July 17, 1997

LICENSEE: Union Electric Company

FACILITY: Callaway Plant, Unit 1

SUBJECT: MEETING WITH UNION ELECTRIC COMPANY AND FRAMATOME TECHNOLOGIES REGARDING INSTALLATION OF FRAMATOME ELECTROSLEEVES IN THE CALLAWAY PLANT, UNIT 1 STEAM GENERATORS

On May 13 through 15, 1997, a meeting was held with Union Electric Company (UEC), Framatome Technologies, Inc. (FTI), and the Nuclear Regulatory Commission (NRC) staff, at FTI, Lynchburg, Virginia, to discuss the FTI steam generator electrosleeving process. The FTI electrosleeving process is being reviewed by the staff as part of a UEC Technical Specification Amendment request that would allow installation of FTI electrosleeves in the Callaway Plant, Unit 1 steam generators.

The focus of the meeting was the review of analysis methods and ultrasonic testing equipment pertaining to FTI's electrosleeving process.

Attachment 1 is the list of attendees. Attachment 2 is the nonproprietary version of the handout material presented at the meeting.

ORIGINAL SIGNED BY

Barry C. Westreich, Project Manager
Project Directorate IV-2
Division of Reactor Projects III/IV
Office of Nuclear Reactor Regulation

Docket No. 50-483

Attachments: 1. List of Meeting Attendees
2. Meeting Slides (nonproprietary version)

cc w/atts: See next page

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WBateman (WHB)	JStrosnider (JRS2)

DOCUMENT NAME: CALFTI.MTS *See Previous Concurrence

OFC	PDIV-2/PM	PDIV-2/LA	NRR:EMCB*
NAME	BWestreich:ye	EPeyton	JStrosnider
DATE	7/17/97	7/18/97	5/28/97

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DF01

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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cc w/atts: See next page

cc w/atts:
Professional Nuclear
Consulting, Inc.
19041 Raines Drive
Derwood, Maryland 20855

Gerald Charnoff, Esq.
Thomas A. Baxter, Esq.
Shaw, Pittman, Potts & Trowbridge
2300 N. Street, N.W.
Washington, D.C. 20037

Mr. H. D. Bono
Supervising Engineer,
Site Licensing
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

U.S. Nuclear Regulatory Commission
Resident Inspector Office
8201 NRC Road
Steedman, Missouri 65077-1302

Mr. J. V. Laux, Manager
Quality Assurance
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

Manager - Electric Department
Missouri Public Service Commission
301 W. High
Post Office Box 360
Jefferson City, Missouri 65102

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
Harris Tower & Pavilion
611 Ryan Plaza Drive, Suite 400
Arlington, Texas 76011-8064

Mr. Ronald A. Kucera, Deputy Director
Department of Natural Resources
P.O. Box 176
Jefferson City, Missouri 65102

Mr. Otto L. Maynard
President and Chief Executive Officer
Wolf Creek Nuclear Operating Corporation
P.O. Box 411
Burlington, Kansas 66839

Mr. Dan I. Bolef, President
Kay Drey, Representative
Board of Directors Coalition
for the Environment
6267 Delmar Boulevard
University City, Missouri 63130

Mr. Lee Fritz
Presiding Commissioner
Callaway County Court House
10 East Fifth Street
Fulton, Missouri 65151

Mr. Alan C. Passwater, Manager
Licensing and Fuels
Union Electric Company
Post Office Box 66149
St. Louis, Missouri 63166-6149

Mr. Garry L. Randolph
Vice President - Chief Nuclear Officer
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

ATTACHMENT 1

ATTENDEES AT MEETING ON MAY 13-15, 1997

ELECTROSLEEVING OF STEAM GENERATOR TUBES

Union Electric Company

E. Kahl
T. Herrmann

Framatome Technologies, Inc.

S. Wilson
R. Pugh
R. Schaefer

Duquesne Light Company

G. Kammerdeiner

NRC

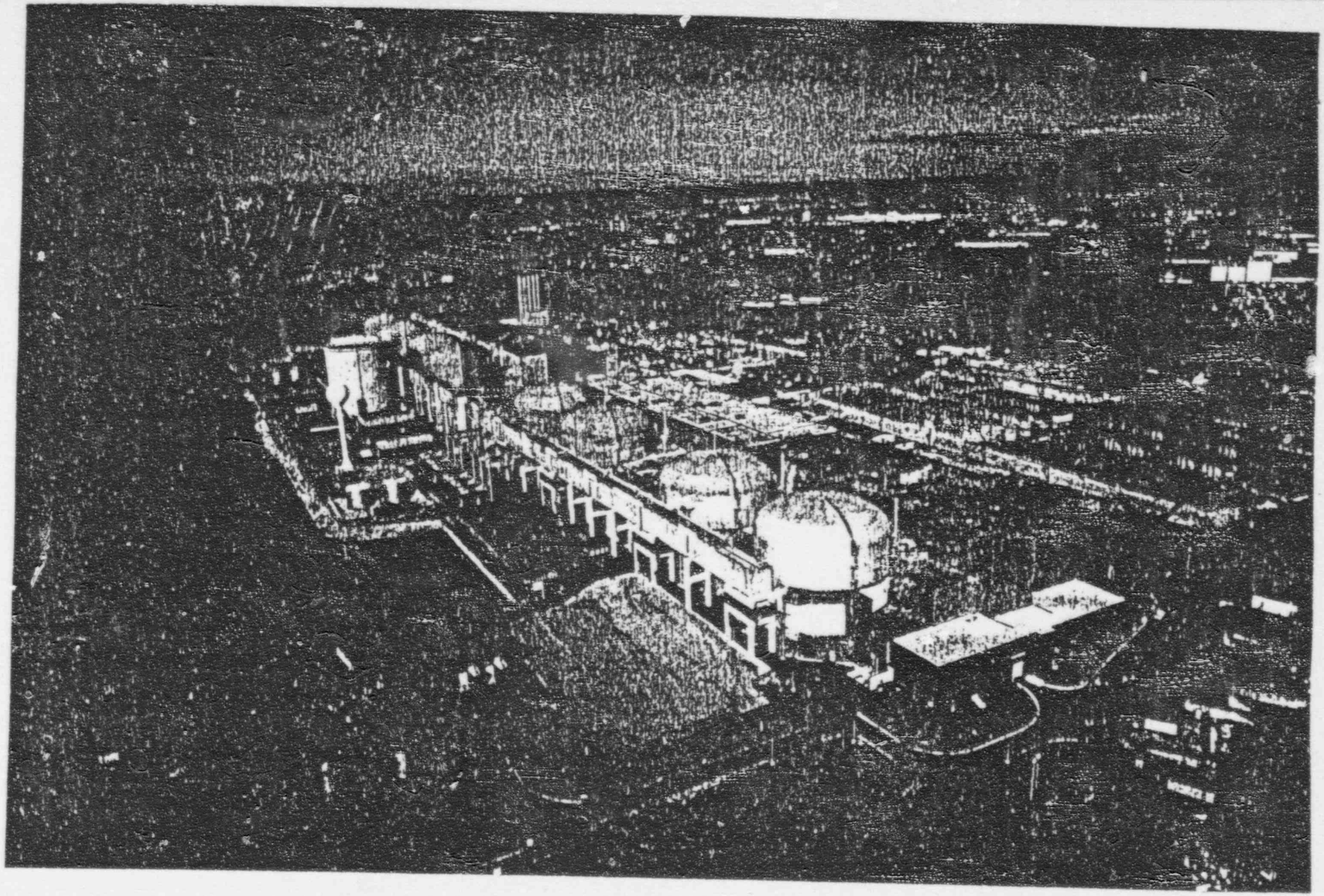
C. Beardslee
G. Hornseth

NRC Meetings/RAIs

- Union Electric Tech Spec, April 12, 1996
- Topical overview with NRC May 28, 1996
- Demonstration in Lynchburg, July 2, 1996
- Presentation Material as RAI, July 18, 1996
- BG&E Tech Spec, July 26, 1996
- RAI Response, September 24, 1996
- HL&P Tech Spec, October 28, 1996
- UT Qual. Presentation , January 15, 1997
- Response to RAI on UT, February 5, 1997
- Maine Yankee Tech Spec, March 5, 1997
- Duquesne Light Co. Tech Spec, March 10, 1997
- NRC Meeting, Maine Yankee UT Issues, March 26, 1997
- NRC Telecon, NDE/UT Review, April 14, 1997
- NRC RAI, 10 Questions, April 28, 1997
- NRC Visited OHT, May 6 - 7, 1997
- NRC Visit, NDE Discussion, FTI, May 13 - 15, 1997

FRAMATOME TECHNOLOGIES

Development of Electrosleeving as a Tube Repair for Pickering NGS "B"



NON-PROPRIETARY

Description of PNGS SG's

- 4 unit station - 500 Mw
- 12 SG/unit - 2753 tubes
- Alloy 400 - 1/2" OD
- SG - Design parameters

PRIMARY SIDE
- Pressure 1450 psig
- Temperature 521 F

SECONDARY SIDE
- Pressure 800 psig
- Temperature 521 F

Description of PNGS SG's
(cont'd)

- SG - Operating Conditions

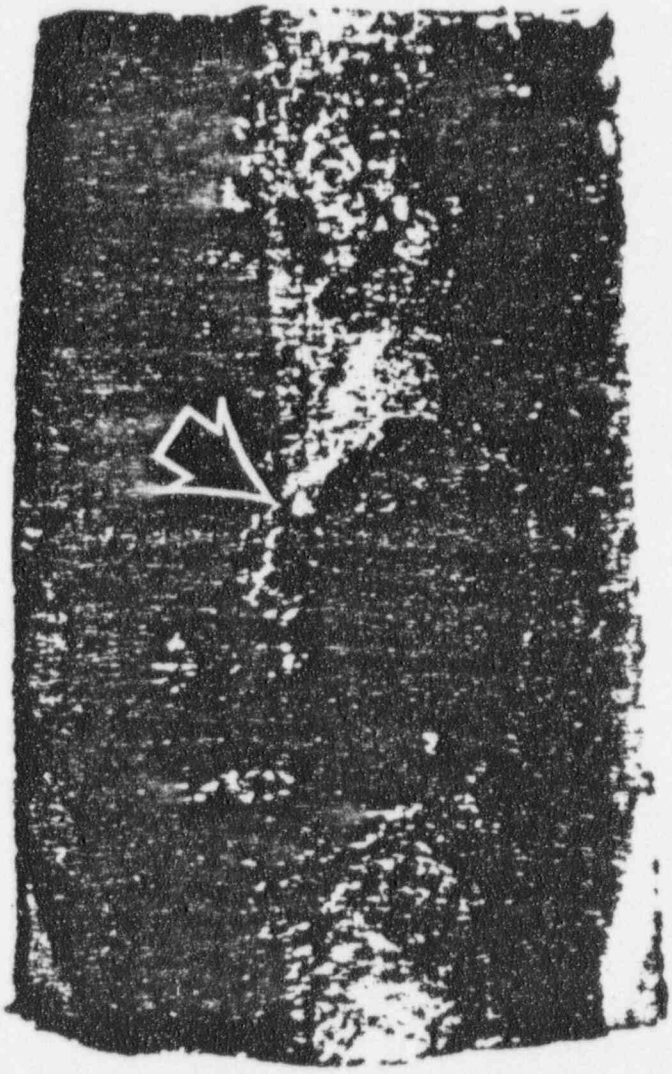
PRIMARY SIDE
- D_2O - pH 10.5 (LiOH)
- H_2 - 20 cc/kg

SECONDARY SIDE
- Cu bearing feedtrain
- Mechanical de-aeration
- Morpholine/hydrazine treatment
- ph - (8.5 - 9.5) 9.2

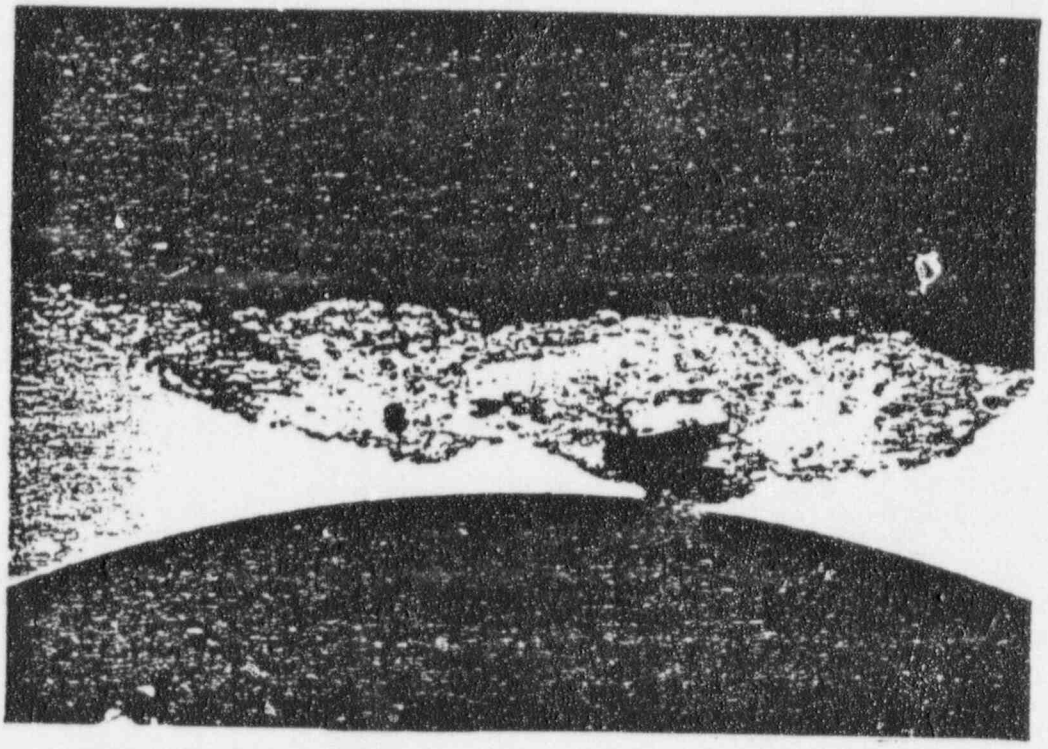
- SG - Radiation Fields
  - Operation 200 R/hr
  - Shutdown - 300 mR/hr

Background

- Pickering NGS "B"
- Unit 5 - SG tube leaks (1992)
- Localized attack
- High degree of fouling
- Operating chemistry practices
- Additional leaks - Units 5 and 6
- Large # of tubes plugged
- Need to de-rate

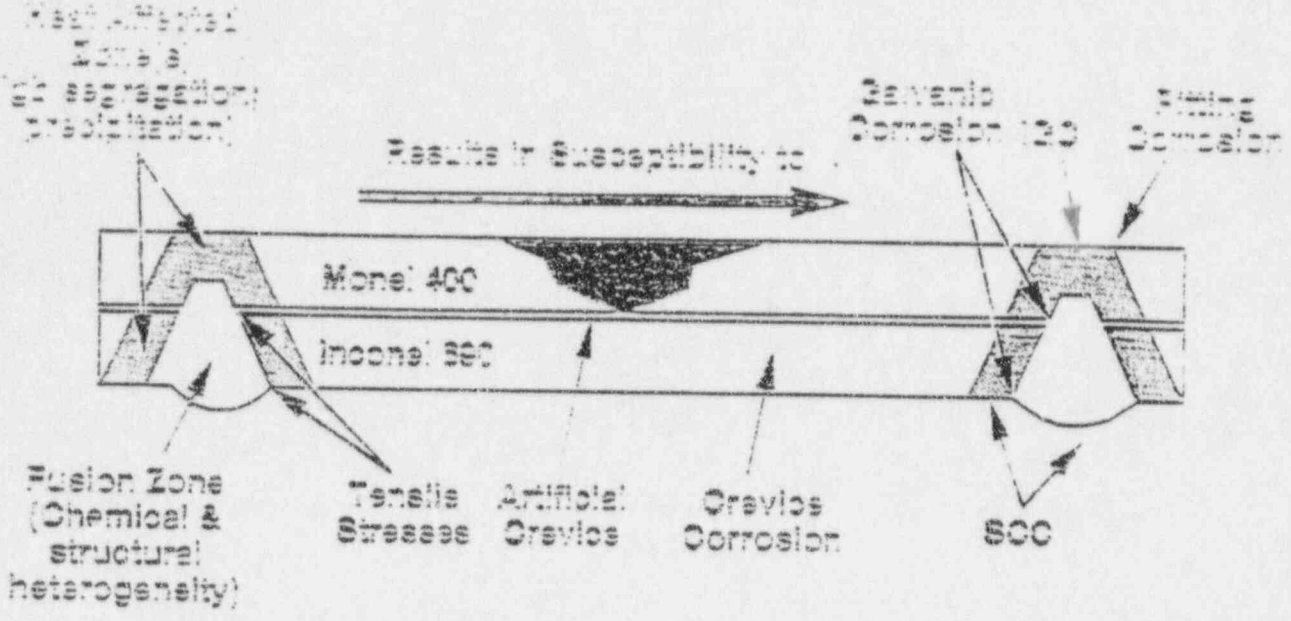


OD pit in the 'B' Monel 400

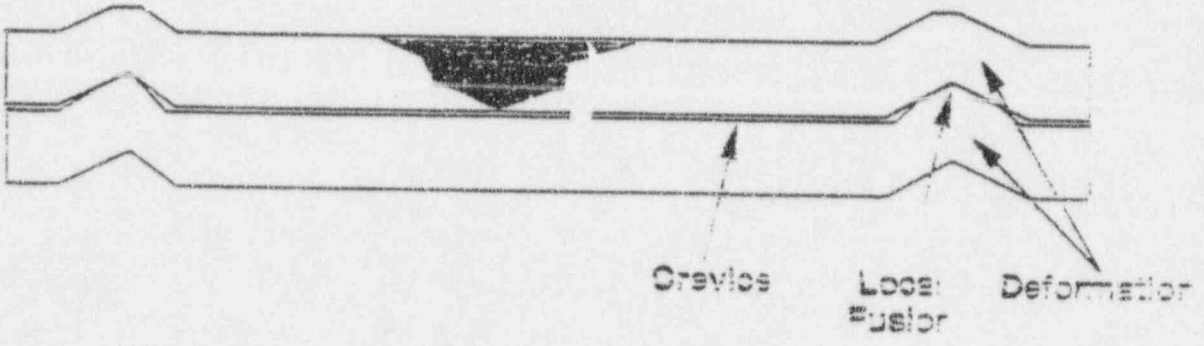


Cross-section through the pit in the 'B' alloy.

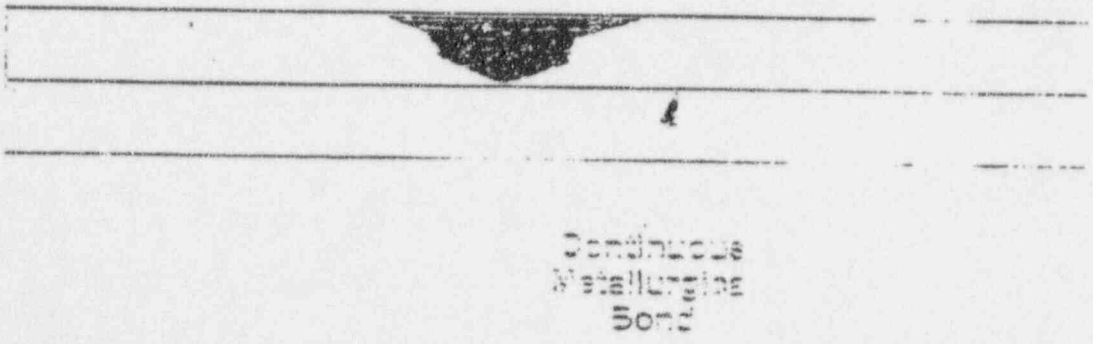
Detail of the degradation inside the pit, metal loss appears to be partly due to intergranular Corrosion.



Conventional Kinetically Bonded Sleeves



Electroformed Integral Sleeves



Results

- Total of 46 electrosleeves
  - 28 Witness
  - 18 In-steam generator
- 44 sleeves acceptable (95% success rate)
- 2 dispositioned (<5% total sleeved area disbonded)
- Witness samples were tested and met or exceeded mechanical and chemical requirements
- The remaining 14 in-steam generator sleeves possessed required properties for satisfactory service performance
- 14 electrosleeves have been in steam generator for 1 year and upon re-inspection have been found acceptable

after 1 yr

General Corrosion Testing

- ASTM G28 - "Susceptibility to JGA"
  - *No cracking*
- ASTM G35 - "Susceptibility to SCC-Polythionic"
  - *No cracking*
- ASTM G36 - "Susceptibility to SCC-Mg Cl_2"
  - *No cracking*
- ASTM G44 - "Susceptibility to SCC-NaCl"
  - *No cracking*
- ASTM G48 - "Susceptibility to pitting & crevice"
  - *No pitting*
  - *Slight C.C.*

Why 'Electrosleeve' M400 Boiler Tubes

1. Corrosion Damaged Tubes
   - Under-deposit pitting
   - Caused by aggresive (Cl^- $SO_4^=$) ion impurities, oxidizers
   - Leaks → forced outages
2. Life Management Remedial Measures
   - Cleaning
   - Cu removal
   - Optimized water chemistry
   - Enhanced inspection

   'cannot guarantee long life for all boiler tubes'
3. Options
   - Tube plugging
   - Reduce power
   - Replace boilers
   - Repair tubes

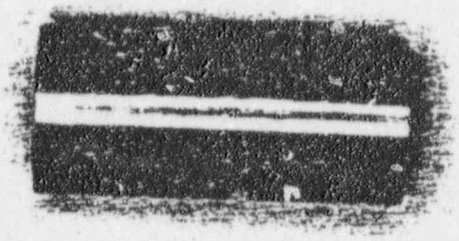
Why 'Electrosleeve' M400 Boiler Tubes

(cont'd)

4. Conventional Repair
   - 'Welded' sleeves (fusion, kinetic)
   - Established technology for (Fe-Ni-Cr) alloys
   - No experience with M400
5. Conventional Sleeving of M400
   - Kinetic: tube bulging, grain growth
   - Welding: burn-through, coring
   - Dissimilar metal welding: heterogeneity
   - Natural crevice formed: crevice corrosion
6. Pickering Monel Experience
   - P-A: 20 years service - (no serious degradation)
   - P-B: 6 years service - (leaks due to UDC)
   - UDC: deposits (CPT)
     : lake water contaminants
     : oxidizing conditions
     : alloy corrosion resistance

Advantages of Electrosleeving

- Electrosleeving can be done on small diameter tubing (1/2") as well as larger tubing.
- Electrosleeving has no adverse physical effects on tubes being sleeved (benign process).
- Electrosleeving is a continuous bond process, leaving no crevice at the ends of the sleeve between the tube and the sleeve and is therefore not vulnerable to crevice corrosion (smooth transition).
- Electrosleeving can be applied beyond (i.e. through) existing sleeves.
- Electrosleeving should be applicable in the U-bends of the tube.
- Electrosleeving can be applied in deformed tubing locations.
- Thinner sleeves can be used as a result of the superior properties of the electroformed material.



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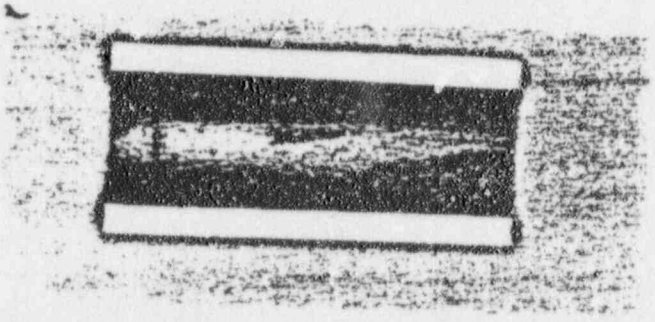
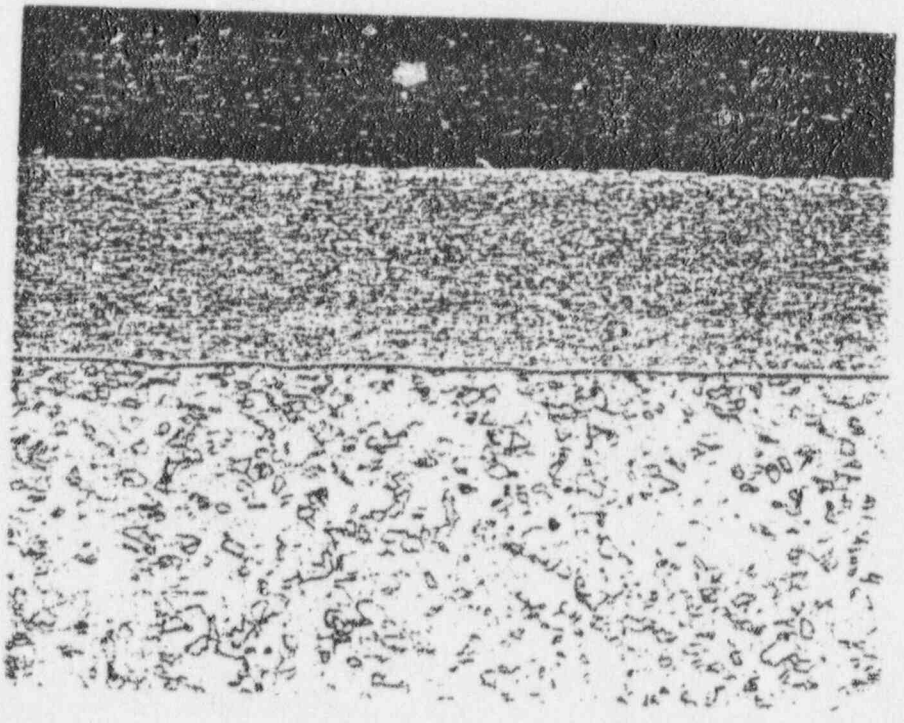
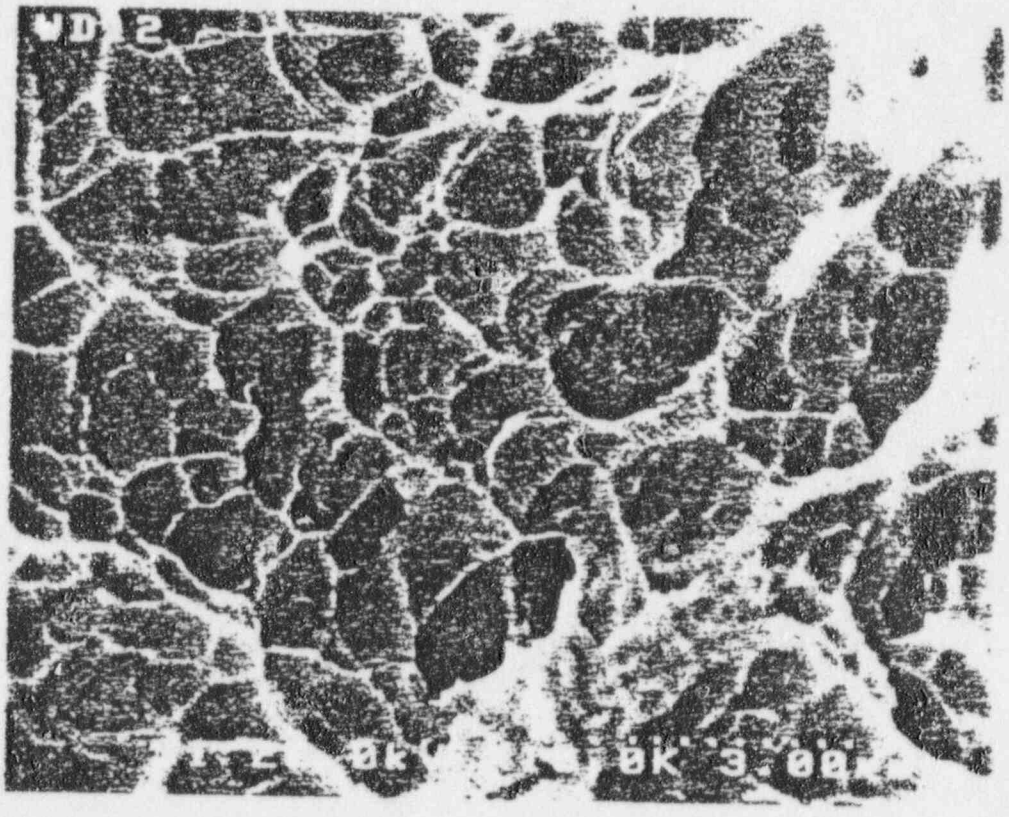


(b)



(c)

Figure 7 Electrosleeved™ specimen supplied by Ontario Hydro using a pure Nickel sleeve. (a,b) OD and ID surface appearance. (c) Optical micrograph of an axial section. Magnification: 50X.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Structural Integrity of Electroformed Ni Sleeves

(Mechanical Properties)

Microhardness	
Monel:	128-132
Ni Electrosleeve:	250-400+
Yield Strength (300°C)	
Monel:	< 30 ksi
Ni Electrosleeve	> 60 ksi
Tensile Strength (300°C)	
Monel:	< 80 ksi
Ni Electrosleeve:	> 100 ksi
Elongation	
Monel:	40%
Ni Electrosleeve:	> 15%
Adhesion (shear) Failure occurs at Monel side of couple, not interface	50 ksi
Fatigue Strength (10^8 cycles) (in air at 20°)	> 40,000 psi
Thermal cycling/aging	600 cycles/305°C

Process Description

Process Description

- Electrosleeve™ Technology based on the in-situ electroformation of a full structural/bonded sleeve on the ID of the tube spanning the defect locations(s)
- Descaling and cleaning are an integral part of the process

P8 Trial Objectives

- **Develop practical in-situ boiler experience**
- **Assess quality, reliability, repeatability under field conditions**

  → *field harden the process*

- **Obtain operating field experience**

Determine what can go wrong in field?

P8 Trial Results

- **Installed 3 sets of 4 sleeves in 2 boilers**
  - *9 in boiler*
  - *200' from rig*
  - *45' elevation*
- **UT inspection capability viable and verified by destructive examinations in lab**
- **All sleeves were defect free, showed some thickness variation and patches of surface roughness**
- **Target sleeve thickness (0.018") attained**
- **Three sleeves were well bonded to the tubes**

What Did We Learn from P8?

- Need to stiffen probe alignment
- Need to improve production rate
- Need to simplify probe installation/removal
- Local post weld heat treatment produced a very stable and adherent surface oxide layer

  → *rigorous honing required*

P1 Trial Objectives

- **To demonstrate production capability**
  - *rate*
  - *sleeve quality*
  - *equipment reliability and robustness*
- **To validate UT measurements with destructive lab evaluations**

P1 Trial Results

- Installed 2 sets of 4 sleeves in 1 boiler
  Pulled 1 tube containing 1 sleeve from each batch

- Probe installation < 15 min.
  Process time < 6 hrs.

- UT inspection of I/B tubes

  - good plating uniformity
  - defect free
  - continuous metallurgical bond in 2nd set

- Tubing in older generators has a thicker magnetite deposit which is more difficult to remove

- Lab inspection of pulled tube confirmed UT results

P1 Trial Conclusions

- Sleeve quality such that we could have left the tubes (2nd set) in service
- Process times consistent with production rate requirements for P5
- Tube cleaning requirements for P5 expected to lay between P8 and P1

Pickering NGS "B"
- Electrosleeving Qualification -

- Electrosleeving was qualified as a repair for Pickering NGS Unit 5
  - ASME B&PV code was followed
  - Testing addressed
    - *mechanical properties*
    - *corrosion resistance*
    - *inspection capability*
  - Special approval from MCCR & AECB was obtained to leave electrosleeves™ in service
  - Large database produced which established variability of critical process parameters

Electrosleeve Design Requirements
(Qualification Program)

- Produced to ASTM B689, ASTM B322 and ASTM B450
- Chem. comp. (99.5% Ni with Co, Si & C each < 0.01%)
- Dimension, surface finish and deposit character (thickness > 0.012", target 0.018")
- Yield strength (> 60 ksi at RT and 305°C)
- U.T.S. (> 120 ksi at RT and 305°C)
- Elongation (> 10% elongation in bending)
- Hardness (> 200 VPN)
- Adhesion (> 8% tensile elongation)

Electrosleeve Design Requirements (Qualification Program) *(cont'd)*

- Fatigue (high & low cycle endurance ≥ M400 ASME B & PV code, Section III)
- Thermal cycling (> 600 cycles)
- Helium leak test (<10^{-4} atm cc/s He with 1 bar He pressure in contact with the external surface at 305°C)
- Corrosion (ASTM G28-85, G35-88, G36-87, G44-83, G48-93, G61-48, capsule tests, refreshed autoclave tests

Structural Integrity of Electroformed Ni Sleeves

(Corrosion Tests)

SCC	• ASTM G35 (polythionic acid) • ASTM G36 (boiling $MgCl_2$) • ASTM G44 (NaCl)
Pitting/Crevice	• ASTM G48 ($FeCl_3$) • ASTM G61 (cyclic polarization)
IGA	• ASTM G28 (H_2SO_4 + $FeCl_3$)
Capsule	• Excellent resistance to neutral and alkaline environments
Autoclave	• Excellent resistance to: 1) non-oxidizing low pH environments 2) oxidizing & non-oxidizing neutral environments 3) oxidizing & non-oxidizing caustic environments

Corrosion Testing
(Secondary Side)

- **Sludge & faulted chemistries**
  - **Bulk fluid**
    - *Condenser leakage*
    - *Acid excursion*
    - *Caustic excursion*
  - **Sludge**
    - *Cl^-, $SO_4^=$, Na^+, HN_4^+, Cu^{++}, Magnetite*
    - *12 combinations tested*
- **Capsule tests**
  - **24 tests**
  - **Various combinations**
    - *C_nCl_n, $NaCl$, Na_2SO_4, $NaOH$, H_2SO_4, N_2H_4, Pb, O_2.*

P5 Sleeve Qualification

- Chemical composition will be established prior to and after installing each batch of sleeves
- The process parameters will be monitored independently for each sleeve during the installation
- Each sleeve will undergo non-destructive testing to determine the quality of the sleeve and its bond integrity with the host surface
- One witness tube will be produced with each batch of I/B sleeves and will undergo prompt mechanical analysis

Other Qualifications

- Application to the CSA N285.6 Materials Standards Committee to include micrograin nickel as an alternative Class 1 pressure boundary material.

- Stress/fatigue analysis to demonstrate the sleeved tubes satisfy ASME Boiler and Pressure Vessel Code, Section III for the Design, Normal and Upset and Hydrostatic conditions expected in the boiler.

Process Qualification

Purpose:

- To form electrosleeves with reproducible material/corrosion resistance properties
- To eliminate the need to test the sleeves destructively

Approach

1. To correlate changes in sleeve properties with changes in process parameters.
2. To produce sleeves under QA with fixed process parameters and subject these samples to a broad spectrum of tests using independent and certified facilities.
3. To confirm material properties using one witness sample for every 7 tubes deposited in the boiler.

Corrosion Tests

Guiding principles

- Standard ASTM tests selected to simulate expected corrosion conditions in boiler
- Tests selected to accelerate possible corrosion processes using high temperature and aggressive chemical conditions
- Tests to simulate geometry, fouling and thermohydraulic conditions in a S/G

Corrosion Tests

- Six standard ASTM tests:
  ASTM G28, G35, G36, G44, G48, G61
- 18 high temperature aqueous environmental tests investigating REDOX, stress, & chemistry known to be detrimental to nickel
- Three long term corrosion tests simulating in-boiler conditions
- Sample size
  - standard ASTM test: 20
  - capsule furnace tests: 18
  - refreshed autoclave tests: 9

Other P5 Sleeve Qualifications

- Operators will be trained and qualified on a full scale prototypic delivery system in accordance with the Sleeving Procedure Document
- Consumable supplies will be provided under the CSA Z299.2 QA Program
- I/B tube preparation will be in accordance with a qualified honing specification

Corrosion Testing
(Conclusions)

- **Primary side**
  - *No attack expected*
- **Secondary side**
  - *No attack expected*
  - *Acidic & oxidizing caused corrosion (not expected in S/G)*

Pickering NGS Unit 5 SG 12 Campaign

- April 25th - May 4th, 1994
- Campaign originally scheduled for 500-600 electrosleeves
- ECT examination results led to a reduced campaign (20 sleeves)
- Two electrosleeving rigs each capable of up to eight electrosleeves was available
- Electrosleeving rig used to half its available capability
- Full scale production of 18 electrosleeves per day
- Witness and in-steam generator electrosleeves were produced

Non-Proprietary Version

Ontario Hydro TECHNOLOGIES

Ultrasonic Inspection of Electrosleeves using TRUSTIE

D.P.Jansen, W.K.Chan, M.D.C.Moles

Ontario Hydro Technologies

E.Choi, J.Huggins

Ontario Hydro Nuclear

NON-PROPRIETARY

Ontario Hydro
TECHNOLOGIES

The TRUSTIE System*

Tiny Rotating UltraSonic Tube Inspection Equipment

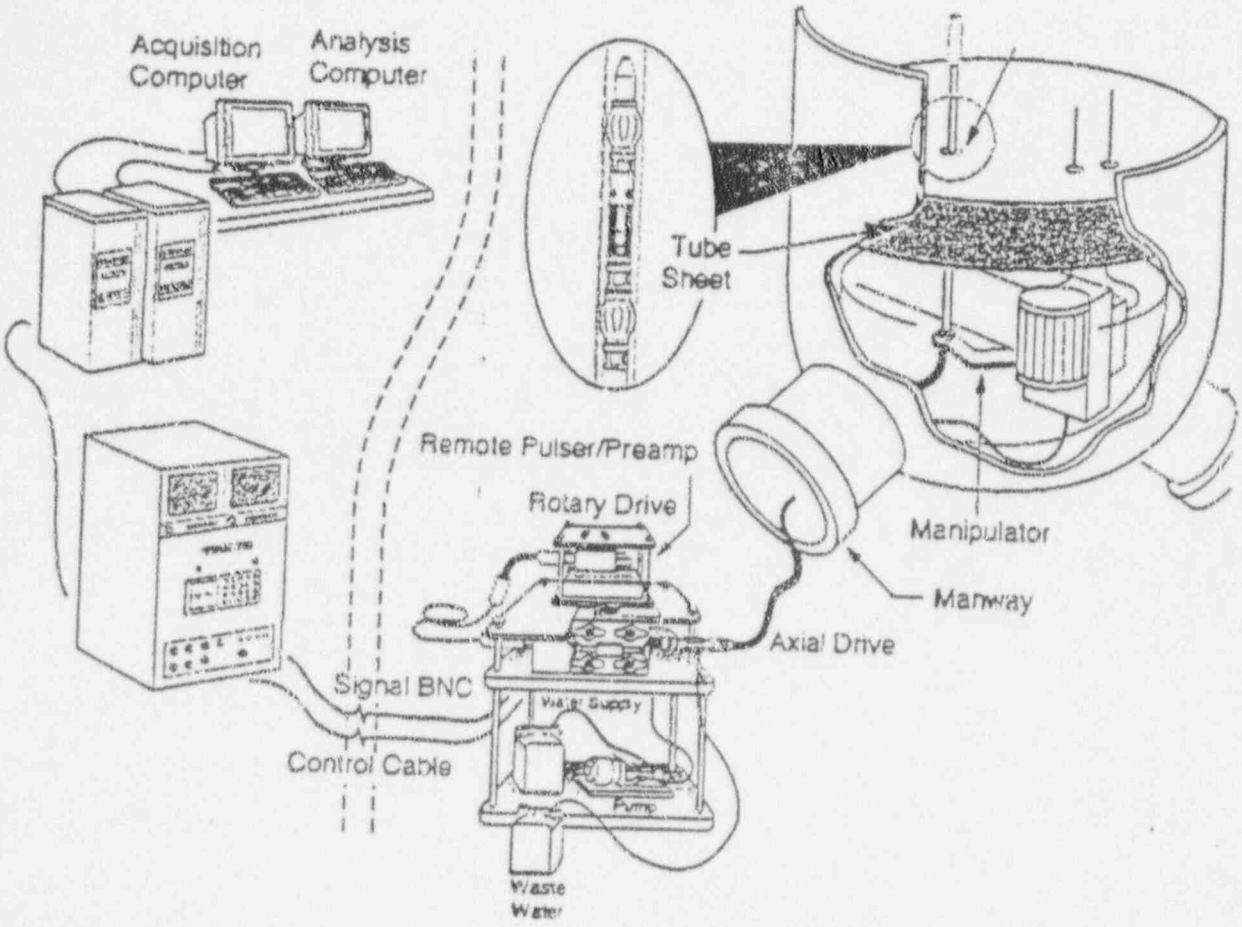
- *OHT developed and operated*
- *Designed for 0.5" OD CANDU steam generators*
- *External rotary drive / driveshaft*
- *Windows 95 based data acquisition and analysis*

TRUSTIE Specifications

- tube IDs from 0.310" to 1.3"
- tube lengths up to 50'
- ultrasonic inspection frequencies from 5 to 25 MHz
- rotation speeds up to 1000 rpm
- typical data collection speeds:
  - 600 rpm for 4 gate C-scans
  - 600 rpm for full waveform scans (at 0.2 mm by 1.5 deg. resolution)
- U-bend inspection on 16" radius for 0.5" OD tubes
- remote operation to 600'

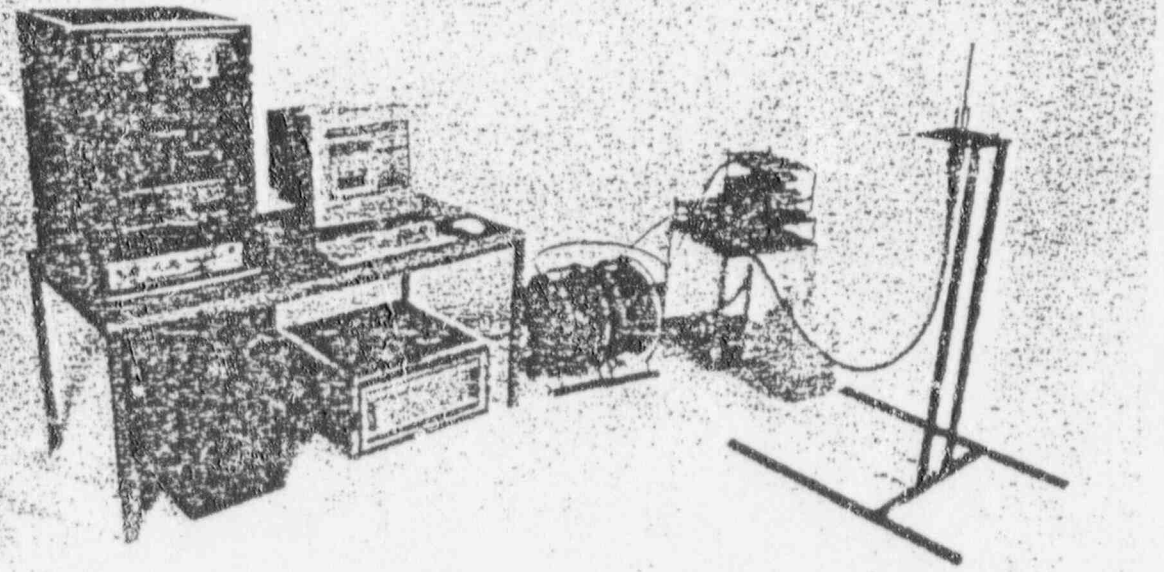
Ontario Hydro
TECHNOLOGIES

System Overview



Ontario Hydro
TECHNOLOGIES

TRUSTIE



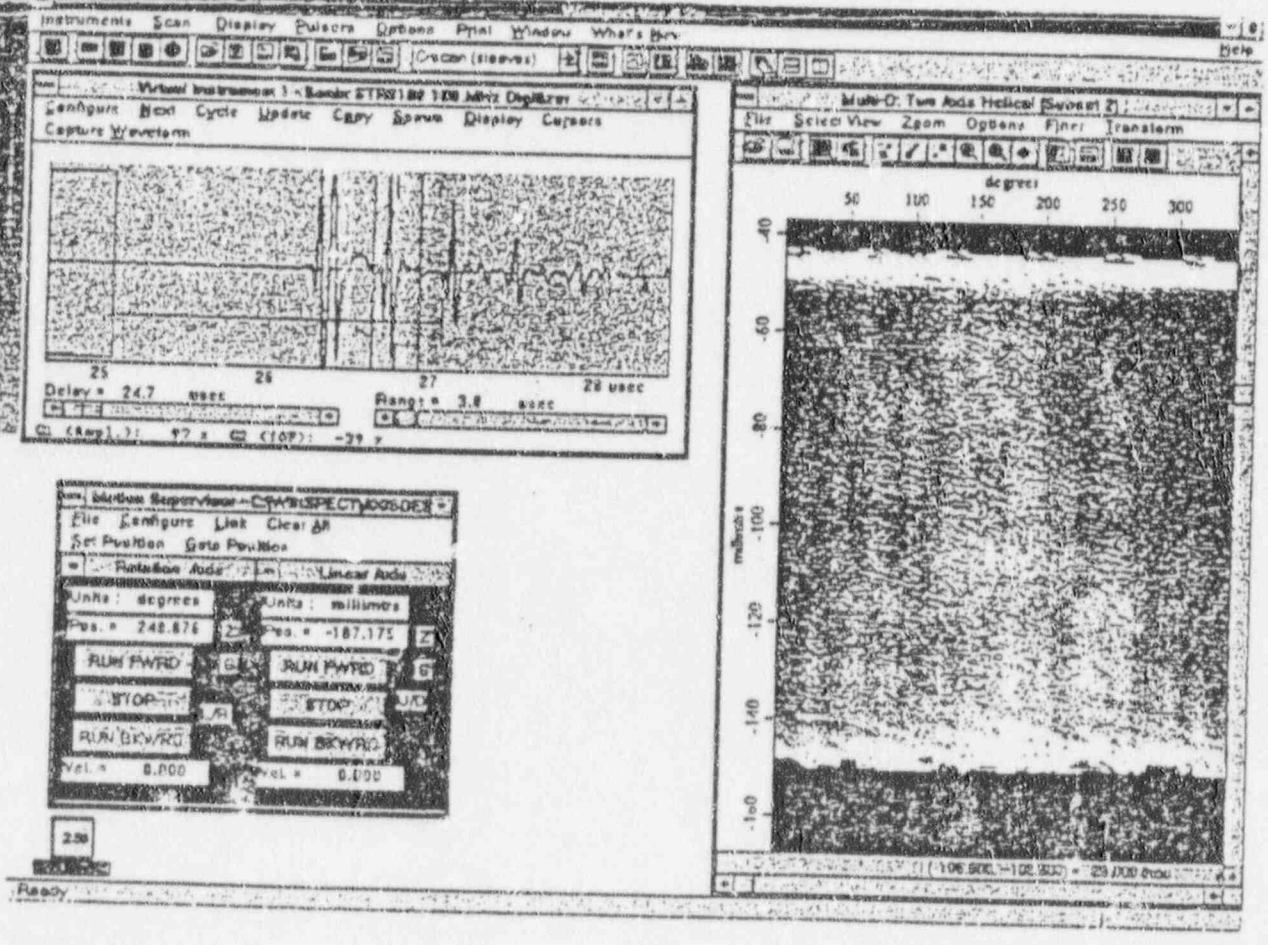
05-97

Inspection capability

- probe types :
  - normal beam (wall thickess/ profilometry)
  - axial facing shear wave (circumferential cracking+ ID profilometry)
  - multiple mode combination (normal beam + circ and axial shear waves)
  - others
- analysis methods:
  - A, B, C and waveform scans
  - line plots, colour plots, isometrics
  - echodynamics
  - integrated signal processing (e.g. filtering, spectral analysis)

Ontario Hydro
TECHNOLOGIES

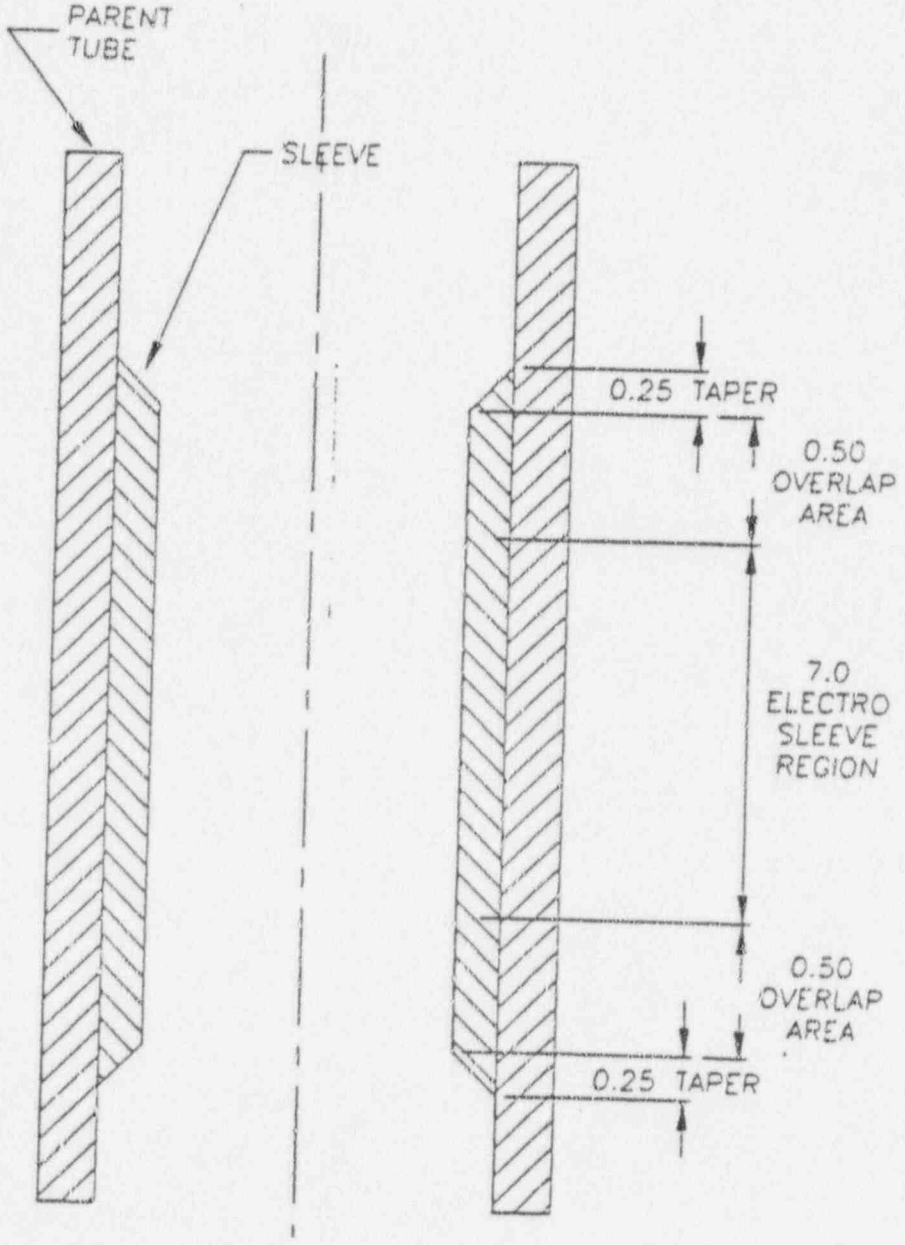
Winspect tm



- *integrated motion control, data acquisition and data analysis*

Ontario Hydro
TECHNOLOGIES

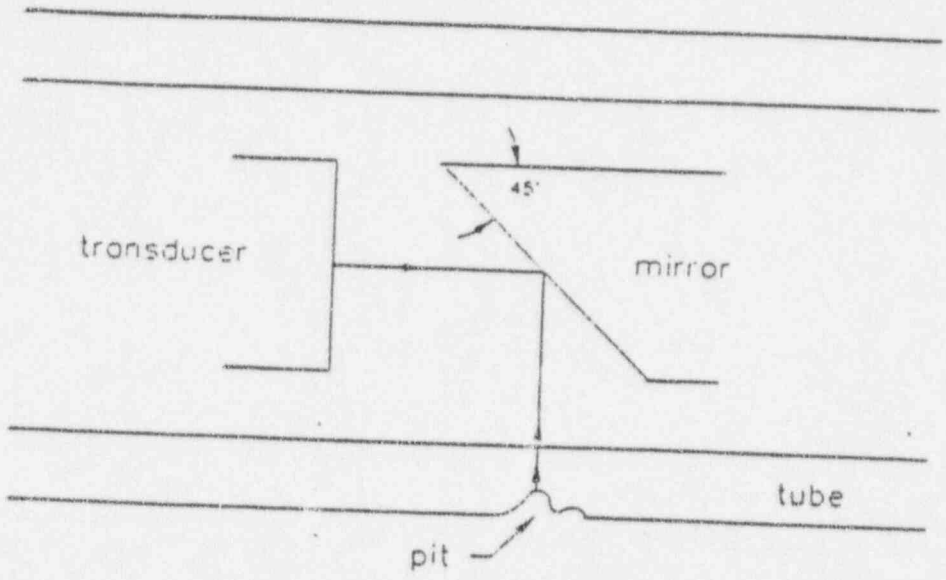
Electrosleeve Inspection

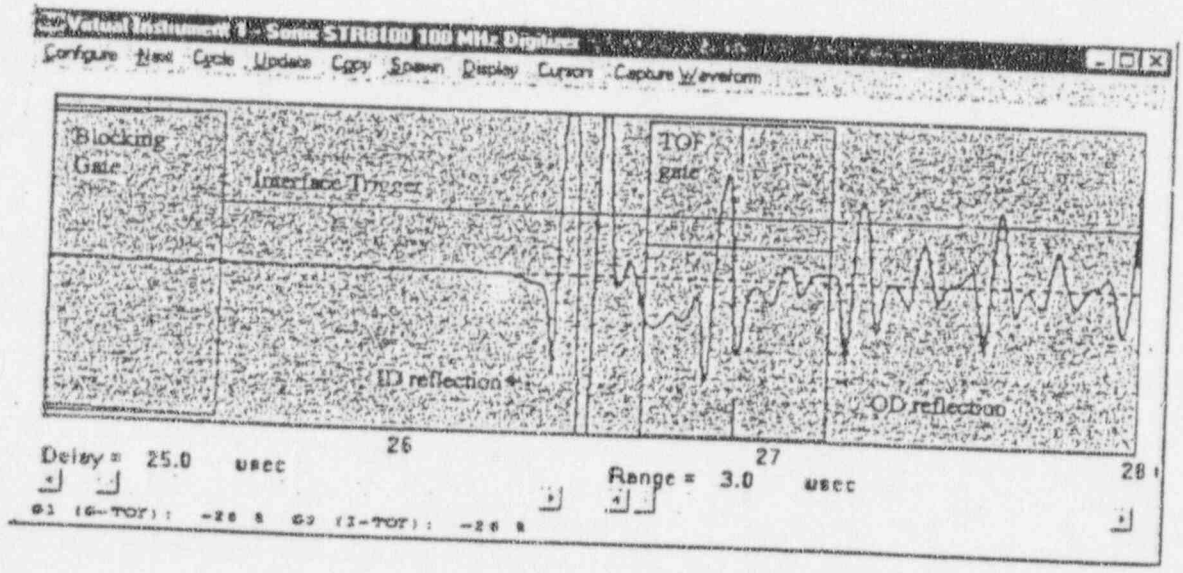


Inspection Requirements

- Nickel sleeve:
  - Thickness > 0.014"
  - Defects > 20% TW reported, any defect > 40% TW dispositioned
  - Disbonding < 5mm square in area
  - OD defect located in this region
- Overlap area of Monel Tube:
  - Defects > 20% TW reported, any defect > 40% TW dispositioned
  - No OD pits > 71% TW
  - No detectable disbonds
- Damaged area of Monel Tube:
  - OD defects monitored
  - Through wall defects acceptable

Normal beam ultrasonics





Inspection technique

- RF signal split into two channels, one 10 dB attenuated
- 4 gates:
  - OD TOF (wall thickness)
  - OD amplitude (defect detection)
  - ID TOF (ID profilometry)
  - ID amplitude (surface finish)
- Scan resolution: 1.5 degree by 0.2 mm

Inspection Procedure

- Axial B-scan encompassing sleeve and upper rolled joint
- C-scan inspection encompassing entire sleeve plus 15 mm either side
- Locate and record sleeve and parent tube defect locations
- Collect full waveforms over all noted defects
- Calibration scans at start and finish of each shift
- analysis: CGSB Level II in UT

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Inspection Qualification

- Verify size and depth of machined defects on calibration tube
- DE to verify sleeve thickness
- Cross-check of visual - UT - mechanical testing of sleeve test runs
- Independent 3rd party review of inspection system

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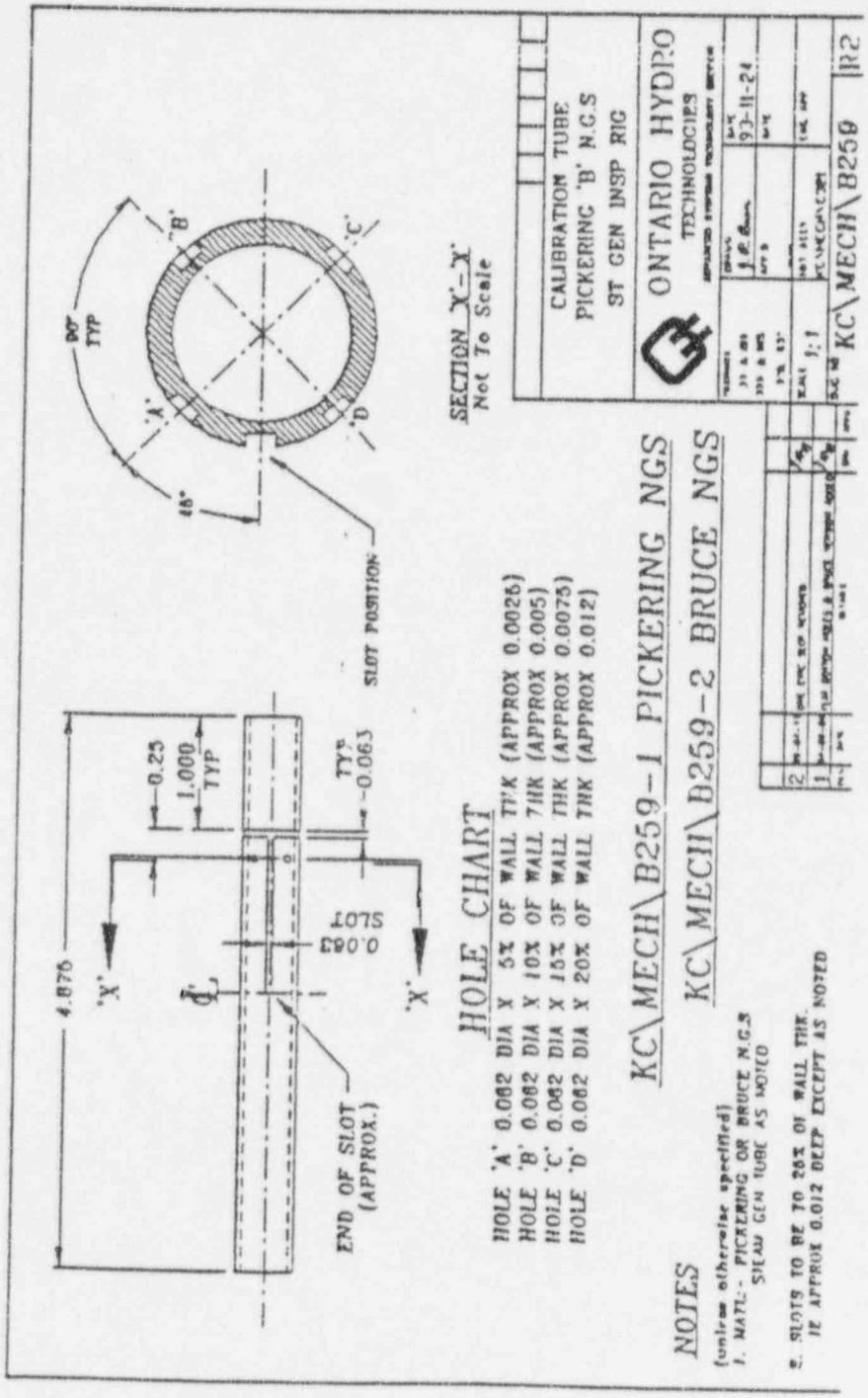
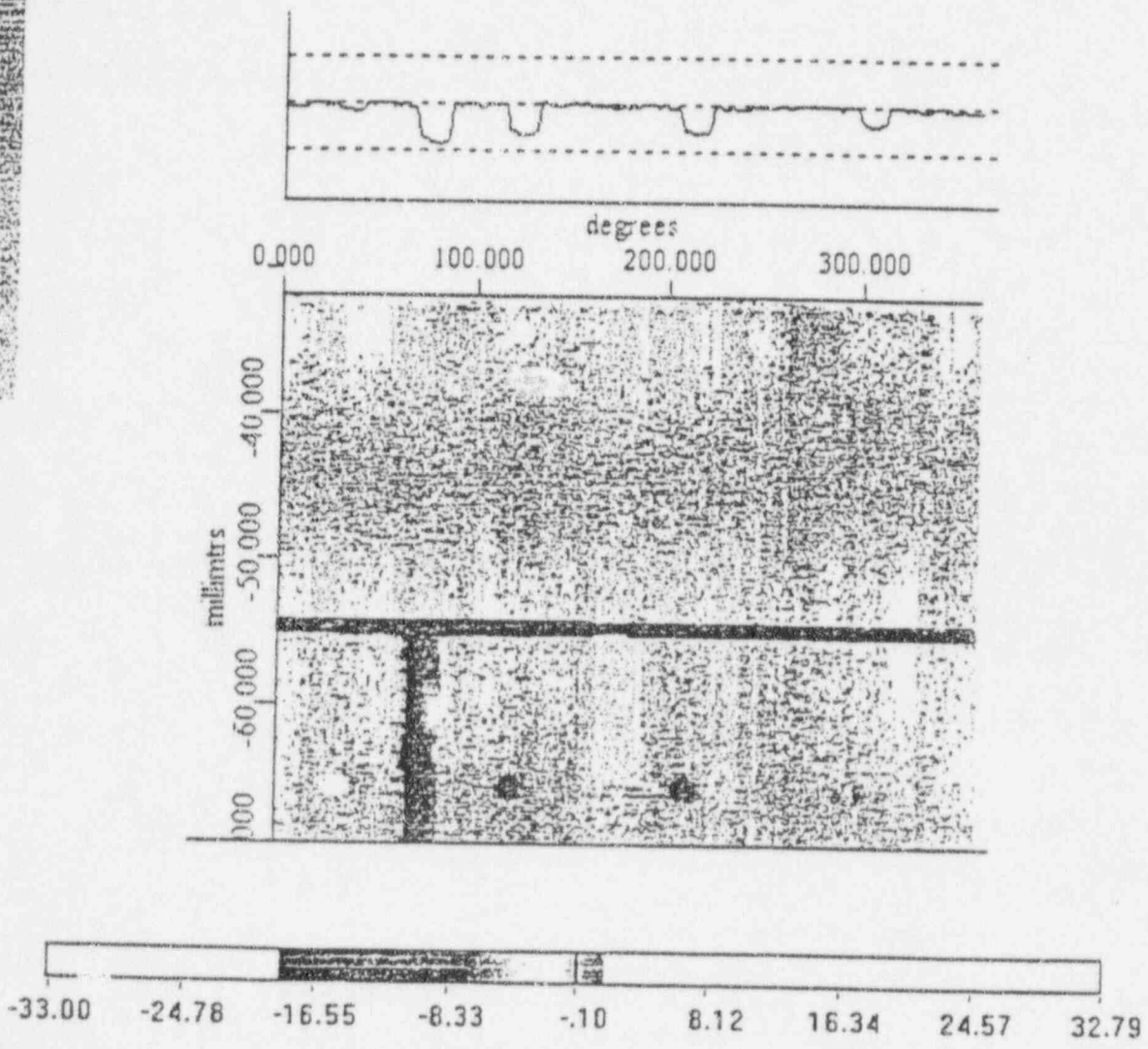
Calibration tube



Calibration tube C-scan



pit depth in thou

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Inspection Records

Pickering NGS Unit 5 Electroformed Sleeving UT Report Sheet

Tube Number (RowCol): 33 043
Batch ID number: C:\ACES\BATCH#4

Date: MAY 3/94

Ind #	Taper, upper and lower (.25"): Upper/lower(1)	Ind. type	Measurement	Overlapped, upper and lower (.2"): Upper/lower(1)	Ind. type	Measurement	Electroplating zone: HCT pit?	Thickness	Ind. type	Measurement	Saved file name
								.016/.023			B12#CL
1							yes		OD pit		B11?FW2
2							yes		OD pit		B12?FW2

Is this sleeve acceptable ? (Y/N) : YES

TOP OF SLEEVE - 599
SLEEVE LENGTH - 206

If not acceptable, which indication(s) caused the rejection : ____________

Notes :

1. Ind. type description includes : OD, ID, pk, LOB (lack of bonding), nodule
2. Indication measurement description includes : mm (mm x mm), % TW (thru wall), % ST (from thickness)
3. Sleeve thickness description should be in inches, eg. .015".
4. HCT pit confirmation should indicate inches from top of electroplated zone.

Analyzed by : W. K[illegible]

Crew Supervisor : ____________

Sleeve Re-inspection

Formation of Unbonded Area

Unbonds Left in Service

May 13-14, 1997 Meeting Information