ARRAY PROBE EVALUATION BY WESTINGHOUSE

D. Stepnick, Westinghouse Electric Company, USA

BACKGROUND

The US nuclear industry experienced a number of unplanned and/or forced outages in the 1980’s. Several of these outages were caused by primary to secondary leakage from degraded steam generator tubes. As a result, the industry recognized the need for more sensitive inspection techniques facilitating the early detection of a variety of tube degradation mechanisms. At the time, there were very few options available relative to ECT probes. The bobbin probe was the standard means to acquire tube end to tube end data. It allowed high test speeds but had less test sensitivity at various locations (i.e. supports, tube sheet, loose parts, etc). Rotating probes were also available but were mainly used for support and tube sheet inspections. They had high test sensitivity but low test speeds. Therefore, the goal was to develop a probe that offered high test sensitivity as well as high test speeds.

Array probes have been in development and various degrees of use for more than 30 years. A few examples of the evolution of these probes are listed below.

- **1980’s - 8 Coil Array Probe & 8 x 1 Array Probe**
  - Originally designed for dent profilometry
  - Circumferential cracks @ Top of Tubesheet
- **1990’s - Cecco**
  - Defect detection (circumferential cracks @ tube support plates)
- **2000’s – X-Probe & Intelligent Probe**
  - With or without a bobbin probe
  - Multiple coil designs
  - Qualification of multiple degradation mechanisms

Based on both field experience and the extensive testing performed by the industry, some clear advantages of the array probe can be found.

- Increased test speeds vs. RPC
  - Up to 30”/sec
- Detection & characterization of Axial, Circumferential and Volumetric Flaws
- Improved POD over bobbin probes
- Single pass inspection (with bobbin probe)
  - Zero to minimal Rotating Probe usage
  - Zero to minimal re-inspection requirements
- Improved wear sizing
- Tube end to tube end data for historical reviews
Example of Increased Sensitivity  
Array vs. Bobbin in Detecting Axial ODSCC @ Supports

2009 Bobbin  
2009 X-Probe

Similarly, some disadvantages of using an array probe have been determined.

- Decreased test speeds vs. Bobbin
- Large volume of data (~30mb/tube)
  - One solution may be to parse the data to concentrate on areas of interest
- Analyst support requirements (quantity & training)
  - Auto analysis programs are available which reduces the analyst burden
- High probe costs
  - Early procurement & volume discounts could reduce costs
- Probe durability (bobbin coils)
  - Recent design changes have resolved this issue
- Limited qualifications (Axial & circ cracks at dings & dents)
  - Qualify new degradation mechanisms, as required, or
  - In the US, use “extended application” per EPRI tube integrity guidelines

In the US, utilities have elected to deploy array technology, mainly the X-Probe, for a variety of different reasons over the past few years. They can be placed into three separate categories.

- In Replacement Steam Generators, an unexpected indication could eliminate planned skipped inspection outages
  - Tube End to Tube End baseline data for a historical review may be used to verify that the indication existed from manufacturing
- In Replacement Steam Generators, a leaker outage caused by loose parts damage may be the most significant concern
  - Array probes provide enhanced detection vs. Bobbin probes
- In Original Steam Generators, large Special Interest programs
  - Higher speeds vs. RPC
  - Enhanced detection @ various supports
RECENT WESTINGHOUSE X-PROBE EXPERIENCE IN THE US

**Plant 1** was interested in obtaining baseline data for potential historical review. It should be noted that this was their 2\textsuperscript{nd} In Service Inspection (ISI) after steam generator replacement, but probe cost & probe life issues precluded prior use of an array probe.

- **General Information**
  - 2 Loop Westinghouse Pressurized Water Reactor
  - BWI 56/19 Replacement Steam Generators
  - .75” x .043” I690 Thermally Treated tubing – 4,868 tubes/SG

- **Existing & Potential Degradation**
  - Wear
  - Loose parts damage

- **Inspection Scope**
  - **X-Probe**
    - HL & CL Straight Section – Rows 1 thru 7 (approximately 800 tests/SG)
    - Full Length – Rows 8 & higher (approximately 4100 tests/SG)
  - **Bobbin Probe**
    - Hot Leg Candy Cane – Rows 1 thru 7 (approximately 800 tests/SG)
  - **Rotating Probe**
    - HL & CL Straight Section SI – (approximately 25 tests/SG)
    - HL & CL U-Bend SI – (approximately 5 tests/SG)

- **Outage Performance**
  - 144 hour ECT window
  - 2 PEGASYS robots (1 per SG, shared between HL & CL) with dual guide tubes
  - RevospECT single pass analysis
  - **Probe usage**
    - 10 X-Probes used @ 28”/sec (711 mm/sec)
    - 4 Bobbin probes used @ 40”/sec (1016 mm/sec)
    - 4 RPC probes used @ .5”/sec (12.7 mm/sec)

- **Outage Summary**
  - Westinghouse/Zetec/Utility team successfully completed the SG inspection scope within the scheduled window
  - Cost neutral when compared to “traditional” standards
    - X-probe vs. Bobbin/RPC

- **Results:**
  - Utility has tube end to tube end baseline date for historical review

**Plant 2** has a history of loose parts & loose parts damage at the top of the tube sheet. They originally planned on an extensive RPC program

- **General Information**
  - 4 Loop Westinghouse Pressurized Water Reactor
  - BWI CFR-80 Replacement Steam Generators
  - .688” x .040” I690 Thermally Treated tubing – 6,633 tubes/SG

- **Existing & Potential Degradation**
  - Loose parts & loose parts damage

- **Inspection Scope**
  - **Bobbin Probe**
    - 100% full length - (approximately 6,600 tests/SG)
  - **Rotating Probe**

---

318
• No scheduled tests
  o X-Probe
    ▪ HL & CL - Tube End to 1st Tube Support Plate – (approximately 1,725 tests/SG plenum or 14,000 total tests)
    ▪ Special Interests – (approximately 400 tests/SG)
• Outage Performance
  o 168 hour ECT window
  o 4 PEGASYS robots (1 per SG, shared between HL & CL) with dual guide tubes
  o Westinghouse Auto/Auto analysis programs
  o Enhanced ADS – “rule-based” program
  o Real Time Auto Analysis (RTAA) – “noise-based” program
  o Probe usage
    ▪ 6 X-Probes (with bobbin) used @ 28”/sec (711 mm/sec)
    ▪ 2 X-Probes (w/out bobbin for low rows) used @ 28”/sec (711 mm/sec)
    ▪ 39 Bobbin probes used @ 40”/sec (1016 mm/sec)
• Outage Summary
  o SG inspection scope successfully completed 24 hours faster than planned
  o X-probe speed vs. RPC speed
  o More economical solution
  o X-probe cost and extended life vs. RPC cost and life
• Results:
  o Utility received a more sensitive test (X-probe) for loose parts detection

**Plant 3** has their original steam generators, with a variety of existing degradation mechanisms and therefore an extensive RPC program planned

• General Information
  o 4 Loop Westinghouse Pressurized Water Reactor
  o Westinghouse D4 Original Steam Generators
  o .75” x .043” I600 Thermally Treated tubing – 4,578 tubes/SG
• Existing & Potential Degradation
  o Tube End (TE) PWSCC – Hot and Cold Leg
  o Tube Sheet, BLG/OXP PWSCC
  o Top of Tube Sheet (TTS) ODSCC and Loose Parts/Wear
  o 18th Baffle Loose Parts/Wear
  o AVB and TSP Wear
  o PWSCC/ODSCC at Dings
  o ODSCC at TSP Locations
  o PWSCC/ODSCC at Expanded Baffles
• Inspection Program
  o Bobbin
    ▪ 100% Straight length of rows 1-5
    ▪ 100% Full length of rows 6 and above
  o X-probe
    ▪ 100% inspection of row 1 U-Bends
    ▪ 35% inspection of rows 2-5 U-Bends
    ▪ 20% inspection of row 10 U-Bends
    ▪ 100% inspection of the hot leg tube sheet (TEH-TSH+3)
    ▪ 2 rows periphery inspection of the cold leg (TEC-TSP1)
    ▪ 50% inspection of existing dents and dings
    ▪ ~400 Special interest inspection
• Outage Performance
o 204 hour ECT window
o 4 PEGASYS robots (1 per SG, shared between HL & CL) with dual guide tubes
o Westinghouse Manual/Auto analysis programs
o ANSER manual analysis program
o EADS automated analysis program
o Probe usage
  ▪ 10 X-Probes (with bobbin) used @ 22”/sec (559 mm/sec)
  ▪ 4 X-Probes (w/out bobbin for low rows) used @ 22”/sec (559 mm/sec)
  ▪ 36 Bobbin probes used @ 40”/sec (1016 mm/sec)

• Outage Summary
  o SG inspection scope successfully completed 36 hours faster than planned
    ▪ X-probe speed vs. RPC speed
  o More economical solution
    ▪ X-probe cost and extended life vs. RPC cost and life

• Results:
  o Utility received a more sensitive test (X-probe) for both Special Interest and Loose Parts detection

SUMMARY

In summary, there are many different applications and approaches to consider when using the X-Probe for the inspection of Steam Generator tubes. Depending on your inspection scope, the X-Probe can provide an economical and time saving solution