ROOT CAUSE ANALYSIS REPORT OVERVIEW

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AGENDA

- OVERVIEW OF EVENT
- PRIMARY TO SECONDARY LEAKAGE
- TUBE RESTRICTION HISTORY
- OTHER ISSUES
- ROW 2 - 1997 VIEWPOINT
- DOMINION ENGINEERING REVIEW

OVERVIEW

February 15, 2000

- Primary/Secondary leakage @ 1915 hrs. 3.5 GPD
- 1929 hrs. 75-100 gpm, plant shutdown
- R2C5 in SG24 leaking at U-bend (2/27/00)
- Welch-Allyn video probe used, shows large axial indication in the U-bend (2/28/00)
- Attempted +Point analysis of R2C5, probe caught in U-bend, obtained partial data from crack tip, location on extrados of tube

OVERVIEW

February 15, 2000 (cont.)

- R2C5 bobbin tested, 1.7-1.8" long located at apex (3/1/00)
- +Point obtained by gluing coil "shoe" down
  - Located on Extrados
  - Axial indication
  - Length between 2 to 2-1/2"
- Secondary side inspections and analysis begin concurrently

OVERVIEW

Analysis of leaking tube begins 2/28/2000

- Reviewed 1997 data for R2C5, 20/20 hindsight, Identified possible indication at U-bend apex
  - Concluded indication Axial PWSCC based on phase angle
  - Analyzed the program to determine any weaknesses
  - Analysis identified low signal-to-noise (S/N) ratio
  - Sources of noise identified
    - OD deposits mask flaw signal
    - Probe rotational speed variations possibly due to ovalization
  - Examined data analysis setup and techniques used in 1997
    - Noise rejection criteria developed
    - Determined that 400kHz has slightly better Signal/Noise ratio
    - 1997 data would be classified as BDA with 2000 criteria

OVERVIEW

Training initiated incorporating lessons learned

- 2000 utilized EPRI rev 5 guidelines for ID phase setup
- Instructions for poor S/N data rejection
- Program of retesting noisy data until acceptable or plugged is instituted
- Training administered to analysts
  - Separate training sessions
- Lessons learned evolved during U-bend inspection

OVERVIEW

Initial Inspection starts

- Inspection scope - 100% of U-bend in rows 2, 3 and 4
- Examined initial scope
- 3 PWSCC axial cracks located on the extrados of the U-bend apex found in row 2
- No indications found in any row 3 or row 4
- Extensive retesting conducted on noisy tubes, many still unacceptable
- First analysis of U-bends complete

OVERVIEW

Independent analysis begins

- Updated training program - second phase
- Senior analysts used, new to project
- Primary/Secondary and Resolution teams
- Analyzed all 2000 U-bend midrange +Point data
- No new indications reported; 3 row 2 indications reconfirmed
- Result - 53% of inspected tubes still unacceptable due to low S/N at this point

OVERVIEW

Higher inspection frequencies to enhance PWSCC detection are investigated

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- Mid range (MR) +Point at 750kHz
- New high frequency (HF) plus point: 0.075" diameter @ 800kHz - 1MHz
- Used both techniques to examine known PWSCC
- HF +point is chosen best
- Qualification is formalized (3/20/00)

OVERVIEW

Production testing with HF +pt begins

- Retest rows 2 and 3, and low S/N tubes in row 4 with HF probe
- 4 new PWSCC flaws discovered in previously noisy tubes
- No new indications found in Initial Program NDD tubes
- No indications in rows 3 or 4 U-bends

OVERVIEW

Production testing with HF +pt begins (cont.)

- 452 tubes recovered from original BDA calls
  - Data quality much better on HF
  - 5 tubes remain bad data, are plugged
- Insitu pressure tests all SAI Ubends
  - 7 tubes tested
  - Exceeded requirement for Insitu test
  - 3 Ubends leaked - met burst criteria
- All row 2 tubes are plugged at the conclusion of U-bend inspections

OVERVIEW

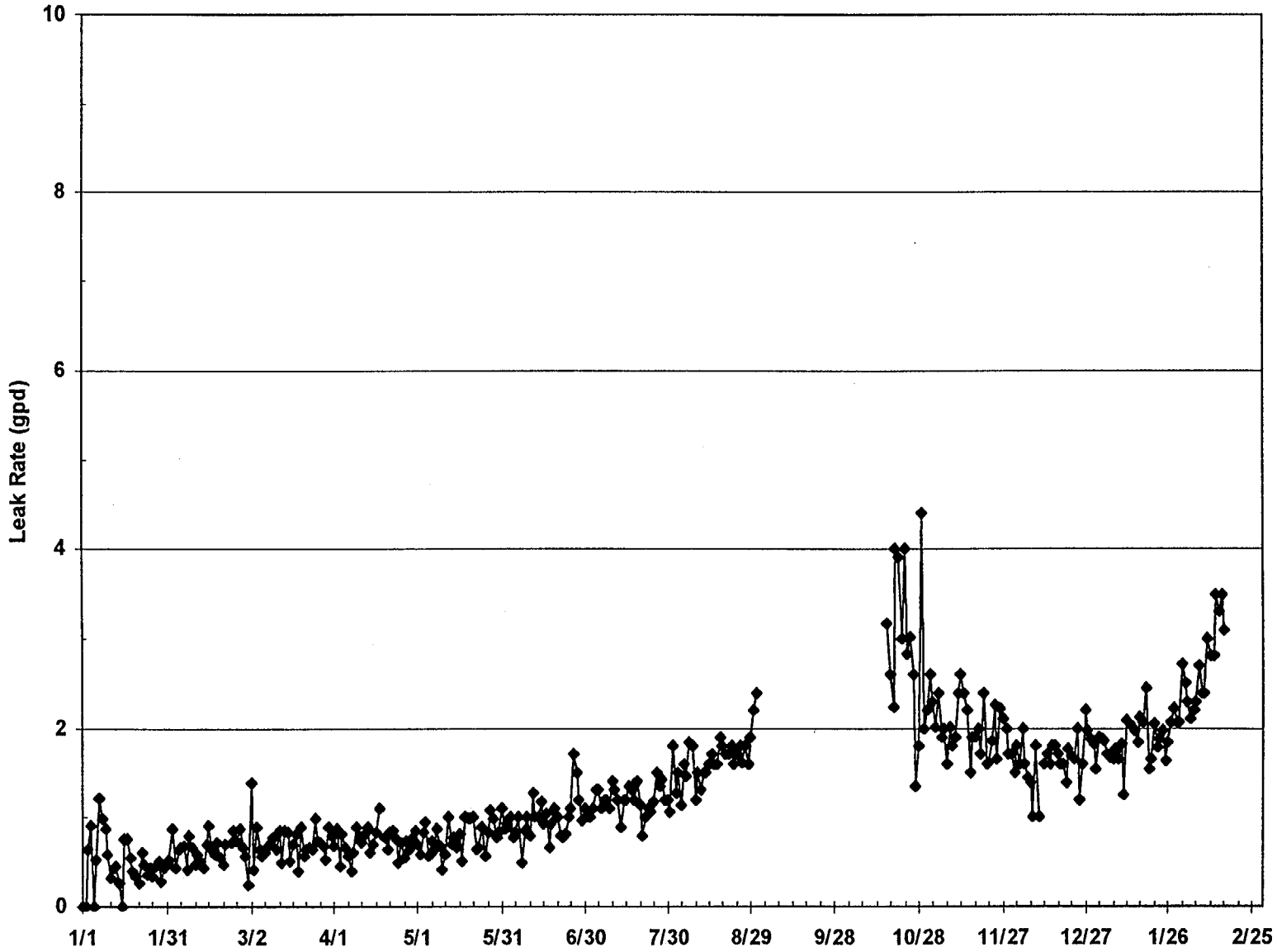
Concurrent Activities

- Secondary side pressure tests on each SG
- Secondary side component inspection and evaluation
- Install hillside ports
- Investigate and measure hour-glassing
- Sludge Lancing/Fosar

PRIMARY TO SECONDARY LEAKAGE

- Prior to February 15, 2000
  - Nitrogen 16 radiation monitor in service
  - Alarm points
    - 10 gallons/day
    - 25 gallons/day
    - 150 gallons/day
    - Recorder out of service
  - Common alarm in Control Room
    - Accident assessment panel
    - Operator responds locally for common alarms
  - Local alarm also
  - Leak rate trend for 1999-2000 is attached

Indian Point 2- Primary to Secondary Leak Rate Calculated from Condenser Off Gas



PRIMARY TO SECONDARY LEAKAGE

- Chemistry routine checks N-16 radiation monitor 1/shift
- Air ejector radiation monitor R-45
  - Rad monitor provides overall trending
  - Chemistry samples pathway – calculates overall leak rate
    - IPCA 110, primary to secondary leak rate calculation
  - 7:15 PM on 2/15/00 chemistry rounds, leak rate = 3.4 GPD per N-16

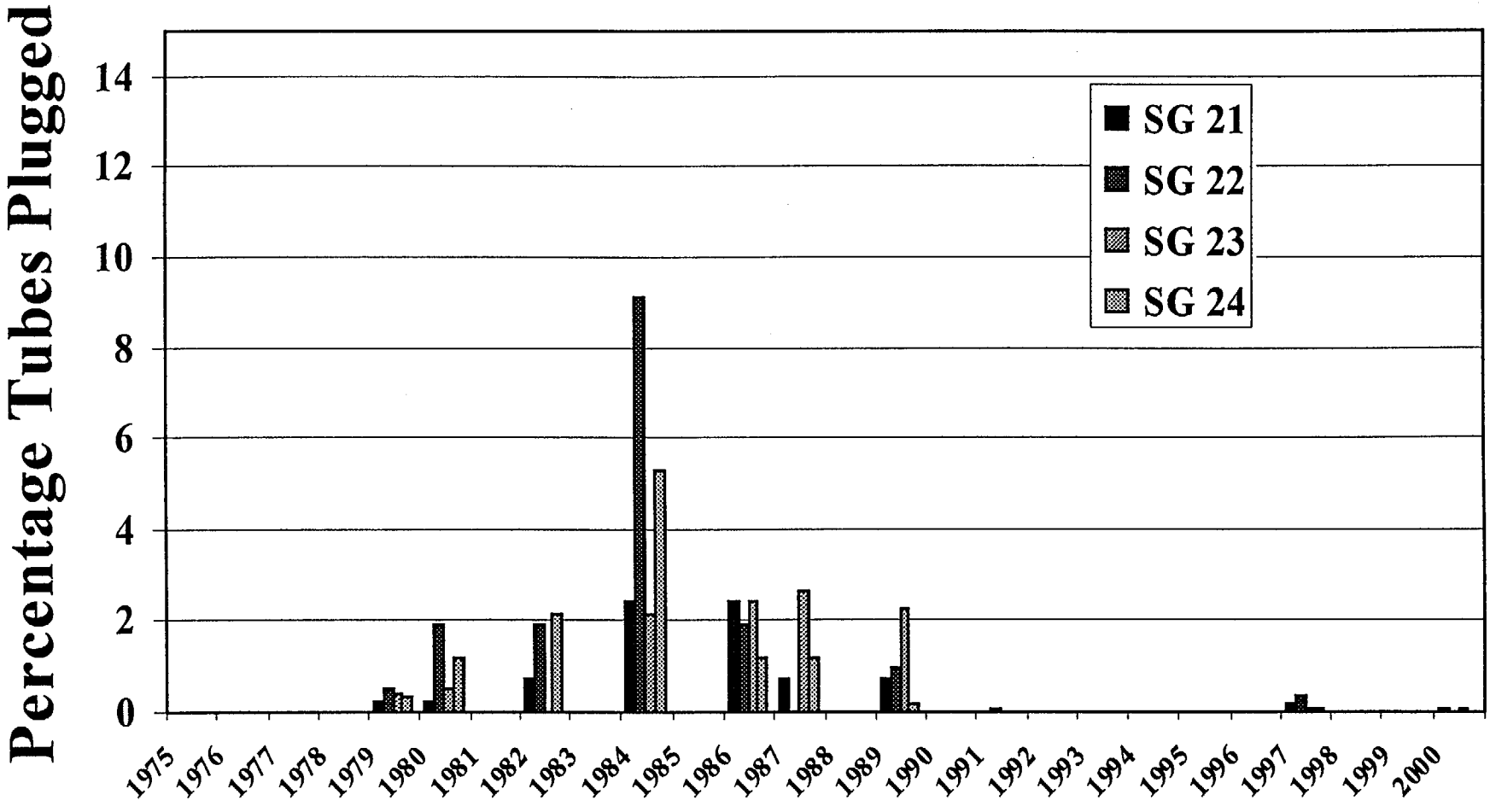
PRIMARY TO SECONDARY LEAKAGE

- Proposed 2000 Primary to Secondary Leak limits
  - Base administrative limits on new EPRI guidelines, February 2000

TUBE RESTRICTION HISTORY

- Frequency of plugging due to 610 probe restrictions has not significantly increased
- 2000 - 2 tubes plugged due to 610 probe restriction
- Data from 1997 & 2000 allows improved tracking

Tubes Plugged For 0.610" Probe Dent Restrictions



COMPARISON OF TUBE/TUBE SUPPORT PLATE RESTRICTIONS FROM 1997 - 2000

STEAM GENERATOR 23

Location	Restriction Size		
TSP	Smaller	No Change	Larger
6H	6	8	4
6C	11	17	5
5H	0	7	0
5C	1	7	3
4H	2	2	2
4C	1	11	2
3H	0	17	0
3C	2	16	8
2H	2	14	1
2C	0	13	2
1H	4	20	4
1C	0	14	2
Total	29	146	33
%	13.94%	70.19%	15.87%

- **13.94% of the intersections became more restricted**
- **70.19% did not change**
- **15.87% of the intersections became less restricted**
- **No history to compare**

OTHER ISSUES

- Susceptibility of ALLOY 600
  - PWSCC is a function of material, stress, environment
- Material Anneal Temps - 1850 F
- Environment, T-hot - 590 F
- Primary Water Chemistry
- Stress - Evaluated separately by ALTRAN & Westinghouse

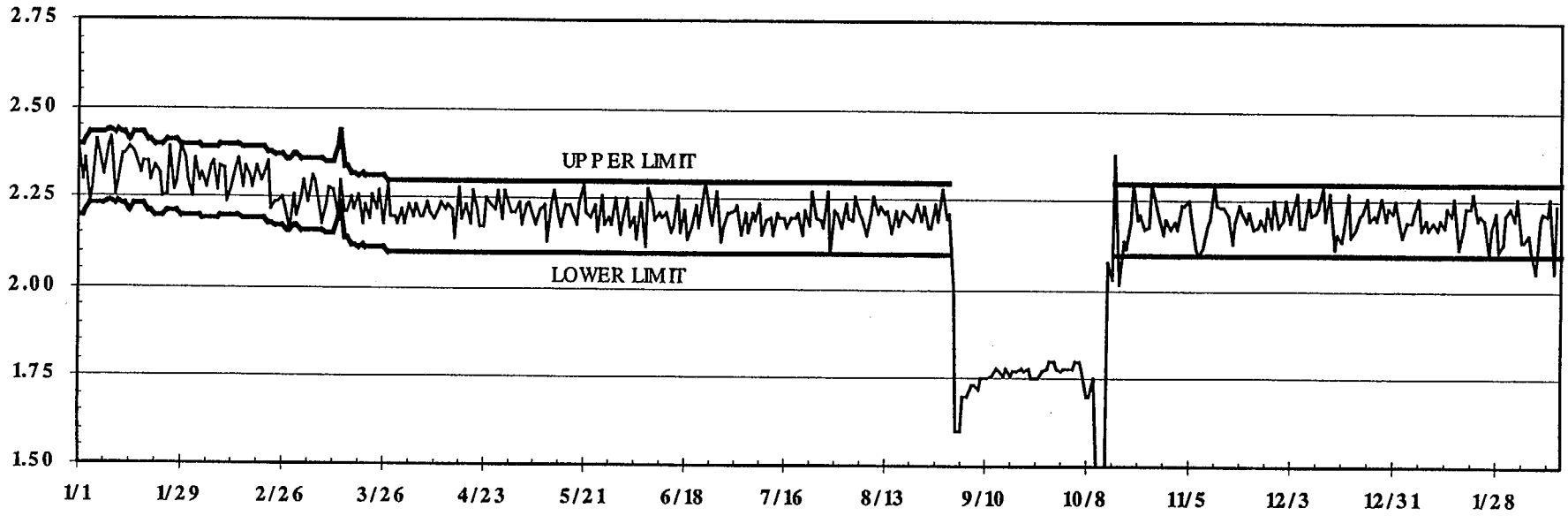
OTHER ISSUES

- Primary Water Chemistry
  - Followed industry guidelines
  - Boron/Lithium curve
  - Hydrogen concentrations
  - Assessed as not an issue

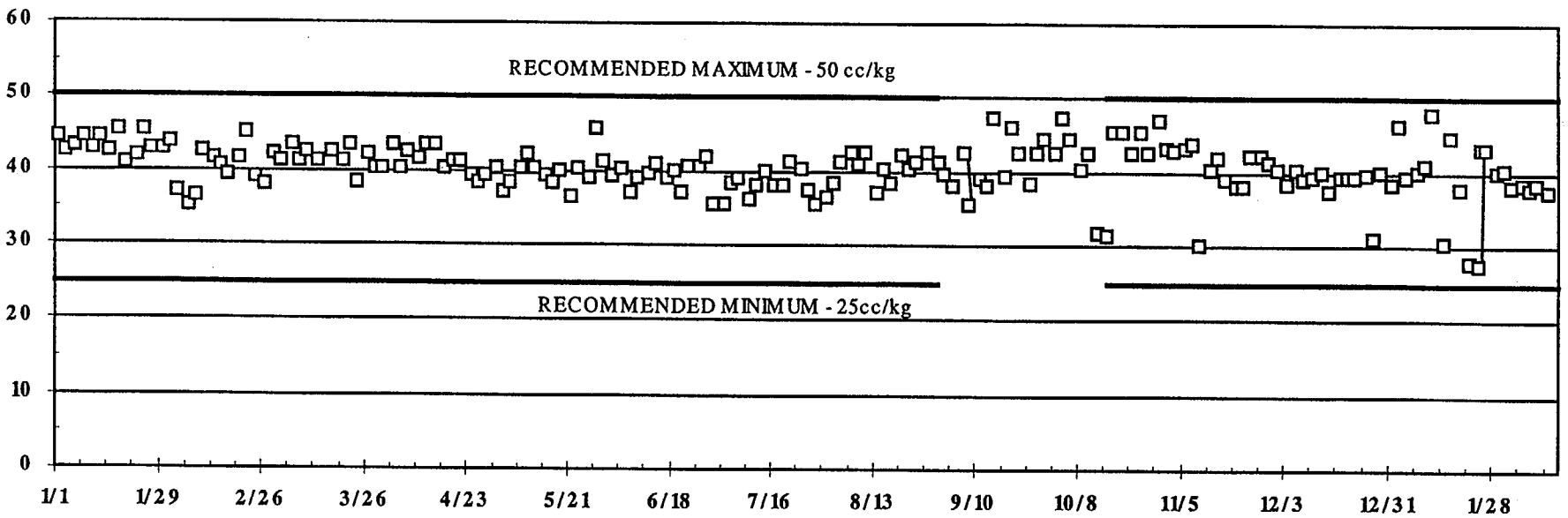
OTHER ISSUES

- ODSCC potential for ROW 2 U-bend apex consideration
  - This was a consideration to plug ROW 2 and examine ROW 3 & 4
  - High frequency detection verified for ODSCC at top of tube sheet
  - Verified OD flaw detection on U-bend samples

REACTOR COOLANT LITHIUM



REACTOR COOLANT DISSOLVED HYDROGEN



ROW 2 - 1997 VIEWPOINT

- 1997 Visual inspection of top support plate
  - Visual inspection performed on 22 & 23 steam generators
    - No cracking in 6TH support plate flowslot in 22 or 23 SG
    - No observable hourglassing

ROW 2 - 1997 VIEWPOINT

- Inspection program consistent with industry standards
- Quality of data issue in EDDY CURRENT
  - +Point probe used for ROW 2 & 3 in 1997
    - Best probe available for U-bend
  - Program detected one PWSCC indication in R2/C67 in 24 SG
  - No indication detected in ROW 3 in 1997

DEI REVIEW

U-BEND PWSCC PREDICTIONS

- DEI was tasked to prepare tube degradation predictions for IP2 in 1995 and 1997.
  - Included U-bend PWSCC
- In 2000, DEI was asked to update 1997 predictions based on re-analysis of 1997 data.

DEI REVIEW

1995 U-BEND PWSCC PREDICTIONS

- No U-bend cracks were detected through 1995.
- Predictions performed using industry data for time of first detection for Huntington tubes, and assumed rate of increase based on industry experience with PWSCC (Weibull slope of 3).
- No Cracks Predicted for 1997 or 2000.
- Main factors for low rate of PWSCC:
  - Low temperature
  - Huntington tubes

DEI REVIEW

1997 U-BEND PWSCC PREDICTIONS

- Single U-Bend PWSCC flaw detected in 1997.
- Predictions developed based on plant specific starting point (1 flaw) and rate of increase of roll transition PWSCC in Huntington tubes (Weibull slope of 4) (known to be consistent with U-bend slopes).
- Predicted 1 new flaw during next operating cycle.

DEI REVIEW

EVALUATION of IP 2 U-BEND PWSCC EXPERIENCE

- Rate of increase of U-Bend PWSCC at IP2 assessed using re-evaluation of 1997 data and mid range +Point results from 2000 (i.e. consistent inspection sensitivity)
- Assumes 3 flaws in 1997
  - 5 cumulative flaws in 2000
- Above data give Weibull slope of 4.7

DEI REVIEW

EVALUATION of IP 2 U-BEND PWSCC EXPERIENCE (Cont.)

- Weibull slope of 4.7 is consistent with industry experience, and indicates that IP2 would experience about 8 new Row 2 flaws in the next fuel cycle (624 EFPD) if not preventively plugged, using high frequency probe
- Industry data:
  - EPRI report NP-7493 (1991) Figures 3-6, 7 & 8: Weibull slopes of 4.5, 4.4, and 4.2 for row 1 and 2 U-bends.
  - EPRI report TR-104030 (1994) Table 5-1: PWSCC median slope for row 1 and 2 U-bends about 4.4.

DEI REVIEW

Comment Regarding SCC Statistics

- SCC typically exhibits large scatter, with small numbers of early failures, and increasing numbers as time progresses.
- This pattern often modeled using Weibull statistics, with Weibull slopes in range of 2 to 6 commonly seen.
- Applying these slopes to IP2 indicates that moderate increases in numbers of new PWSCC flaws at Row 2 would be seen in future cycles, if tubes were not preventively plugged.

DEI REVIEW

Potential for Row 3 U-Bend PWSCC

- No known cases of row 3 U-bend PWSCC leaks in industry.
- No detected PWSCC in IP2 row 3 U-bends.
- Crack initiation in row 3 expected to be significantly later than in row 2 based on lower stresses and lower cold work.
- Crack growth rate expected to be lower than in row 2 based on lower stresses and lower cold work.

DEI REVIEW

Potential for Row 3 U-Bend PWSCC (cont.)

- Conclusion: Very low likelihood of large flaws developing during next inspection interval based on:
  - Low potential for crack initiation
  - Low growth rate
  - Modified operating interval