NRC FORM 658
(9-1999)

U.S. NUCLEAR REGULATORY COMMISSION

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DATE OF MEETING
02/27/2001

The attached document(s), which was/were handed out in this meeting, is/are to be placed in the public domain as soon as possible. The minutes of the meeting will be issued in the near future. Following are administrative details regarding this meeting:

Docket Number(s)	
Plant/Facility Name	
TAC Number(s) (if available)	
Reference Meeting Notice	2001-0120
Purpose of Meeting (copy from meeting notice)	Steam Generator Workshop to discuss recent events and technical issues concerning nuclear power plant steam generators

NAME OF PERSON WHO ISSUED MEETING NOTICE	TITLE
Robert Rothman	SG Workshop

OFFICE
NRR

DIVISION
DE

BRANCH
EMCB

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NRC STEAM GENERATOR WORKSHOP

UNITED STATES NUCLEAR REGULATORY COMMISSION

FEBRUARY 27 - 28, 2001

BETHESDA, MARYLAND

Volume I

SG Workshop Program and Schedule

TIME	DURATION	TOPIC	PRESENTER
February 27, 2000			
7:30 - 8:30		Registration	
8:30 - 9:00		Opening Remarks - NRC Management	B. Sheron E. Sullivan
9:00 - 10:30		SG Programmatic Issues – Chair: L. Lund	
Session 1	20 min	• NEI 97-06, Revision 1 (Industry)	J. Riley
	15 min	• Schedule and Documentation Structure of Generic Licensing Package (NRC)	L. Lund
	20 min	• Integration/Responsibility of Industry Organizations (Industry)	R. Exner
	15 min	• Review Process/Resources for ARCs, CM/OAs, Reports, etc. (NRC)	T. Sullivan
	20 min	• Industry Actions on Lessons Learned (Industry)	D. Goetcheus
10:30 - 10:45		Break	
10:45 - 11:15		Panel Discussions (All) - Moderator: K. Sweeney	
11:15 - 12:30		Lunch	
12:30 - 1:30		SG Inspection Oversight Issues – Chair: C. Khan	
Session 2	30 min	• Plans for NRC Inspections of SG Programs (NRC)	D. Coe
	10 min	• Guidance/Training for NRC Inspectors and Outage Phone Call Protocol (NRC)	C. Khan
	20 min	• INPO SG Review Visit Objectives and Approach (Industry)	A. Smith
1:30 - 1:45		Break	
1:45 - 2:15		Panel Discussions (All) - Moderator: R. Pearson	

SG Workshop Program and Schedule

TIME	DURATION	TOPIC	PRESENTER
2:15 - 2:30		Break	

2:30 - 4:30
Session 3
	
	15 min
	45 min
	
	15 min
	15 min
	30 min
		SG Inspection Technical Issues – Chair: S. Coffin
		• Analyst Guidelines (NRC)
		• EPRI Examination Guidelines (Industry):
		  • Rev 5
		  • Rev 6
		• Steam Generator Eddy Current Inspection Challenges (NRC)
		• NDE Issues (ANL)
		• NRC SG Mockup Round Robin (NRC)
			
			C. Dodd
			
			S. Redner
			D. Mayes
			S. Coffin
			D. Kupperman
			J. Muscara

4:30 - 4:45		Break	
4:45 - 5:15		Panel Discussions (All) - Moderator: K. Karwoski	
February 28, 2000			
8:30 - 10:30 Session 4	 20 min 40 min 20 min 20 min 20 min	SG Tube Integrity Technical Issues – Chair: E. Murphy • Steam Generator Integrity Assessment Guidelines (Industry) • NRC Perspective on Several Tube Integrity Issues (NRC/ANL) • In Situ Pressure Testing Guidelines (Industry) • NRC Expectations Regarding ARC/Repair Methods/OAs Supported by Risk Assessment (NRC) • Primary to Secondary Leak Guidelines (Industry)	 K. Sweeney E. Murphy S. Majumdar H. Cothron S. Long F. Hundley
10:30 - 10:45		Break	
10:45 - 11:15		Panel Discussions (All) - Moderator: K. Karwoski	
11:15 - 11:30		Closing Remarks (NRC/NEI)	

Opening Remarks

Brian W. Sheron
Associate Director for
Project Licensing and Technical Analysis
NRC/NRR

Steam Generator Workshop
February 27-28, 2001

Opening Remarks

- Industry needs to direct serious attention to steam generator integrity
- Indian Point 2 was a painful experience; it was not a success story for either NRC or industry
- IP2 put a lot of burden on both the NRC and the industry
- Con Ed's credibility suffered and so did NRC's credibility

Opening Remarks

- Unfortunately, this translated into a loss of industry credibility with some members of Congress and with local communities

- In large measure NRC was held as accountable for the accident as was the licensee

- Tube ruptures are part of the PWR design basis; nevertheless, the IP2 tube failure was avoidable

Opening Remarks

- NRC expects licensees to take reasonable actions to prevent conditions such as those that existed at IP2
- Licensees have to be cognizant of unique circumstances at their plants that EPRI guidelines may not address
- We recognize industry programs getting better because guidelines improving and because licensees are now following NEI 97-06

Opening Remarks

- Based on IP2 it is clear that lessons learned need to be addressed in the guidelines and incorporated into licensee SG programs

- NRC is serious about operational assessments - we need to have a way to verify that licensees have assurance of tube integrity for the upcoming cycle

Opening Remarks

- NRC is holding industry accountable for conducting inspections appropriate to the plant, to prevent those tube ruptures that could be predicted from an adequate integrity assessment

- NRC has four strategic goals that we continually look to for carrying out our regulatory programs: Maintain Safety, Reduce Unnecessary Burden, Improve Efficiency and Effectiveness and Improve Public Confidence

Opening Remarks

- For the workshop I recommend that all of us keep in mind these four strategic goals and ask ourselves - what have we learned and what can all of us do better?

Opening Remarks

Edmund J. Sullivan
Section Chief, NDE & Metallurgy Section
NRR/DE

NRC Steam Generator Workshop
February 27 - 28, 2001

Historical Overview

- 2/15/00 - Indian Point 2 Tube Failure Event
- 2/28/00 - NRR request to RES for independent review
- 3/16/00 - RES response to NRR
- 5/24/00 - Task Group Charter issued
- 8/29/00 - Office of the Insp. General (OIG) Report issued
- 8/30/00 - Chairman's request for staff review of OIG Report
- 10/23/00 - Lessons-Learned Report issued
- 11/3/00 - Staff Review of OIG Report issued
- 11/16/00 - Steam Generator (SG) Action Plan issued

SG Action Plan

- SG Action Plan was issued on 11/16/00. The purpose of the action plan is to:
  - Direct and monitor the NRC's efforts in the SG tube integrity area
  - Ensure that the associated issues are appropriately tracked and dispositioned
  - Ensure the NRC's efforts result in an integrated SG regulatory framework (e.g., licensing, inspection, research) which is effective and efficient

SG Action Plan (cont.)

- The action plan consolidates numerous activities related to SGs including:
  - Evaluation and implementation of recommendations from the IP2 Lessons-Learned report
  - Evaluation and implementation of recommendations from staff review of OIG report
  - NRC review of NEI 97-06, "Steam Generator Program Guidelines" - revised and updated regulatory framework in generic change package
  - Resolution of GSI-163, "Multiple Steam Generator Tube Leakage"
  - Resolution of SG Differing Professional Opinion

SG Action Plan (cont.)

- The action plan also includes non-SG related issues that arose out recent SG activities (e.g., Emergency Planning issues from OIG report)
- The action plan does not address plant-specific reviews or industry proposed modifications to GL 95-05 (voltage-based tube repair criteria)

SG Action Plan Activities

- Regulatory Issue Summary - SG Lessons Learned
- Staff review of ACRS recommendations on DPO
- Determine GSI-163 resolution strategy
- Review and develop SE for NEI 97-06
- Guidance for NRC inspectors
- Formal written guidance for NRC technical reviewers
- Guidance for review of licensee SG inspection results, conference calls during outages
- SG Workshop with stakeholders
- Industry response to IP2 Lessons Learned

SG Action Plan Management

- Resolution of issues will be coordinated with internal and external stakeholders
- Status of action plan milestones will be updated on quarterly basis and published in the NRR Director's Quarterly Status Report
- Completion of each action plan milestone will be documented via memo from lead division to associate directors in NRR

Session 1
February 27, 2001

NEI 97-06 Revision 1

NRC SG Workshop

Jim Riley, NEI

Presentation Outline

- Background
- SG Program Guidelines
- Industry SG Program Initiative
- Creation of NEI 97-06 Revision 1
- Revision 1 Changes
- Industry Communication
- Continuing Evolution
- Summary

NEI

Background

- EPRI SGMP organized in 1976 to address SG corrosion concerns
- NUMARC and SGMP worked with the NRC since 1993 to establish a framework for SGDSM and ARCs
- NEI SGIWG and SGTF chartered in 1995 to meet with the NRC on the SG rulemaking

Background

- Regulatory approach shifted from rule to Generic Letter and Draft Guide (DG 1074)
- During the same time frame the industry SGDSM framework developed into NEI 97-06
- In 1999 the NRC and industry focused on endorsing the SG Program requirements in NEI 97-06

NEI

NEI 97-06, *SG Program Guidelines*

- NEI 97-06 written as upper level guidance for SG Program requirements
  - Detailed requirements are contained within the EPRI SG Guidelines
- Framework incorporates a balance of prevention, inspection, evaluation, repair, maintenance, and leakage monitoring

NEI

NEI 97-06, *SG Program Guidelines*

- Establishes performance criteria that define the basis for SG operability
- Defines the essential elements of a steam generator program

Degradation assessment
Integrity assessment
Leakage monitoring
Foreign material exclusion
Self assessment

Inspection
Maintenance and repair
Water chemistry
Secondary side integrity
NRC reporting

NEI

NEI 97-06, *SG Program Guidelines*

- Requires meeting the intent of directive EPRI SG Guidelines:

SG Examination Guidelines	Primary-to-Secondary Leak
Secondary Water Chemistry	Primary Water Chemistry

- Revision 0 of NEI 97-06 issued in December 1997

NEI

Industry SG Program Initiative

- In December 1997 the NEI NSIAC voted to adopt a formal industry Initiative on SG Program requirements:

> *Each licensee will evaluate its existing steam generator program and, where necessary, revise and strengthen program attributes to meet the intent of the guidance provided in NEI 97-06, Steam Generator Program Guidelines, no later than the first refueling outage starting after January 1, 1999.*

- Initiative committed all PWRs to the specified actions

Creation of Revision 1

- Industry experience and NRC comments indicated that revision 0 could be improved
- SGTF and NRC met frequently between late 1998 and mid 2000 to address issues
- NEI 97-06 revision 1 incorporates the resolution to most of these issues

Revision 1 Changes

- Users must follow the intent of the referenced EPRI SG Guidelines:

SG Examination (NDE)	• Integrity Assessment
In Situ Pressure Testing	• Primary-to-Secondary Leakage
Primary Water Chemistry	• Secondary Water Chemistry

- Structural integrity performance criteria includes safety factors against burst and requirements on yield

NEI

Revision 1 Changes

- Accident induced leakage performance criteria related to accident analysis limits and 1 gpm
- Appendices include guidance for justifying deviations from requirements
- Revises / incorporates the definitions of tube burst, normal full power operations, SG tubing, and others

Revision 1 Changes

- Revises NRC reporting requirements:
  - Results of inspections if the number of degraded tubes exceeds a threshold value
  - Failure to meet performance criteria during condition monitoring
  - Failure to implement a required plugging or repair

Industry Communication

- SG Program requirements include numerous means of communicating SG experience to PWR plants
  - NEI SG Review Board interpretations (as requested)
  - Interim guidance (as needed)
  - NEI APC Letters
  - SGMP TAG (3 times a year)
  - SGMP Workshops (annually)
  - EPRI SG Guideline revision (biannually)

NEI

Continuing Evolution

- NEI 97-06 and EPRI SG Guidelines are living documents - they are changed in response to new technologies and experience
  - NEI 97-06 revised as necessary
  - EPRI SG Guidelines are evaluated for revision biannually

NEI

Continuing Evolution

- NEI and SGMP will continue to work with the NRC to improve the program and to address emerging issues

NEI

Summary

- The industry is committed to safe operation
  - Long term program
  - Industry commitment to requirements
  - Prepared and guided by industry experts
  - Living documents - responsive to changes in technology and experience
  - Extensive communication
  - NRC interaction

NEI

Schedule and Documentation Structure of NEI 97-06 Generic Licensing Package

Louise Lund
NRC/NRR/DE/EMCB

NRC Steam Generator Workshop
SG Programmatic Issues Session
February 27 - 28, 2001

Regulatory Framework for SG Tube Integrity Program

Tech Specs:
- Implement **program** to ensure performance criteria are met
- Performance criteria, plugging limits, and repair methods shall be NRC approved

Licensee Controlled Document:
- Lists site-applicable, NRC approved performance criteria, plugging limits, and repair methods

Program Guidelines (NEI 97-06)
- Defines the key programmatic elements
- Provides general guidance for implementing the programmatic elements

Detailed Guideline Documents, e.g.:
- Tube examination
- In situ pressure testing
- Tube integrity assessment
- Leakage monitoring
- Water Chemistry

NEI 97-06 Generic License Change Package

- Current regulatory framework is outdated and prescriptive and not directly focused on ensuring that tube integrity is maintained throughout the period of operation between inspections

- Package represents the culmination of efforts to develop a revised and updated regulatory framework that include the following characteristics:

  - performance based: establishes performance criteria for ensuring tube integrity and limiting operational leakage

  - performance criteria are tolerable

  - flexible: manner of addressing performance criteria are up to the licensee

  - adaptable: written to address various modes of degradation, tube repair techniques and inspection technology

  - risk-informed

NEI 97-06 Generic License Change Package (cont'd)

- Provide regulatory framework for licensee management of SG tube integrity
- NEI 97-06, proposed Technical Specifications and Technical Requirements Manual in the generic license change package will be reviewed for endorsement; EPRI guidelines will not be specifically endorsed
- Outstanding technical issues (e.g., noise, data quality, POD, etc.) will exist regardless of the regulatory framework and do not need to be resolved before generic license change package can be implemented
- NRC recommending establishment of a protocol agreement with industry to resolve outstanding technical issues

Features of the New TSs and Technical Requirements Manual

- Includes structural and accident-induced leakage performance criteria in administrative TSs
- Revises operational leakage LCO to incorporate operational leakage performance criterion
- Plant-specific repair criteria (e.g., 40% plugging limit), repair methods (e.g., sleeves) and approved alternate repair criteria from existing TSs will carry forward to the TRM
- Prior NRC approval necessary to change performance criteria and associated definitions, repair criteria, repair methods, and alternate repair criteria in TRM
- Ability to use generically approved repairs and ARCs, subject to limitations in generic staff approvals
-

Regulatory Issue Summary

- Staff plans to issue the NEI 97-06 SE in a Regulatory Issue Summary (RIS)

- Target Date for Completion - 10/31/01

- RIS will discuss the basis for approval of the generic change package

- RIS will include staff expectation that the licensees will submit plant-specific TS change requests modeled on the template in the generic change package (including commitments)

- RIS will include staff expectations that licensees would commit in their amendment transmittal letter to implementing their SG management program consistent with NEI 97-06

Schedule

▪ Recommence work on NEI 97-06	1/31/01
▪ Staff completes review and draft SE of NEI 97-06 SG generic license change package	5/31/01
▪ Staff briefs CRGR on NEI 97-06 SG generic license change package	7/31/01
▪ Publish SE on NEI 97-06 SG generic license change package in FR for public comment	7/31/01
▪ ACRS review of NEI 97-06 SG generic license change package	8/31/01
▪ Staff briefs Commission on endorsing NEI 97-06 SG generic license change package	10/31/01

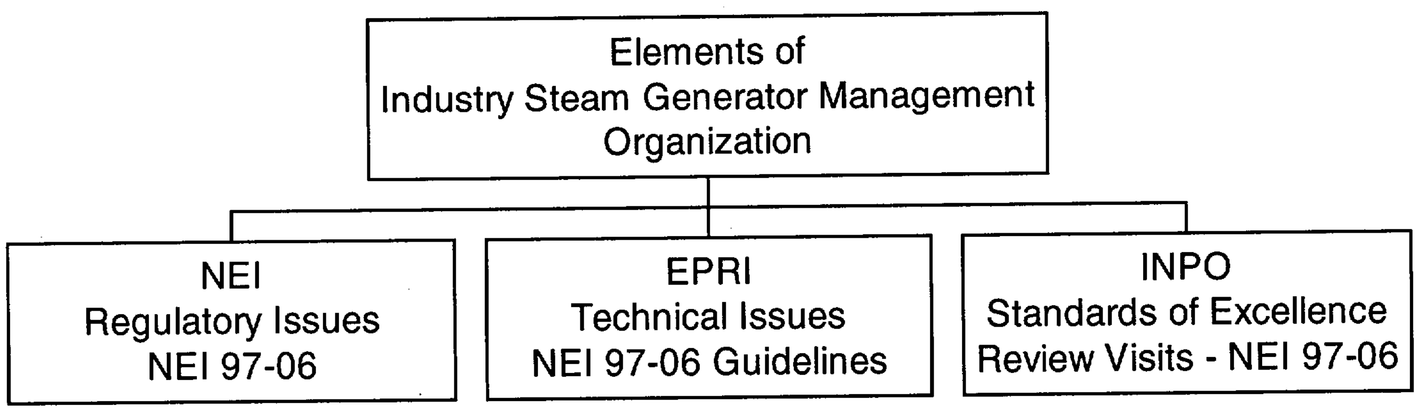
Items That Could Potentially Affect Schedule

- Resolution of the DPO
- Operability issue
- Changes made to the generic change package TS and TRM since before the IP2 event that will require resolution

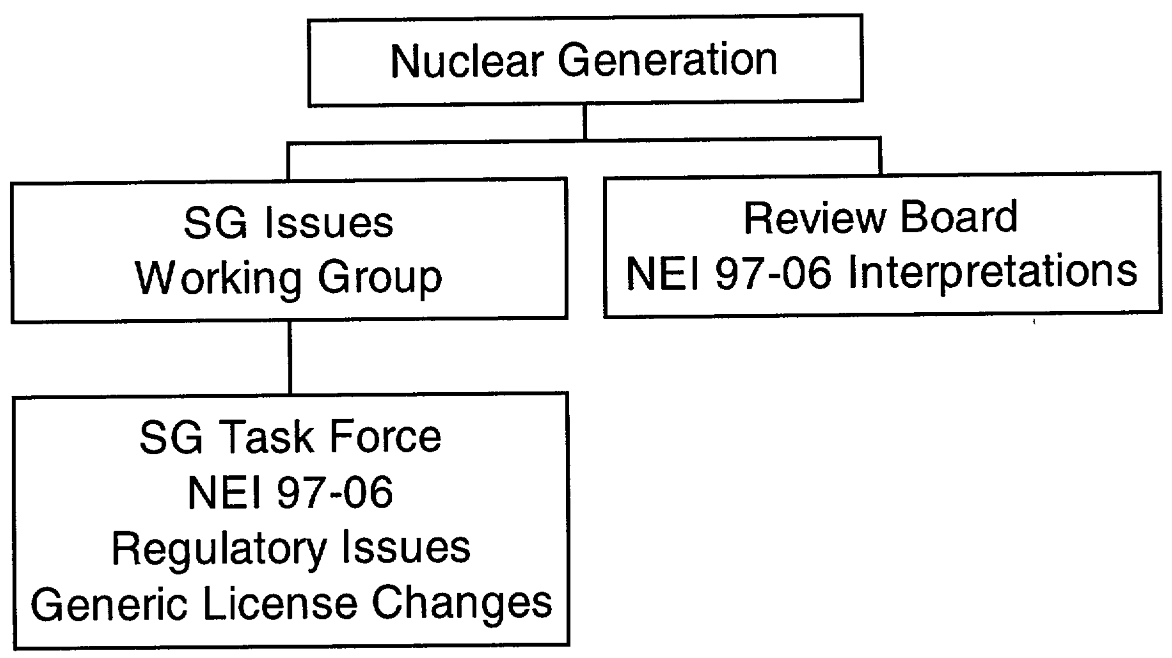
Overview of Industry Steam Generator Management Organization

Bob Exner
Pacific Gas & Electric Co
Diablo Canyon Power Plant
February 27, 2001

Industry Organization



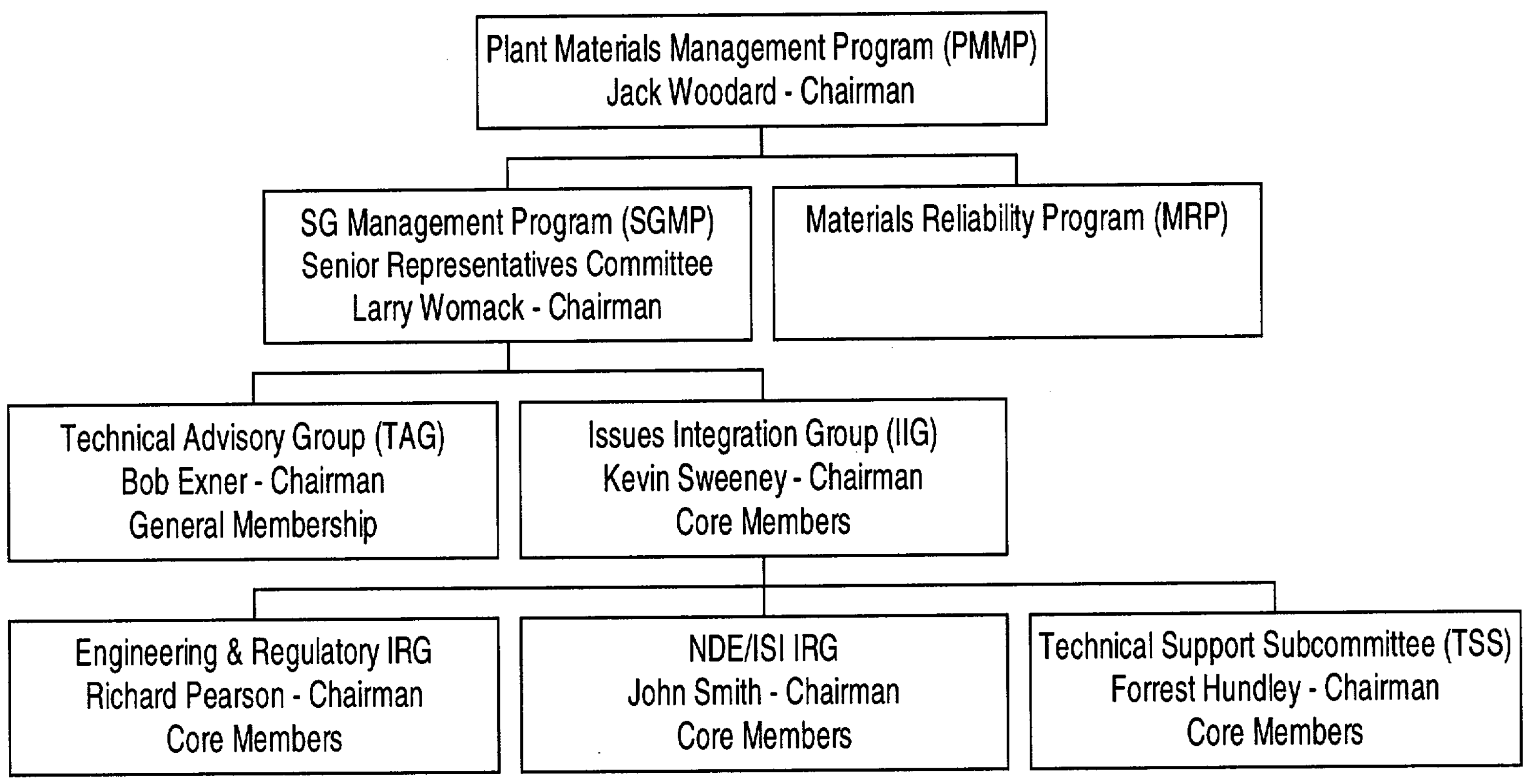
NEI Organization



NEI Organization

- NEI SG Issues Working Group/Task Force
  - Developed NEI 97-06
  - Generic License Change Package
  - SG Action Plan
  - Membership - attached
- NEI 97-06 Review Board Process
  - Resolve generic questions about NEI 97-06 and EPRI guidelines
  - Advisory Panels – Members From SGMP
  - Review Board – Members From IIG
  - Interpretations – Posted on Web
  - SGMP Administrative Procedure
  - Membership - attached

Industry/EPRI Organization



Industry/EPRI Organization

- PMMP
  - Executive Group
  - Overall Policy/Budget Approval
  - Approves EPRI Guidelines
- SGMP
  - General Organization
    - US and Foreign Utilities - Manage SG issues and technology development
  - SGMP Administrative Procedures
  - EPRI Guidelines
    - Revision process through Ad Hoc committees – include vendors and consultants
    - Guidelines assigned to specific subcommittees
  - SG Degradation Database - Website

Industry/EPRI Organization

- Technical Advisory Group (TAG)
  - Information Sharing/Working Groups/Policy Review and Approval
  - Reviews EPRI Guidelines
  - 3 Meetings/Year – 1 with Senior Reps
  - Chemists/Engineers/NDE Specialists
    People Responsible for SG Programs
  - Information Forum – NRC Presentations are Invited

Industry/EPRI Organization

- Issues Integration Group (IIG)
    - Interface between TAG and Executive Group
    - Issue Prioritization – Resource Allocation
    - Members represent all three NSSS and SG designs
  - Engineering and Regulatory Issue Resolution Group (E & R IRG)
    - Respond to Engineering/Regulatory Issues
    - SG In Situ Pressure Test Guidelines
    - SG Integrity Assessment Guidelines
  - In-service Inspection / Non-Destructive Examination (ISI/NDE IRG)
    - Respond to NDE Issues
    - PWR SG Examination Guidelines

Industry/EPRI Organization

- Technical Support Subcommittee (TSS)
  - Long term R&D
  - PWR Secondary Chemistry Guidelines
  - PWR Primary Chemistry Guidelines
  - PWR Primary-to-Secondary Leak Guidelines

INPO Organization

- Industry's Assessment Organization
- SG Review Visit Program
  - Peer Participation – Information Sharing
  - SG Program Recommendations and Strengths
  - Year end Summary Provided to Industry
  - Some Follow-up Items
- Operating Experience Programs
  - Notification of events
  - Information Sharing
  - Website

Summary

- Industry has a SG Management Program in place that:
  - Addresses issues promptly
  - Uses broad based utility participation
  - Encompasses all SG types/vintages
  - Issues guidelines and policy
  - Self monitors through peer reviews
  - Interfaces with NRC through NEI
  - Maintains research/improvement efforts

NEI SG Issues Working Group and Task Force

Members	SG Issues Working Group	SG Task Force
Chairman	Mike Tuckman	Kevin Sweeney
NEI Members	Dave Modeen	Jim Riley
EPRI Members	Chuck Welty	Mati Merilo, David Steininger
INPO Members	Bill Webster	
Utility Members	Jack Woodard	Helen Cothron
	Larry Womack	Bob Exner
	Jack Bailey	Greg Kammerdeiner
	Sherry Bernhoft	Dan Mayes
	David Goetcheus	Rick Mullins
	Vicki Hull	Richard Pearson
	John Jensen	Mike Short
	David Mauldin	
	Tim Olson	
Vendor Members	Gary Elder – Westinghouse	Bob Keating - Westinghouse
	Jeff Fleck - FTI	Don Streinz – W/ABB

NEI Review Board

Review Board	ISE/NDE Advisory Panel	Chemistry & P-S Leakage Advisory Panel	Tube Integrity Advisory Panel	Policy and Miscellan Advisory Panel	Secondary Side Inspection and Assessment Advisory Panel
Kevin Sweeney	Scott Redner	Rick Eaker	Roman Geisior	Rick Mullins	Helen Cothron
David Steininger (EPRI)	Mohamad Behravesh (EPRI)	Peter Millet (EPRI)	Mati Merilo (EPRI)	Jim Benson (EPRI)	Al McIlree (EPRI)
Bob Exner	Gary Henry	Scott Wilson	Rick Mullins	Craig Hengge	John Arhar
David Goetcheus	Al Metheny	Ron Baker	Darol Harrison	Ron Baker	Rick Coe
John Smith	Gary Alberti	Gail Gary	Helen Cothron	Al Metheny	Ben Mays
Forrest Hundley	Tom Bipes	Tim Olson	Joe Eastwood	Roman Geisior	Rich Freeman
Dan Mayes	Tim Hanna	Dan Meatheny	John Arhar	Tim Pettus	Ron Baker
Richard Pearson	Tim Pettus	Victor Linnenbom	Rick Coe	Darol Harrison	
Rick Barley	Steve Swilley	David Hughes		Scott Redner	
Greg Kammerdeiner	Gene Navratil	Myra Burgess			
		Sam Harvey			
		Matt Kearns			

EPRI SGMP

SGMP	IIG	E&R IRG	NDE IRG	TSS
Chairman	Kevin Sweeney	Richard Pearson	John Smith	Forrest Hundley
EPRI Project Manager	David Steininger	Mati Marilo,	Mohamad Behravesh	Paul Frattini
Core Members	Ron Baker	John Arhar	Gary Alberti	Ron Baker
	Rick Barley	Rick Barley	Tom Bipes	Debby Bodine
	Rick Eaker	Jay Cate	Al Metheny	Guy Bucci
	Bob Exner	Rick Coe	Joe Mate	Rick Eaker
	David Goetcheus	Helen Cothron	Dan Mayes	Billy Fellers
	Forrest Hundley	Steve Leshnoff	Ian Mew	Jeff Gardner
	Greg Kammerdeiner	Rick Mullins	Dave Morey	Gail Gary
	Richard Pearson	Vince Zabielski	Tim Olsen	Sam Harvey
	John Smith		Tim Pettus	
	INPO – Jeff Ewin		Scott Redner	
	NEI – Jim Riley		Harry Smith	
			Steve Swilley	

Review Process/Resources for ARCs, CM/OAs, Reports, etc.

Edmund Sullivan
NRC/NRR/DE/EMCB

Steam Generator Workshop
SG Programmatic Issues Session
February 27-28, 2001

Background

- OIG Report contained a number of criticisms of staff review processes
- NRC Lessons Learned Task Group looked at these issues. Report included recommendations in the areas of:
  - Guidance for reviewers
  - Handling of licensee inspection summary reports
  - Staff expertise
- Other lessons learned recommendations related to the Reactor Oversight Process will be discussed in the next session

Recent NRC Changes/Improvements

Expected to Increase Staff Effectiveness and Efficiency

- Guidance for Technical Reviewers
  - Not intended as a checklist
  - Sets out basic principles for review
  - Provides references, background technical information
- Internal SG Web Page
  - Being developed by SG staff at HQ
  - One-stop shopping for SG-related documents
  - Background pages on design, degradation modes, repair, replacements, inspection, events and operating experiences, NEI 97-06, SG Action Plan
  - Vehicle to share information in a timely way from SG group to other NRC staff at HQ, regions

Recent NRC Changes/Improvements (cont'd)

- SG Expertise
  - Recent reorganization - moving to 3 sections, instead of 2 sections, in Materials and Chemical Engineering Branch (EMCB)
  - Will reduce staff-to-manager ratio - section chief for SG work will have more time to focus on SG issues
  - EMCB currently recruiting more mid-level staff (GG-13)
  - EMCB will be getting interns soon - will be distributed across branch
  - Takes time for new employees to acquire expertise

NRC Staff Recommendations to Industry

- EPRI Guidelines do not have regulatory standing - if submittals are sent in just according to guidelines, it may lead to protracted review
- Quality of submittals also affects amount of staff review time
- Staff has pointed out areas, in the past, we believe should be treated more rigorously
  - Examples include differences between the draft guide we issued and the EPRI guidelines
  - IP2 restart review encountered these issues and are discussed in RIS-2000-22
  - These issues will be discussed in the technical sessions that follow

Industry Lessons Learned

David Goetcheus
Tennessee Valley Authority

NRC Workshop
February 27-28, 2001

Background

TVA

- EPRI SGMP and INPO supported IP2 with NDE and SG engineering expertise during investigation of tube failure
- Industry, through SGMP, issued Information Letters Concerning Lessons Learned from a Review of Recent SG Related Issues
  - Effort to supply the industry with timely information to consider when planning inspections, condition monitoring, and operational assessments
  - Information from IP2 tube failure, recent integrity assessments, and 1999 INPO review visit recommendations
  - Re-emphasized or further defined and explained specific requirements of NEI 97-06 and the supporting guidelines

Background

- Lessons learned letter addressed the following issues as reminders of good practices
  - Degradation assessments
  - Data quality
  - Site qualification of NDE techniques
  - Calibration standards and setup
  - In situ pressure testing
  - Steam generator program ownership
- Interim guidance on in situ testing changed technical requirements in an EPRI guideline
  - Pressurization ramp rate
  - Hold times

TVA's Implementation

- Requirement in NEI 97-06 and plant procedures to perform a degradation assessment prior to a SG inspection
  - This assessment shall consider industry experience
- The degradation assessment for Watts Bar and Sequoyah Unit 2 fall outages considered the lessons learned from recent industry events
- NRC's web site on IP-2
  - Review of industry's communications
  - Review of NEI Review Board decisions
- TVA Nuclear's Operating Experience Review Organization tracked TVA's implementation of the recent industry events

Application to TVA's Fall Outages

- Reviewed our current degradation assessments to ensure emphasized areas were being addressed
  - Validated that all input data was current
    - All potential initiators or accelerators had been considered
  - Placed emphasis on ensuring appropriate growth data was available
  - Validated that current ETSSs were being used
    - Appropriate setups and calibration standards
  - Evaluated the need for special inspection techniques

Application to TVA's Fall Outages

- Data quality was emphasized
  - ECT tester is energized by a dedicated conditioned power supply
  - Noise suppression kits are onsite to provide filtering if electromagnetic interference is encountered
  - Probes are receipt inspected with a test run of a calibration standard to identify defective probes
  - Six QA/QC personnel are assigned to monitor ECT process
  - Two data analysts were dedicated to identifying marginal or poor quality data prior to the analysis process

Application to TVA's Fall Outages

- Analyst training was enhanced
  - Each analysts is responsible for identifying conditions that inhibit the evaluation of data
  - Anomalous or "off-normal" signals are identified for Lead Analyst Review
    - These tubes are retested until good data is acquired or the tube is plugged
  - All analysts received training on the leaking tube from IP-2 as it appeared in the 1997 examination data
  - A circumferential filter was used to assist in flaw detection when bend geometry presented interfering signals

Application to TVA's Fall Outages

TVA

- Site validation of NDE Techniques
  - Exam techniques were selected to provide the best detection available for known and potential damage mechanisms
  - No signal interference associated with deposits
  - Tubing is not severely dented (small localized dents)
  - Apex is not ovalized due to hour glassing of flow slots
  - High frequency probe was considered for the U-Bend inspection
    - EPRI qualification data was reviewed and compared to site data
    - Proved that mid range magnetically biased probe had a clear advantage

Application to TVA's Fall Outages

- Calibration standards were validated
  - All were in compliance with Revision 5 of the EPRI PWR Examination Guidelines
  - Acquisition and analysis parameters were established in accordance with EPRI technique qualifications
  - Setups were verified by on-line QA surveillance

Application to TVA's Fall Outages

- In Situ Testing
  - Pressurization rate issue was entered into TVA Nuclear's Corrective Action Program
  - Validated all analysis input was appropriately conservative
  - In Situ pressure test screening and implementation utilized recent SGMP communications and NEI Review Board decisions
    - All indications above screening criteria tested
    - Two minute hold times at accident condition, then every 500 psig up to 3 times normal operating differential pressure
    - Pressurization rate did not exceed 200 psi/sec

Application to TVA's Fall Outages

TVA

- SG Program Ownership and Implementation
  - TVA's SG Program has expertise in the following areas:
    - Eddy current
    - Metallurgy
    - Steam generator design
    - Steam generator corrosion
    - Code requirements
    - Structural mechanics
    - Programmatic expertise
  - During inspections, the vendor works through the SG Technology Department
    - TVA prepares and oversees the training and testing of analysts
    - Reliance on vendors for tube integrity is minimal

Summary

TVA

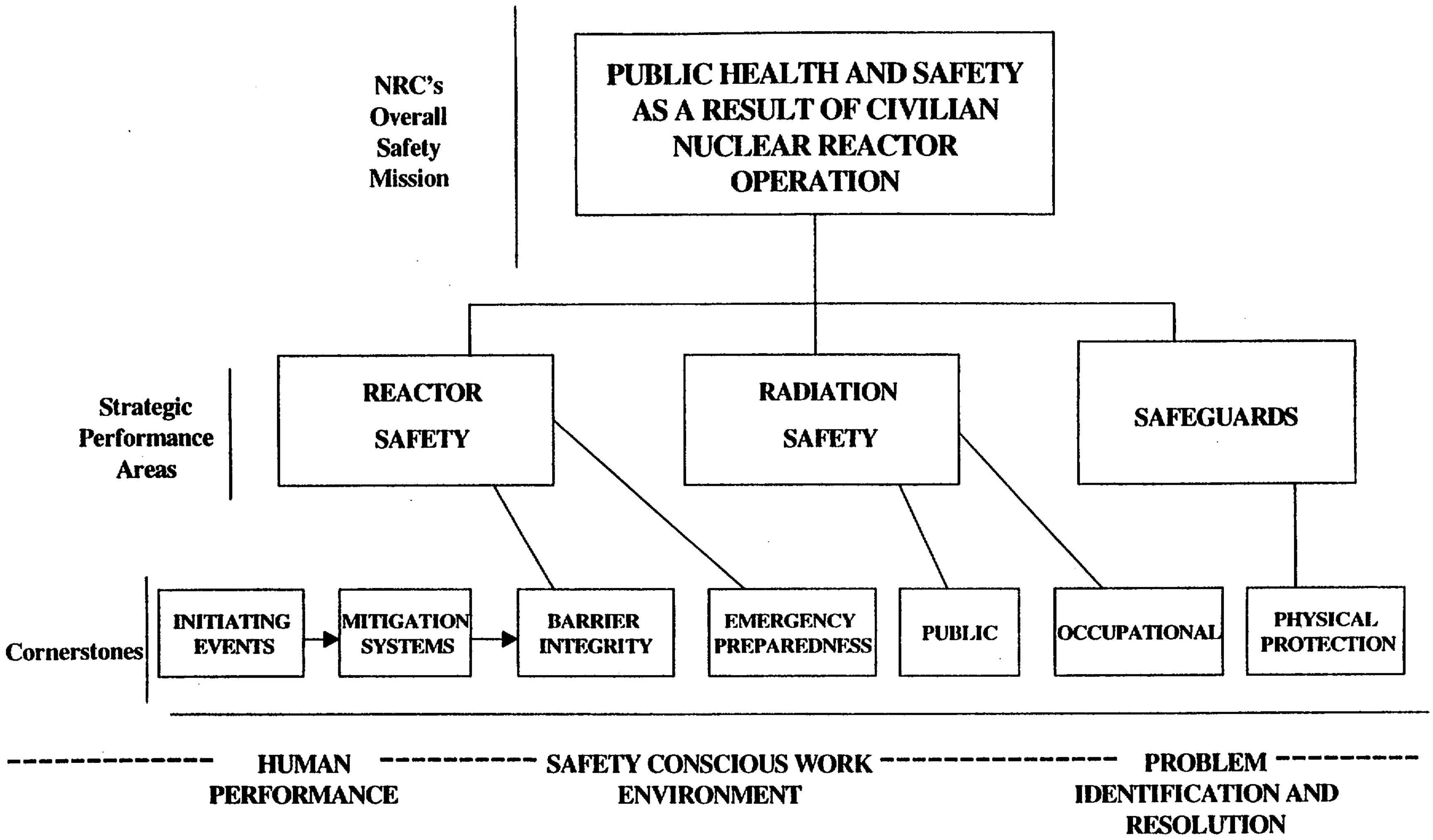
- One utility's approach
- Fine tuned an existing extensive program
- Impacted all utilities
  - U-bend inspections
  - Evaluation of techniques
  - More conservative repair criteria
  - Other ameliorative measures

Session 2
February 27, 2001

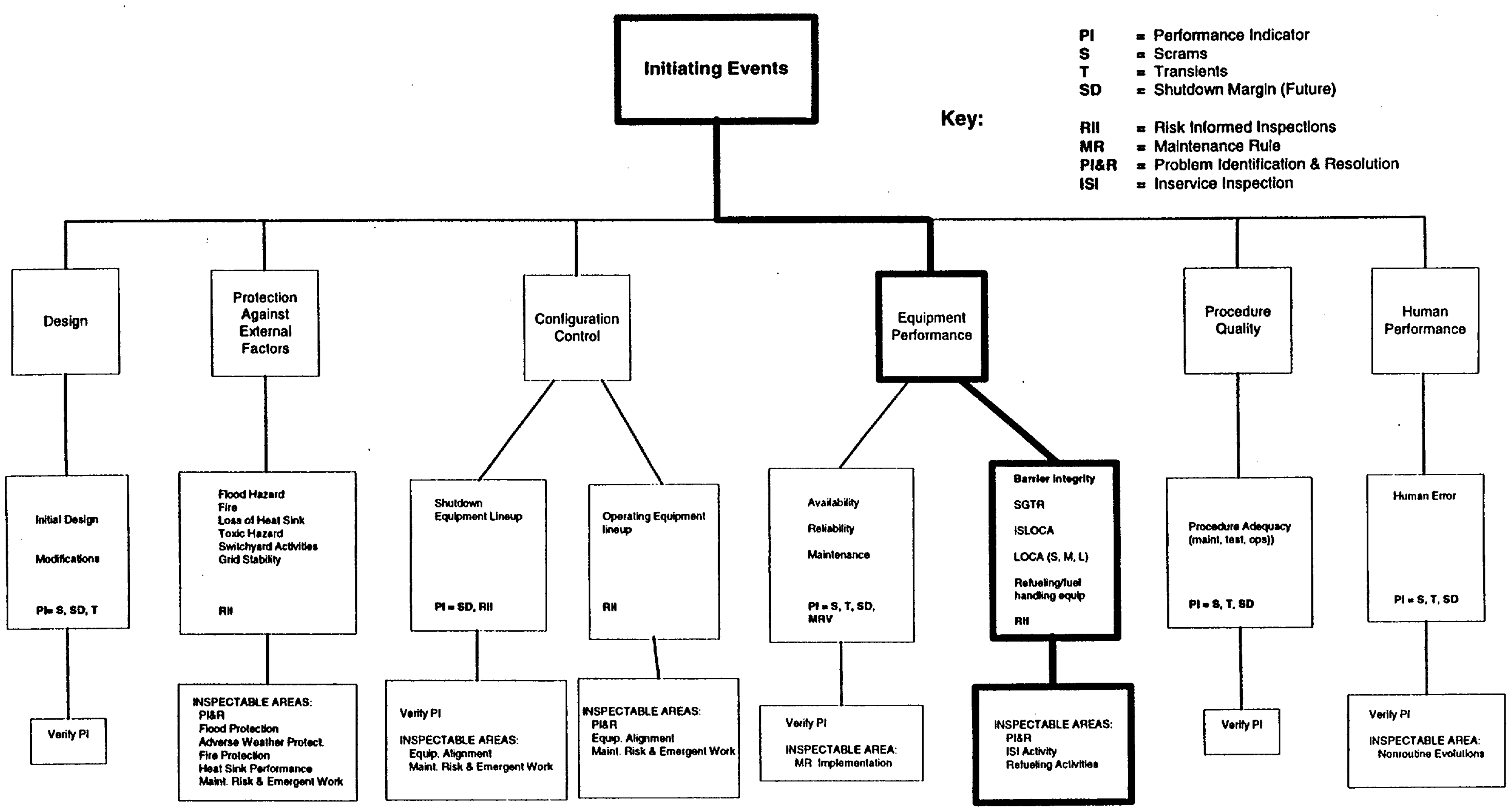
Plans for NRC Inspections of Steam Generator Programs

NRC Steam Generator Workshop
SG Inspection Oversight Issues
February 27 - 28, 2001

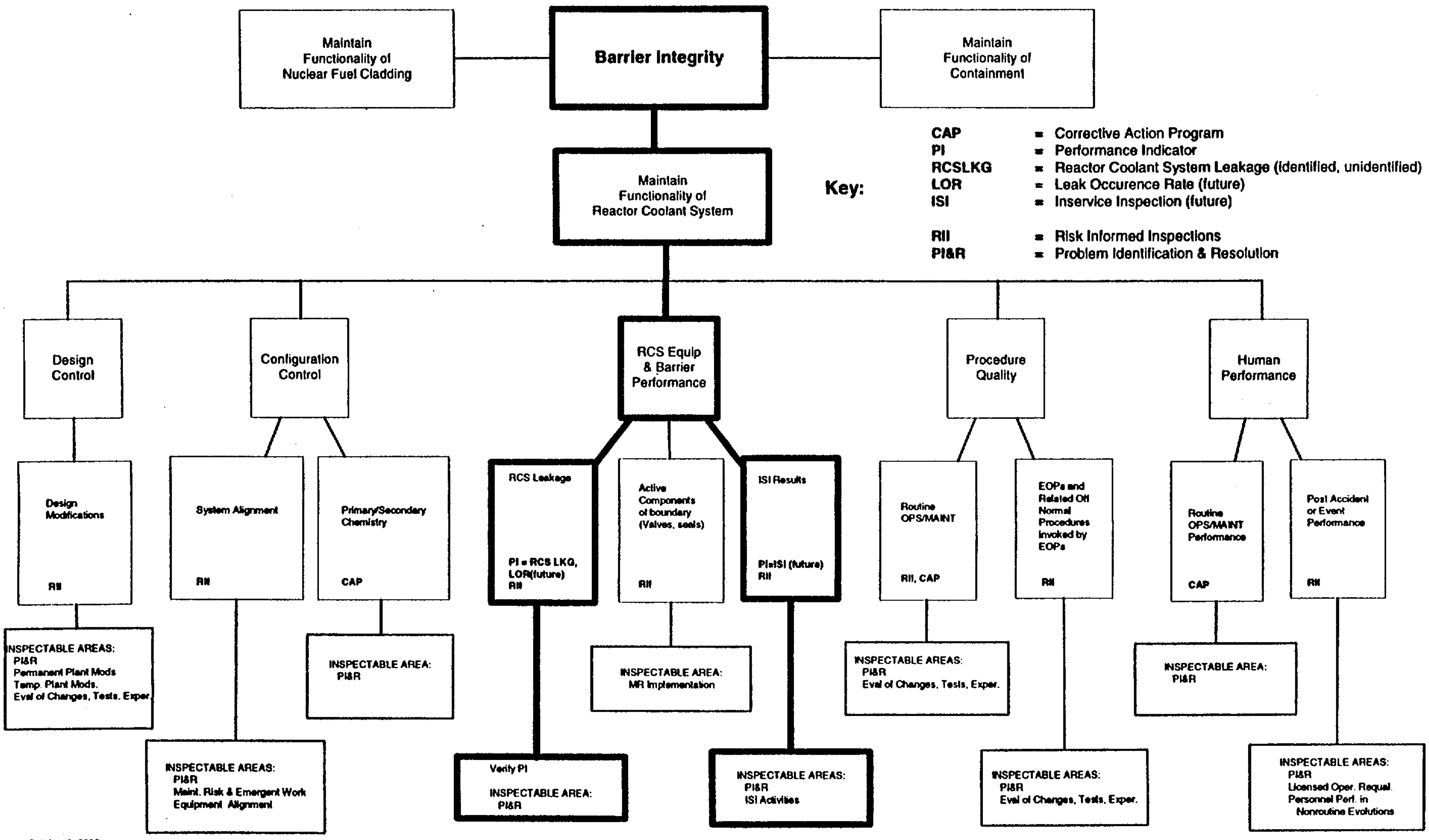
Doug Coe, Section Chief
NRR/IIPB



- PERFORMANCE INDICATOR
- INSPECTION
- OTHER INFORMATION SOURCES
- DECISION THRESHOLDS



October 6, 2000



October 6, 2000

OVERVIEW OF REACTOR OVERSIGHT PROCESS

- Seven Cornerstones of Safety
- Key Attributes of performance, e.g., Design, Configuration Control, Equipment and Barrier Performance, Procedure Quality, Human Performance, etc. in each Cornerstone
- Performance within each Key Attribute is assessed by Performance Indicators and Inspections
- Inservice Inspection (ISI) activities include Steam Generator Program inspections
- Inspection findings must be evaluated for significance in terms of contribution to Core Damage Frequency (delta CDF), Large Early Release Frequency (delta LERF), or other measure

ROP CHANGES TO ADDRESS SG TUBE INTEGRITY ISSUES

The following changes to the ROP are under consideration:

- **Revise ISI procedure to include inspection requirements and guidance specific to steam generators**
- **Integrate NRR outage phone calls with licensee into inspection program**
- **Consider immediate response/followup capability for potential degraded conditions**
- **Provide technical guidance to inspectors for monitoring plants with primary to secondary leakage**
- **Determine need for and define any additional inspector training to implement revised inspection procedure**
- **Above actions are scheduled to be completed during April - September 2001**

Guidance/Training for NRC Inspectors and Outage Phone Call Protocol

NRC Steam Generator Workshop
SG Inspection Oversight Issues
February 27 - 28, 2001

Cheryl B. Khan
NRR/DE/EMCB

Guidance/Training for NRC Inspectors

- Additional guidance is being developed for inspectors - baseline inspection and technical guidance

- Additional training for inspectors will be provided, but extent is dependent on final revisions to the baseline inspection procedure

SG Phone Call Protocol

- **Purpose:** Monitor trends (for occasional INs) Provide feedback when staff has concerns

- **Plants Affected:** A subset of those utilities performing SG inspections

- **Timing:** Approximately 75% of data analysis is complete

- **Topics:** Inspection scope, results and relevant activities (see attached "Discussion Points")

SG Phone Call Protocol (cont.)

- Expectations

- Changes to Phone Call Protocol?
  - No significant changes expected
  - Docketing requests for phone calls and "Discussion Points"
  - Potential minor modifications to "Discussion Points" regarding expectations
  - Staff working on means to incorporate phone calls in inspection process (per lessons learned recommendation)

Discussion Points

Steam Generator Tube Inspection Results

Licensees' steam generator (SG) tube eddy current (EC) inspections play a vital role in the management of SG tube degradation. The results are used to demonstrate adequate structural and leakage integrity of the SG tubes. NRC staff is interested in discussing the licensee's steam generator inspection plans and results, although the licensee is not required to participate in this discussion.

In addition to the traditional areas of discussion listed below, the staff is also interested in having the licensee discuss and describe any actions taken in response to the Indian Point 2 lessons learned.

Typical areas of discussion include:

- Primary to secondary leakage prior to shutdown
- Results of secondary side hydro
- For each steam generator, a general description of areas examined; include expansion criteria and specify type of probe used in each area
- For analyzed EC results, describe bobbin indications (those not examined with RPC) and RPC/Plus Point/Cecco indications. Include the following information: location, number, degradation mode, disposition, and voltages/depths/lengths of most significant indications.
- Description of repair/plugging plans
- Discussion of previous history; "look backs" performed; consideration of similar plants' experiences
- Discussion of new inspection findings, including loose parts indications
- Description of in-situ pressure test plans and results; include tube selection criteria, test pressure plans, test configuration
- Describe tube pull plans and preliminary results; include tube selection criteria and evaluation plans
- Assessment of tube integrity for previous operating cycle
- Assessment of tube integrity for next operating cycle
- Provide schedule for steam generator-related activities during remainder of current outage

- Discuss what steps have been taken, or will be taken, in response to the lessons learned from the Indian Point Unit 2 tube failure. In addition, please be prepared to discuss the following:

  a) Discuss the actions that are taken in response to identifying a new degradation mechanism, and

  b) Discuss the actions taken to ensure that data noise levels are acceptable, and

  c) Address data quality issues and the need for criteria to address data quality."

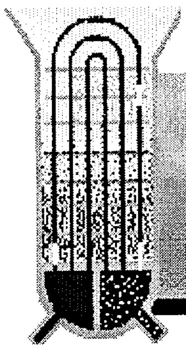
Note: It may facilitate the discussion of the licensee provides details on the topics listed above prior to the conference call (e.g., simple tables and figures).

NRC Steam Generator Workshop

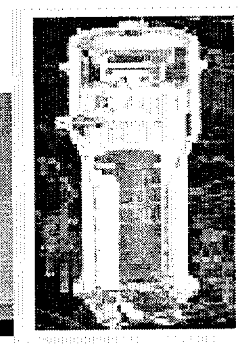
INPO Steam Generator Review Visit Program

Alan Smith

February 27, 2001

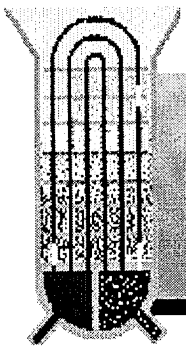


Program Purpose

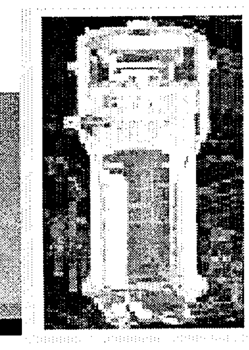


Ensure that utilities have steam generator management programs in place that promote safe and reliable steam generator operation. Program scope includes:

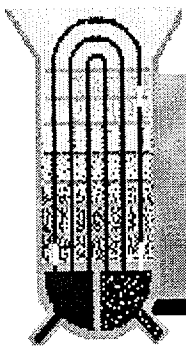
- conditions affecting reliability and availability
- in-service inspection and repair
- leak detection, monitoring, and action levels



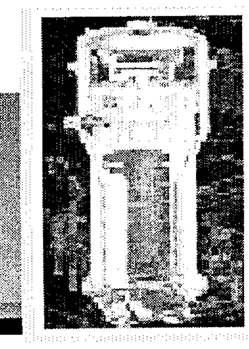
Program Development



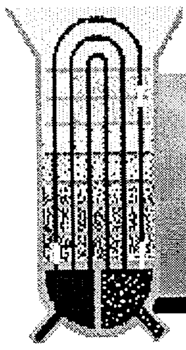
- industry/INPO recognize need for safe and reliable steam generator performance
- separate and distinct from INPO's evaluation process
- steam generator review visit guidance developed and periodically revised with industry input
- applicable EPRI and NRC documents serve as technical basis
- review visits go beyond determining how a station is implementing NEI 97-06



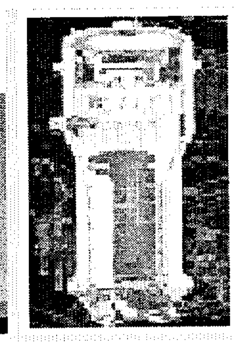
Program Development (cont.)



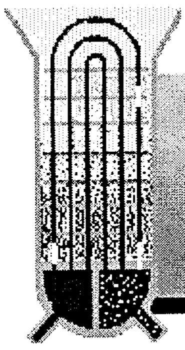
- review visits began in 1995
- industry peer involvement
- ISI vendor involvement
- assistance role
- year-end summary of results sent to industry



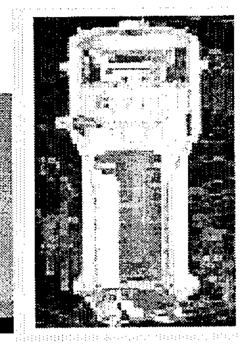
Program Logistics



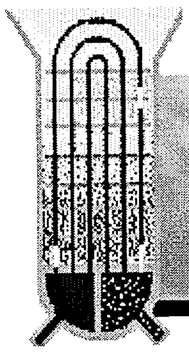
- one week of preparation followed by one week detailed station review conducted approximately three months prior to a refueling outage
- review team includes INPO engineering and chemistry evaluators and two or three industry peers experienced in steam generator program management and data analysis



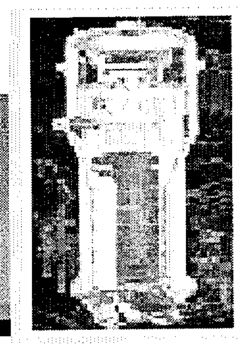
Program Logistics (cont.)



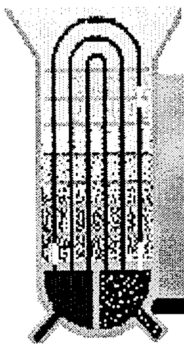
- identified strengths and recommendations for improvement are sent in a report to utility senior management
- safety-significant issues require a utility response and are followed up during next INPO evaluation



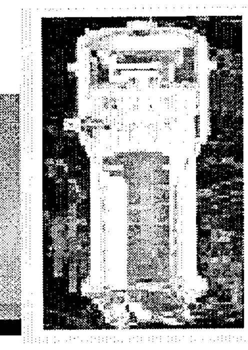
Program Status



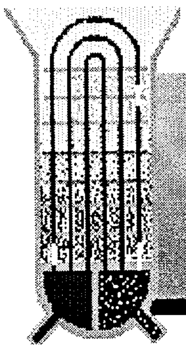
- 41 domestic and 2 international station review visits performed to date
- 92 utility and vendor peers have participated
- 6 assistance visits conducted or facilitated
- continuing participation in industry steam generator groups



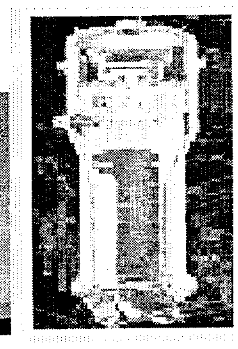
Program Highlights



- identified important industry and individual station issues
- assisted stations in implementing repair plans
- promoting industry self assessment, peer reviews, and benchmarking
- IIG participation and TAG presentations
- INPO web page dedicated to steam generator operating experience, lessons learned, news, etc.



Future Plans



- 12 domestic and one international review visit planned for 2001
- beginning follow-up visits to previously reviewed stations
- additional emphasis on stations with original steam generators

Session 3
February 27, 2001

Analyst Guidelines

Caius V Dodd

US-NRC

Public Workshop to Discuss Nuclear Power Reactor Steam Generator Tube Issues

February 27-28, 2001

Holiday Inn, Bethesda

Good analyst guidelines are essential for a good inspection

- Utilities spend a lot of money for the training and use of analysts.
- There is a severe shortage of good QDA's during the peak outage seasons.
- Analysts may make mistakes form using poor guidelines.
- Writing the best guidelines possible will save the utilities money.

The purpose of the Data Analyst's guidelines is to inform the analyst:

- With the type of plant you have.
- How data should be analyzed at your plant.
- The prior history of your plant.
- The expected present conditions at this outage.
- The prior history of similar plants.

The purpose of the Data Analyst's guidelines is to provide:

- A training and reference tool for the analyst.
- A training and reference tool for the analyst.
- A valuable reference about how the data were analyzed.

Good analyst guidelines:

- Are easy to read.
- Are complete without being too long.
- Are plant and unit specific.
- Follow the same general EPRI format.
- Have a separate section for each type of probe.
- Make liberal use of high quality graphics, preferably in color.

Good analyst guidelines:

- Do not require the level IIA analysts to know all the details of data management.
- Have tabs in the analyst guidelines for quick reference.
- Contain the ETSS sheets in an appendix.
- Contain a table summarizing the standards used for each probe type.

At present, eddy-current analysis of steam generator tubing is very graphic oriented and the guidelines should also be. Each figure should be self-contained. The text accompanying the figure should be next to the figure.

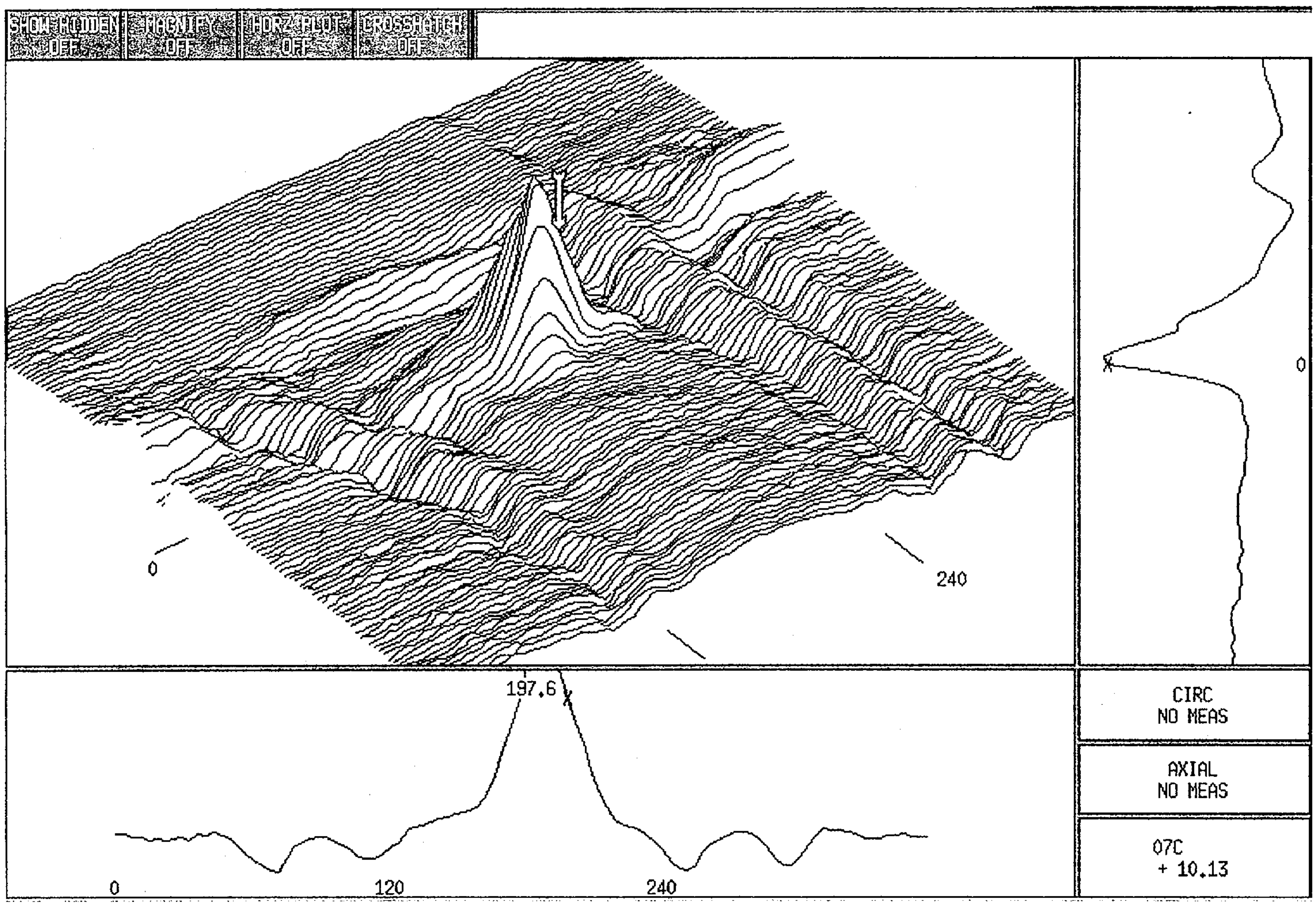


Figure 1 Plus point scan of a circumferential id defect at 300 kHz with the midrange probe before pressurization. This is the P2-process channel with the circumferential defects in the vertical direction. This tube leaked at 0.005 gpm at 5500 psig. Note the axial ridges of noise on the tube.

The figures can be created from the Hewlett Packard computer screen using the XV program

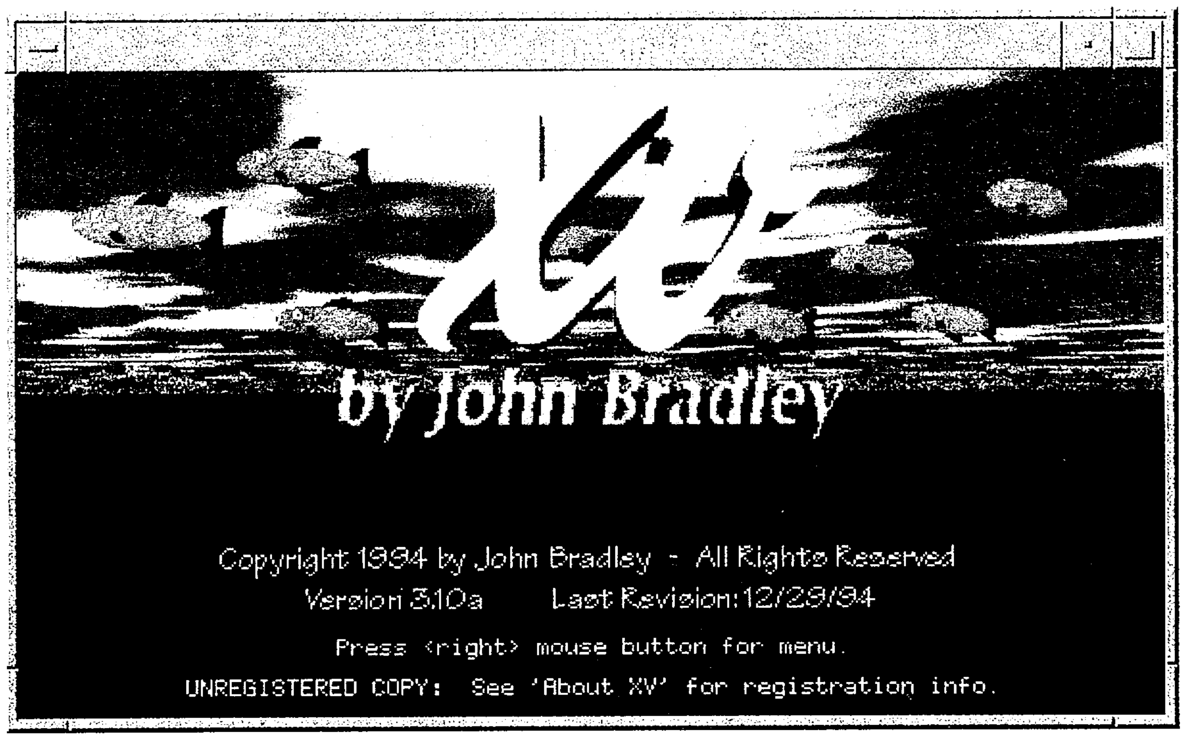


Figure 2 The XV program is a shareware program that operates under Hewlett Packard HP-US software, and costs $25 to register. The program can be run by selecting it from the Eddynet Utilities list or by typing xv in a command window. The above logo will appear on the screen. Right click on the mouse on this logo to bring up the next capture screen, shown in the next figure.

Grab the desired graphic screen and save it to a file in the appropriate format

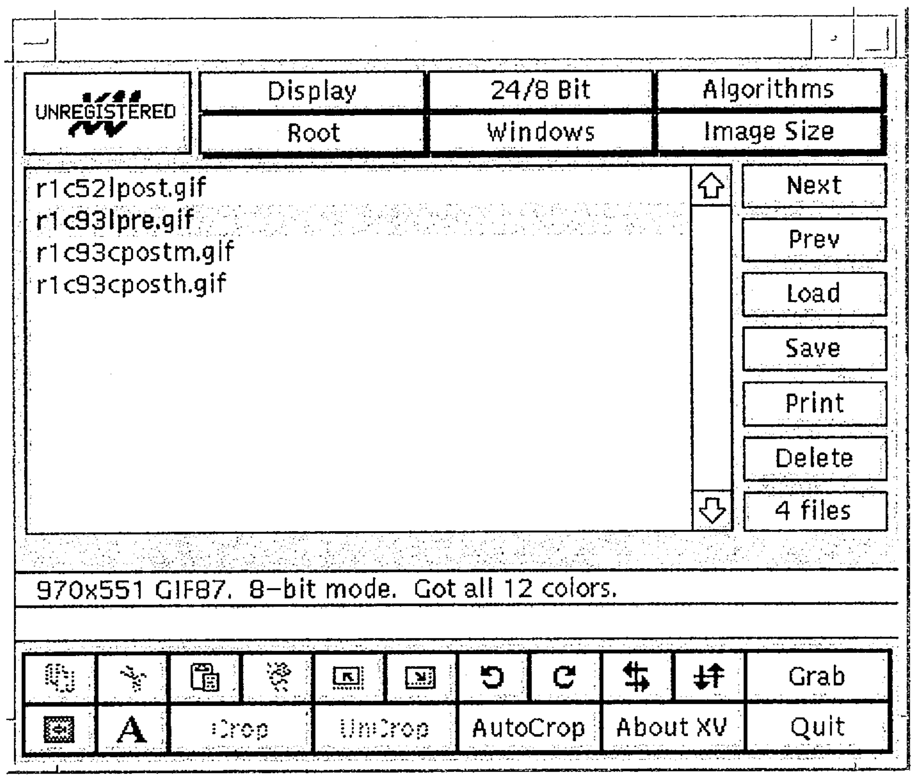
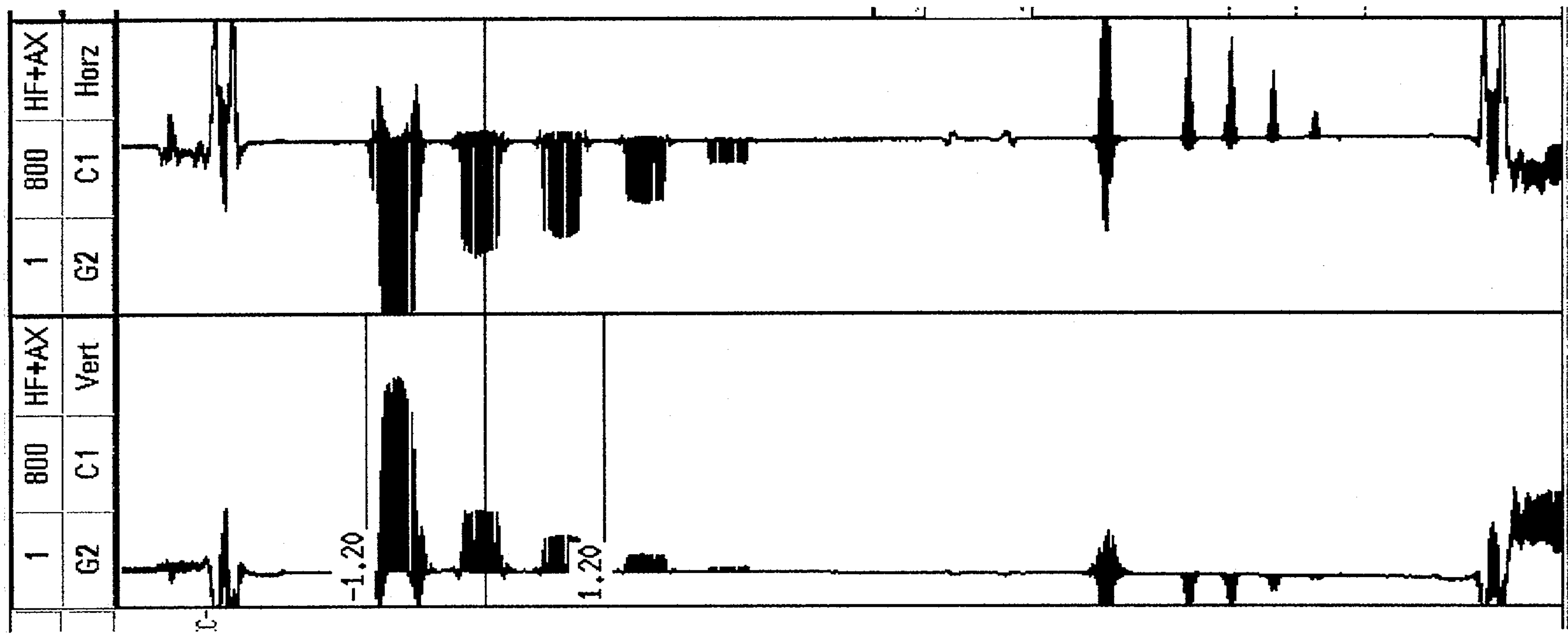


Figure 3 Click on the grab of this screen, the grab of the next screen that appears, and then the graphic that you wish to grab. Then click on save. A screen then appears that allows you to type in the file name (with the extension), which defaults to the last one you used. You can select a new format by holding the mouse on the default extension and dragging it down to the new one you want. The preferred format is Compuserve's .gif format. This is a vector graphics format, as are most of the screens in the eddy-current software. The files take up much less storage and can be magnified much more without losing resolution. Also, this format is used for graphics on the web if you wish to post your guidelines there.

Standards used for each probe type should be summarized in a table.



Dist (in.)	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.5**	**9.0**	**10.5**	**11.5**	**12.5**
Id Depth (%)	**100**	**79**	**61**	**41**	**22**			**100**	**83**	**39**
Type	**Ax**	**Ax**	**Ax**	**Ax**	**Ax**	**Ring**	**Dent**	**Cir**	**Cir**	**Cir**
Od Depth (%)		**80**	**58**	**40**	**20**			**100**	**79**	**41**
Type		**Ax**	**Ax**	**Ax**	**Ax**			**Hole**	**Cir**	**Cir**

Summary

A well-written set of guidelines will help in the training of the analysts, provide a valuable reference to the analyst while the test is being performed, and document how the inspection was performed when questions arise in the future. While the initial cost may be higher, it will improve the inspection and save money in the long run.

PWR SG EXAMINATION GUIDELINES
Revision 5

NRC S/G Workshop
February 27-28, 2001
Washington, DC

Scott Redner
Xcel Energy

Guidelines Purpose and Scope

- Purpose
  - Provide inspection requirements that:
    - identifies degradation,
    - applies valid inspection techniques,
    - and assures tube integrity
- Scope
  - Provide requirements for:
    - performing S/G assessments,
    - selecting an inspection sample,
    - validating NDE systems to detect and size flaws,
    - and qualification of techniques and data analysts

Background

- PWR Steam Generator Examination Guidelines is an industry developed document based on:
  - Plant operating experience and lessons learned
  - Current technology and practices
  - Available resources - What's practical
- Recent revisions have been developed by utility representatives with input from NSSS and ISI vendors

Guideline Revisions

- First edition developed in 1981 by the EPRI NDE Center
- Rev. 1 was formally published as an EPRI report in 1984
- Rev. 2 published in 1988 benefited from input from Utilities, NSSS vendors and ISI vendors
- Rev. 3 published in 1992 introduced the protocol for performance demonstration through Appendices G & H
- Rev. 4 published in 1996 introduced specific guidance on sampling for various degradation modes
- Rev. 5 published in 1997 transferred prior guidance into specific requirements
- Rev. 6 is under development for 2001 publication

Revision 5 Organization

- 1 - Introduction and Background
- 2 - Compliance Responsibilities
- 3 - Sampling Requirements for Technical Specification Type Examinations
- 4 - Sampling Requirements for Performance Based Examinations
- 5 - Steam Generator Assessments
- 6 - System Performance
- 7 - Summary of Requirements
- Appendices - A through K

Revision 5 Highlights

- **Performance Demonstration**
  - Appendix G - Analyst Qualification
  - Appendix H - Technique Qualification
- **System Performance**
  - Section 6
- **Summary of Requirements**
  - Section 7
- **Inspection Requirements Due To Leakage Forced Outages**
  - Appendix K

Appendix G
Analyst Qualification

- Establishes an industry standard for the qualification of S/G data analysts
  - Requires a written program for control and administration
  - Requires a minimum of 40 hours training
  - Requires both a written and a practical examination
  - Requires 8 hours of annual training and re-qualification every 3-5 years

Appendix G
Written Examination

- Written examination based on:
  - Known tube degradation
  - Babcock & Wilcox OTSG operating experience
  - Combustion Engineering operating experience
  - Westinghouse operating experience
  - Tube examination techniques
- A passing grade of 80% is required to proceed with the practical examination

Appendix G
Practical Examination

- Practical examination based on:
  - All damage mechanisms
    - Thinning
    - Pitting
    - Wear
    - ODSCC
    - PWSCC
    - Impingement
  - Test data is from actual S/G's using data acquired with Appendix H techniques

Appendix G
Practical Examination

- The practical examination requires evaluation of approximately 5000 intersections
- The correct answer is based on expert opinion (similar to the NRC Program at Argonne)
- A passing grade on each mechanism is required to be considered a Qualified Data Analyst (QDA)
  - 80% POD @ 90% CL on repairable indications, $\geq$80% detection of non-repairable indications, $\leq$10% RMS sizing error, $\geq$80% on RPC orientation and <10% overcall rate

Appendix H
Technique Qualification

- Establishes an industry standard for the qualification of S/G ET techniques
  - Provides Performance Demonstration Qualification Requirements for:
    - documenting essential variables
    - the detection and sizing sample set
    - the detection and sizing performance measurers
    - equipment characterization and equivalency
    - technique inclusion in the QDA
    - peer review and acceptance criteria

Appendix H
Technique Qualification

- Sample Set
  - Samples may be fabricated using mechanical or chemical methods as long as they produce signals similar to those observed in the field
    - However, we prefer tube pulls when available
    - EDM notch samples are replaced with crack samples as they become available
  - Flaw dimensions for samples shall be verified
    - Expert opinion is not acceptable
    - Metallurgical depth is averaged over the coil width

Appendix H
Technique Qualification

- Detection sample set
  - Minimum of 11 flawed grading units $\geq$ 60% TW
    - Provides 80% POD @ 90% CL $\geq$60% TW
- Sizing sample set
  - Minimum of 5 additional flaws 20-59% TW

- Peer Review and Acceptance Criteria
  - A minimum of 5 QDA's review the technique documentation and based on a majority either accept or reject the technique

Section 6
System Performance

- Site-Qualified Techniques
  - Site validation process that compares site data and variables to a qualified technique
- Analyst Performance Tracking
  - Feedback loop to increase consistency
- Site Specific Performance Demonstration
  - Miniature QDA examination that orientates data analysts to site specific conditions
  - Provides performance measures on utility techniques not covered by the QDA

Section 7
Summary of Requirements

- Section 7 compiles the 168 requirements (SHALL) found in Sections 1 through 6
- Prairie Island developed a conformance matrix with Section 7 when Rev. 5 was first issued as part of a Self Assessment
  - We found we were not in conformance
  - A Condition Report with 10 Corrective Actions was issued
  - We are now in conformance w/o deviation

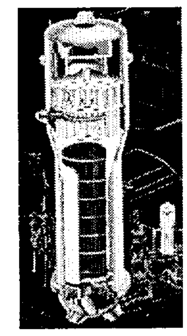
Appendix K
Leakage Forced Outages

- Summary of engineering and inspection aspects to be considered
  - Guides Utility to find and understand source of leakage
  - Identifies program deficiencies
  - Proposes corrective actions and mitigation
  - Assures continued tube integrity

Guidelines Implementation

- Rev. 5 of the SG Examination Guidelines is used by all US PWR utilities in developing plant specific SG inspection programs
- Rev. 5 is also used by INPO in its periodic review visits of SG inspection programs at US PWRs

EPRI

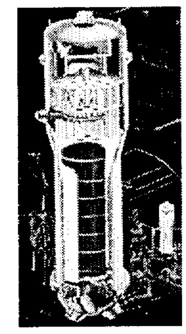


SG Examination Guidelines Revision 6

NRC Workshop
February 27-28, 2001
Washington, DC

Dan Mayes

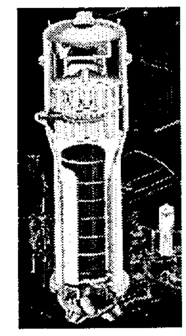
Duke Power



Background

- Revision 5 of the NDE G/L requires that the need for G/L revision be assessed at least once every two years
- Revision 5 was issued in November 1997. A utility group met in April 1999 and decided that no revision was needed as of that date
- With NEI 97-06 initiative and increasing number of 2nd generation steam generators, there was a need to address G/L revision again in 2000

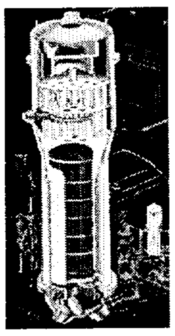
EPRI



Background, Cont..

NDE Guidelines Workshop

- A workshop was conducted on February 3-4, 2000 in Orlando, FL.
- 45 participants representing utilities and all of the major ISI vendors
- Background presentation on:
  - Risk-based ISI
  - Data quality standards
- Utility and vendor presentations on:
  - Implementation Experience
  - Strengths and weaknesses of the Guidelines
  - Suggested revisions

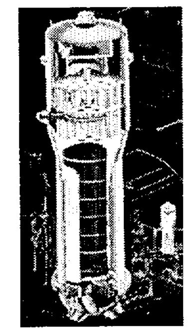


Background, continued

Summary of suggested changes

- Clarifications and editorials
- Allow dual automated analysis
- Update and refine Appendices G and H
- Relaxation of requirements for replacement S/G
  - 100% ISI within 60 EFPM
  - No S/G can go longer than 2 cycles without ISI
- Inclusion of new topics in new revision:
  - Risk-based considerations
  - Data quality standards

EPRI



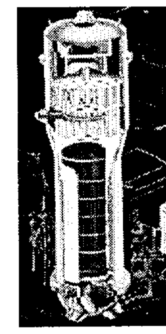
Background, continued

Workshop Conclusions

- The ISI Guidelines has served the industry well
- Unanimous recommendation to produce Revision 6 to incorporate the suggested changes

Actions

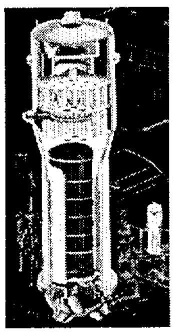
- Take workshop recommendations to the NDE IRG and SGMP IIG for approval to proceed
- Form a utility group to produce Revision 6



Development of Rev. 6

- EPRI solicited utility participation and the following responded by participating in one or more working meetings:

  Ed Addison / EOI
  Al Matheney / SCE
  Scott Redner / Xcel
  Clayton Webber / TVA
  CJ Conner / PSE&G
  John Smith / RG&E
  Gary Henry / EPRI
  Tom Bipes / CP&L
  Ian Mew / Entergy
  Steve Swilley / TXU
  Dan Mayes / Duke
  Doug Hansen / APS
  M. Behravesh / EPRI

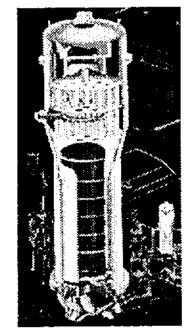


Approach to Revision 6

<u>General and up front resolutions</u>

- Use comments on Revision 5 as general guidance in developing Revision 6
- Produce Revision 6 in a single volume and include justifications where needed
- Maintain Revision 5 organization in Revision 6. -- Seven sections with similar headings and retain appendices

EPRI

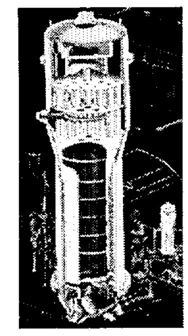


Approach to Revision 6

General and up front resolutions

- Include new and updated material on data quality, risk-informed considerations, and visual inspections
- Modify existing guidance and provide new guidance to better accommodate the needs of improved-material and replacement SGs
- Modify guidance on auto analysis to better reflect current technology and experience
- Track and respond to all comments on Revision 6

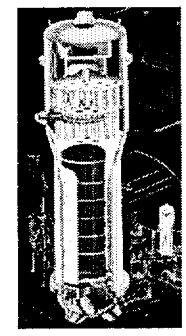
EPRI



Migration From Revision 5 to Revision 6 and Ownership of Various Sections

The following have assumed the lead role and primary responsibility for development of each of the following sections:

- Al Matheney -- Sec.1, Introduction and Background
- Steve Swilley -- Sec.2, Compliance Responsibilities
- Redner/Henry -- Sec.3, Sampling for Tech. Spec. Exams
- Dan Mayes -- Sec. 4, Sampling for Perfor.-Based Exams
- Dan Mayes -- Sec. 5, SG Assessments
- Scott Redner -- Sec. 6, System performance
- Matheney / Henry -- Appendices G and H
- Sears / Exner -- Appendix K



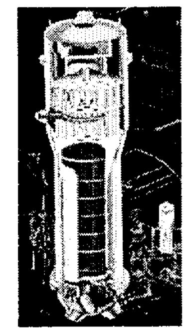
Important Changes Underway

Separate sampling requirements in Section 3 for 600 MA, 600TT, and 690TT materials

<u>600 MA:</u>

- Inspect 100% of tubes in each SG every 60 EFPM
- No SG may go more than 2 cycles without inspection

EPRI

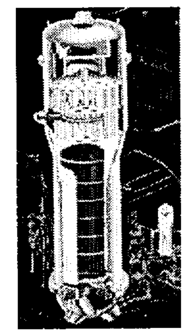


Important Changes Underway

600 TT:

Inspect 100% of tubes in each SG in 120, 90, and 60 EFPMs and with the following conditions:

- Examine at least 50% of tubes in each SG by 1/2 way through each period and the remaining 50% by the end of the period and
- Examinations are to be performed at the nearest refueling cycle provided that no more than 12 months will be added to the inspection cycle.



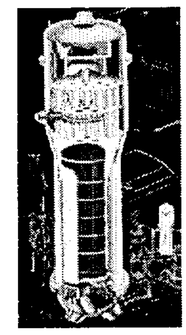
Important Changes Underway

<u>690 Alloy:</u>

Inspect 100% of tubes in each SG in 144, 108, 72, and 60 EFPMs with the following conditions:

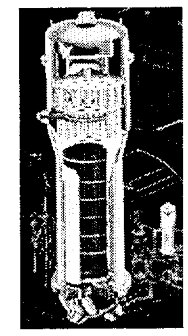
- Examine at least 50% of tubes in each SG by 1/2 way through each period and the remaining 50% by the end of the period and
- Examinations are to be performed at the nearest refueling cycle provided that no more than 12 months will be added to the inspection cycle.

EPRI



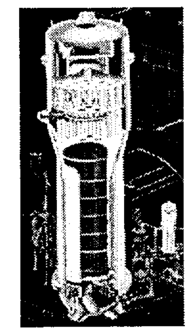
Important Changes Underway

- Data Quality requirements
  - Generic, bobbin, rotating +Point, rotating pancake and array probes.
  - The tables provide a frequency, location, acceptance criteria, and corrective action for each of the listed quality parameters.
- Probe Manufacturing Quality requirements
  - Coil type
  - Acceptance criterion for each of the quality parameters



Progress to Date

- Monthly working meetings have been held since March 2000.
- Drafts of all sections have been completed and reviewed by the group
- Extensive effort has been devoted to the development of data quality parameters. Draft quality parameters for commonly used probes have been developed and reviewed by vendors.



Schedule

- Draft Revision 6 is currently expected to be ready for its industry review cycle by April and publication in the 2nd half of 2001

Steam Generator Eddy Current Inspection Challenges

Steam Generator Workshop
February 27-28, 2001

Session on Steam Generator Inspection Technical Issues

Stephanie Coffin
NRR/DE/EMCB

UNITED STATES NUCLEAR REGULATORY COMMISSION

SG Eddy Current Inspections

- What is success?
  - Defective tubes removed from service prior to exceeding performance criteria
- How are defective tubes identified?
  - Eddy current testing
- When are defective tubes repaired?
  - "Upon detection" for most cracklike indications

SG Eddy Current Inspections

- Three challenges:
  - Data quality
  - Flaw detection performance (POD)
  - Flaw sizing performance

SG Eddy Current Inspections

- Lack of rigorous treatment of data quality during inspections
  - Limits ET inspection capabilities
- Lack of rigorous treatment of POD and flaw sizing performance during condition monitoring and operational assessment
  - Limits tube repair options

Data Quality

- Recognition that noise cannot be eliminated completely but ET inspections can sometimes be improved
  - Particularly vulnerable areas include U-bend and sludge pile regions
- Ability to detect flaws that could potentially impact performance criteria over the next operating cycle
  - The signals of such flaws may be small in size relative to the noise
- Supplemental information can provide additional assurance
  - In situ pressure testing
  - Historical reviews

Data Quality

- Data quality needs to be explicitly considered and addressed
  - Simple comparisons to the Appendix H qualification data set may not be sufficient
    - There are limits to these techniques' applicability to specific defect types and associated plant-specific extraneous test variables (e.g., denting signals, noise, S/N ratios, tube geometry, etc.)
  - Noise levels should be sufficiently low such that flaws of potential tube integrity significance are detectable

Data Quality

- Recent Example: IP2
  - Hindsight analysis of 1997 inspection revealed four missed indications.
  - One of the missed indications was in the tube that failed on February 15, 2000
  - Detection difficult because of poor quality ET inspection data

POD

- POD is a key input parameter for operational assessments
- Results of operational assessments are typically very sensitive to this specific input
- Rigorous performance demonstration can be used to justify less conservative, more realistic POD assumptions (e.g., varying POD as a function of indication size)

POD

- Recent Example: IP2
  - Absence of directly applicable POD data for PWSCC at low row U-bends
  - EPRI qualifiation set primarily EDM notches
  - Licensee used POD from a formal performance demonstration program for PWSCC at dented TSPs
    - Staff found lack of justification for applying to IP-2 U-bends. Comparative noise levels were an important consideration.
  - OA results very sensitive to POD assumptions

Flaw Sizing Performance

Condition Monitoring

- Sizing uncertainties must be considered when choosing in situ pressure test candidates
  - Recent experiences emphasize the importance of explicitly considering flaw sizing uncertainties and conservatively choosing candidates to reflect those uncertainties
  - Completed in situ pressure test results often provide a more reliable indication that tubes retain adequate integrity than engineering analysis

Flaw Sizing Performance

Condition Monitoring

- Recent Example: ANO-2, November 1999
  - Six tubes found to exceed in situ pressure test screening criteria
  - The NDE measured size of the respective flaws in four of the six tubes were bounded by the size of flaws successfully in situ pressure tested during a previous inspection outage
  - Testing on one of the four tubes was terminated at a pressure below 3ΔP criterion when leakage through the flaw exceed the capacity of the system
  - Staff concluded that the tube was about to burst when the test was terminated
  - Underscores the importance of allowing for flaw size measurement errors when selecting in situ pressure test candidates

Flaw Sizing Performance

Operational Assessments

- Flaw sizing error uncertainty distributions are another key input parameter for operational assessments
- Results of operational assessments are typically sensitive to this specific input
- Availability of a rigorous performance demonstration enables the direct consideration of the ET inspection results

Flaw Sizing Performance

Operational Assessments

- Recent example: Sequoyah PWSCC ARC
  - Performance demonstration supported flaw sizing error uncertainty distributions for average depth, maximum depth, and length
  - Repair criteria no longer “upon detection” for PWSCC located within the TSPs

Performance Demonstrations

Quantifies performance of the total system (personnel and technique) relative to ground truth

- Major components of a performance demonstration include:
  - Data sets include representative flaw morphology(ies) as well as extraneous signals representative of those experienced in the field (e.g., similar voltage amplitude, complexity, and S/N ratios)
  - Blind data acquisition and analysis
  - Statistically valid sample set of flawed and unflawed grading units with a range of defect sizes

Conclusions

Performance Demonstrations

- Reduce/quantify POD uncertainties
- Reduce/quantify NDE sizing uncertainties
- Lead to enhanced ET inspection capabilities
- Support expanded tube repair options

NRC Steam Generator Workshop

NDE Issues

D. S. Kupperman
Argonne National Laboratory
February 27-28, 2001
Bethesda, Maryland

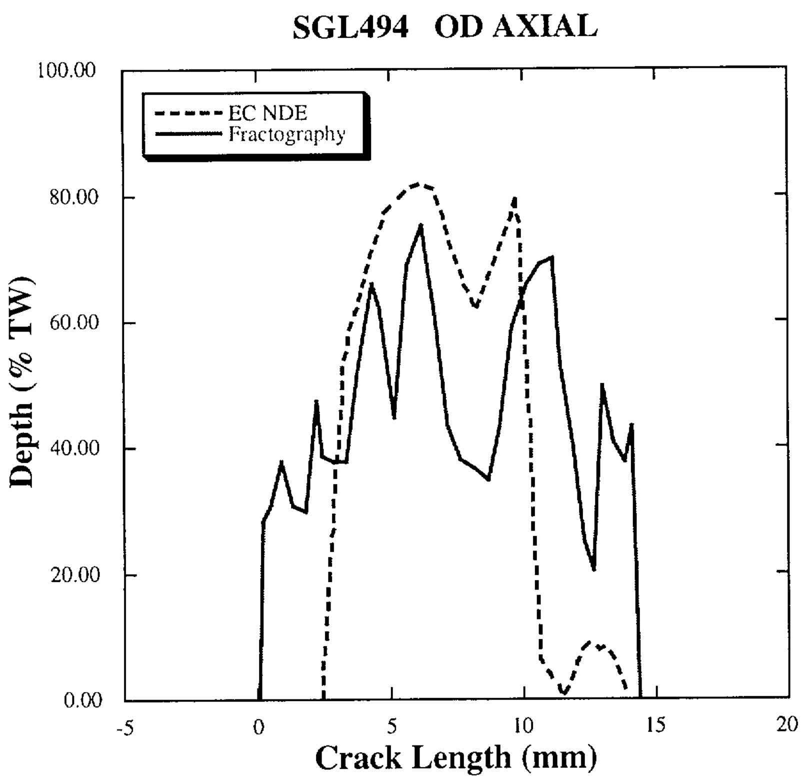
Performance Demonstrations

- Need more representative data set for testing personnel
  - Realistic samples with true state
  - Higher passing criteria: better than 80% for >60%TW
  - Test analysts with high noise situations (deposits, RTZ etc.)
  - Demonstrate ability to judge data quality

Rotating Coil Data Does Not Always Lead to Better Characterization

- MRPC Signal may be to complex
- MRPC may be less sensitive to volumetric flaws (I.e IGA)
- BC "I" code call with no MRPC flaw call possible
  - For Argonne Mock-up RR about 10% of the time flaws >40%TW with BC "I"code calls and BC voltage in 2.0-5.6 v range were dismissed with MRPC +Point analysis

Flaws Detectable by MRPC could be missed by BC screening



- No detectable BC flaw signal above few tenths background level
- Low level but detectable +Point indication
- Crack 75%TW and 1/2 inch long

Data Quality

- Noise Levels
  - Use improved data acquisition systems to filter out noise
- Increase number of flaws in standards to better quantify quality of data
- Quantify quality of data needed for sizing which is different for detection

Data Screening

- Log scale or two traces to cover wide dynamic range in EC signal voltage
  - Help avoid missing large signals

- Development of array probes may improve screening
  - Axial and circumferential flaws detectable and distiguishable

Argonne SG Mock-up NDE Round Robin

J. Muscara

U. S. Nuclear Regulatory Commission

NRC Steam Generator Workshop

Bethesda, Maryland
February 27-28, 2001

Introduction

- NRC has been developing new regulatory guidance for SG tube integrity
  - Condition monitoring (evaluate as-found condition of tubes)
  - Operational assessment (demonstrate that performance criteria for SG tube integrity will continue to be met)

- Quantitative information is needed to estimate true state of the SG after ISI
  - POD
  - Sizing accuracy

Introduction (cont.)

- One task of the NRC-sponsored SG TIP at ANL is to evaluate and quantify reliability of current, advanced and emerging technology used for ISI

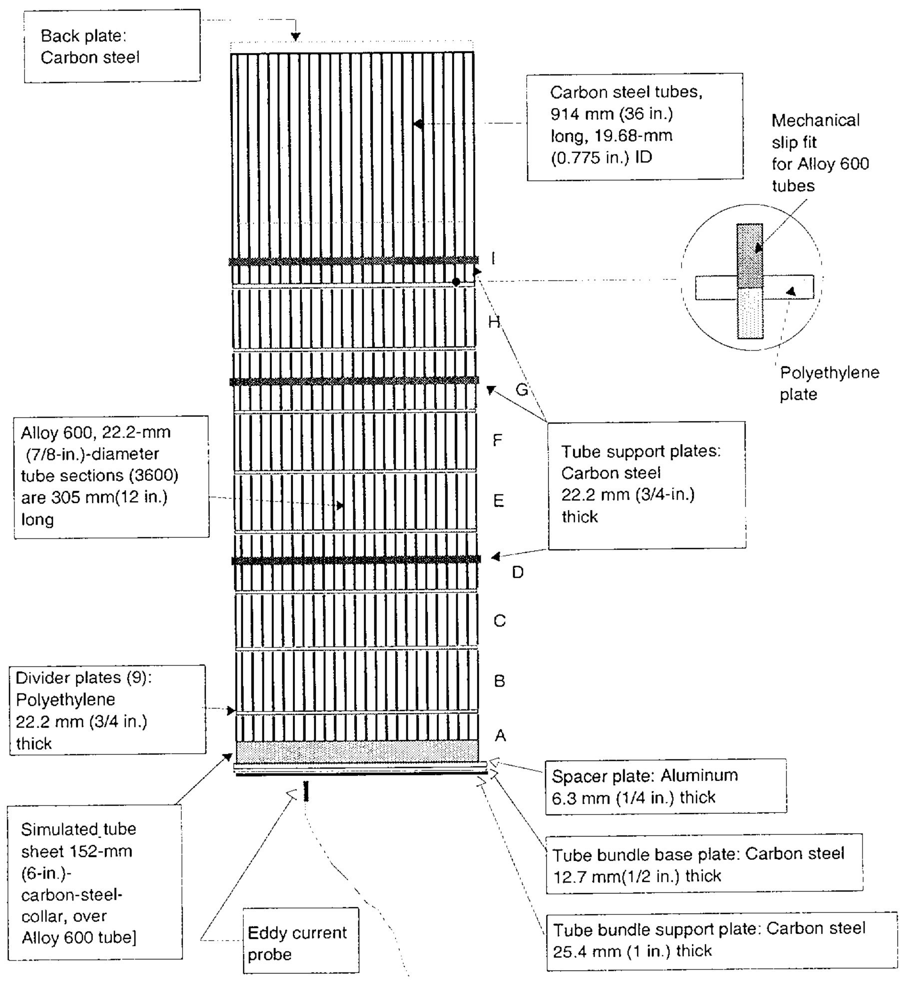
- Approach to establishing ISI reliability is to carry out RR exercises on SG mock-up with flaws and conditions representative of SGs in service

- Data acquisition and analysis for the RR was performed by qualified commercial teams

Mock-up Design

- **Tube bundle consists of aproximately 300 flaws in 12-in. long, 7/8-in.diameter Alloy 600 test sections with various forms of degradation (mainly ANL produced but some from Westinghouse, PNNL, ENSA and PISC)**
  - Circumferential and axial ID and OD in roll transition
  - Axial ODSCC (planar and segmented) in TSP
  - Axial IDSCC in dents at TSP
  - ODSCC (planar and segmented) in free span
  - IGA and wear in small numbers at different locations
- **The tube bundle consists of 400 tube openings, each with 9 levels, for a total of 3600 test sections.**
  - One tube sheet simulation.
  - Three drilled hole TSP simulations
  - Five free-span levels

Mock-up Schematic



Mock-up Degradation

Location	EDM & Laser Cut Slots	IGA	ODSCC	PWSCC	Wear/ Wastage	Fatigue
Top of Tube sheet			21	47		
Free Span	14	8	95	4	3	
TSPs	7	5	65	31	9	3

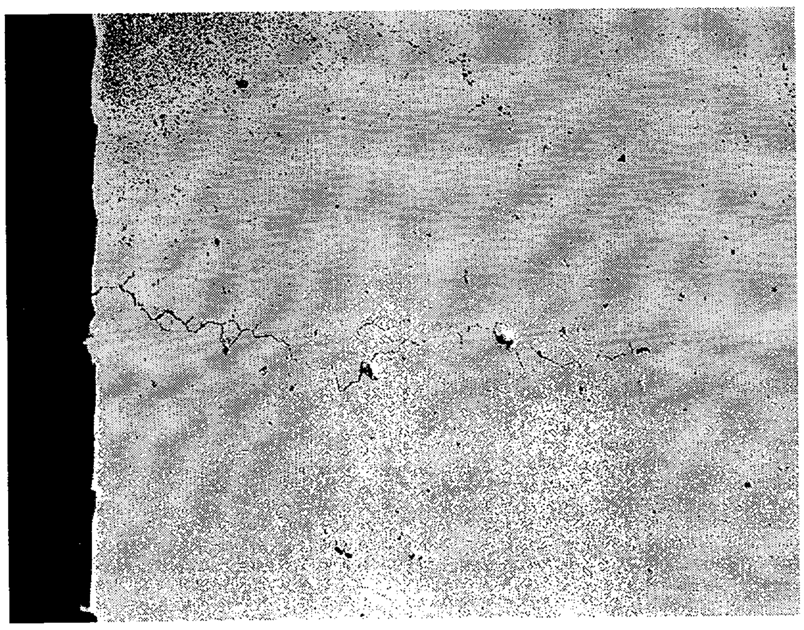
Artifacts

- **Other conditions and artifacts that can produce or distort EC signals in actual SGs are simulated in the mock-up**
  - Roll transitions at TS level
  - Magnetite has been applied to the TSP region
  - Sludge has been incorporated above the TS and some TSP
  - Dented tubes (with and without SCC) were made with a device provided by FTI have been installed at TSP locations (elliptical and circular)

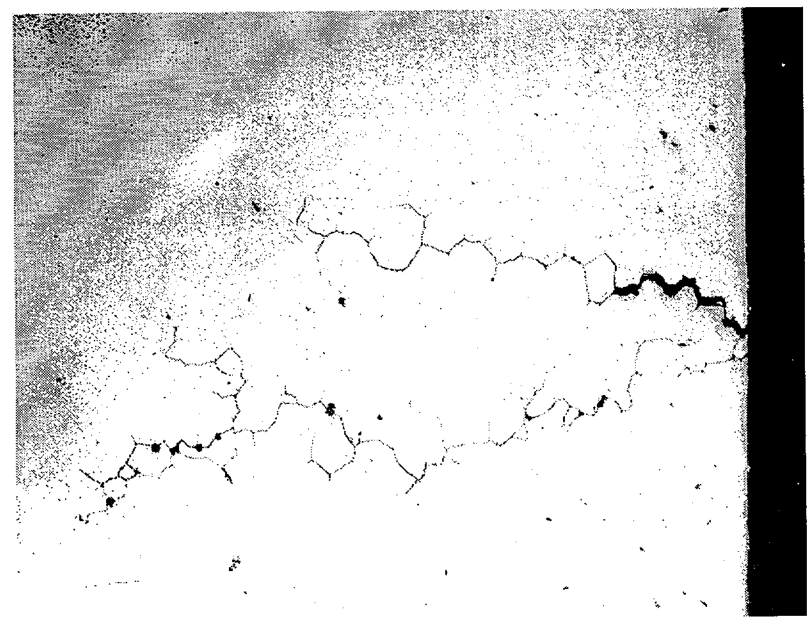
Cracks are Realistic

- SCC grown by aqueous solution of sodium tetrathionate at RT and ATM pressure
- Examination techniques used to evaluate nature of flaws
  - EC NDE
  - Dye penetrant examination
  - fractography
  - Optical microscopy
  - Scanning electron microscopy

Optical Metallography



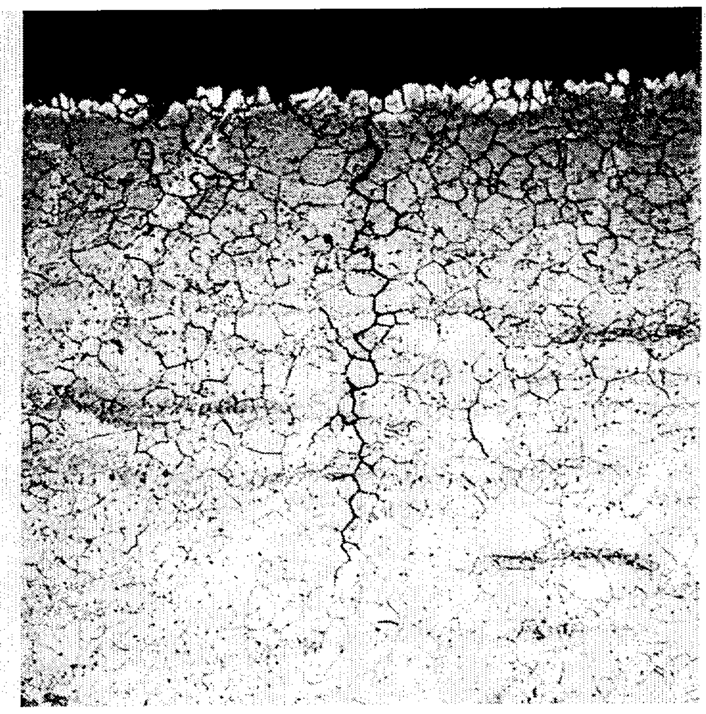
Axial ODSCC



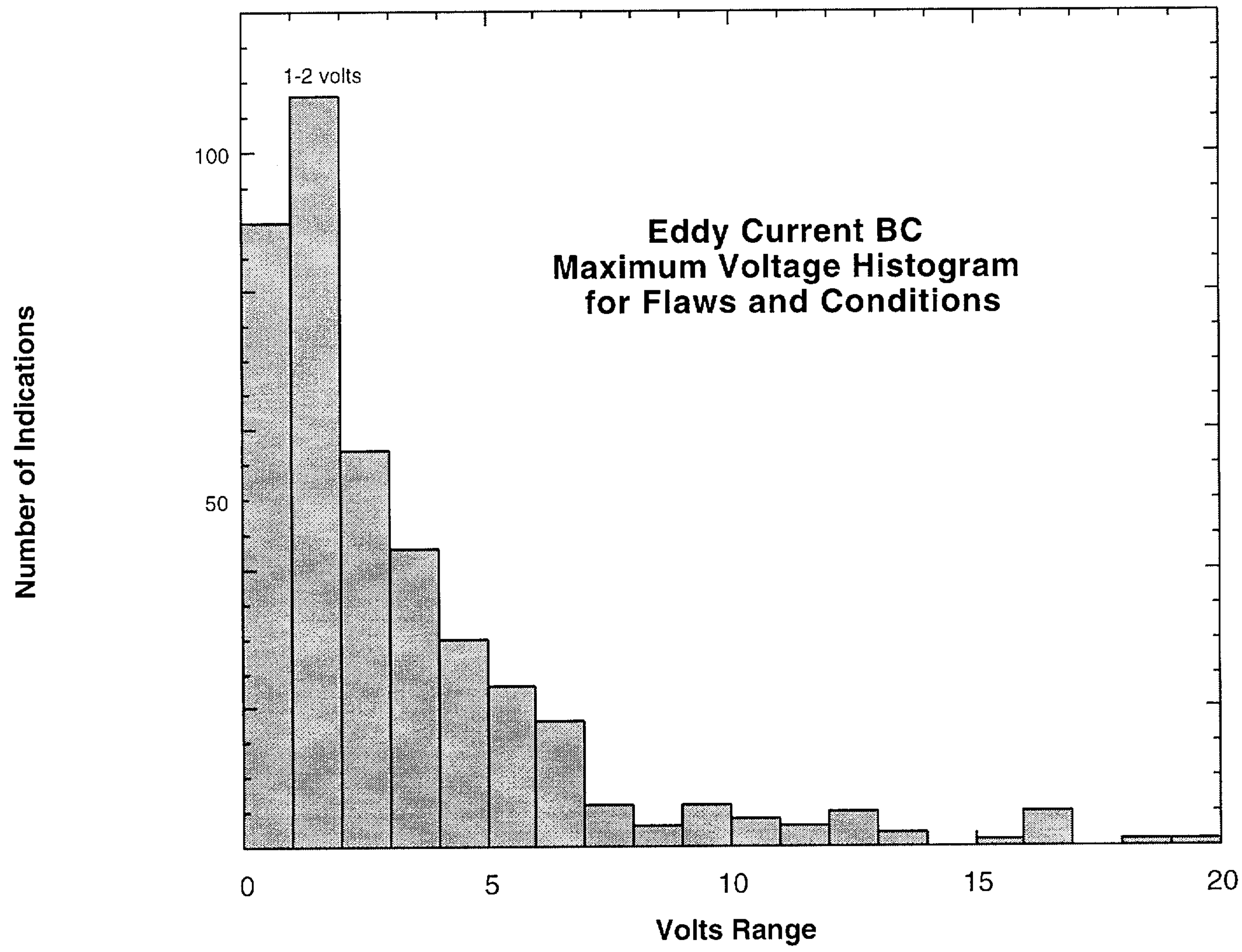
Branched Axial ODSCC

Figure A1. Cross Sectional Optical Metallography

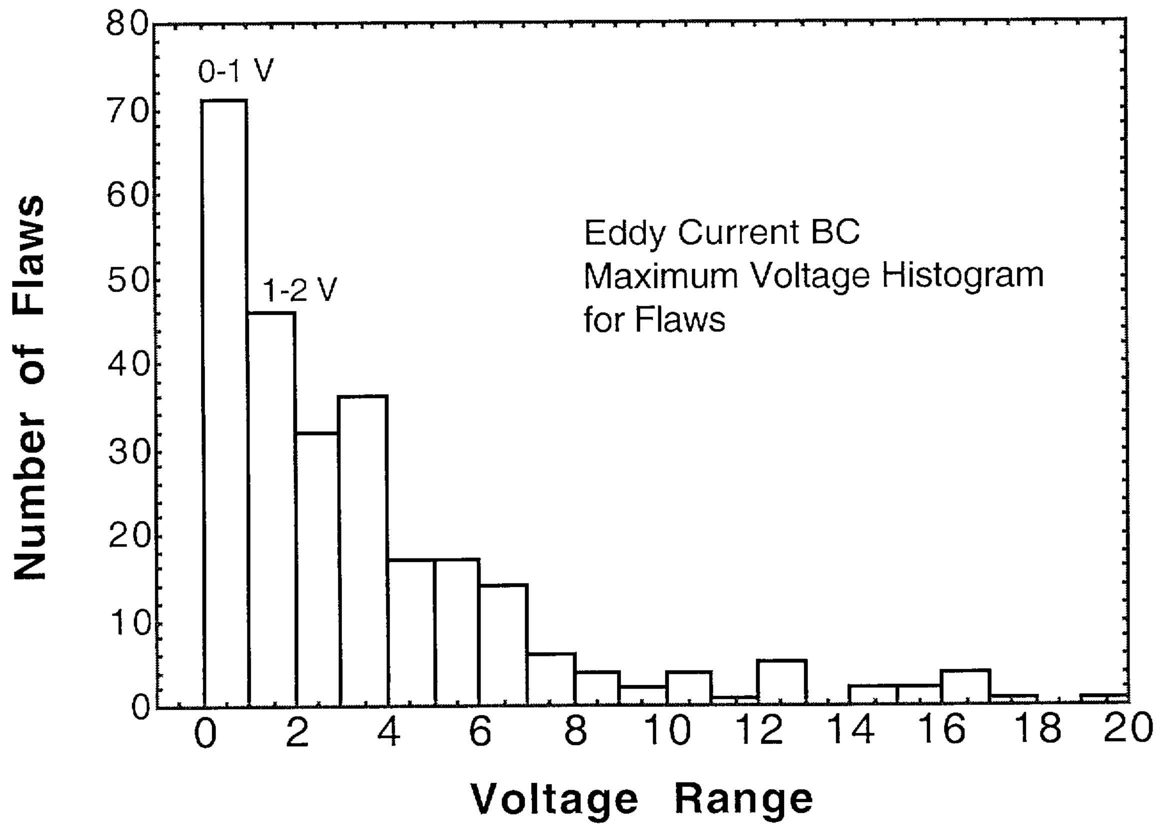
Optical Metallography



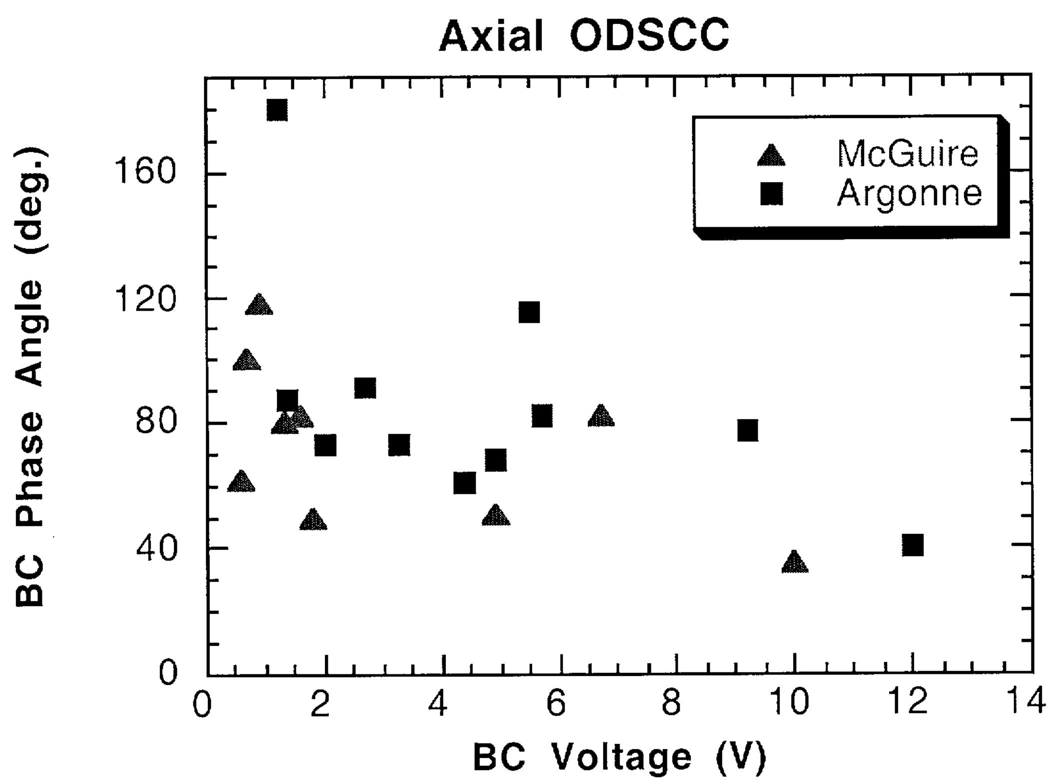
BC Voltage Histogram for Mock-up Flaws and Conditions



BC Voltage Histogram for Mock-up Flaws



McGuire vs. Mock-up



Evaluation of NDE Techniques for Characterization of Mock-up Flaws

- True state of mock-up flaws is needed to estimate POD and sizing accuracy from the inspection results without destroying the mock-up samples

- Effort undertaken to identify laboratory techniques for accurate characterization of the mock-up flaws

Evaluation of NDE Techniques for Characterization of Mock-up Flaws (Cont.)

- A subset of twenty specimens from the mock-up test sections was inspected using several NDE techniques:
  - Phase analysis of EC +Point data
  - Multivariate regression analysis of EC data
  - Multiparameter analysis of EC data with neural networks
  - High-frequency UT from the OD
  - Ultrasonic Lamb waves
  - Acoustic microscopy
  - Combination of UT and EC data (from the ID)
  - Dye penetrants

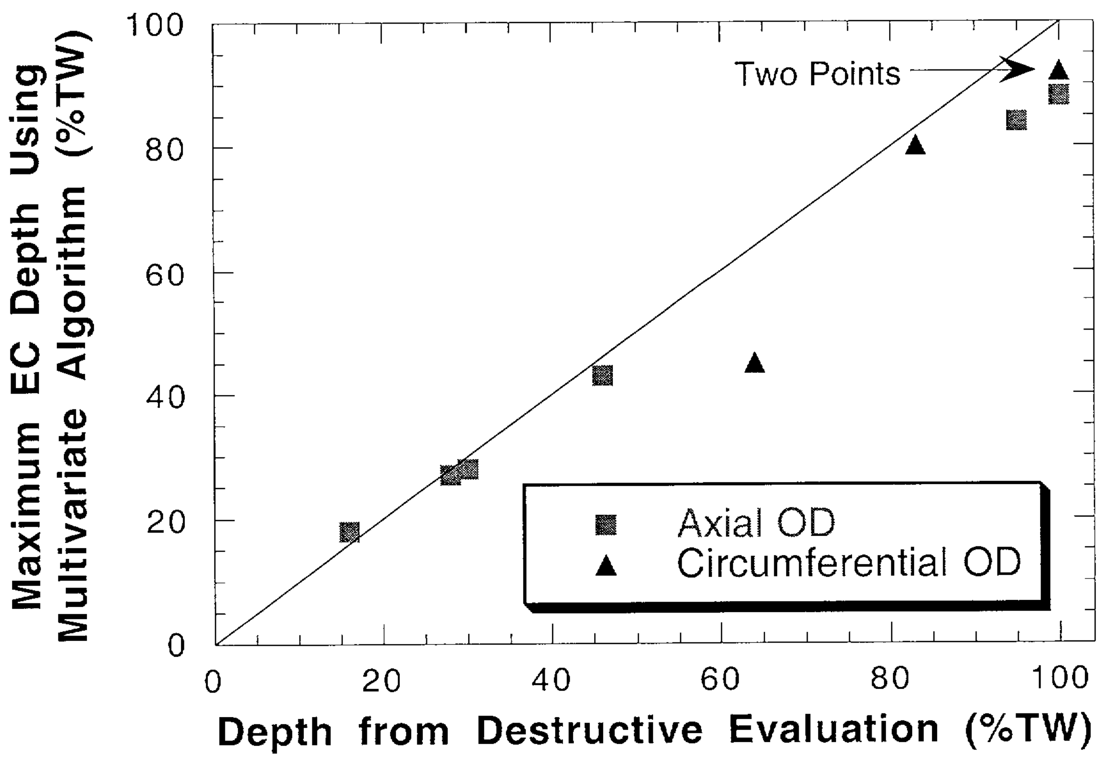
Evaluation of NDE Techniques for Characterization of Mock-up Flaws (Cont.)

- Conducted metallographic examinations to evaluate the sizing accuracy of the different methods and analysis techniques

- Analysis of the results indicated that most of the techniques did not provide desired accuracy for sizing the various flaws

- Multivariate regression techniques of EC data provided the best accuracy for sizing the cracks

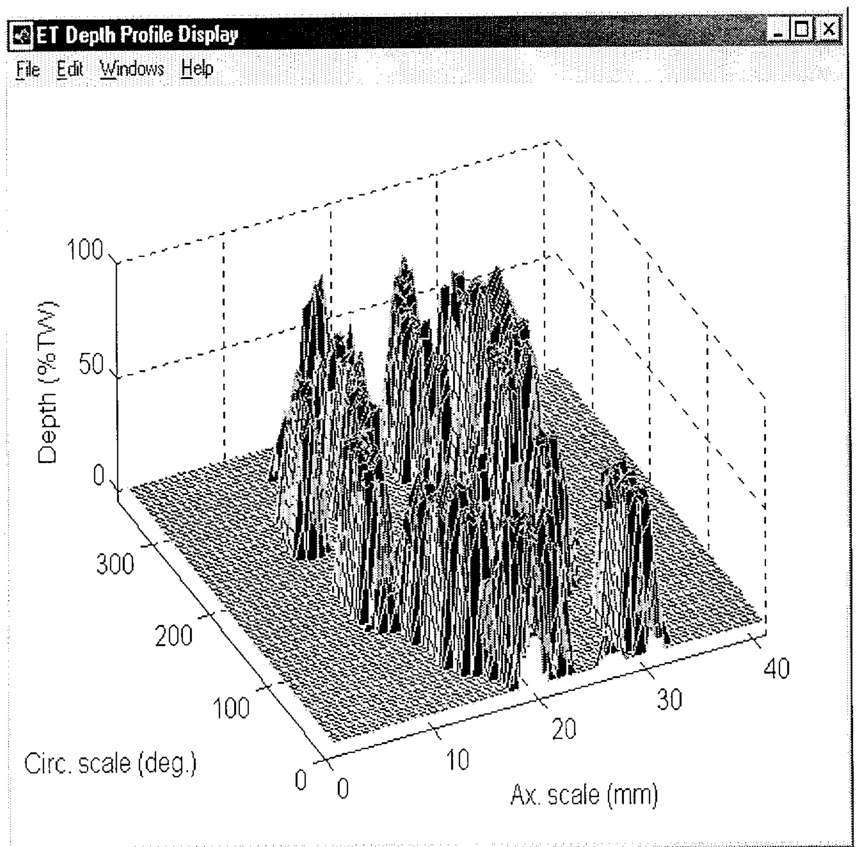
Maximum Depth as %TW Using Multiparameter Algorithm



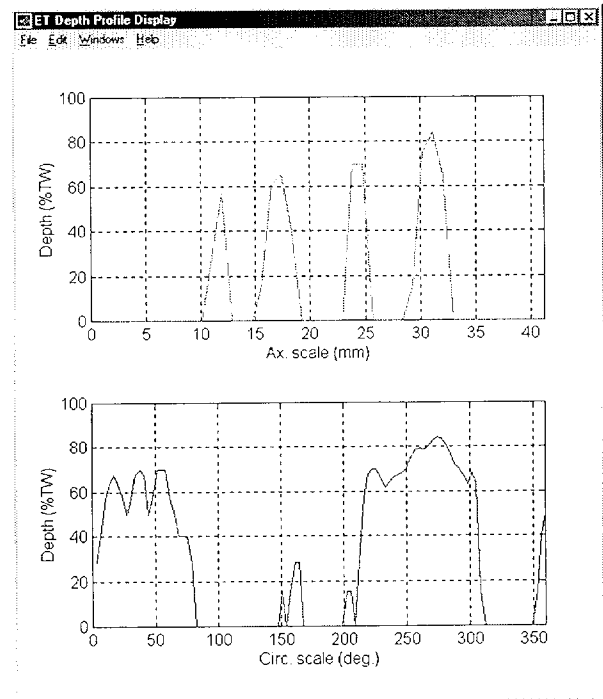
Evaluation of NDE Techniques for Characterization of Mock-up Flaws (Cont.)

- Development of an automated imaging and analysis algorithm for the analysis of RPC data.
  - Automated calibration
  - Filtering and deconvolution for improved S/N
  - Rule-based expert system
  - Multifrequency, multiparameter correlations for flaw size
  - Method provides graphical display which helps visualize cracking especially in cases like the roll transition where geometry greatly complicates analysis

Isometric and Cross Sections of Lab Grown ODSCC Using Advanced EC Analysis

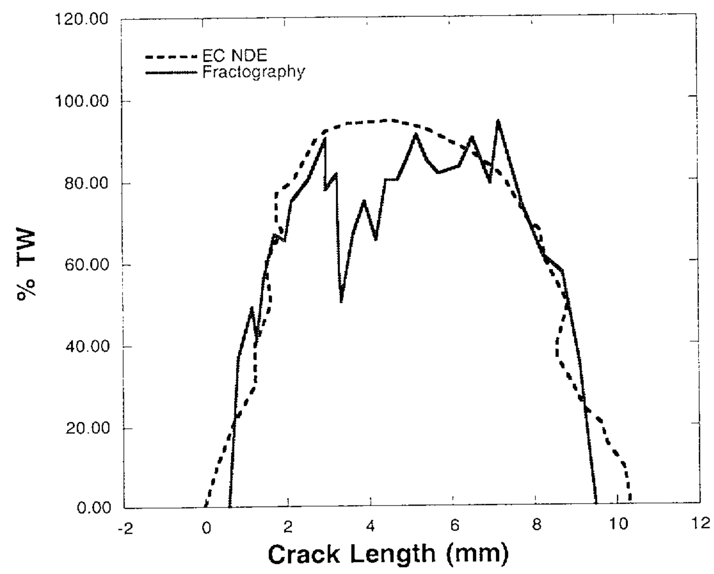


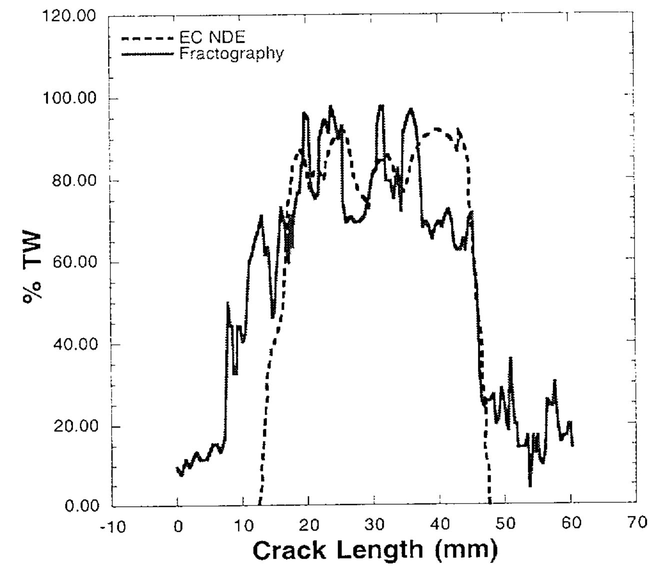
Lab-grown circumferential ODSCC ≈360° staggered cracking with maximum depth >80% TW.

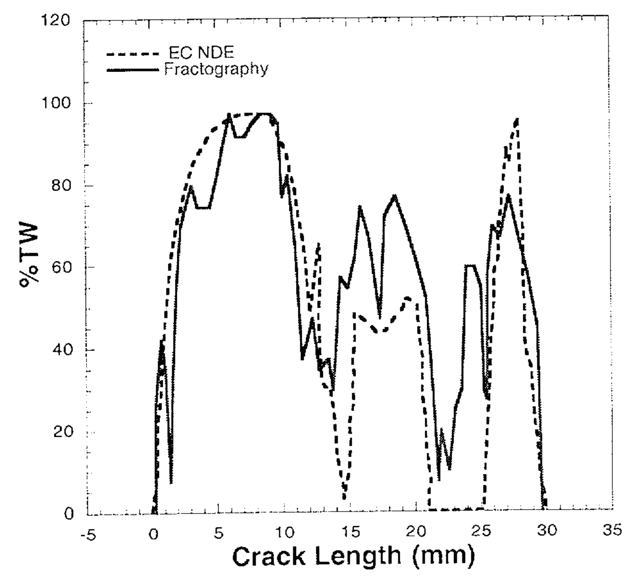


Axial or circumferential cross-sections can be taken to get profiles of the crack

Validation of Multiparameter Eddy Current Profiles vs. Destructive Analysis

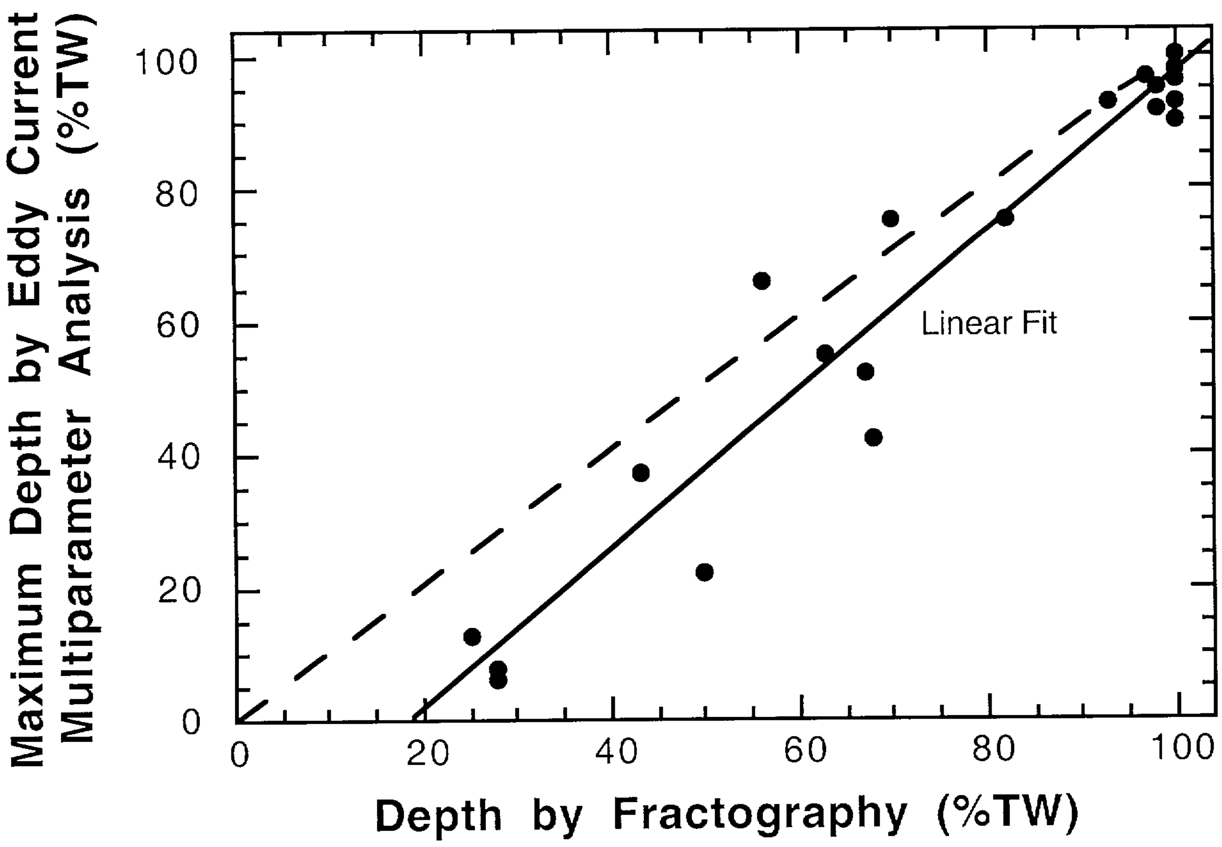




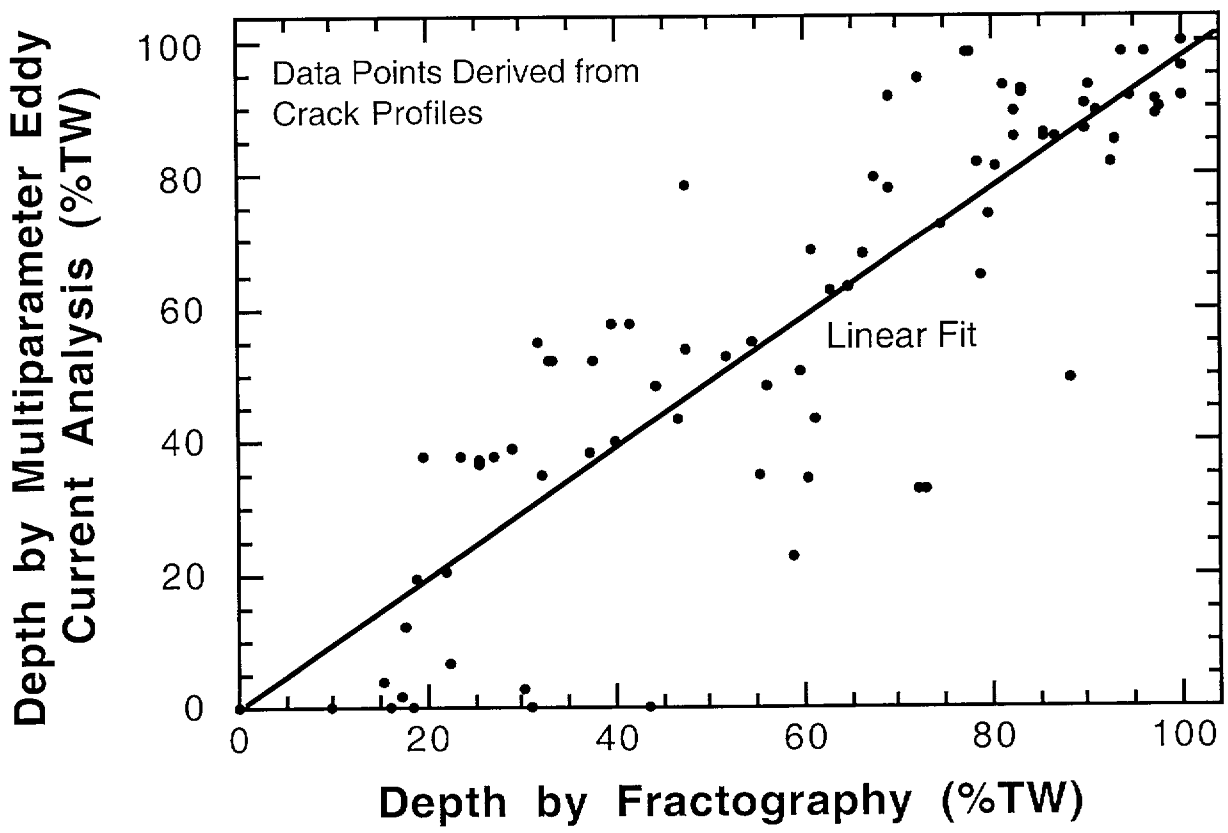


Destructive analysis of 29 tube set performed to validate capability of multiparameter analysis to better size and characterize a variety of flaws

Multiparameter Eddy Current Maximum Depth vs. Destructive Analysis



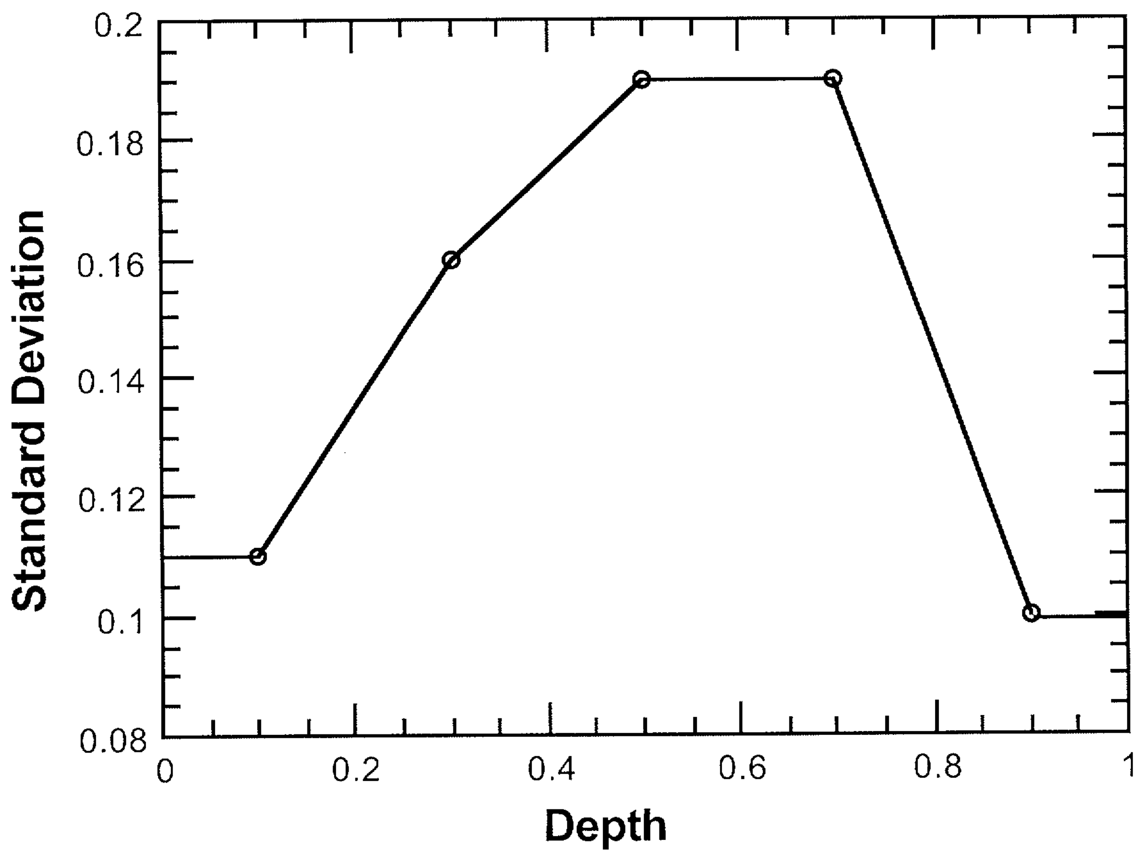
Multiparameter Eddy Current Point-by-Point Depth vs. Destructive Analysis



Depth Estimates by Multiparameter Algorithm as Function of Metallographic Crack Depth

Depth Range (%TW)	RMSE Max Crack Depth (%TW)
0-100	13.7
80-100	9.7

Standard Deviation Determined from Comparisons with Fractography



NDE Round Robin Objectives

- Establish POD for current day flaws as a function of size, type and location using the types of equipment, procedures and personnel qualified to conduct ISIs of SG tubes in the USA

- Quantify the accuracy of different methods and procedures for sizing the different flaw types

NDE Round Robin(cont.)

- Inspection of the mock-up and data analysis mimics the inspection process conducted on operating SGs
- NDE Task Group was formed to provide input to RR protocol and inspection procedures
  - Members are industry experts and practitioners were nominated by the program participants
- Using input from the Task Group, ANL developed protocol, documentation and requirements for "ISI of the mock-up"

Active Task Group Members (other than ANL and NRC)

- EPRI: G. Henry, J. Benson
- XCEL Energy (NSP): S. Redner
- Westinghouse: D. Adamonis, R. Maurer (ABB-CE)
- FTI: T. Richards, R. Miranda
- Zetec: N. Farenbaugh
- Duke Power: D. Mayes

NDE Round Robin (cont.)

- Degradation assessment for mock-up was carried out and qualified techniques selected
  - Examination Technique Specification Sheets for the inspection have been documented
- NDE Task Group members reviewed EC signals to ensure signals are realistic
- Metallographic examination results of cracks in the mock-up tubes showed that they were similar to cracks removed from service
- Comparison of signals from mock-up flaws with those from McGuire shows flaw responses are comparable

NDE Round Robin (cont.)

- Site specific essential variables for the mock-up were reviewed to ensure consistentcy with those of the qualified techniques
- Data was collected with a MIZ30 instrument and analyzed with Eddynet 98 software
- Data analysis RR carried out by 11 qualified teams from various ISI vendors

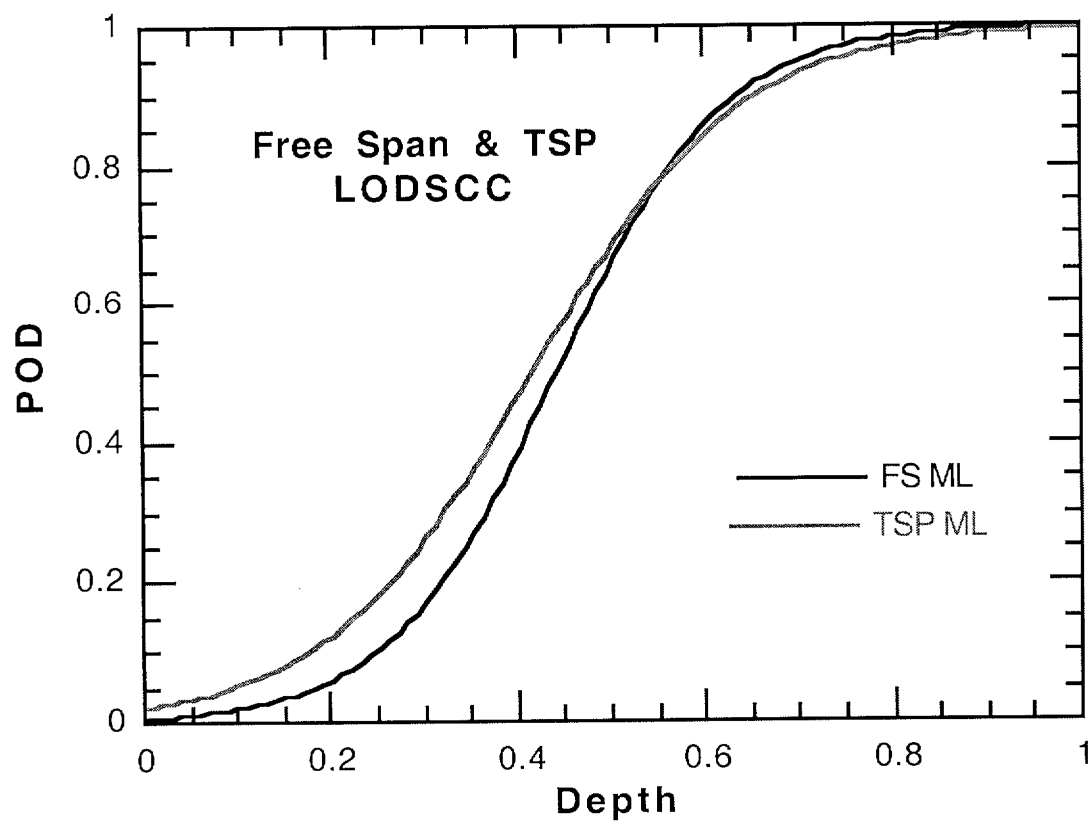
NDE Round Robin (Cont.)

- **Each team consisted of a primary, secondary, two resolution analysts and a QDA**
- **Analysts were subjected to site specific training and performance demonstrations**
- **Inspection of the mock-up was carried out June and August 1999 with analysis completed Dec 2000.**

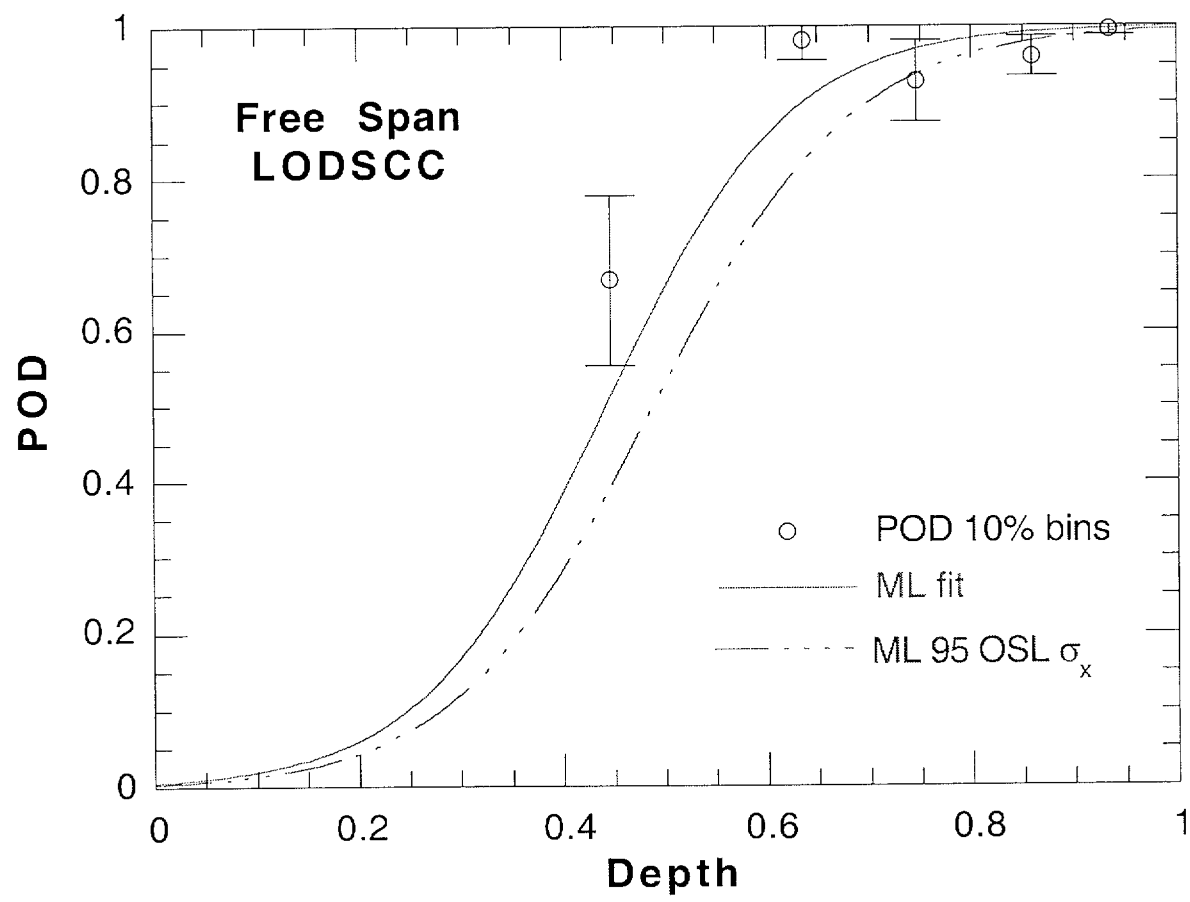
NDE Round Robin (cont.)

- **Eleven teams have participated in the round robin exercise:**
  - FTI (2),
  - ABB-CE,
  - Anatec,
  - Zetec (2),
  - Kaitec,
  - Duke Engineering and Services
  - Ontario Power Generation
  - Westinghouse (2).
- **Analysis took 6-8 working days to complete**

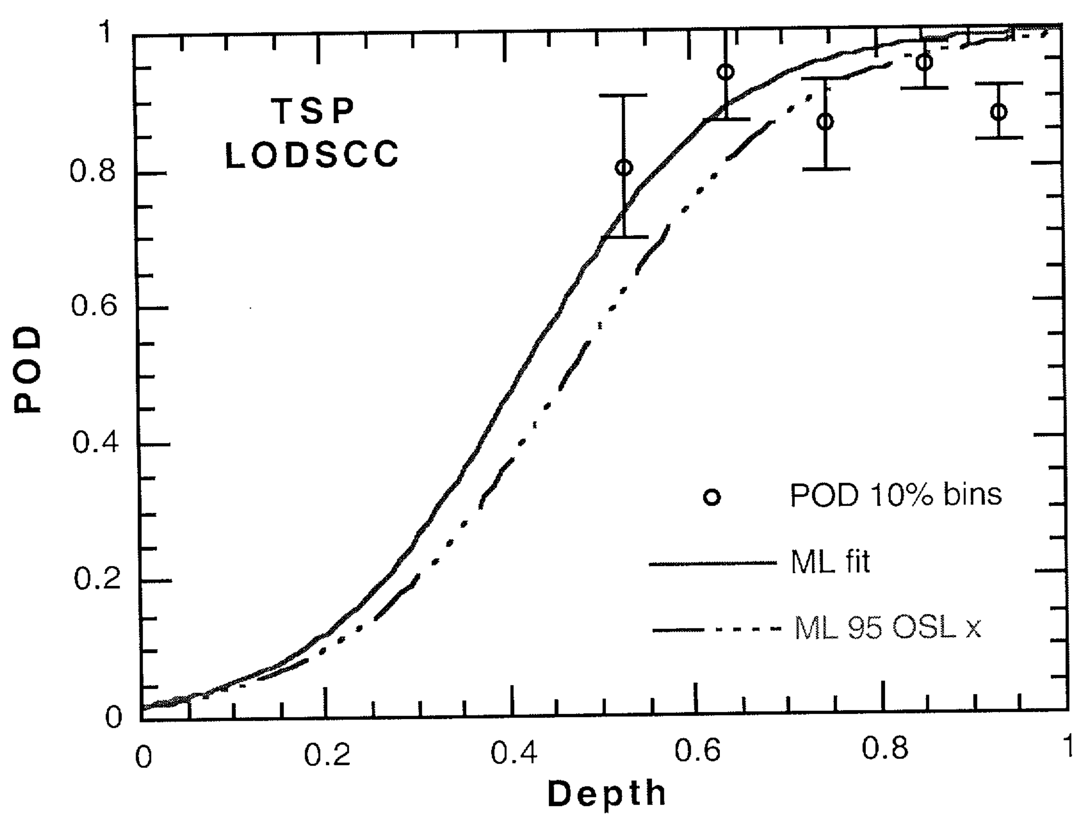
Preliminary Example Results: TSP and Free Span POD Fits for LODSCC >40%TW



Preliminary Example Results Including Error in Depth: Free Span LODSCC >40%TW



Preliminary Example Results: Including Error in Depth: TSP LODSCC >40%TW



Summary

- A SG tube bundle mock-up was assembled for evaluation of ISI reliability
- Inspection of the mock-up and analysis of the data mimics industry ISI practices conducted on operating SGs
- All documentation for conducting the inspections was prepared and the realism of the mock-up was established
- Data was acquired in June and August of 1999 and analysis of this data by 11 commercial teams was completed in December 2000
- Preliminary results indicate that good POD can be achieved for deep flaws when commercial techniques are used in a similar manner to that of the RR exercise
- Evaluation of results is continuing

NRC
STEAM GENERATOR
WORKSHOP

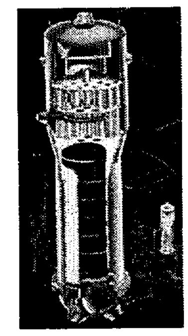
FEBRUARY 27 - 28, 2001

BETHESDA, MARYLAND

Volume II

Session 4
February 28, 2001

EPRI

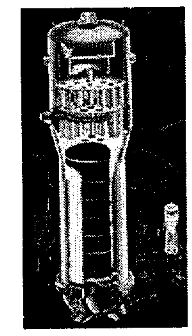


Steam Generator Integrity Assessment Guidelines

Kevin Sweeney

Arizona Public Service

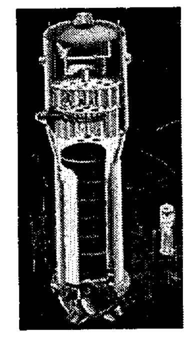
February 28, 2001



Agenda

- Guideline Objective
- Background
- Guideline Format
- Key Terms in Integrity Assessment
- Tools
- Summary

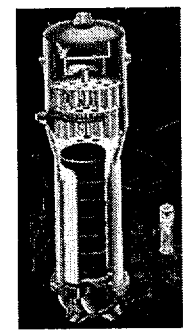
EPRI



SG Integrity Assessment Guidelines

- Objective
  - Develop industry guidance for performing Condition Monitoring (CM) and Operational Assessments (OA)
    - Required per NEI 97-06
    - Should function with other Integrity Element Guidelines
- Challenge
    - No previous industry or regulatory standard for tube integrity assessment
    - Sufficiently flexible to address all forms of SG degradation and several assessment strategies
- Purpose
    - Demonstrate compliance with performance criteria

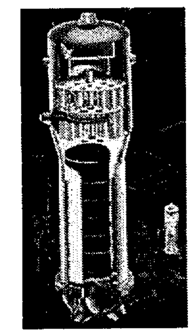
EPRI



Guideline Background

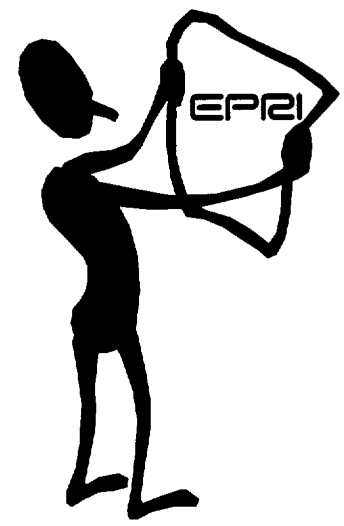
- Significant industry effort to develop guidance
  - Working Group established 2/97
    - Several significant draft revisions
  - Early feedback
    - Complicated/confusing
    - Industry and regulatory criteria evolving
  - Final draft issued 10/98
    - Comments received from utilities and vendors
      - Over 200 comments resolved
  - Document issued March 2000
  - Changed to Integrity Element in NEI 97-06 Rev 1

EPRI



Guideline Format

- Section 1 - Introduction
- Section 2 - Fundamentals of SG Tube Integrity Assessment
- Section 3 - Degradation Assessment
- Section 4 - NDE Techniques
- Section 5 - Structural Integrity Assessment Limits
- Section 6 - Degradation Growth Rate
- Section 7 - Allowable Accident Induced Tube Leakage
- Section 8 - Condition Monitoring
- Section 9 - Operational Assessment
- Section 10 - Operational Leakage
- Section 11 - Documentation and Reporting Requirements
- Section 12 - Glossary
- Section 13 - List of Abbreviations and Acronyms
- Section 14 - References



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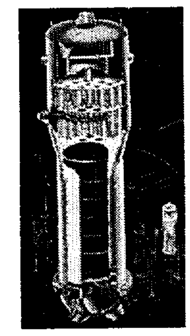
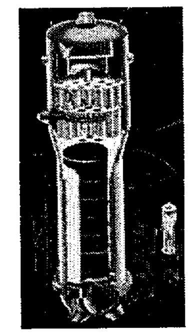
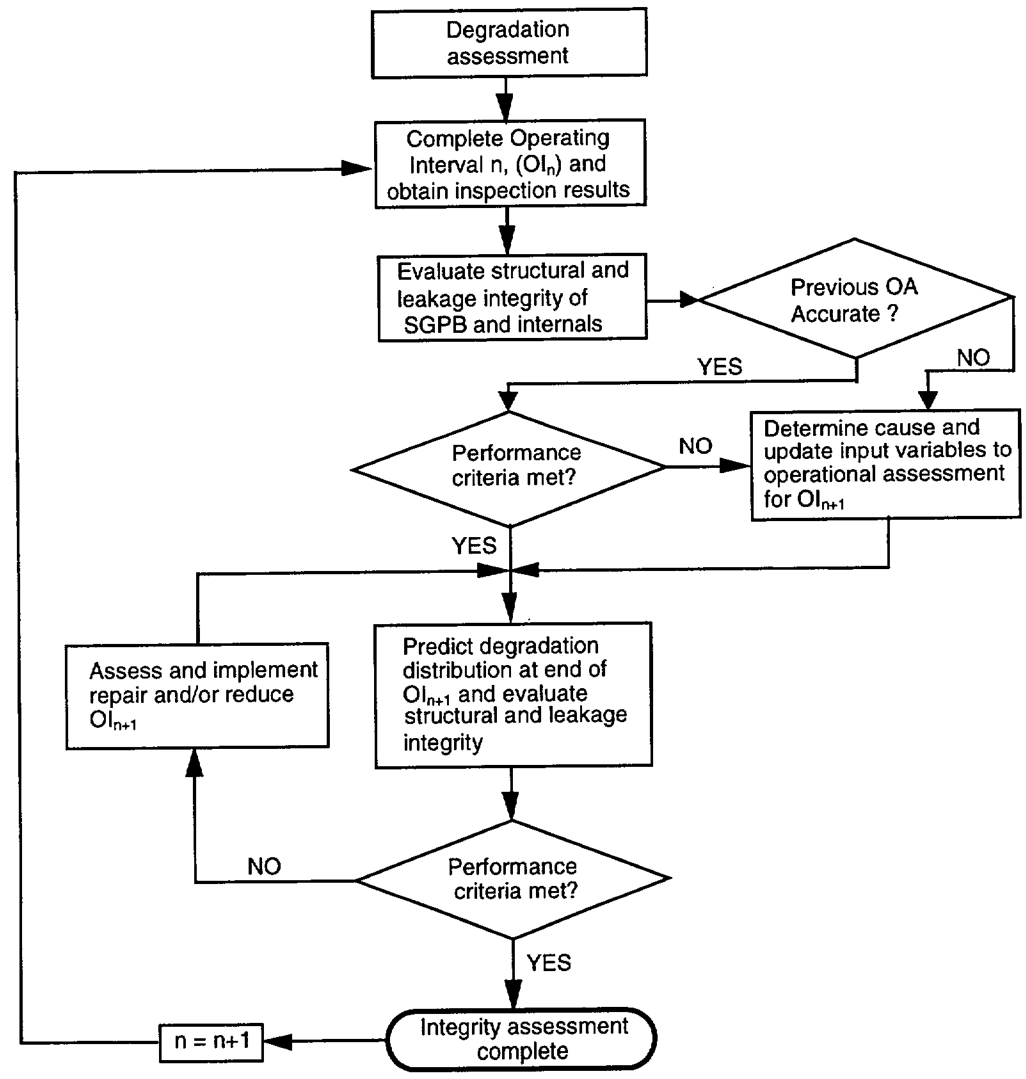


Guideline Format (cont)

- Appendices
  - Appendix A - Example of Degradation Assessment and Inspection Requirements
  - Appendix B - Sample Checklist for Pre-Outage Assessment
  - Appendix C - Calculation of Steam Generator Tube Leakage
  - Appendix D - Summary of SG Integrity Assessment - Example Form
  - Appendix E - Example of OA Limit Determination for Tube Wall Thinning
  - Appendix F - Illustration of Voltage-based Simplified Statistical and Monte Carlo Methods
  - Appendix G - Monte Carlo Analysis
  - Appendix H - Method for Combining Data Sets
  - Appendix I - POPCD Example and POD Procedures
  - Appendix J - Risk Informed Inspections
  - Appendix K - Radiological Assessment Guidelines
  - Appendix L - SGDSM On-Line Data Base Use
  - Appendix M - Industry White Papers Defining Burst and Pressure Loading for Structural Integrity Assessment



Integrity Assessment Process



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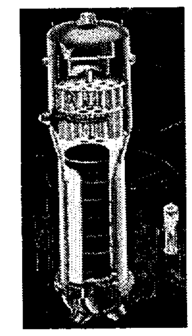
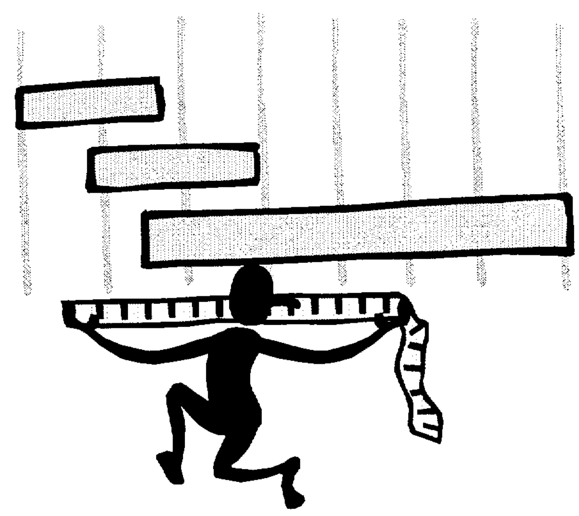
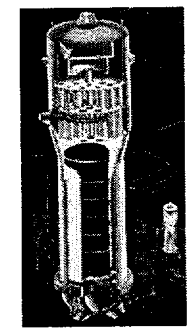


Terms - Performance Criteria

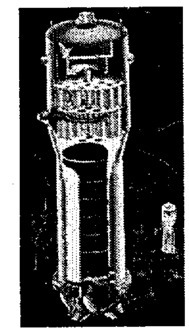
- NEI 97-06 Performance Criteria designed to provide reasonable assurance the SG RCPB capable of fulfilling safety function
- Performance Criteria should also be:
  - Measurable
    - Program effectiveness
  - Achievable
    - Should not be an issue to safe, well run programs
  - Lead to corrective actions, if required
    - Flag problem areas
    - Self Assessment





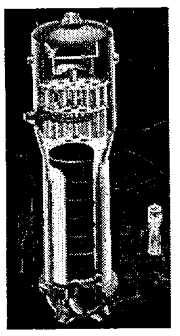
Performance Criteria - NEI 97-06

- NEI 97-06 specifies three (3) performance criteria
  - Structural Integrity
    - Protection against burst during accidents which tube integrity is assumed
      - Defined Margins of Safety (3NODP, $1.4P_{acc}$)
  - Accident Induce Leakage Integrity
    - Maintain licensing basis assumptions for accidents other than SGTR
      - Dose consequences
      - Not to exceed 1 gpm per SG without NRC approval
  - Operational Leakage
    - Based on Industry Experience
      - Protection against spontaneous rupture



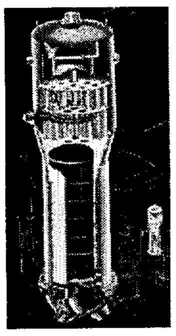
Terms - CM and OA

- Condition Monitoring
  - Assessment (***Monitoring***) of the "as-found" ***condition*** of the steam generator relative to performance criteria
    - Determines if performance criteria were satisfied for the just completed operating cycle
      - Failure to satisfy criteria requires reporting to NRC
- Operational Assessment
  - Assessment differs from condition monitoring as it is "forward looking"
    - Involves evaluating/modeling Steam Generator Program
      - Inspection, repair and operation processes
    - Provide reasonable assurance that performance criteria will be satisfied for the next operating period

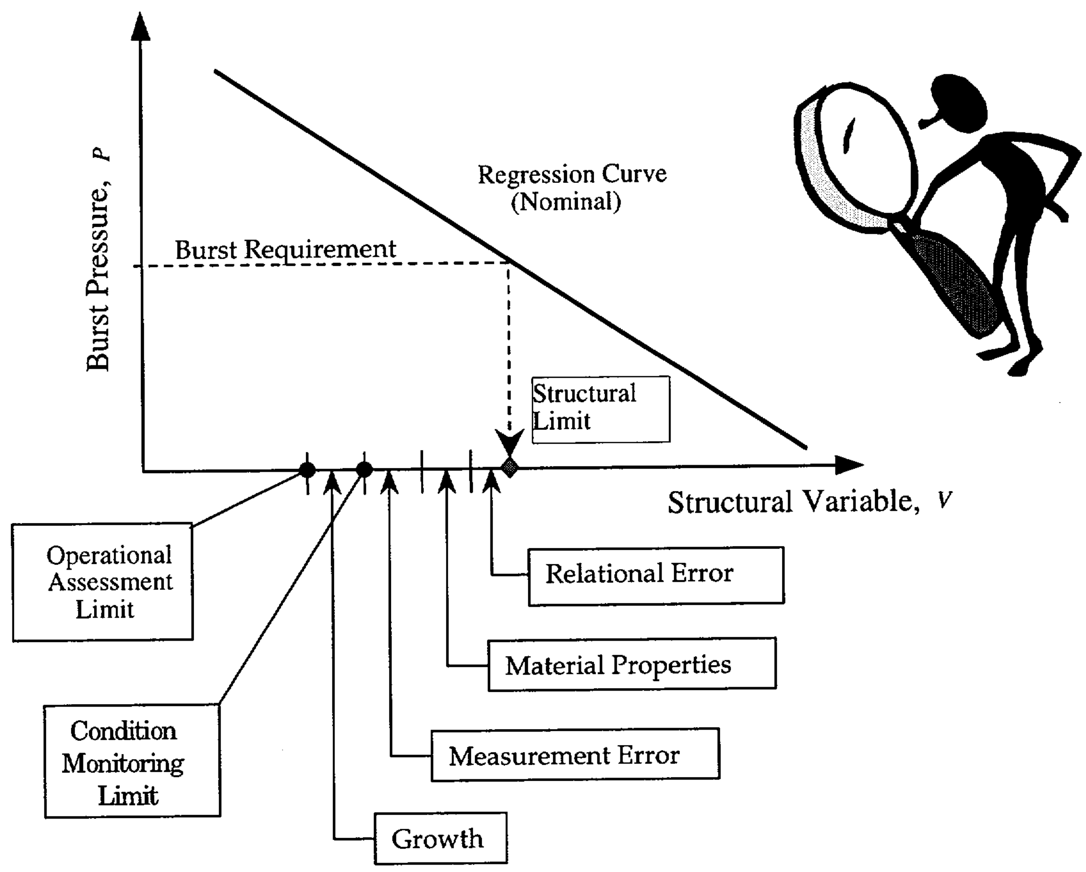


Terms - Assessment Strategies

- Integrity guideline provides computational hierarchy of analytical techniques to verify tube structural and leakage integrity
  - Arithmetic
  - Simplified Statistical
  - Monte Carlo
- Strategies use similar structure to assess EOC tube integrity
  - Burst Pressure = f {BOC, Growth, NDE, Materials)
    - Each strategy is dependent on the availability and accuracy of input data



Terms - Tube Integrity Elements



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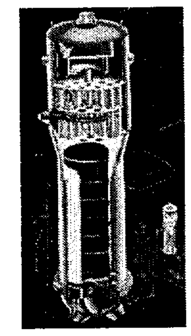
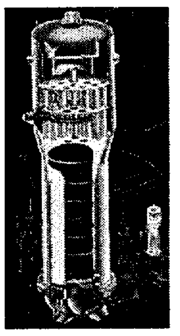


Tools - Degradation Assessment

- EPRI SG Integrity Assessment Guideline
  - Chapter 3 - Methodology
  - Appendix A - Checklist
- EPRI PWR SG Examination Guideline
  - Section 5.2
- EPRI Steam Generator Database
  - Electronic database
    - Industry inspection and repair results
- Industry Participation
  - EPRI, NEI, INPO, Owners Groups, NSSS vendors
  - Workshops
- EPRI R&D Efforts

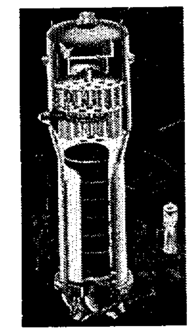
EPRI



Tools - NDE Inputs

- EPRI PWR SG Examination Guideline
  - Analyst and Technique Qualification
    - Consistent application
    - POD and NDE uncertainty - key inputs
  - Site Specific Performance Demonstration
- EPRI SG Integrity Assessment Guideline
  - Chapter 4
- ERPI Steam Generator Databases
  - Reference to tube pull and in situ data
- EPRI NDE Center
  - Utility technical support and product qualification

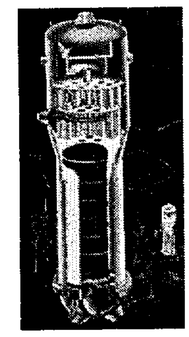
EPRI



Tools - Degradation Growth

- EPRI SG Integrity Assessment Guidelines
  - Chapter 6
- EPRI - Degradation Statistics & Predictions
  - Methodologies
  - Effects of Thot, material differences
  - Laboratory results
- EPRI Steam Generator Database
  - Defect data, operating conditions, tube pull results

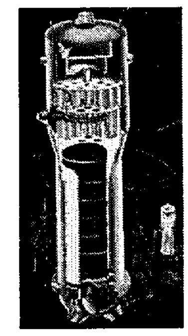
EPRI



Tools - Structural and Repair Limits

- EPRI SG Integrity Assessment Guideline
  - Chapter 5
- EPRI Flaw Handbook
- EPRI ARC Topical Reports
  - Axial ODSCC @ TSP, Circumferential Indications
  - ODSCC Database
- EPRI R&D Efforts
  - Burst Correlation Data
  - Pressurization Ramp Rate
- EPRI In Situ Test Guidelines

EPRI



Summary

- Guideline meets industry objectives as initial standard for tube integrity assessment
- Industry expects guideline to evolve as experience dictates
  - Similar to experience with Examination GL and Primary to Secondary Leakage GL
- Issues
  - Incorporate Lessons Learned
  - Continue industry education via meetings, self assessment and workshops
  - Develop/improve industry tools
  - Formation of Ad Hoc Tube Integrity Committee

NRC Perspective on Several SG Tube Integrity Issues

Emmett L. Murphy, (301) 415-2710
Office of Nuclear Reactor Regulation, NRC

Steam Generator Workshop
Bethesda, Maryland
February 27-28, 2000

Staff Perspective/Detailed Industry Guideline Documents

- Have contributed significantly to improved SG tube integrity performance.
- Consideration of these guidelines is essential to ensuring SG tube integrity performance criteria are met.
- Have no regulatory standing; staff has no plans to endorse.
- These guidelines still contain numerous shortcomings.
- Adherence to these guidelines may not be sufficient.
- Actions beyond these guidelines may be necessary to ensure performance criteria are met and to be in compliance with 10 CFR 50, Appendix B, Criterion 16.
- The industry should continue to work with the staff to identify and discuss existing shortcomings and needed improvements.

Tube Integrity Assessment Issues

- Treatment of Uncertainties
- NDE flaw detection and sizing performance
  - in situ screening criteria
  - operational assessment
- Fractional flaw methodology
- Definition of limiting accident
- Benchmarking of operational assessments
- Interpretation of in situ pressure test results
- Pressurization rate issue (Majumdar)
- Need for higher capacity in situ pressure test systems (Majumdar)

Treatment of Uncertainties

- NEI 97-06 provides general guidance.
- Tube integrity assessment guidelines:
  - Structural limits are set such that a flaw evaluated to be at the limits satisfies the structural performance criteria with probability of 0.9 evaluated at a 50% confidence level.
  - Probability of burst of one or more tubes (for the population of degraded tubes) < 0.1 at applicable performance criteria.
- These values are less than those proposed by the staff in DG-1074 and approved for a recent ARC application:
  - .95/.95 for operational assessment
  - .95/.50 for condition monitoring

NDE Flaw Detection and Sizing Performance

- Detection and sizing performance given in EPRI ETSS sheets may be inappropriate for use in defining in situ test screening criteria and for use in tube integrity assessments.
  - Of particular concern for cracks
- Detection and sizing performance should ideally be based on a performance demonstration which:
  - quantifies performance of the total NDE system (technique and personnel) in blind test relative to ground truth
  - includes a statistically significant number of flawed tube specimens over the full range of flaw sizes of interest
  - utilizes flawed tube specimens representative of conditions in the field in terms of flaw morphology, tube and support geometry, flaw signal response, noise, and signal to noise.

NDE Flaw Detection and Sizing Performance (Cont)

- For flaw mechanisms for which such a performance demo is not available:
  - A sample of affected tubes should be in situ tested. Field sizing measurements should only be used to help prioritize tubes for testing.
  - A cautious, conservative approach should be taken during operational assessments when applying POD and flaw sizing error assumptions. These assumptions should be assessed against actual inspection and/or in situ pressure test results for consistency.
  - Initiate rigorous performance demo.

Interpretation of In Situ Pressure Test Results

- In-situ testing may fail to reach target pressure (e.g., 3 delta P) due to leakage in excess of test system capacity.

- Guidelines permit engineering assessment to assess burst or leakage integrity relative to applicable performance criteria.

  - These guidelines should be upgraded to ensure an objective assessment (i.e., an assessment which is uniquely consistent with all the available evidence).

- The engineering assessment should account for the uncertainties in the NDE flaw size measurement and the models used to assess local and gross ligament tearing, burst, and leak rate. Leak rates exhibit a high degree of scatter for a given through wall crack length.

Fractional Flaw Methodology

The fractional flaw method is based on the assumption that for each flaw found by inspection, there are flaws of the same size which were not detected by inspection (i.e., 1/POD - 1).

- Approved by NRC for voltage-based ODSCC alternate repair criteria ARC at support plate intersections and PWSCC ARC at dented support plate intersections.
  - Licensees currently assuming a constant POD of 0.6 for these applications.
- An operational assessment for IP-2 utilized the fractional flaw methodology in conjunction with a POD assumption which varied as a function of crack size.

Fractional Flaw Methodology (Continued)

- The staff's review found that use of variable POD in conjunction with the fractional flaw method led to results which were insensitive to the size of the indications found by inspection.
  - The staff considered this finding unrealistic.
- The industry should assess this issue and revise the guidelines as needed.

Limiting Accident

- The tube integrity assessment guidelines and the NEI steam generator generic change package define "limiting accident" to be an accident that from a structural standpoint results in the largest pressure differential across the steam generator tubes, normally a main steam line or feed water line break.

- The definition should more properly state that

  - from a structural standpoint, "limiting accident" means an accident which in conjunction with a safe shutdown earthquake results in the minimum margin against burst (i.e., gross failure).

Benchmarking of Operational Assessments

- Should be performed as part of each operational assessment to confirm that analysis methodology is conservative and to ensure that NDE detection and sizing uncertainties and growth rate uncertainties have been adequately accounted for.
- Should consider both best estimate and bounding predictions from operational assessments.
- Should avoid taking credit for NDE procedural improvements implemented during current inspection unless supported by quantitative data concerning the expected degree of detection or sizing performance (ideally by performance demonstration).

Pressurization Rate Effect

- Pressure tests performed on EDM notched specimens intended to replicate ODSCC flaw at ANO-2 which leaked during in situ testing.
- Ligament tearing and burst pressure results varied as a function of the pressurization rate (from essentially quasi-static to 2000psi/sec).
- Argonne (ANL) data also indicates a pressurization rate effect.
- Potential implications:
  - empirical burst models, if high pressurization rates used
  - analytical ligament tearing and burst models
  - procedures for laboratory and in situ burst testing

Pressurization Rate Effect (Continued)

- Preliminary industry assessment:
  - Rate effect limited to planar cracks greater than 90%.
  - Time dependancy effect is essentially complete within 1 minute.
  - No impact on empirical burst pressure correlations.
  - Analytical models are conservative.
  - Test procedures should be revised.
- NRC staff is also investigating this issue and will review the industry's findings when completed.
- In meantime, the staff has not accepted new ARC applications involving use of empirical burst correlations for part TW cracks.
- Recent revisions to the in situ test procedure guidelines are a significant improvement, reducing the potential for missing time dependant ligament behavior.

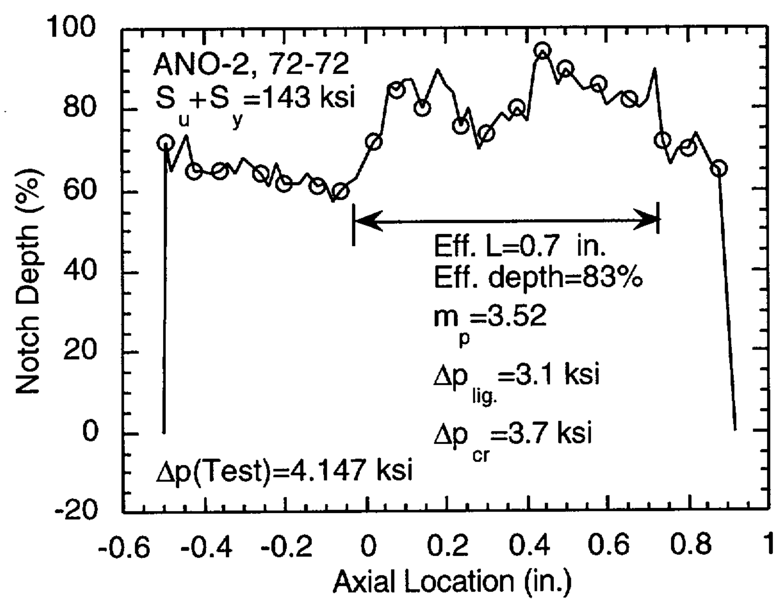
Pressurization Rate Effect on Burst Pressure/ Pumping Requirements for $3\Delta p_{NO}$ Tests

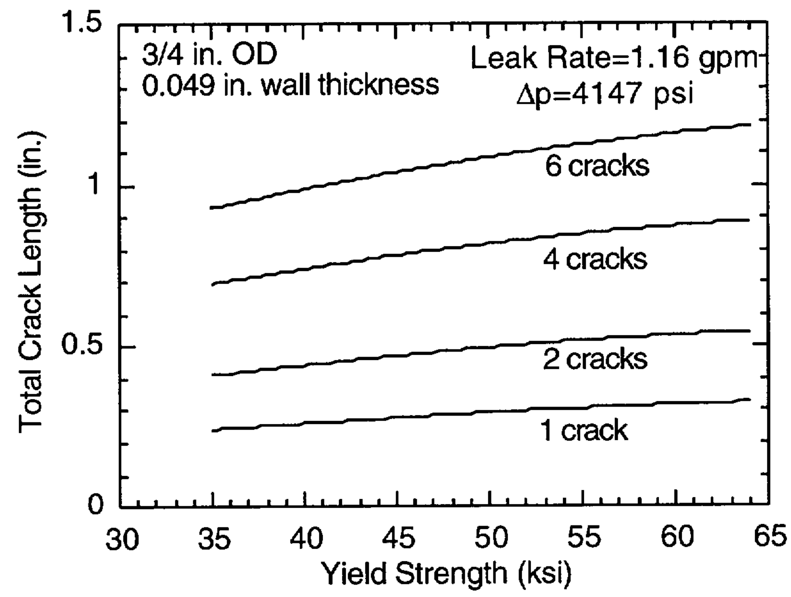
by

Saurin Majumdar
Energy Technology Division
Argonne National Laboratory

Presented at the Steam Generator Workshop in Bethesda on Feb. 27-28, 2001.

Comments on Westinghouse Tests on ANO-2 Tubes





- Type 14 specimen design assumed EC had overcalled depth in 72-72
- Aternative interpretation suggested by leakage and burst analyses is that there may have been 2-4 cracks separated by axial or circumferential ligaments
- Planar notch (Type 14) w/o ligament is not a good simulator of 72-72 crack

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Pressurization Rate Effect on Ligament Rupture (Burst) Pressure of Type 14 Specimen

- Slow rate tests resulted in ligament rupture but no unstable burst
  - Post-ligament-tearing tests showed lower unstable burst pressures
  - Specimens would have burst unstably with higher capacity pump
- Fast rate tests (using bladder and foil) resulted in unstable burst
  - Unstable burst occurred immediately after ligament rupture
- Rate effect (average 30% increase in ligament rupture (burst) pressure from quasi-static to 2 ksi/s) was established from the cumulative distribution of ligament rupture (burst) pressures
- Measured notch profiles significantly different from designed profile

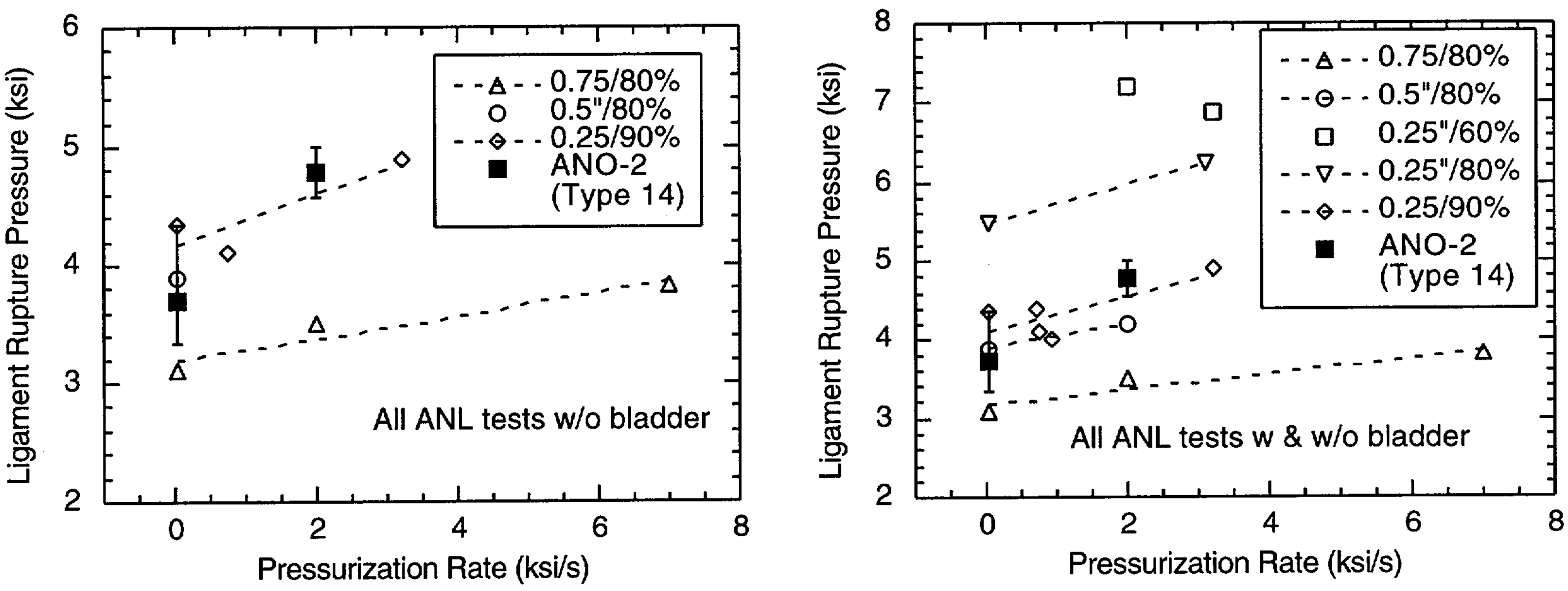
Potential Sources for Rate Effect in Type 14 Specimen

- Bladder and foil may have artificially increased burst pressures of fast rate tests.
  - General consensus is that bladder and foil effect, if any, is small.
- Systematic differences in notch profiles between slow and fast rate test specimens may have skewed the results.
  - Analysis shows that these differences may account for some of the observed "rate effect" but not all of it.
- There is a "true" residual pressurization rate effect on radial ligament rupture pressure that cannot be explained by artifacts.

Conclusions from ANL Rectangular Notch Tests

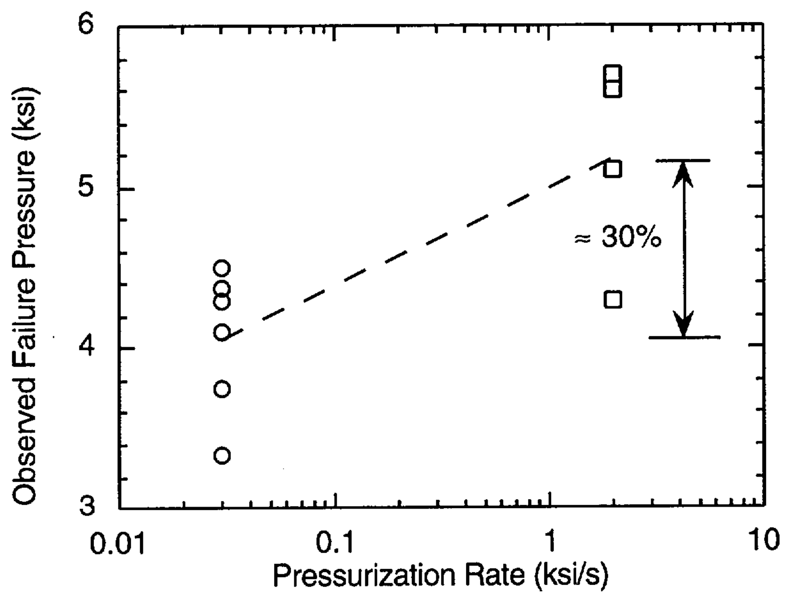
- Tests on 0.25"/90% and 0.75"/80% notches w/o bladder showed a pressurization rate effect on radial ligament rupture pressure above 1ksi/s.
  - Rupture pressure increases by ≈ 10% from quasi-static to 2 ksi/s.
- Tests on 0.5"/60% notches showed no effect of bladder (1/8" Tygon) on unstable burst pressure.
- No difference in unstable burst pressures of 0.5"/100% notches between tests using bladder with foil (0.005" brass) and bladder w/o foil.

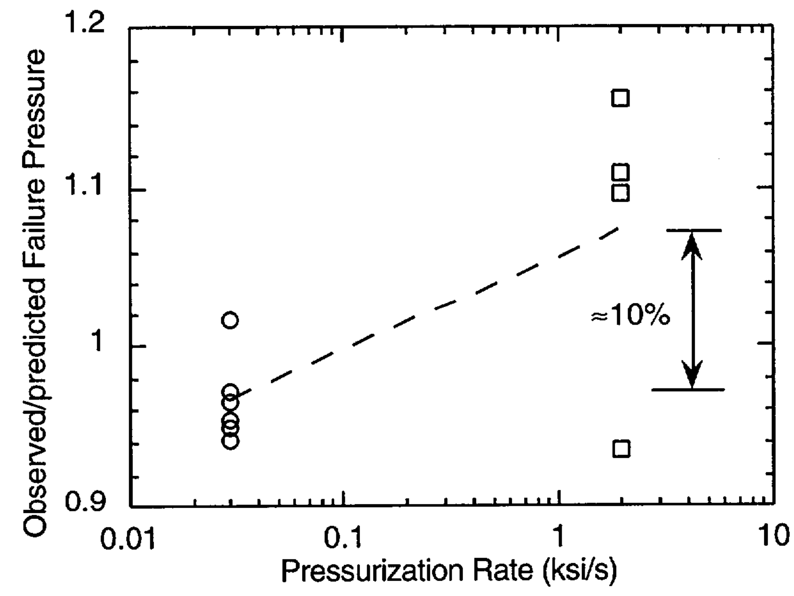
Pressurization Rate Effect on Ligament Rupture Pressure of EDM notches – Rectangular vs. Type 14



- Increase in pressurization rate from quasi-static to 2 ksi/s increases ligament rupture pressure in deep (≥ 80%), rectangular flaws by ≈ 10% and apparent ligament rupture pressure in Type 14 flaws by ≈ 30%.

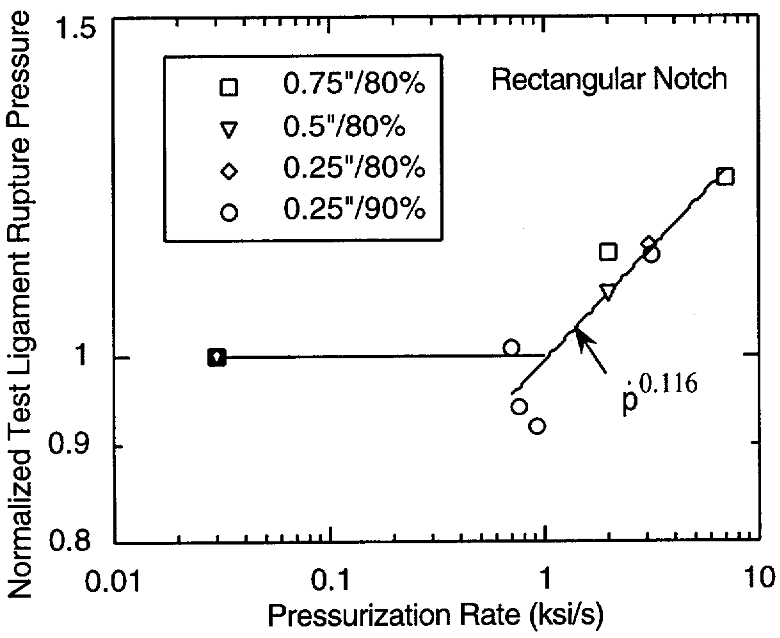
Apparent and "True" Rate Effect in Type 14 Specimens

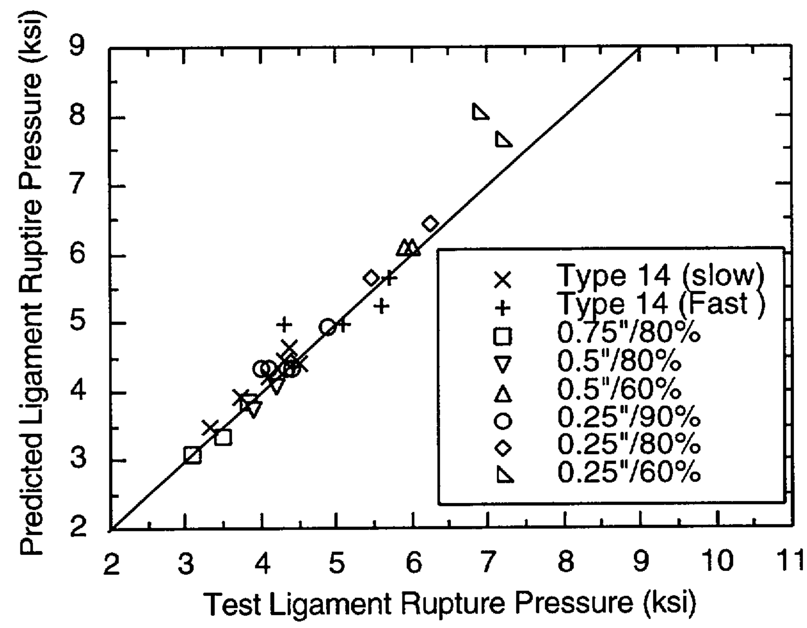




- Variation of ligament rupture pressure due to variation in notch geometry can be normalized out by plotting observed/predicted ligament rupture pressure (calculated with actual notch geometry).
- The "true" rate effect (from quasi-static to 2 ksi/s) on ligament rupture pressure is close to that observed for ANL rectangular notches (≈ 10%).

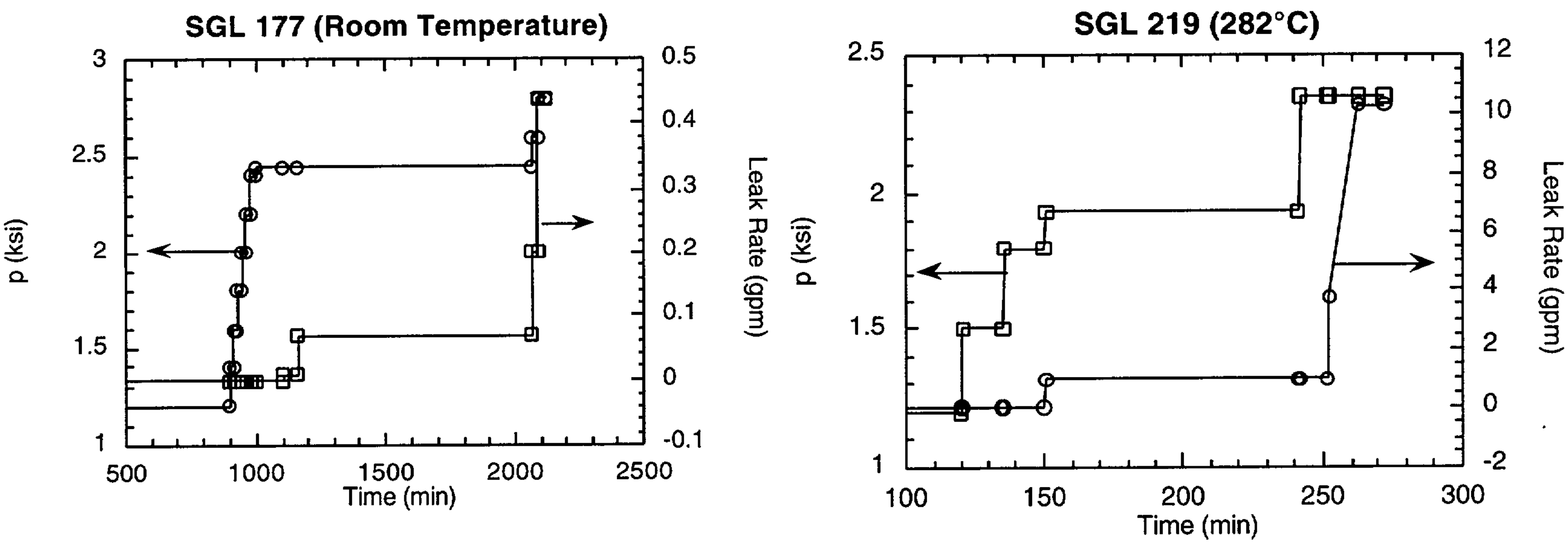
Accounting for Rate Effect in Rectangular and Type 14 Notch Specimens





- All deep rectangular and Type 14 notch radial ligament rupture pressure data can be predicted by assuming rate effect to kick in above 1 ksi/s with a pressure rate exponent of 0.116.
- More tests are needed to verify the assumption.

Time-Dependent Effects in Pressure Tests on SCC Specimens (Annealed & Sensitized) at Room Temperature and 282°C



- Sudden and/or gradual increase in leak rate under constant pressure hold
- Not all specimens show time dependent leak rate at constant pressure hold.

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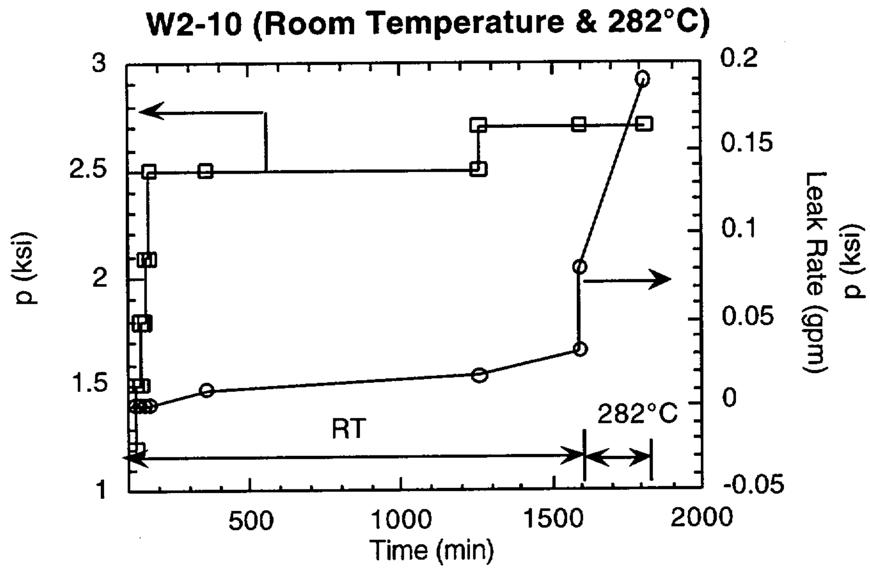
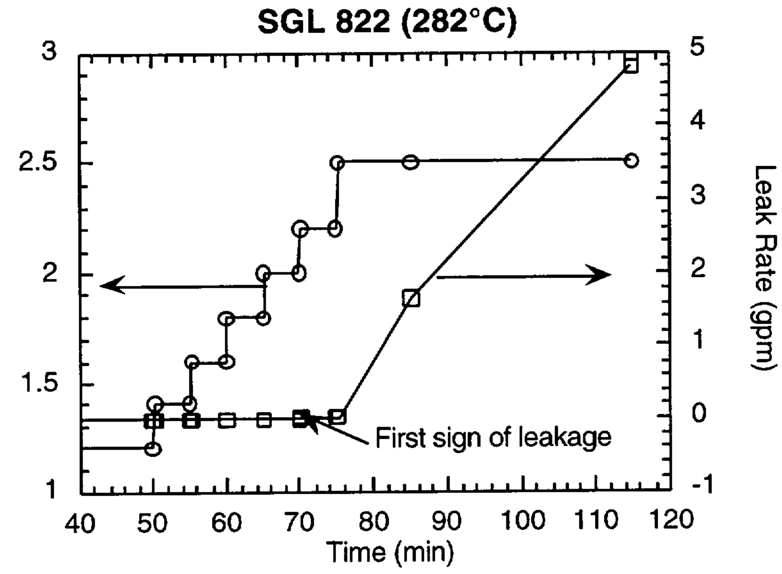
Pressure Tests on Specimens w/o Annealing Treatment





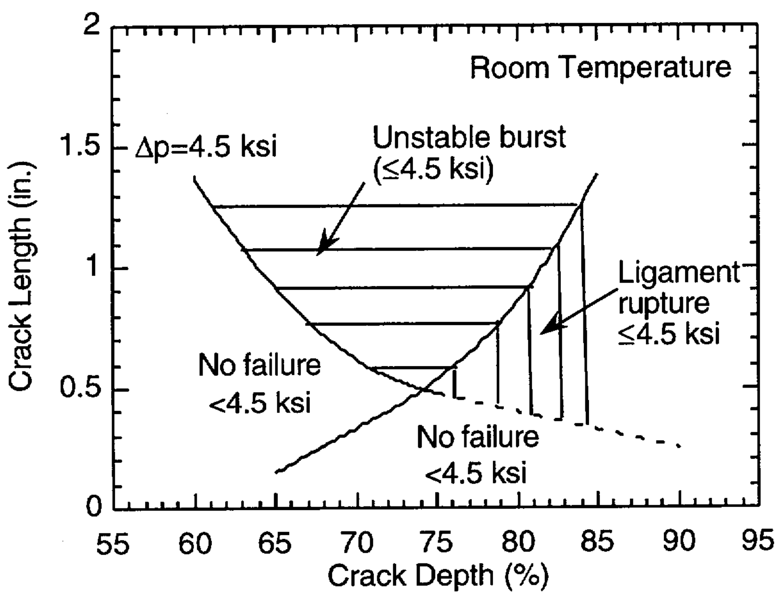
- Both the Westinghouse (doped steam) and ANL (sensitized w/o high temperature annealing) specimens leaked air at 40 psi and showed time dependent increase of leak rate under constant pressure hold during tests.
- Time-dependent ligament rupture at constant pressure suggests rate-dependent ligament rupture pressure for deeply cracked SCC specimen.

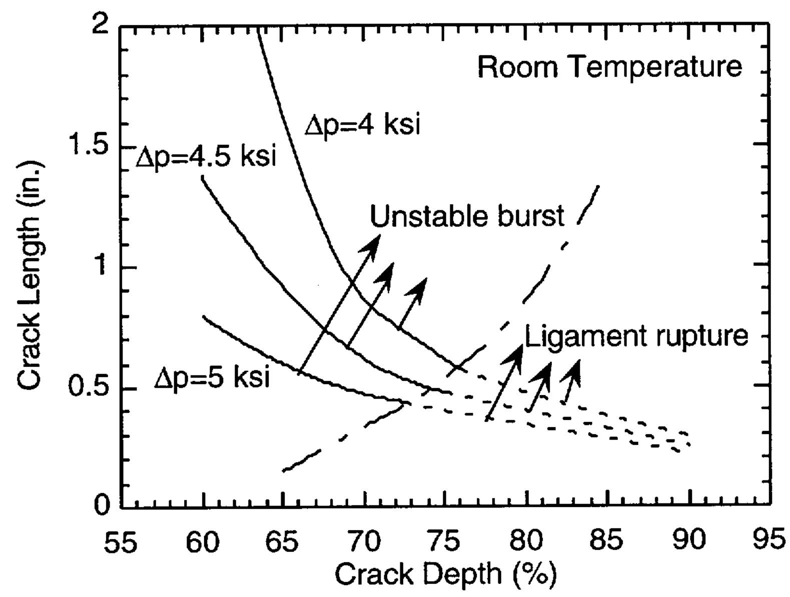
Rate Effect on Unstable Burst Pressure

- Pressure-rate-independence of voltage vs. burst pressure correlation supplied by Westinghouse is at best indirect evidence for rate independence, because data plotted have been normalized for voltage calibration and flow stress variation between USA and European countries.
  - Some data seem to consistently fall on the wrong side of correlation.
  - Unstable burst pressures for part-throughwall notches that fail unstably immediately after ligament rupture may be rate-dependent.
- Barring direct experimental evidence, rate dependence of unstable burst pressure cannot be ruled out.
  - Burst tests are difficult to conduct at low pressurization rate because bladder and foil tend to get squeezed out through the notch.

$3\Delta p_{NO}$ Tests - Ligament Rupture or Unstable Burst ?

7/8 in. OD, 0.05 in. wall thickness, S_y = 43 ksi, and S_u = 98 ksi.





- Shallow/long cracks are likely to cause unstable burst during $3\Delta p_{NO}$ test
- Deep cracks are likely to see ligament rupture w/o unstable burst unless pump has sufficient flow rate capability.

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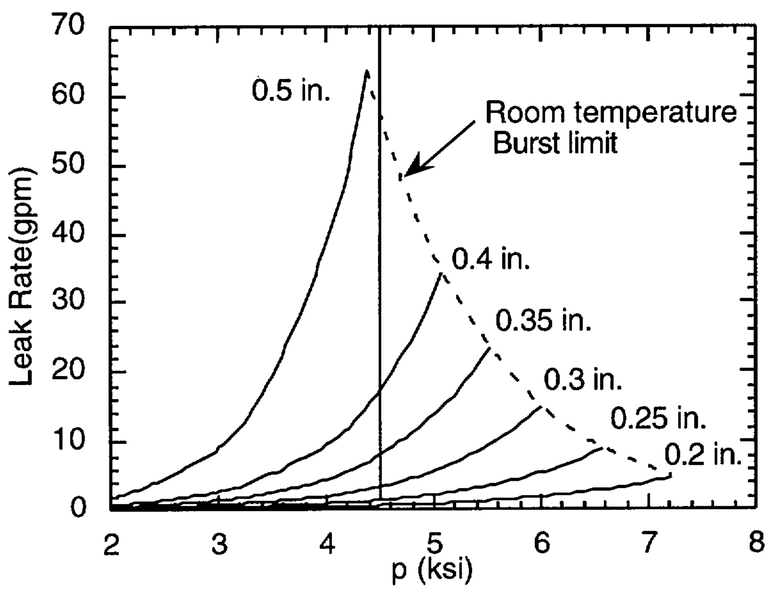
Pumping Requirements for $3\Delta p_{NO}$ Tests



7/8" OD, 0.05" wall thickness

Yield = 43 ksi

UTS = 98 ksi

$3\Delta p_{NO}$ = 4.5 ksi

- 12.5 gpm, 8 ksi pump can burst cracks that are at most 0.2-0.25 in. long.
- Throughwall cracks ≥ 0.5 in. cannot meet $3\Delta p_{NO}$=4.5 ksi criterion because of burst and flow rate limitations.
- 0.4 in. crack requires ≥20 gpm capacity pump to demonstrate compliance

Conclusions - Rate Effects

- Rate dependence of ligament rupture and burst pressures of rectangular notch is about the same as those of Type 14 specimen if specimen-to-specimen variation of notch geometry is taken into account.
- An increase of pressure rate from quasi-static to 2 ksi/s appears to cause a ≈ 10% increase in ligament rupture pressure.
- Tests on specimens with variable notch-tip ligament thickness and with multiple notches with axial and circumferential ligaments are needed to establish rate effects for ligament rupture and unstable burst pressures.
- Rate-effects could be greater for SCC specimens than EDM notches because, unlike rectangular EDM notches, specimens with deep SCC show time-dependent ligament rupture at constant pressure.
  - Incremental material damage due to high stresses in ligaments may introduce time dependent rupture processes

Conclusions – $3\Delta p_{NO}$ Tests

- Deep cracks are likely to experience ligament rupture w/o burst during $3\Delta p_{NO}$ tests.

7/8 in. OD, 0.05 in. wall thickness, $S_y = 43$ ksi, and $S_u = 98$ ksi.

- 0.5 in. long cracks >75% deep cannot meet $3\Delta p_{NO}$=4.5 ksi criterion
- To show compliance of deep cracks ≤0.4 in. long, need 20-gpm pump.

TVA

In Situ Pressure Test Guidelines Revision 1

Helen Cothron
Tennessee Valley Authority

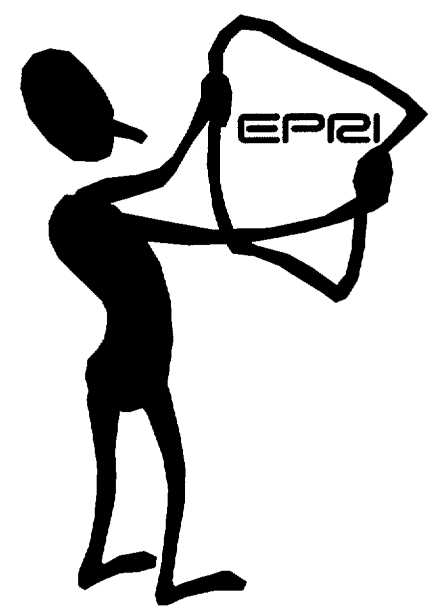
NRC Workshop
February 27-28, 2001

SG In Situ Pressure Test Guidelines

- Objective
  - Standardize approach to in situ pressure testing
    - Test objectives, procedures, and conditions
    - Screening parameters
    - Test conditions
    - Equipment requirements
  - Supplement the CM/OA process
    - Provide a direct measurement of SG tubing structural and leakage integrity for normal and accident conditions
- Background
  - Revision 1 issued June 1999
  - Ad Hoc committee being formed to write Revision 2
    - Incorporate lessons learned from recent industry events

Guidelines Format

- Section 1 - Introduction
- Section 2 - Pressure and Leak Test Objectives
- Section 3 - Compliance Responsibilities
- Section 4 - Screening Parameters/Tube Selection
- Section 5 - Test Procedure
- Section 6 - In-situ Test Conditions
    - Test pressures and adjustments
- Section 7 - Data Analysis
- Section 8 - Industry Database
- Section 9 - Reporting



Guideline Format (cont)

- Appendices
  - Appendix A - Equipment specification/Tool Qualification
  - Appendix B - Selection Protocol
    - Axial Indication
    - Circumferential Indications
    - Volumetric Indications
    - Mix Mode
    - Pitting
  - Appendix C - Statistical Screening Methodology
  - Appendix D - In Situ Pressure Testing and Leak Rate Adjustments
  - Appendix E - In Situ Testing of Indications Restricted From Burst

Pressure Test Objectives

- Demonstrate structural integrity at EOC satisfies performance criteria (e.g. 3ΔP, MSLB)
  - Provides absolute measure for CM assessments
  - All appropriate loads should be considered
- Define relationship between NDE data and structural thresholds for OA
  - Provides information to support uncertainty assumptions
  - Requires knowledge of tube material properties and operating conditions of upcoming cycle

TVA

Leak Testing Objectives

- Demonstrate leakage integrity at EOC
  - Per licensing basis and site dose assessments
- Obtain information to support NDE thresholds for accident conditions
- Provide test data to support predictions of MSLB leak rates

Selection Protocol

- Guidelines provide screening logic for selecting tubes for in situ pressure testing
  - Screening protocol for pressure and leakage testing
  - Utility is required to develop site-specific screening criteria
  - Sequential logic provided
  - Guidance on sample size as well as expansion criteria
  - Selection of candidate indications is dependent upon the capability of the NDE technique to characterize the flaw
  - Indications tested should ensure that the most limiting tubes are included from both a structural and leakage standpoint

NEI Review Board Questions/Resolutions

- Should temperature correction be applied prior to multiplying by the safety factor
  - *Response - Guidelines require increasing the test pressure by the correction first then apply the prescribed margin of safety*

- How should past in situ pressure test results be used to support/bound threshold screening values
  - *Response - In order to use past test results or test results from another plant, material and NDE uncertainties must be appropriately applied in addition to other considerations such as test pressures, flaw morphology, NDE technique, tube geometry, etc.*

TVA

SGMP Interim Guidance

- SGMP issued interim guidance October 13, 2000, on emergent issues
  - Test all indications above screening criteria
  - A minimum hold time of 2 minutes is required to verify crack stability at conditions of normal operating, limiting accident, and 3dP, regardless of pressurization rate
  - Intermediate hold pressures with the minimum 2-minute hold times at approximately every 500 psig or less, above the limiting accident differential pressure should be used to approach the proof pressure
  - Pressurization rates should be maintained less than 200 psi/sec
  - If leakage develops, insert a sealing bladder prior to raising pressure, if possible, but not before demonstrating leakage integrity at the limiting accident
  - Perform proof test even if screening criteria indicates a need for only leak testing

SGMP Lessons Learned Letter

- SGMP issued information letter concerning lessons learned from a review of recent steam generator related issues on September 29, 2000
  - Emphasized the importance of considering NDE uncertainties when selecting tubes for in situ pressure testing
  - Emphasized the need to use a bladder if leakage exceeds the pump capacity
  - Emphasized the use of the NEI Web site for posing questions about interpretation of the guidelines and for reviewing resolution of current issues

Summary

- With few exceptions guidance has been successful in test consistency and demonstration of tube integrity
- Industry proactive in dealing with emerging issues and questions
  - NEI Review Board
  - Interim Guidance
  - Lessons Learned letter

NRC Expectations for Risk-Informed Applications for ARCs, Repair Method, OAs, etc.

Steve Long, (301) 415-1077
Office of Nuclear Reactor Regulation, NRC

Steam Generator Workshop
Bethesda, Maryland
February 27-28, 2000

NRC Expectations for Risk-Informed Applications for ARCs, Repair Methods, OAs, etc.

IPEs and other PSAs for PWRs generally indicate that SGTR is a major, sometimes the dominant contributor to public health effects.

Current industry PSAs rarely include all the sequences that involve induced tube rupture probability.

The suite of DBAs in USAR Chapter 15 does not include high-pressure core melts in the containment design basis. (Event equivalent to Large LOCA with core damage is included.) So, risk of weak tubes is not fully captured by licensing basis.

NRC's policy and staff guidance is to use risk information to the maximum extent permitted by the state of the art in PRA.

- Licensee submission of risk-informed requests
- Staff use of risk information during review of deterministic requests

What are the Important Risk Sequences?

Spontaneous Tube Ruptures

(Large variations in human error modeling create large range of results)

Secondary Depressurizations (AKA Main Steam Line Breaks)

(A range of depressurization events may be required, including stuck relief valves, small pipe breaks, MSIV failures and large pipe breaks)

Primary Over-pressurizations

ATWS is only known initiator (except when tubes are near spontaneous rupture)

Severe Accidents

Pressure induced ruptures if secondary depressurizes before RCS

Thermally-induced ruptures if secondary is depressurized during occurrence of core damage

Some Thoughts About Modeling Thermally-Induced Ruptures

Cutting of adjacent tubes by gas/particulate jets from cracked tubes has recently been shown to have little effect on accident progression

However, leakage through tube cracks may affect mixing in the steam generator inlet plenum for U-tube SGs and flow to tubes in OT generators, which increases tube temperatures in a manner that cannot be adequately modeled with current knowledge and techniques. *So, SG tube leakage under accident conditions is a risk concern.*

Depressurization of the RCS through the accumulator discharge phase before core oxidation occurs has been shown to be effective in preventing creep failure of weakened tubes. *The crux is to have a means of depressurization that is reliable under the conditions that are causing the high-pressure core damage event.*

Risk-informed Submittal Contents

RG 1.174 describes 5 principles, *plus* need to consider uncertainty

1. meet current regulations (unless requesting exemption or rule change)
2. preserve defense-in-depth
3. maintain sufficient safety margins
4. keep risk increases small (ΔCDF and ΔLERF guidance, sensitive to total CDF and LERF)
5. monitor risk impact with performance measurements

plus

evaluate and consider uncertainties in analysis, including program for monitoring, feedback, and corrective action to address uncertain parameters

Risk should be addressed in an *integrated manner* as part of an overall risk management approach

Which Requests Should be Risk-Informed?

Changes that increase allowable accident leakage above 1 gpm. (Although ARCs for degradation in areas that are closely confined, such as tube sheets, may have ARC-specific leakage values calculated as if the degradation is in the free-span, this is not normally a risk-significant issue, unless actual leakage is expected to exceed 1 gpm.)

Changes in materials that would result in different behavior under severe accident conditions.

Exemptions from normal pressure capability requirements

Continued operation when operational assessments that do not meet normal deterministic criteria for continued operation without mid-cycle inspections

Do's and Don'ts

Do address LERF as well as CDF

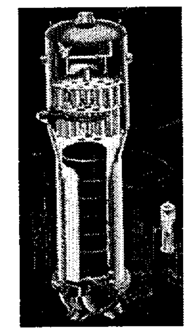
Do address PRA level 2 (accident progression) issues with respect to SG tube integrity. (That is, for accident sequences in which *core damage* is *not* dependent on tube failure, consider whether challenges to tube integrity *can* occur that would cause containment bypass.)

Don't use arbitrary definitions of LERF to exclude accidents with core damage and containment bypass from the LERF category. (If radiation releases are not of the same order as the core damage accidents with successful containment, count it as LERF, not as a contained accident.)

Don't use flaw POD estimates that are inconsistent with plant experience as the basis for risk estimates.

Do address all potentially significant physical factors that can be involved in estimating a probability. If some of those factors are not important to the quantification of the risk for the current application, state the reason. (This allows for identification of parameters that may need to be included as monitored conditions, such as flaws not extending beyond the confines of the tube support plates.)

EPRI

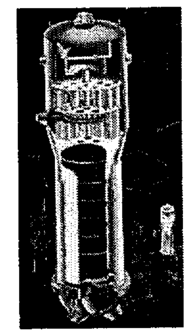


Primary to Secondary Leak Guidelines, Revision 2

Forrest Hundley
Southern Nuclear Operating Company
February 28, 2001

NRC Steam Generator Workshop

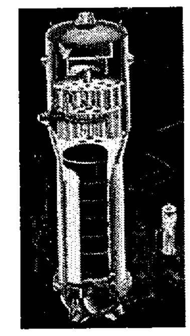
EPRI



Primary to Secondary Leak Guidelines

- Background
  - Original recommendations (Rev. 0) dated May 1995
  - Updated (Rev. 1) in November 1997
  - Revision 2 published in May 2000
  - Since Revision 0 Indian Point-2 is the only large tube leakage event that has occurred
    - Integrity Analysis
    - Improved inspection methods and NDE interpretation
    - Improved Water Chemistry Programs
    - SG Pri-to-Sec leakage guidelines provided defense-in-depth to insure leakage has a low probability of escalating to a tube rupture

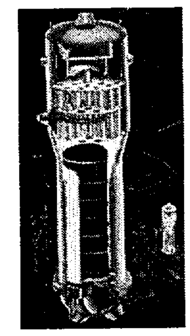
EPRI



Primary to Secondary Leak Guidelines

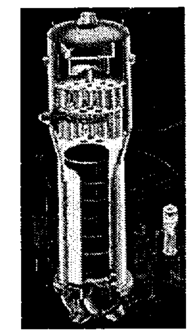
- Objective
  - A technically justified program for use by utilities to develop a station specific Pri-to-Sec leakage program
  - Reflect recent field experience
  - Reflect the issuance of NEI 97-06
  - Insure guidelines help utilities to manage small leaks
  - Insure the propagation of flaws to tube rupture is minimized under normal and faulted conditions

EPRI



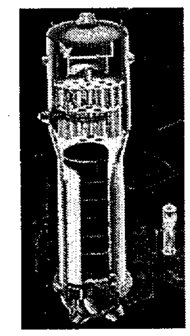
Guidelines (Rev. 2) Preparation

- Ad Hoc committee formed representing
  - 18 Utilities
  - INPO
  - 3 NSSS Vendors
- Four meetings held and draft produced in 2000
- Approval Process
  - Ad-Hoc committee
  - SGMP TSS
  - SGMP IIG
  - SGMP Executive committee



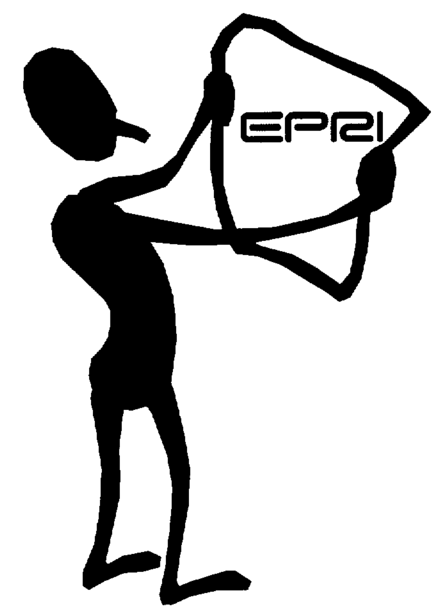
Guidelines (Rev. 2) Implementation

- Guidelines transmitted to the utilities on April 14, 2000 via cover letter signed by the SGMP Executive Chairman
  - Licensees shall implement guidelines by October 14, 2000
  - If licensees had a refueling outage within the 6 month implementation period, licensees may delay implementation by 3 months



Guidelines Format

- Section 1 - Introduction and Management Responsibilities
- Section 2 - Technical Bases for Pri-to-Sec Leakage Limits
- Section 3 - Operating G/Ls for Pri-to-Sec Leakage
- Section 4 - Continuous Radiation Monitoring
- Section 5 - Leak Rate Calculation



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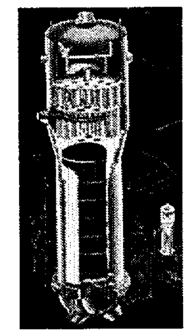
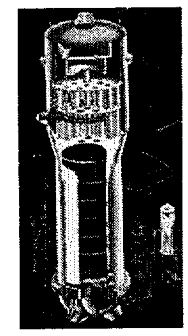


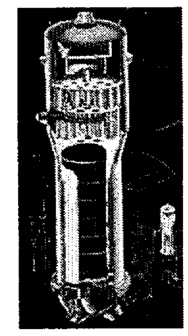
Guideline Format (cont)

- Appendices
  - Appendix A - Data Interpretation
  - Appendix B - Condenser Off Gas corrections
  - Appendix C - Leak Rate Calculation Methodology for the blowdown analysis
  - Appendix D - Pri-to-Sec Leakage Quantification during non-operating conditions
  - Appendix E - Examples of computer calculated Pri-to-Sec leak rate for condenser air ejector monitor



Key Changes to Revision 2

- Added detailed technical bases
- Increase emphasis on use of inline monitors verse grab samples
- Changed limits based on strong technical bases including new field data
  - Lowered limit for sustained leakage to 75gpd
  - Retained limit of 150 gpd for spikes
  - Lowered limit for rate of change to 30 gpd/hr and increased time to shutdown to 3 hours
- New Action Level when no on-line quantitative monitors ($\leq$ 30 gpd) are operable



IP2 Implications Relative to Rev 2

- Very low leak rate (<4 gpd) detected over the last year
- No difference between Rev 1 and Rev 2 for leakage at this level
- Guidance (in both revisions) is as follows:
  - **"Increased Monitoring" is triggered at 5 gpd**
  - **Below 5 gpd "Normal Operation" no specific actions are recommended**
- Grab samples should quantify leakage at 5 gpd
- Rad monitors should detect a 30 gpd leak

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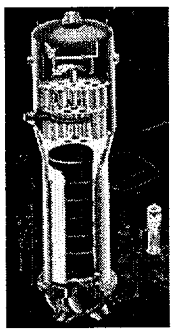

Summary

- Provides margin to the current Tech Spec leakage limit
- Leakage monitoring is not a surrogate for structural integrity
- Provides utilities with guidance:
  - To insure the propagation of flaws to tube rupture is minimized
  - To develop a technically justified Pri-to-Sec leakage program
  - To manage small leaks
  - To insure on-line leakage monitoring is both reliable, dependable and provides accurate measurements

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Attendance List for Steam Generator Workshop Rockville, MD 2/28/01

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