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2. AUTHOR(s)

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U.S. OPERATING EXPERIENCE WITH THERMALLY TREATED ALLOY 600 STEAM GENERATOR TUBES

EPRI Steam Generator NDE Workshop
July 15, 2002

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BACKGROUND

- Mill annealed Alloy 600 SG tubes susceptible to various forms of degradation
- 31 plants have replaced SGs as of 07/01/02
  - 1 600 MA; 8 600 TT; 22 690 TT
- Thermal treatment of Alloy 600 improves microstructure
- Other design improvements
  - Hydraulic expansion of tubes into tubesheet
  - Stainless steel tube support plates with quatrefoil holes
  - Stress relief of low row tubes

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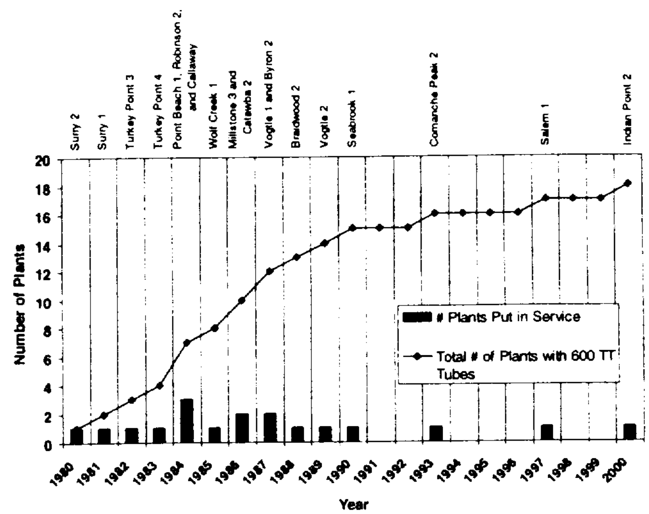
Installation of Steam Generators with Alloy 600 TT Tubes as a Function of Year



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STEAM GENERATOR MODELS WITH ALLOY 600 TT TUBES

Plant	Date	Model	Number of SGs	Replacement
Braidwood 2	1988	D5	4	N
Byron 2	1987	D5	4	N
Callaway	1984	F	4	N
Catawba 2	1986	D5	4	N
Comanche Peak 2	1993	D5	4	N
Indian Point 2	2000	44F	4	Y
Millstone 3	1986	F	4	N
Point Beach 1	1984	44F	2	Y
Robinson 2	1984	44F	3	Y
Salem 1	1997	F	4	Y
Seabrook 1	1990	F	4	N
Surry 1	1981	51F	3	Y
Surry 2	1982	51F	3	Y
Turkey Point 3	1982	44F	3	Y
Turkey Point 4	1983	44F	3	Y
Vogtle 1	1987	F	4	N
Vogtle 2	1989	F	4	N
Wolf Creek 1	1985	F	4	N

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OPERATING EXPERIENCE
Forced Outages

- Eight unplanned outages related to SG issues
- 3 Leakers
  - Byron 2 (2002) - 75 gpd, secondary side foreign object
  - Byron 2 (1996) - 120 gpd, secondary side foreign object
  - Surry 2 (1986) - Shut down for another issue but addressed small SG leak – secondary side foreign object

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OPERATING EXPERIENCE
Forced Outages (cont'd)

- 5 "non-leaker" outages - all attributed to loose parts identified through loose part monitoring systems
  - 3 outages due to Control Rod Guide Tube Support Pin Nuts:
    - Wolf Creek (2002), Vogtle 1 (1996), Robinson 2 (1989)
    - Damaged tubesheet and tube ends on hot-leg side
  - Point Beach 1 (2000) - No loose part found
  - Robinson 2 (1994) - Shut down for another issue but addressed secondary side loose part
    - In previous outages, 2 nearby tubes had been plugged (may have been related to this loose part)

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OPERATING EXPERIENCE
Inspection Results

- ~281,000 Alloy 600 TT tubes in service
- Average age = 14.4 calendar years
- Results of SG tube inspections submitted to NRC
- Experience grouped by models
  - Model D5, Model F, and Replacement models (44F, 51F, and Salem Model F)
- Inspection scope and frequency varies
  - D5 – typically all 4 SGs examined
  - F – typically 2 of 4 SGs examined
  - Replacement – varies - inspect all SGs, skip cycles, 1 of 3 then 2 of 3, or 1 of 3 each outage

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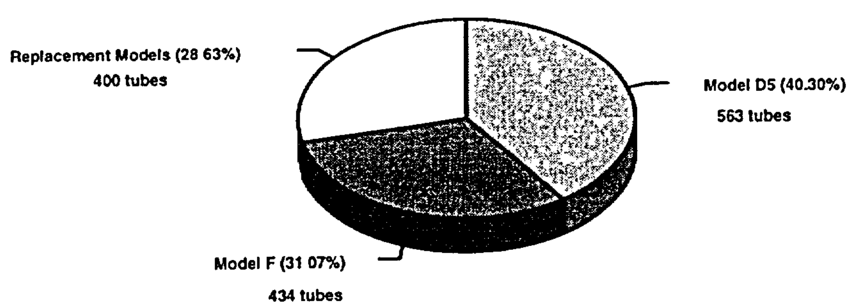
Percentage of Plugged Tubes by Model



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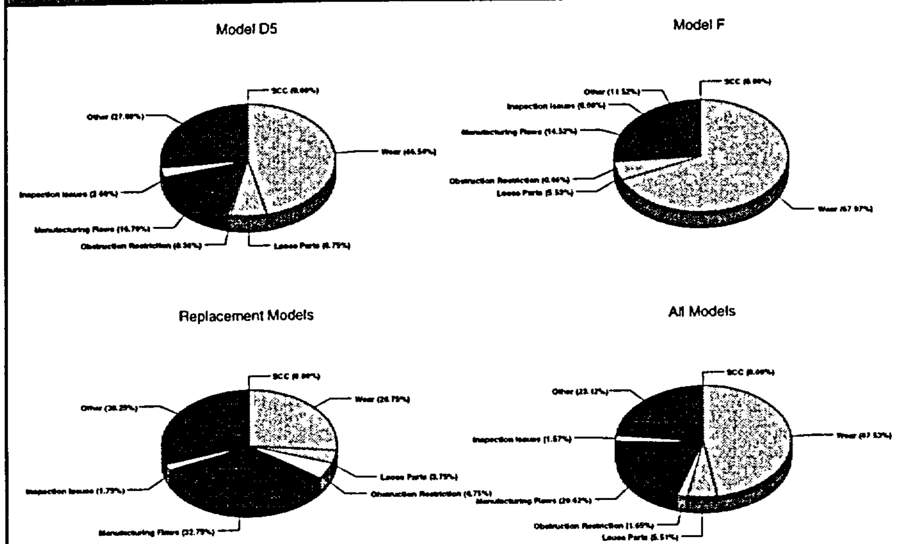
Causes of Tube Plugging (12/31/01)



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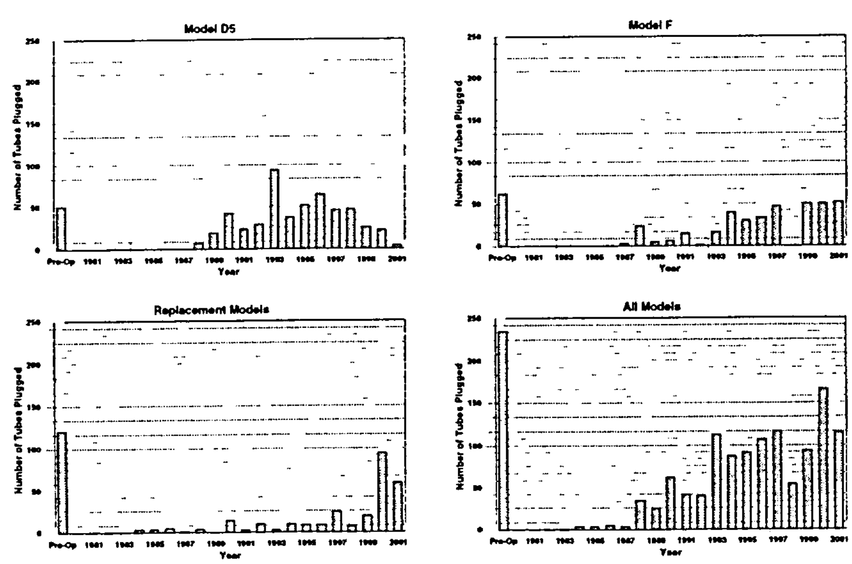
Number of Tubes Plugged Per Year



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OPERATING EXPERIENCE
Observations

- Seabrook axial crack-like indications at tube supports
- Mechanical denting at tubes supports
- Wear at tube supports - only 18 tubes plugged (12 at one plant last year)
- Volumetric indications attributed to tube wear in interior of tube bundle is not well explained

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OPERATING EXPERIENCE
Observations (cont'd)

- Causal mechanism for tube obstructions that prevent the passage of a bobbin coil is not readily ascertainable from "outage reports"
- Tube stabilization may be necessary as a result of continued degradation of plugged tubes
  - Several plants have been evaluating
- Tubesheet anomalies – not expanded, under expanded (i.e., not full length), or over expanded may require more frequent examination or preventive plugging

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OPERATING EXPERIENCE
Observations (cont'd)

- Tube inspections before and/or after secondary side maintenance
  - Before: may miss opportunity to detect loose parts left in SG
  - After: may not be able to conclusively determine if loose part was the cause of indication
- Manufacturing anomalies
  - Comprehensive preservice inspection could establish a baseline for dispositioning "anomalous" signals

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OPERATING EXPERIENCE
Tube Pulls

- Seabrook - 2002
- Byron 2 – 1998
  - Removed portions of 3 tubes with circumferential indications at expansion transition
  - Manufacturing related indications
- Surry 1 – 1990
  - Removed portions of 2 tubes to examine indications near expansion transition
  - Manufacturing related indications
- Surry 1 – 1986
  - Removed portion of 1 tube to examine indications near uppermost tube support
  - No degradation

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Operating Experience
Tube Pulls (cont'd)

- Needed to:
  - Conclusively determine nature of "manufacturing related" eddy current signals which can't be traced to baseline
  - Conclusively determine nature of indications being detected at a number of plants
    - Volumetric
    - Loose Part Wear in interior of bundle
    - Support plate wear and denting
    - Obstructions/Restrictions
    - Cracking
- Uncertainties in determining type of degradation should be accounted for in operational assessments

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CONCLUSIONS

- Relatively good operating experience attributed to:
  - Thermal treatment
  - Hydraulic expansion
  - Quatrefoil tube support hole design
  - Stainless steel tube supports
- Although experience has been favorable, there is a continued need to monitor for tube degradation including cracking
- Better understanding of inspection results will be needed to determine appropriate intervals between inspections

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