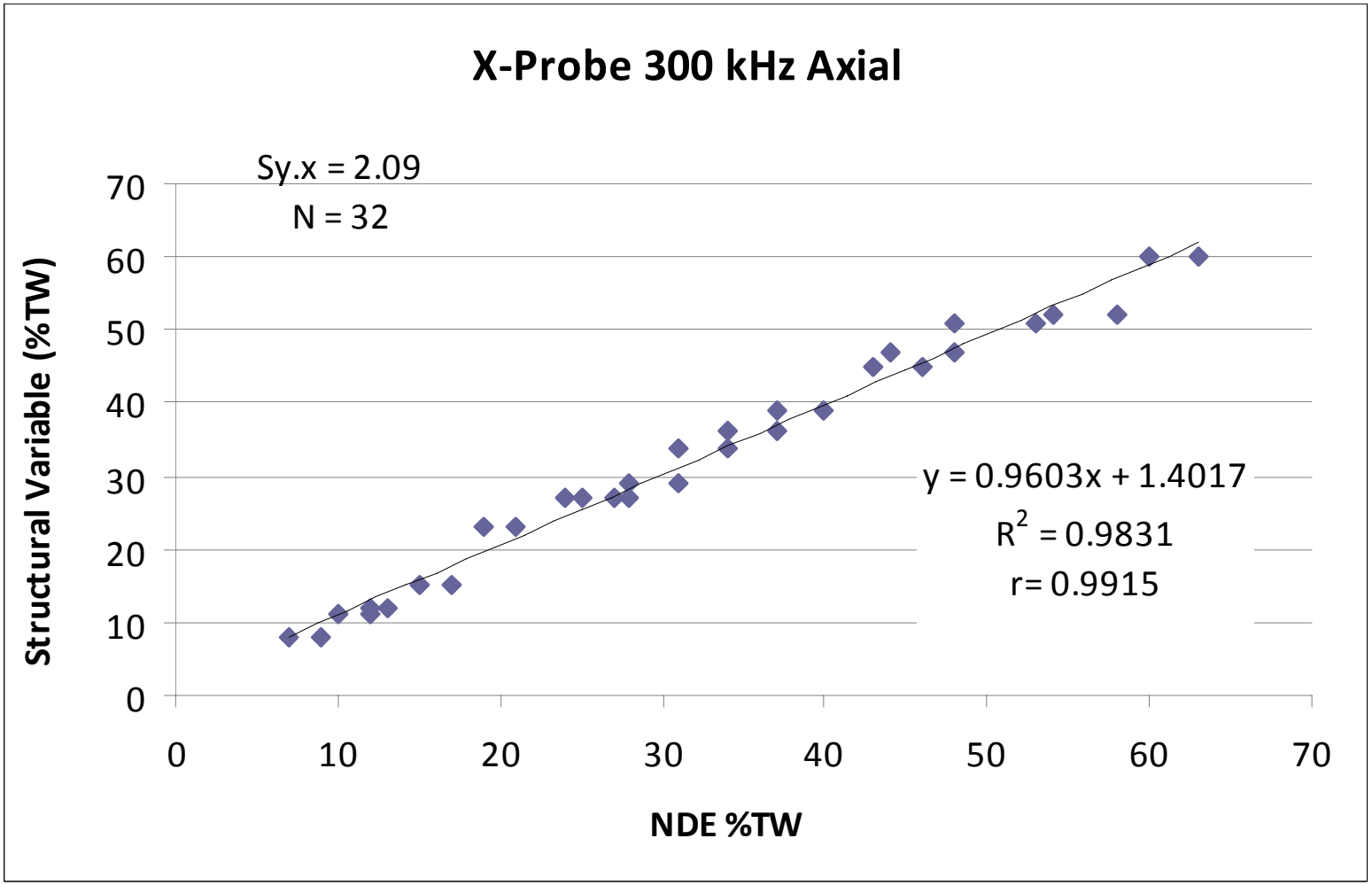
X-Probe Calibration Curve Validation



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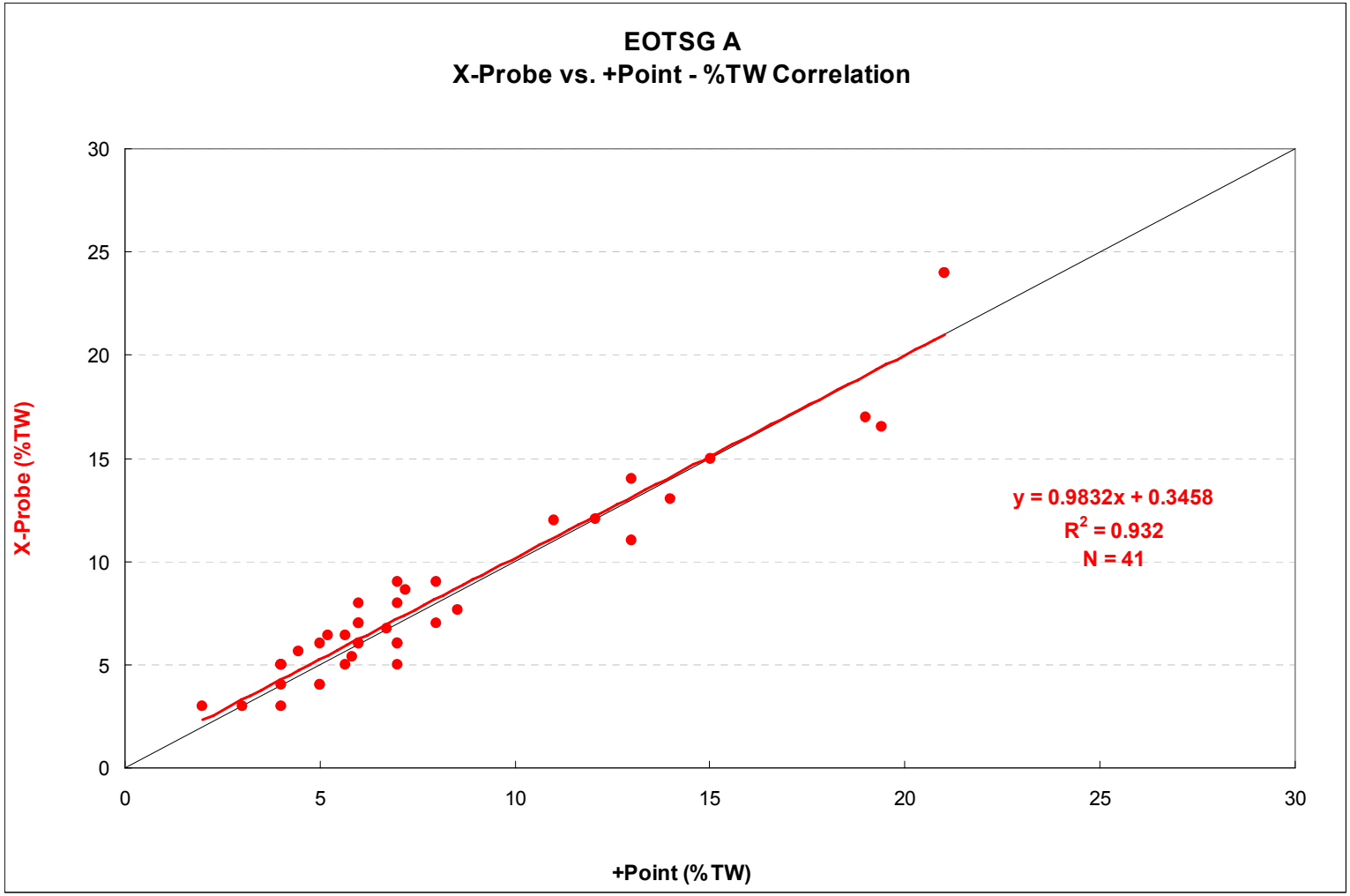
Comparison of +Point and X-Probe



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T1R19 T-T Wear Summary

- ✓ A total of 257 tubes were identified with T-T wear
  - EOTSG A: 89 indications in 74 tubes
  - EOTSG B: 206 indications in 183 tubes
- ✓ Wear depths range from 1% to 21% through wall (TW)
- ✓ Wear axial lengths range from 2” to 8”
- ✓ No proximity or tube contact detected
  - Tubes are in tension at cold conditions and in compression at hot conditions
- ✓ Sizing performed by +Point Technique 27905.3 and a site qualified X-Probe Technique
  - Good correlation between Bobbin, +Point, and X-Probe techniques
- ✓ All tubes met condition monitoring limits and in-situ pressure testing was not required

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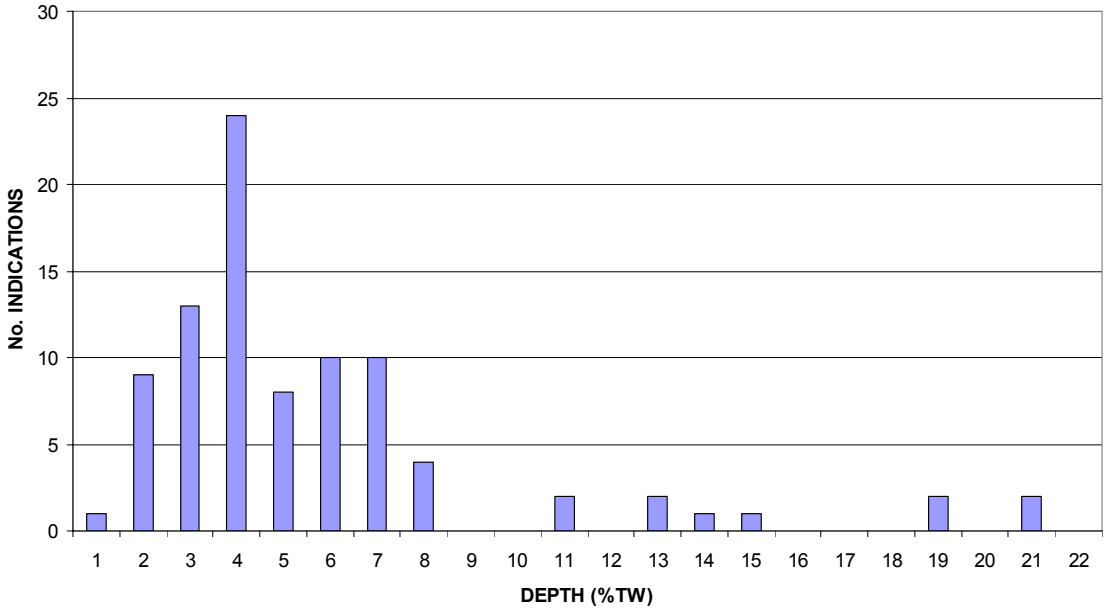
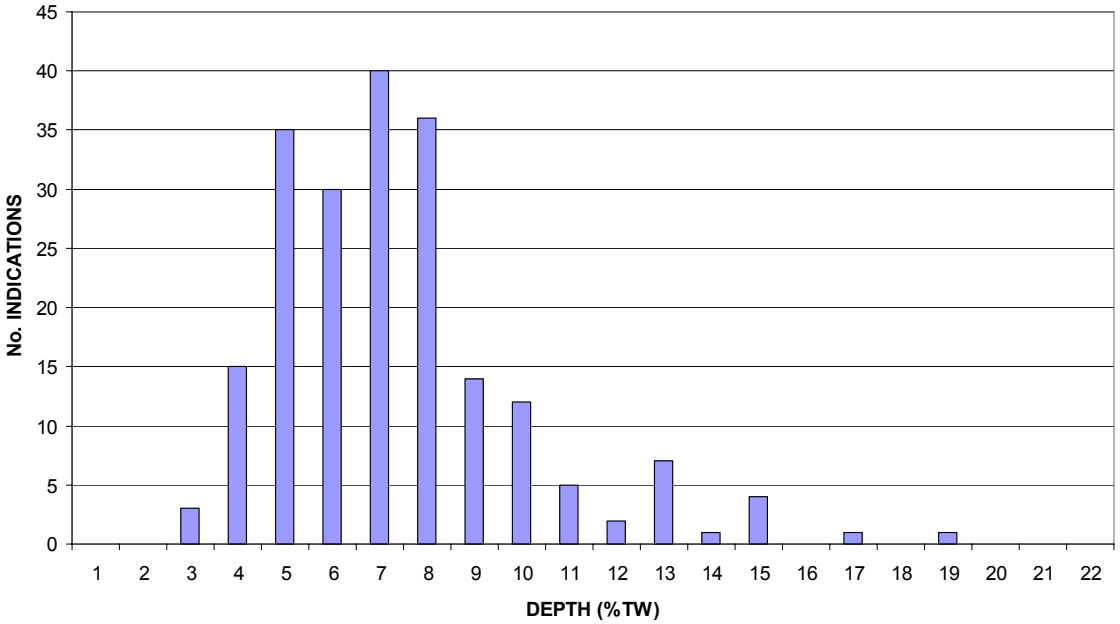
T-T Wear Depth Distribution

EOTSG A





EOTSG B

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T1R19 T-T Wear Summary

	EOTSG A	EOTSG B
Total number of In-Service Tubes	15597	15597
Number of T-T Wear Indications	89	206
Number of Tubes T-T Wear	74	183
Average Depth of T-T Wear	5.8%	7.4%
Maximum Depth of T-T Wear	21%	19%
Number of T-T Wear Indications >40% TW	0	0
Average Growth Rate T-T Wear	3.4%/EFPY	4.3%/EFPY
95 th Percentile Growth Rate T-T Wear	9.3%/EFPY	7.6%/EFPY
Maximum Growth Rate T-T Wear	12.2%/EFPY	11.1%/EFPY
Number of Tubes Plugged for T-T Wear	4	3

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Condition Monitoring Summary for T-T Wear

✓ Condition Monitoring Satisfied

- Utilized maximum depth and bounding length of 39” for 3 X normal operating pressure differential conditions (3ΔP)
- Substantial margin against accident leakage and structural limits
- Large break loss of coolant accident (LBLOCA) loading conditions evaluated and satisfied
  - Assumed 180 degree circumferential extent of wear

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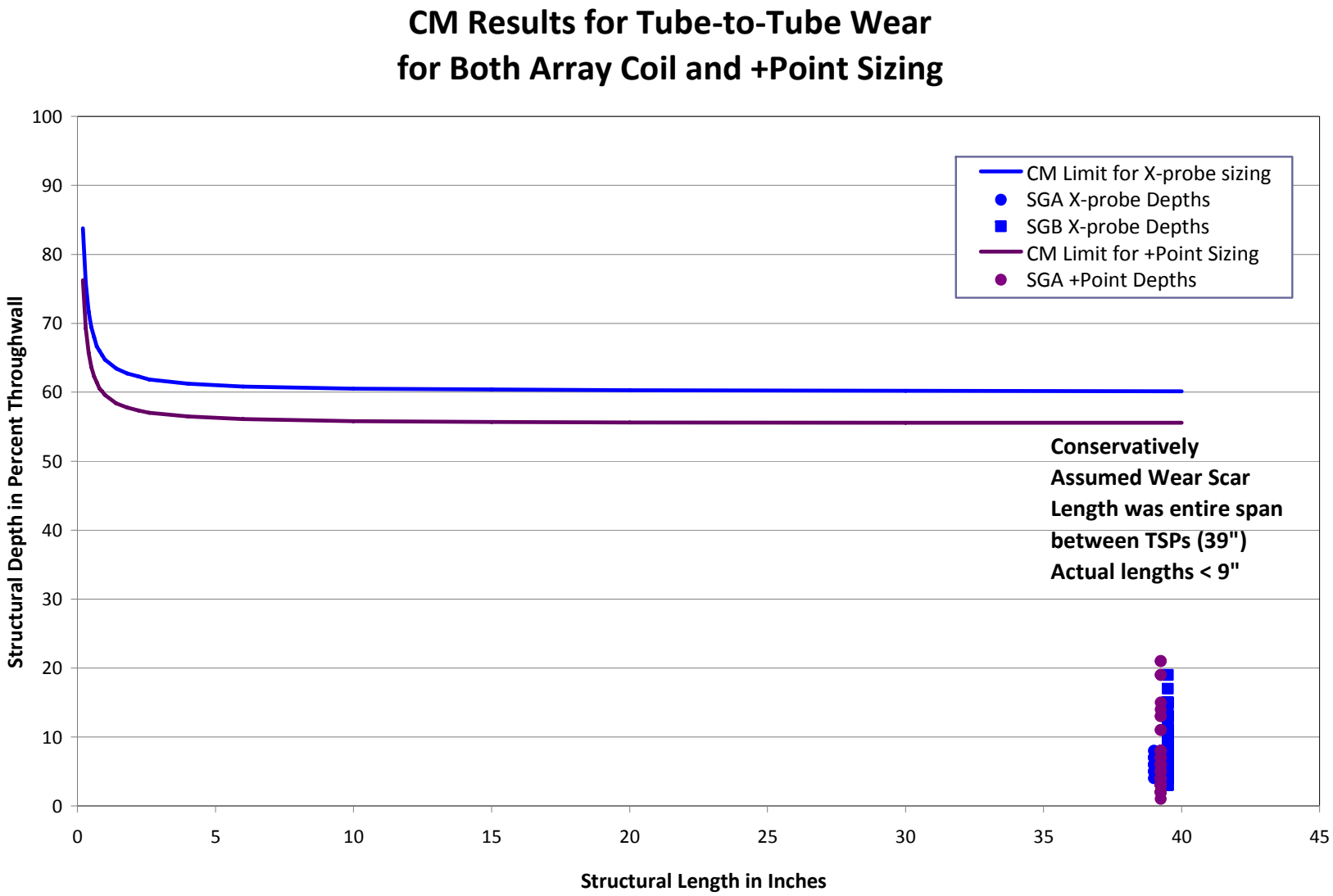
Condition Monitoring Assessment for T-T Wear



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Operational Assessment for T-T Wear

- ✓ Mixed arithmetic/Monte Carlo method utilized
  - Cycle length 1.927 EFPY
  - Addressed indications sized with +Point and X-Probe separately
  - End of cycle (EOC) length conservatively assumed 39”
  - Used maximum growth over previous cycle
    - Conservative relative to ANO experience
- ✓ Significant margin to leakage and burst at EOC
  - Margin ~17% for worst case flaw at EOC
- ✓ LBLOCA evaluation also demonstrates significant margin

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Planned Future Actions

- ✓ Update Site Specific Performance Demonstration (SSPD) training to include T-T wear
- ✓ Convert TMI-1, X-Probe site qualification to EPRI "Appendix H, Qualified Technique"
- ✓ Provide raw data to EPRI
- ✓ Perform 100% eddy current examinations during T1R20 (Fall 2013)
- ✓ Support AREVA root cause analysis
- ✓ Implement appropriate actions based on the results of the root cause

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TMI-1 Tube-to-Tube Wear Conclusions

- ✓ T-T wear was identified during the first inservice inspection of the TMI-1 EOTSGs
- ✓ All T-T wear indications meet Condition Monitoring and Operational Assessment performance criteria
- ✓ T-T wear does not impact inspection interval length for Cycle 19

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