March 25, 1997

See Reports

LICENSEE: Pacific Gas and Electric Company

FACILITY: Diablo Canyon Nuclear Power Plant

SUBJECT: SUMMARY OF MEETING HELD ON NOVEMBER 20, 1996 WITH PG&E AND WESTINGHOUSE TO DISCUSS STEAM GENERATOR TUBE SUPPORT PLATE ISSUES AND ALTERNATE REPAIR CRITERIA

The NRC staff met with representatives of PG&E and Westinghouse on November 20, 1996, in Rockville, Maryland to discuss steam generator alternate repair criteria (ARC) and tube support plate (TSP) issues. Enclosure 1 contains the list of attendees at this meeting. Enclosure 2 contains the non-proprietary handouts used by the licensee for their presentations.

The first topic discussed was related to an ARC called W* (W-star) for steam generator tube degradation existing within explosively-expanded tubesheet expansions. The basis for the proposed tube repair criteria is similar to that for the F* ARC approved for a number of Westinghouse plants with mechanically rolled tubesheet expansions. Due to the similarities between W* and F*, the NRC informed PG&E that its review would focus, in part, on the areas addressed in F* license amendment applications.

The second topic of discussion during the meeting involved the influence of a corrosion product build-up on the structural behavior of TSPs and its effect on tube structural and leakage integrity. Westinghouse suggested that the locking of the TSPs from corrosion products could decrease the potential for tube burst or leakage during normal operating and accident conditions. Therefore, an ARC for degradation within TSPs could potentially rely, in part, on the additional structural restraint provided by the build-up of corrosion products in TSP crevices. The NRC staff noted that such an approach involves policy implications that would need to be addressed prior to commencing any technical review. The licensee was subsequently informed that the staff would not be amenable to an approach that relies on corrosion product build-up.

ORIGINAL SIGNED BY
Steven D. Bloom, Project Manager
Project Directorate IV-2
Division of Reactor Projects III/IV
Office of Nuclear Reactor Regulation

Docket Nos. 50-275
and 50-323

Attachments: 1. List of Attendees
2. Handout

cc w/atts: See next page

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DATE	3/21/97	3/21/97	3/20/97

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

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Attachment 1

MEETING WITH PACIFIC GAS AND ELECTRIC

STEAM GENERATOR ALTERNATE REPAIR CRITERIA AND TUBE SUPPORT ISSUES

ATTENDEES

November 20, 1996

PACIFIC GAS & ELECTRIC COMPANY

Chris Groff
Bob Exnor
Henry Thailer
Roger Johnson
John Arhar

TENNESSEE VALLEY AUTHORITY

David Goetcheus
David Hughes

DUQUESNE LIGHT

Rich Bologna

SOUTHERN CALIFORNIA EDISON COMPANY

Allen Matheny

PUBLIC SERVICE ELECTRIC & GAS COMPANY

Joseph Moaba
Dean Alexander

WESTINGHOUSE

Richard Smith
Tom Pitterle
Rob Wepfer
Jerry Lilly

McGRAW-HILL

David Stellfox

FRAMATOME TECHNOLOGIES

Jeffrey Fleck

NJ DEP

Ariadni Kapsalopouloui

EPRI

Bob Thomas

NRC

Steven Bloom
Ed Sullivan
Phillip Rush
Ken Karwoski
John Tsao
Jai Rajan
Staphanie Coffin

NRC/Utility Meeting on
Model 51 SG Tube Integrity and ARC Methodology

November 20, 1996

AGENDA

Topic	Presenter	Time
Meeting Purpose and Objective	PG&E/TVA	10
W* ARC		
• W* Criteria and Overview	Pitterle	35
• W* Length Basis	Wepfer	20
• SLB Leak Rate Methodology	Lilly	30
Limited SLB TSP Displacement with Packed Crevices		
• Summary of Submitted WCAP-14707	Pitterle	10
• Local TSP Structural Analyses	Smith	30
- Hot to Cold Condition		
NDE Uncertainty for Sizing Axial PWSCC at Dented TSPs	Pitterle	40
• Pulled Tube and Laboratory Specimen Data		
• NDE and Destructive Exam Depth Profiles		
• Edge Effects and Adjustment Procedure		
• NDE Uncertainty - length, avg. depth, max. depth		
ARC Concept - Axial Cracks at Dented TSPs	Pitterle	15
• Negligible TSP Displacement		
• ARC Concept		
• SLB Leakage Analysis Basis		
Discussion	All	15

W* ARC and Overview

NRC/Utility Meeting

November 20, 1996

Presented By:

T. A. Pitterle

Nuclear Services Division

Westinghouse Electric Corp.

Discussion Topics

General Approach

W* Tube Repair Criteria

- Repair basis
- Inspection requirements

W* SLB Leak Rate Evaluation

WEXTEX Inspection Results and Growth Rates

NDE Uncertainties

Conservatisms in W* Criteria

Elements of ARC for Tubesheet Region

W* Builds Upon Fundamental Basis for L* ARC

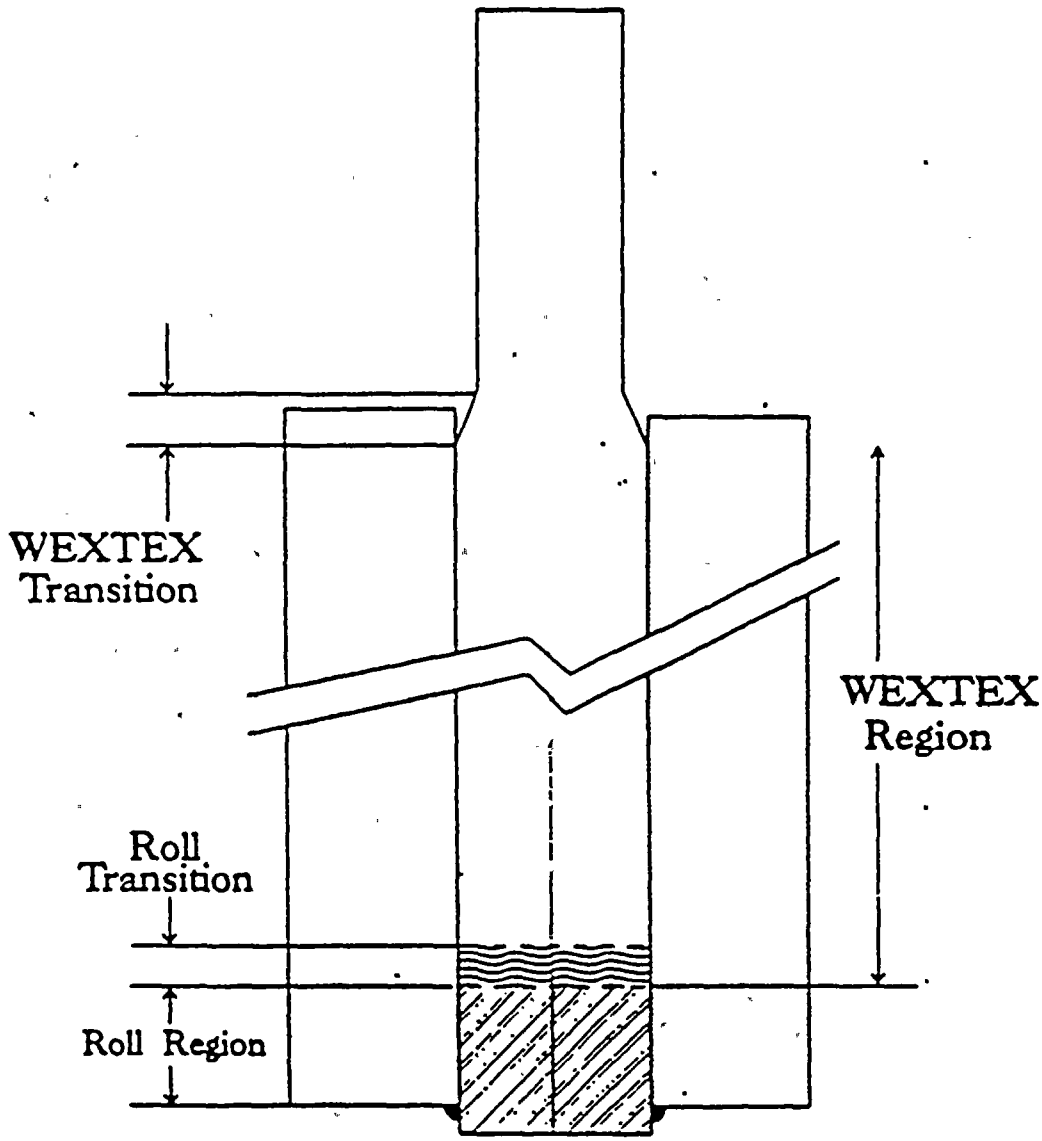
- Basic principles of L* applied, differing primarily in method of leak rate evaluation
- Pullout load reaction lengths (W* lengths) are dependent upon the type of tubesheet joint

Elements of Repair Criteria

- Pullout load reaction length
  - Flexible W* distance dependent upon length of degradation
  - Undegraded lengths below BWT must sum to W* distance
- Allowable tube degradation
- SLB leak rate evaluation

Principle Differences Between L* and W*

- W* lengths > hardroll lengths due to lower WEXTEX contact pressure
- L* undegraded length of about 0.5" below BRT not applied to W* as not applicable to limit leakage to negligible levels
- Allowable degradation within W* distance simplified compared to L*
  - Closely spaced, multiple cracks not found in WEXTEX expansions



Regions in the WEXTEX Full Depth Tube-to-Tubesheet Expansion

General Approach to ARC Within Tubesheet Region

Provide for Disposition of Indications Found by Bobbin or RPC Inspections

Tube Must be Capable of Withstanding Axial Pullout Forces

- RG 1.121 criterion for $3\Delta P_{XO}$ is generally limiting
- Pullout force resistance is sum of: WEXTEX expansion + thermal expansion + pressure differential + tubesheet bow

W* Distance of Undegraded Tubing Below BWT

- Flexible distance such that tube to tubesheet contact forces prevent pullout of a postulated severed tube below this distance

Cracks Within Tubesheet Cannot Burst Due to Tubesheet Constraint

- Axial crack length limits not required for W*

Pullout Distance and Leakage Restriction Models Supported by Tests for Prototypic Expansions

W* Tube Repair Criteria

Any Tube Degradation Acceptable Below Flexible W* Distance

- Minimum W* distances below BWT ($3\Delta P_{NO}$ R.G. 1.121 Guideline)
  - Zone B: 6.4" hot leg
  - Zone A: 5.0" hot leg

- Minimum W* lengths increased by:
  - Uncertainty in W* NDE length measurement relative to BWT
  - Sum of overall axial crack length within flexible W* distance
    - Crack lengths increased by uncertainty in NDE length measurement and crack growth

Axial Indications Within W*

- Crack tip must be below BWT by allowances for:
  - NDE uncertainty on distance between BWT and crack tip

- Multiple axial cracks must be circumferentially separated such that the RPC amplitude returns to null between indications
  - Bands of unresolved axial ind. require repair unless confirmed to be separate axials with no circumferential involvement by UT inspection

- Axial cracks must be inclined < (45°-NDE unc.) from tube axis where NDE uncertainty applies to measurement of the crack angle

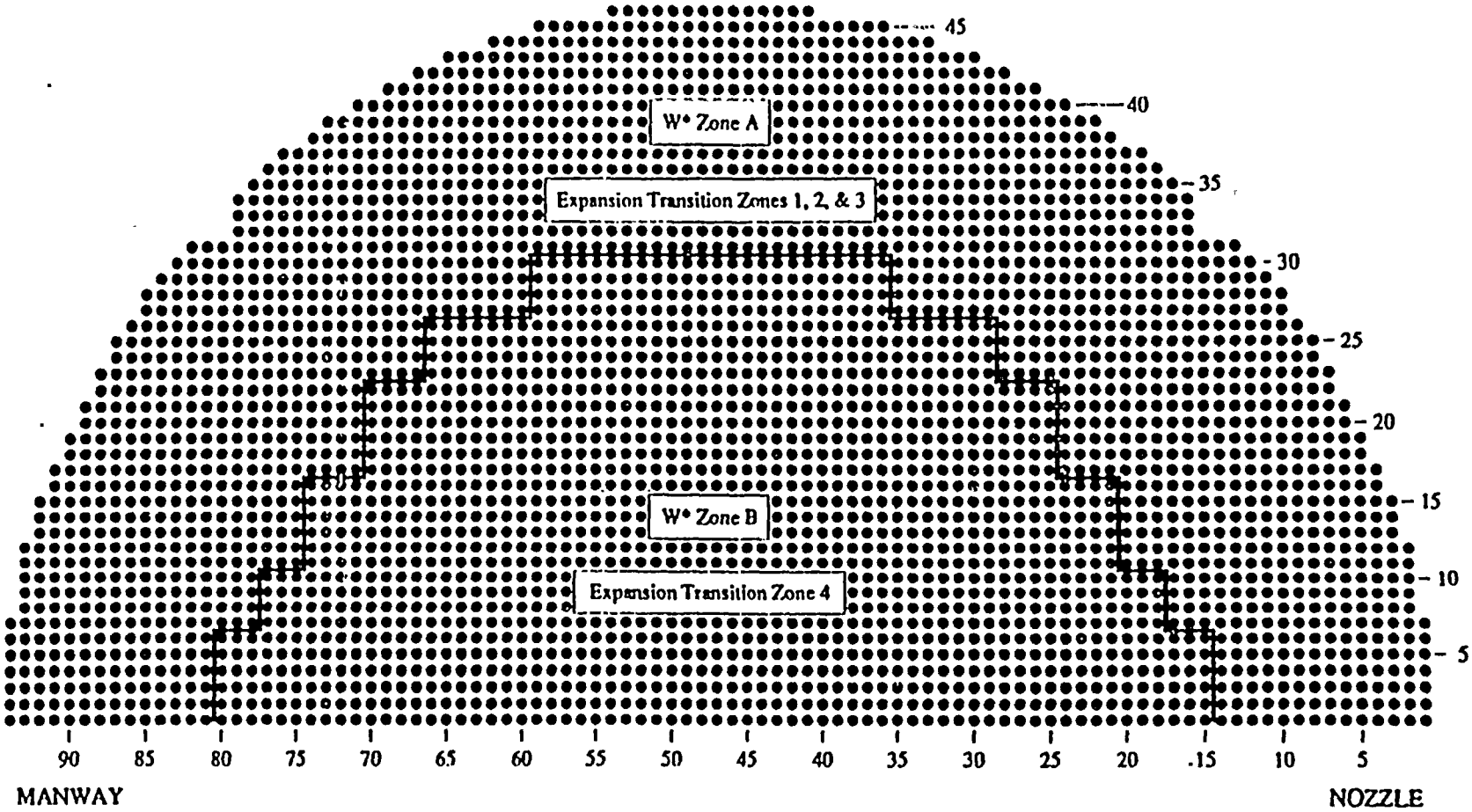
Circumferential Indications Within W* Distance are Repaired

SLB Leakage Must be Within Site Specific Allowable Leakage Limits

- Total leakage from all indications within W* distance as adjusted for percent inspection
  - Total leak rate from all indications within W* region divided by the fraction of tubes inspected (RPC or bobbin which is frequently 100%)

- W* leakage added to SLB leakage for other applied ARCs (i.e., GL 95-05)

W* Zone A and Zone B Boundaries



W* Tube Repair Criteria Inspection Requirements

Extent of Inspection

- Extent of inspection determined by plant Tech Specs as supplemented by plant specific guidelines
- Application of W* ARC does not mandate extent of inspection

Indications Within Flexible W* Length

- Bobbin indications must be RPC (or equivalent coil) inspected to measure crack lengths and elevations

RPC (or equivalent) Inspection

- When RPC inspection of WEXTEX region is performed, the inspection shall include the full length of the flexible W* region
  - Confirm absence of circumferential indications
- Measurements required
  - Bottom of BWT relative to TTS
  - Distance of crack tip within W* length relative to BWT or TTS
  - Crack length of axial indications within W* distance
  - Crack angle relative to tube axis when crack is clearly inclined to the tube axis
    - Crack angles clearly < 30° to tube axis do not require angle measurement

W* SLB Leak Rate Evaluation

SLB Leak Rate Summed Over Individual Ind. Within W*

- Deterministic analysis methodology
- Total leak rate based on leakage from sum of indications divided by fraction inspected (RPC or bobbin)

Leak Rate for Each Indication is Function of Distance of Crack Tip Below BWT and W* Zone

- Leak rates are independent of crack length due to tubesheet constraint
  - Constraint results in an effective crack length as a function of tube to tubesheet contact pressure
- Leak rate variation with tubesheet radius results from change in contact pressure with varying tubesheet bow
- Radial dependence simplified by defining only two W* zones

Crack Distance Below BWT Adjusted for NDE Uncertainties and Crack Growth

- Reduced by NDE uncertainty on measurement of length from BWT to upper tip of crack
- Reduced by crack growth allowance for projected EOC leak rate (Operational Assessment)
  - Growth allowance not required for current EOC analysis (Condition Monitoring)

Leak Rate Model

Test Basis for Leak Rate Model

- Constrained crack leak rate tests
  - Leak rates for fatigue cracks with varying contact pressure and zero contact pressure (gaps < 1 mil)
  - Leak rates measured at tip of crack

- WEXTEX crevice leak rates
  - Leak rates from large openings through varying lengths of WEXTEX expansion

Leak Rate Model

- Effective throughwall crack length as function of tubesheet contact pressure
  - Freespan, throughwall crack length (from CRACKFLO code) that gives measured leak rate at tip of crack
  - Throughwall cracks 0.3" to 0.6" throughwall reduced to effective throughwall lengths of 0.05" to 0.2" by restricted crack opening due to tubesheet constraint
  - Effective length is independent of actual crack length

- Crevice loss coefficient as function of tubesheet contact pressure
  - Developed from WEXTEX crevice leak tests

- Effective length and loss coefficient applied at 95% confidence on mean regression fit to test data

- Leak rate is a series model of leakage from effective crack length through crevice based on crevice loss coefficient

- Leak rates are a function of distance between upper crack tip and BWT

Leakage Model is a Generic Approach

Generic Leak Rate Model for Constrained (contact pressure to small gaps) Cracks

- Effective crack length approach applicable from expected contact pressure to gaps < 1 mil
- Loss coefficient varied to specific crevice conditions (expansion or packed crevices)

Potential Applications

- Applicable to cracks within fully expanded tubesheet for hardroll and hydraulic expansions as well as WEXTEX expansions
  - Different loss coefficient correlations for hardroll and hydraulic expansions
- Packed TSP crevices
  - Constrained crack opening model with zero contact pressure and different loss coefficient correlation

WEXTEX Inspection Results

Types of Indications Below TTS

- Field data reviewed from four plants
- Axial indications are dominantly SAIs (227 of 231 axials)
  - 2 MAIs reach null point between ind. and 2 do not reach null point
- Four circumferential and one volumetric (by + Point call)
  - Small circumferential involvement
- Two inclined indications within 30° of tube axis

Location of Indications Below TTS

- Distributed across tubesheet with a bias toward center
- Circumferential indications within or at bottom of expansion transition
- Axial indications principally within first few inches below TTS
  - Need for flexible W* length to permit indications to remain in service

Bobbin Detection of Indications Below BWT

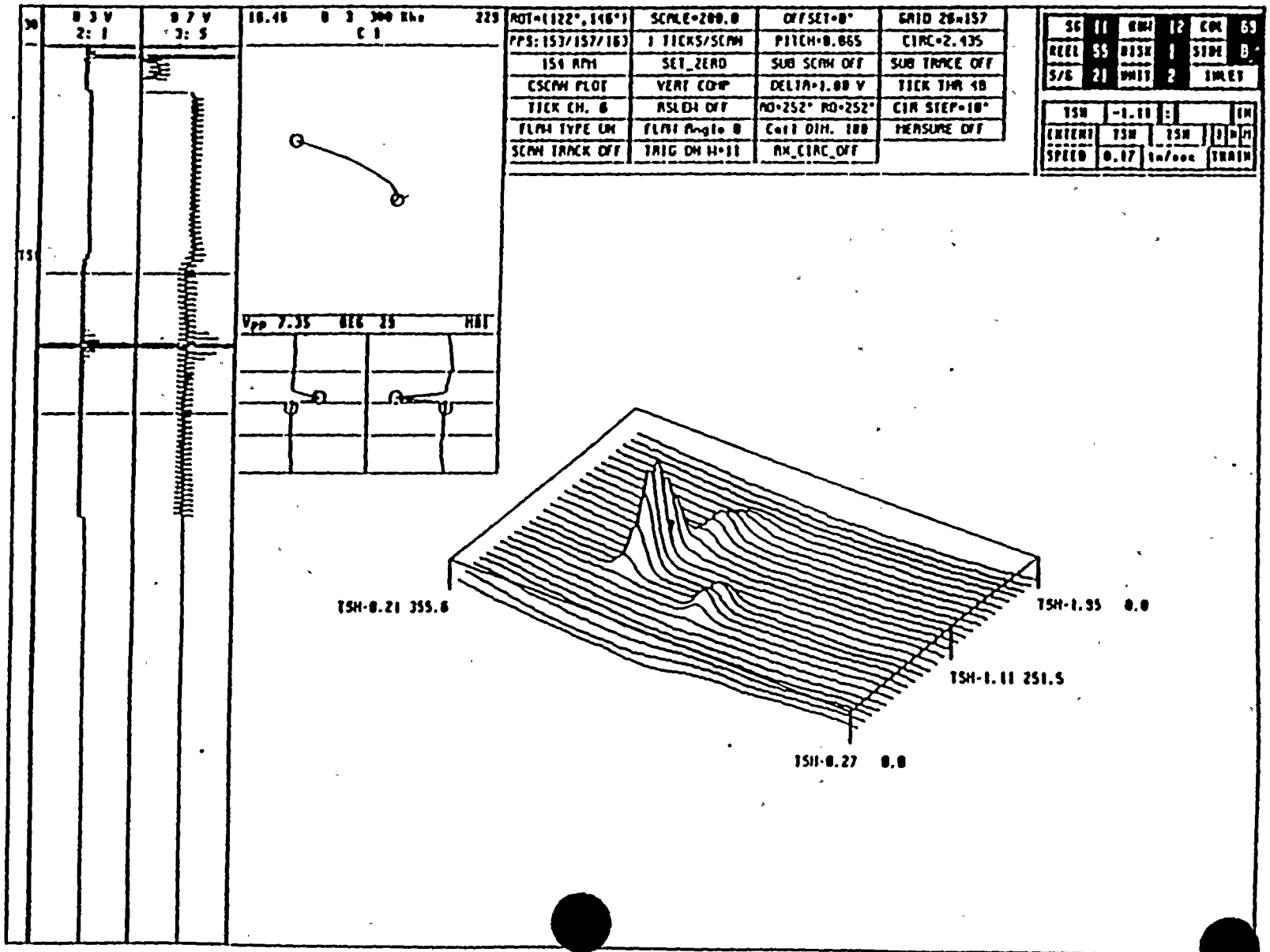
- Data review indicates bobbin detection of 30 to 40% of RPC indications below BWT
- Larger voltage (> 5 volts) appear to be detectable by bobbin inspection
  - Recent in situ testing of 32 TTS hardroll transition, axial PWSCC indications found no leakage
    - Consistent with French integrated SG leak tests
    - Tubesheet constraint apparently increases tightness of cracks
- Bobbin inspection judged adequate to detect indications which could be potential axial leakers or could reduce tube to tubesheet contact pressure

Table 7.1-1

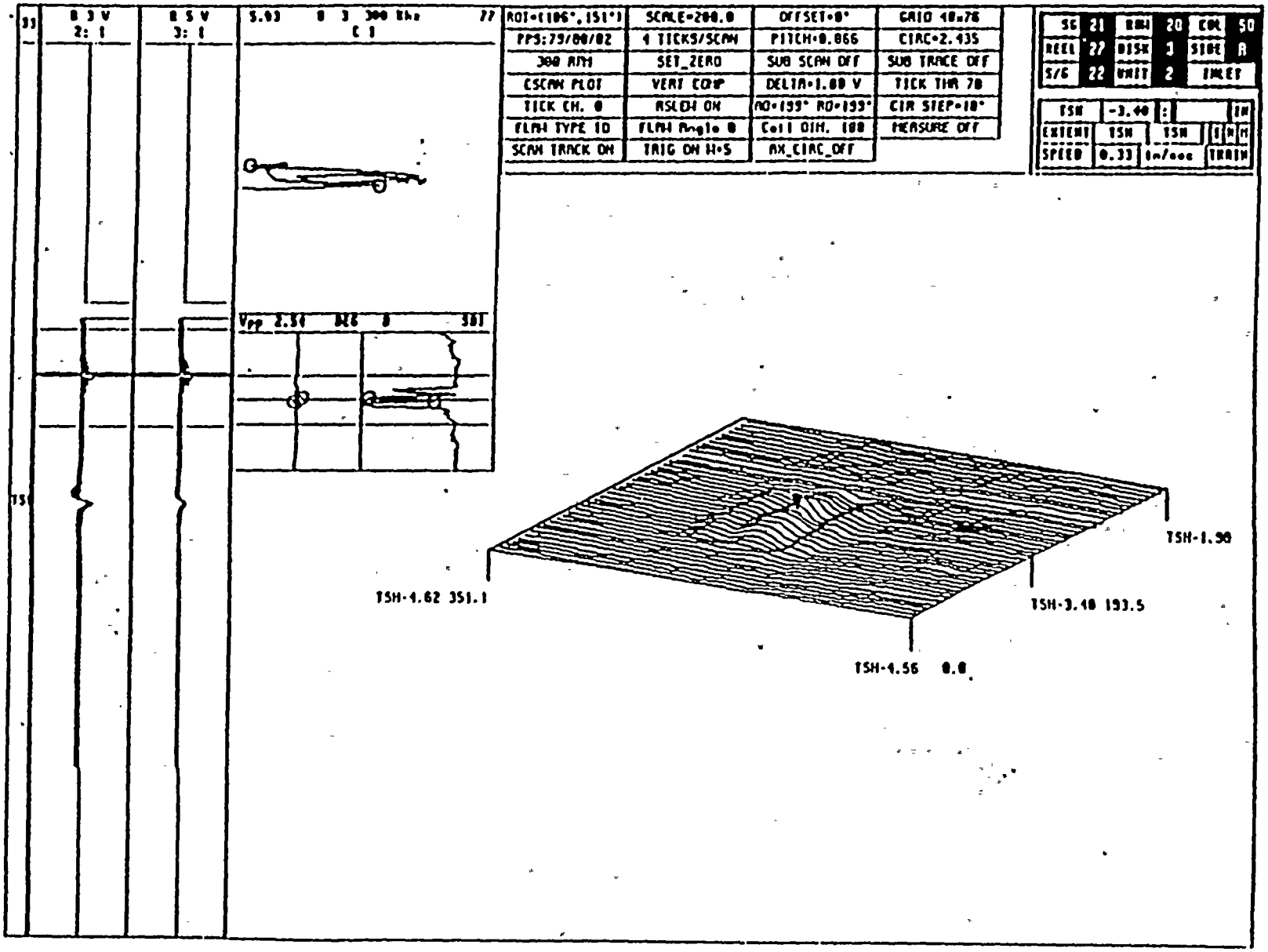
	SAI	MAI		SVI	Circ. (SCI or MCI)
	Single Axial Indication	RPC Null Point Reached Between Cracks	RPC Null Point Not Reached Between Cracks or Indeterminate*	Single Volumetric Indication*	Single or Multiple Circumferential Indication*
Depths Measured Relative to TTS					
<-0.4"	180	2	2	1	4
-0.4" to <-0.2"	24	0	0	0	23
-0.2" to <-0.1"	9	0	0	0	52
-0.1" to < 0.0"	14	0	0	1	52
Totals	227	2	2	2	131
					364
Depth Measured Relative to BWT**					
<-0.4"	13	0	0	0	0
-0.4" to <-0.2"	3	0	0	0	0
-0.2" to <-0.1"	1	0	0	0	0
-0.1" to < 0.0"	1	0	0	0	0
Totals	18	0	0	0	0

* Criteria Not Applicable
** Circ. Cracks not included in BWT study

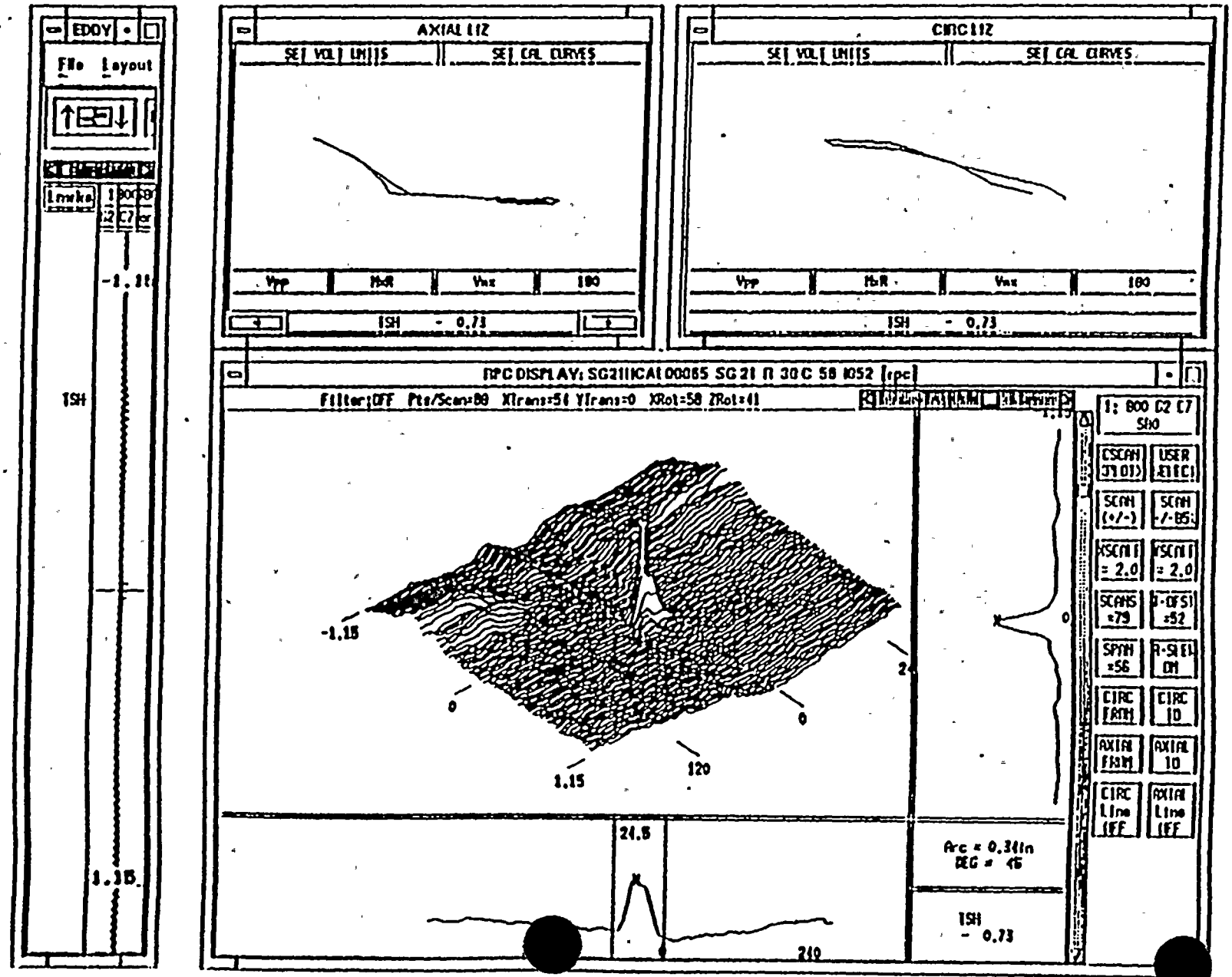
Plant Z2 SG-1
November 1994 R12C69



Plant Z2 SG-2
March 1993 R20C58



Plant Y2 SG-1
April 1994 R30C56



Plant Y2 SG-3
March 1993 R4C18

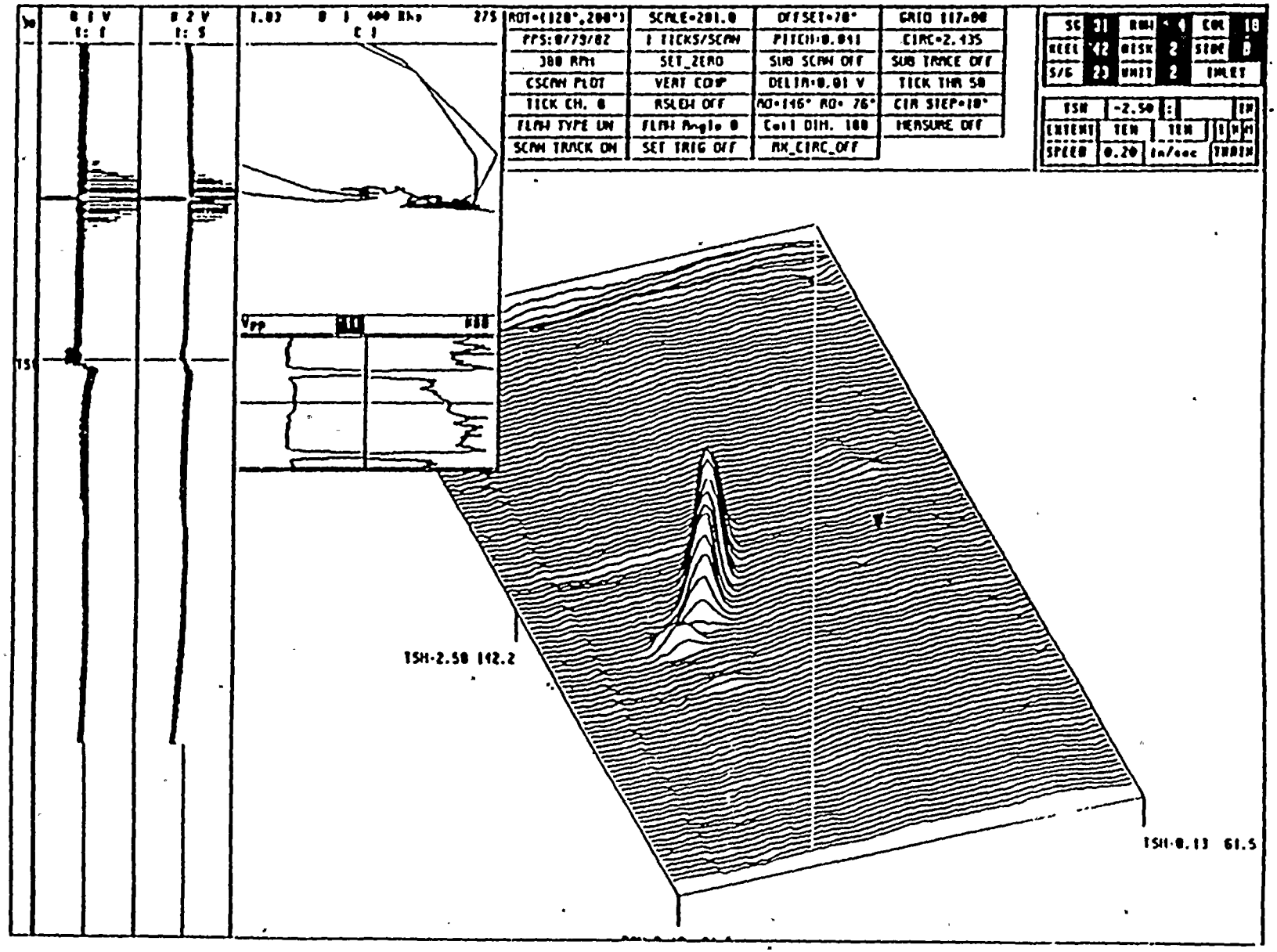
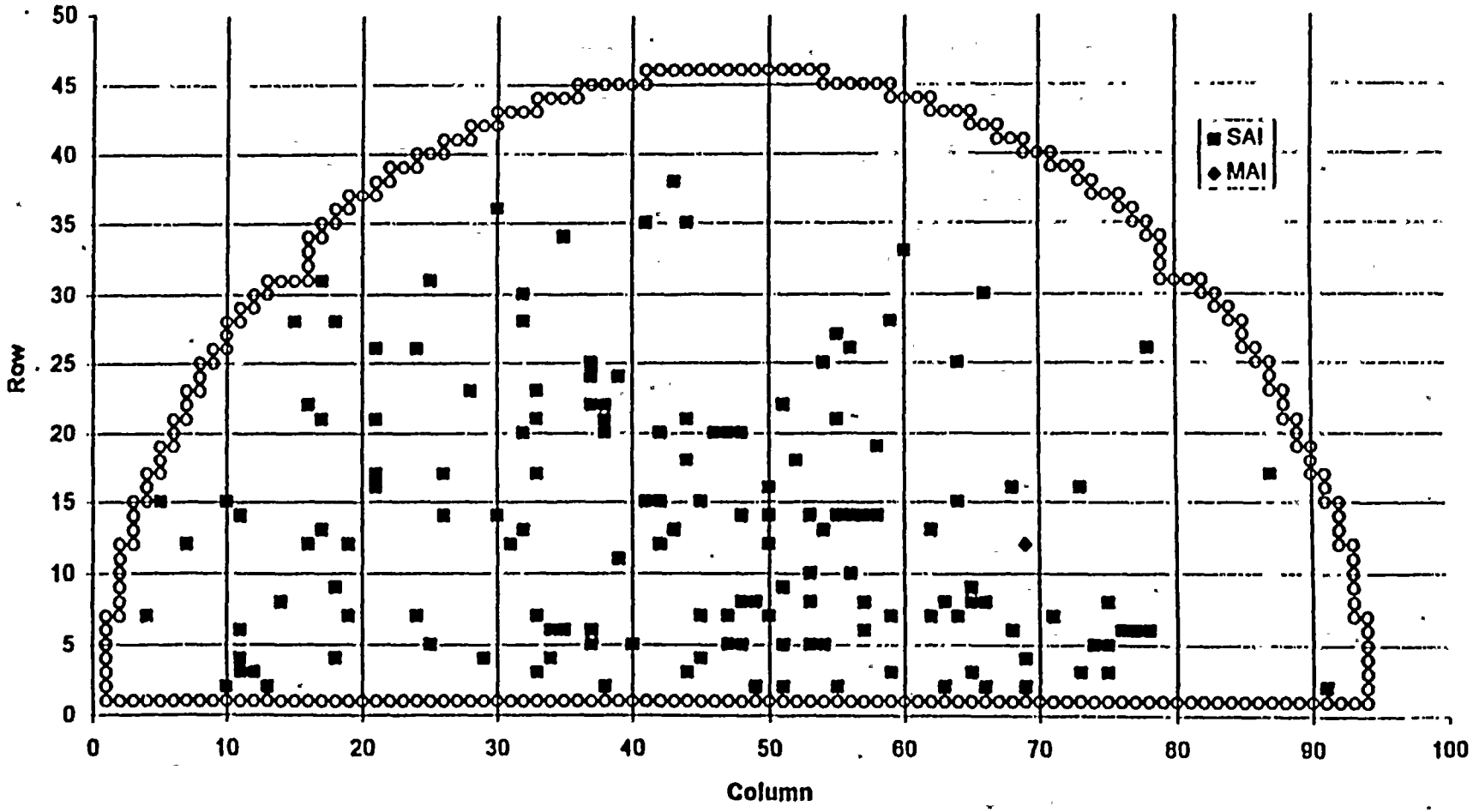


Figure 7.1.2-1
WEXTEX Single and Spaced Multiple Axial Indications Below TTS



Q:\wexdex\report\WEXTEX4.XLS:SAI_MAI Map (Outline)

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Figure 7.1.3a - Number of WEXTEX Circumferential and Volumetric Indications vs. Depth Below Top of Tubesheet

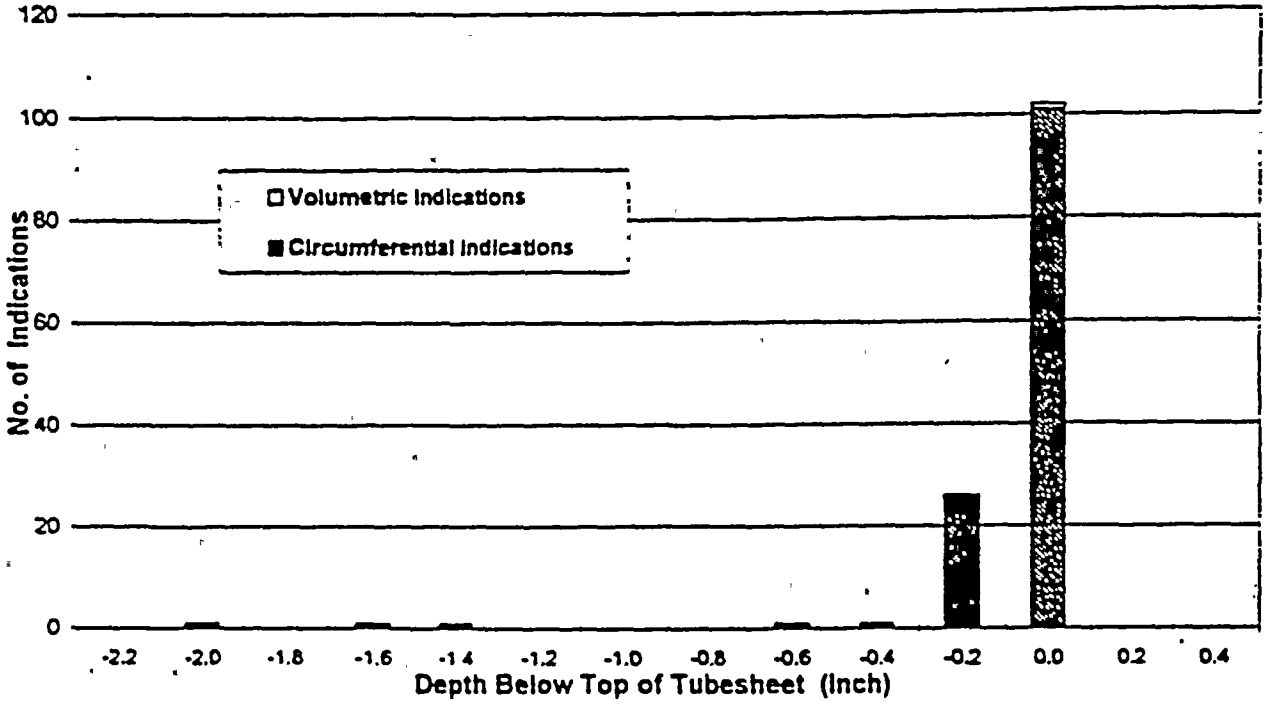


Figure 7.1.3b - Number of Single and Multiple Axial Indications vs. Depth Below Top of Tubesheet or BWT

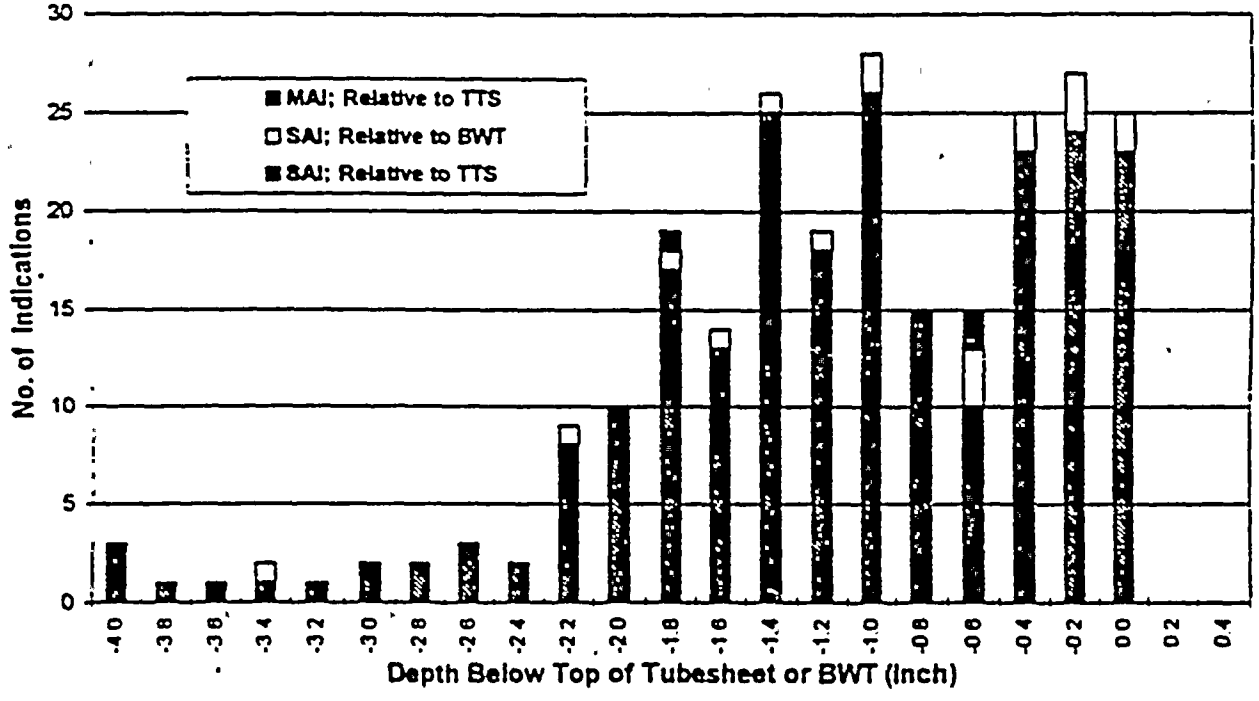
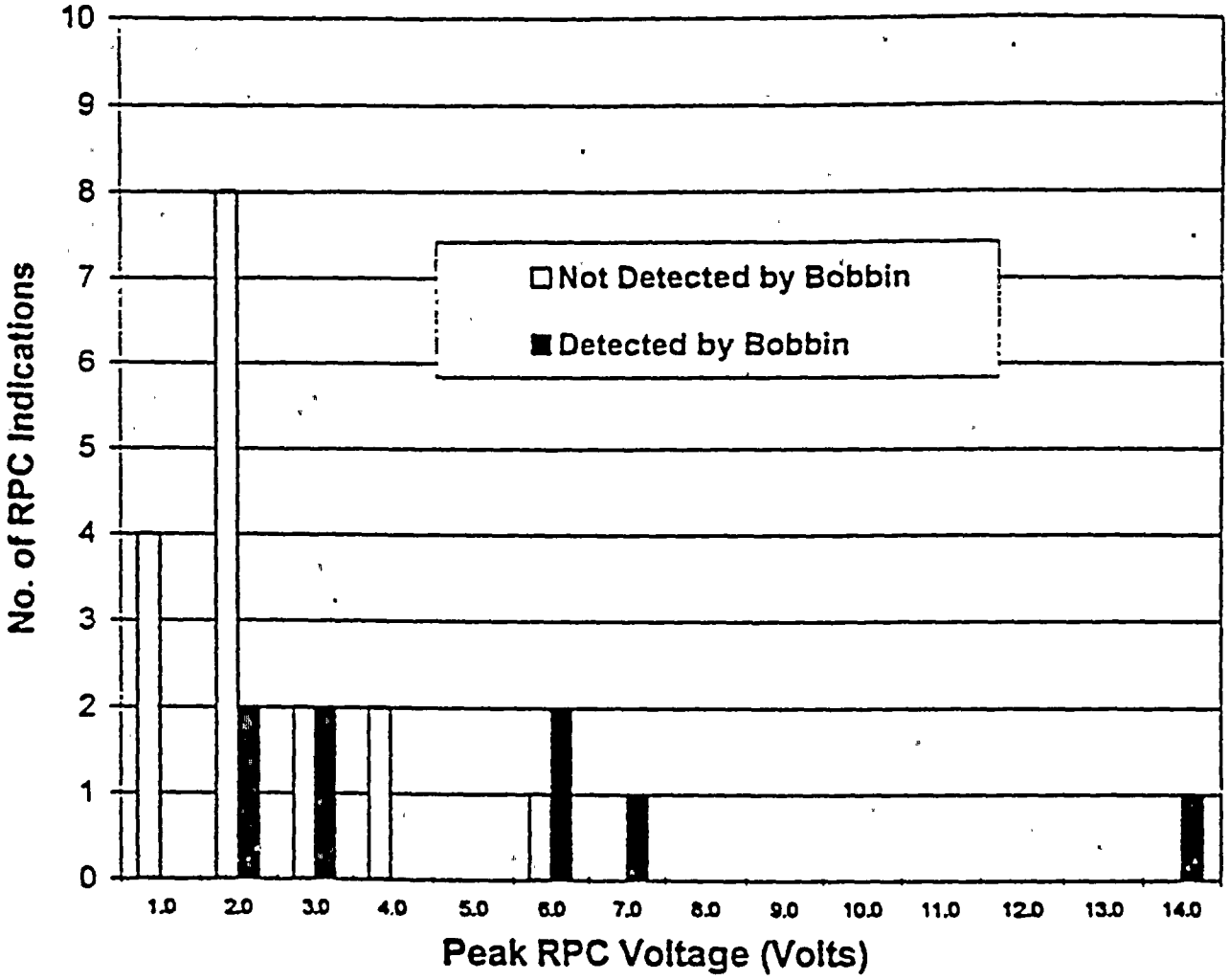


Figure 7.2-1
Bobbin Detection of RPC-Confirmed SAIs vs. Peak RPC Voltage



Growth Rates of Axial Indications Below BWT

Growth Rates Evaluated for Two Plants

- 30 indications evaluated for growth in length

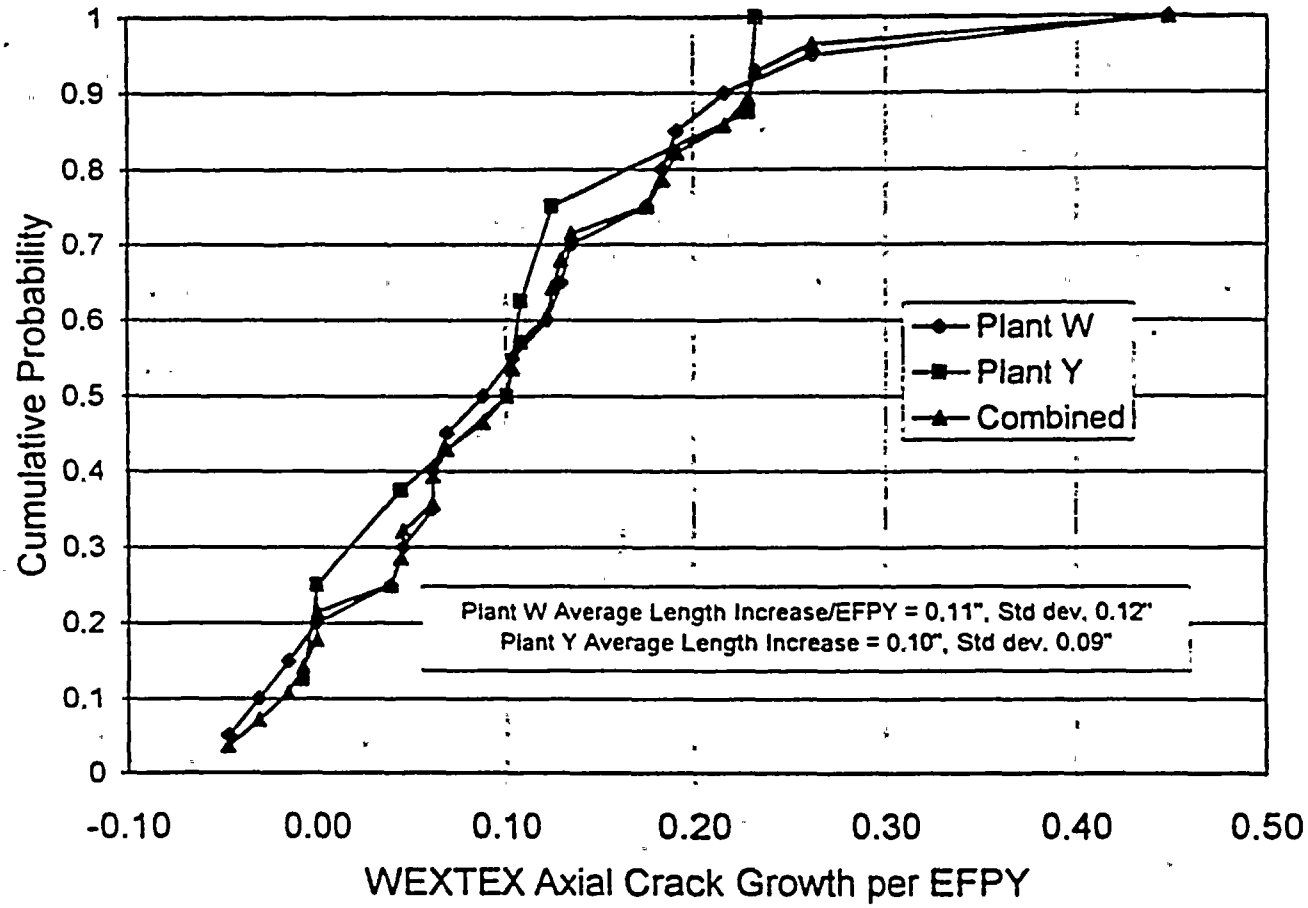
Crack Length Growth Rate of 0.236" per EFPY at 95% Cumulative Probability

- Judged conservative due to difficulties in sizing initial crack lengths

Growth Rate Options for W* Applications

- Apply generic growth value of 0.24" per EFPY or develop plant specific values
- Not considered mandatory to develop plant specific growth rates for W* applications due to overall conservatism in W* criteria

Cumulative Probability Distribution for Growth of W* Region Axial Indications



Compogro xls Growth CDF Chart 2 11/18/96

NDE Uncertainties

Test Specimens

- Tube and tubesheet collar with WEXTEX expansions
- Full length tubesheet mockup with multiple, WEXTEX expanded tubes
- EDM notches
  - Judged conservative for applicable W* length measurements since coil lead-in and lead-out effects, which increase crack length measurements, are larger for EDM notches than for tapered cracks

NDE Data Collection

- Robotic inspection in SG mockup to simulate field conditions
- Probes for which data collected
  - Bobbin
  - + Point
  - Pancake coils - 80, 115 mil

NDE Data Analysis by Field Resolution Analysts

Analyses of Test Data to Obtain NDE Uncertainties is in Process

Summary of Conservatisms in W* ARC

Length of crack assumed to provide no contribution to pullout force

- Likely only that WEXTEX expansion pullout resistance affected and thermal expansion, pressure differential and tubesheet bow not affected

W* lengths are most limiting tube in each of two zones and bound all other tubes in the zone

Axial cracks assumed throughwall for SLB leakage analyses

SLB leak rates are most limiting tube in each of two zones

All expansions assumed to have a small gap over upper 0.7" of distance below BWT

All growth is assumed toward the BWT for leakage analysis

W* Pullout Load Evaluation

Robert M. Wepfer

Senior Engineer

Westinghouse Electric Corporation
Nuclear Services Division

Elements in the W* Pullout Load Evaluation

- Analysis Conditions and Criteria
- Pull Force Testing
- Analysis of Contact Pressure
- Calculation of Pullout Load Reaction Length (W* Length)

- Analysis results subject to completion of final checking process

Analysis Conditions and Criteria

W* Analysis Conditions

Parameter	Value	Basis
T_{hot}	590°F	Lower bound hot leg temperature estimate
T_{cold}	535°F	Lower bound cold leg temperature estimate
P_{pri}	2250 psia	Operating primary pressure
	2650 psia	Feed Line Break pressure conservatively used instead of 2560 SLB value
P_{sec}	900 psia	Upper bound steam pressure - for tubesheet interaction pressure analysis
	760 psia	Lower limit steam pressure - for 3ΔP burst pressure analysis selected from review of plant operating data

W* Design Parameters

Parameter	Value
Tube O.D.	0.875 inch
Tube I.D.	0.775 inch
Tubesheet Hole Diameter	0.890 inch

Tube Burst - Normal Operating Conditions

- RG 1.121 Criteria for Tube Burst of $3\Delta P_{n.o.}$
- Load Developed from Pressure Acting on Area of Expanded Tube OD (0.890" dia)
- Bounding Min. Steam Pressure of 760 psia Selected from Review of Plant Operating Data
- Normal Condition Axial Pullout Load Criterion:

$$F = 3*(P_{Pri} - P_{Sec})*(\pi/4)*(\text{Tube OD})^2$$

$$= 3*(2250 - 760)*(\pi/4)*(0.890)^2 = 2781 \text{ lbs.}$$

Analysis Conditions and Criteria

Tube Burst - Faulted Conditions

- Feedline Break (FLB) ΔP of 2650 psia used as compared to Steam Line Break (SLB) of ΔP of 2560 psia
- Load Developed from Pressure Acting on Area of Expanded Tube OD (0.890" dia)
- ASME factor of safety of 1.0/0.7 = 1.43 applied
- Faulted Condition Axial Pullout Load Criterion:

$$F = 1.43 * (P_{Pri} - P_{Sec}) * (\pi/4) * (\text{Tube OD})^2$$

$$= 1.43 * (2650 - 0) * (\pi/4) * (0.890)^2 = 2358 \text{ lbs.}$$

Pull Force Testing

Test Objectives and Description

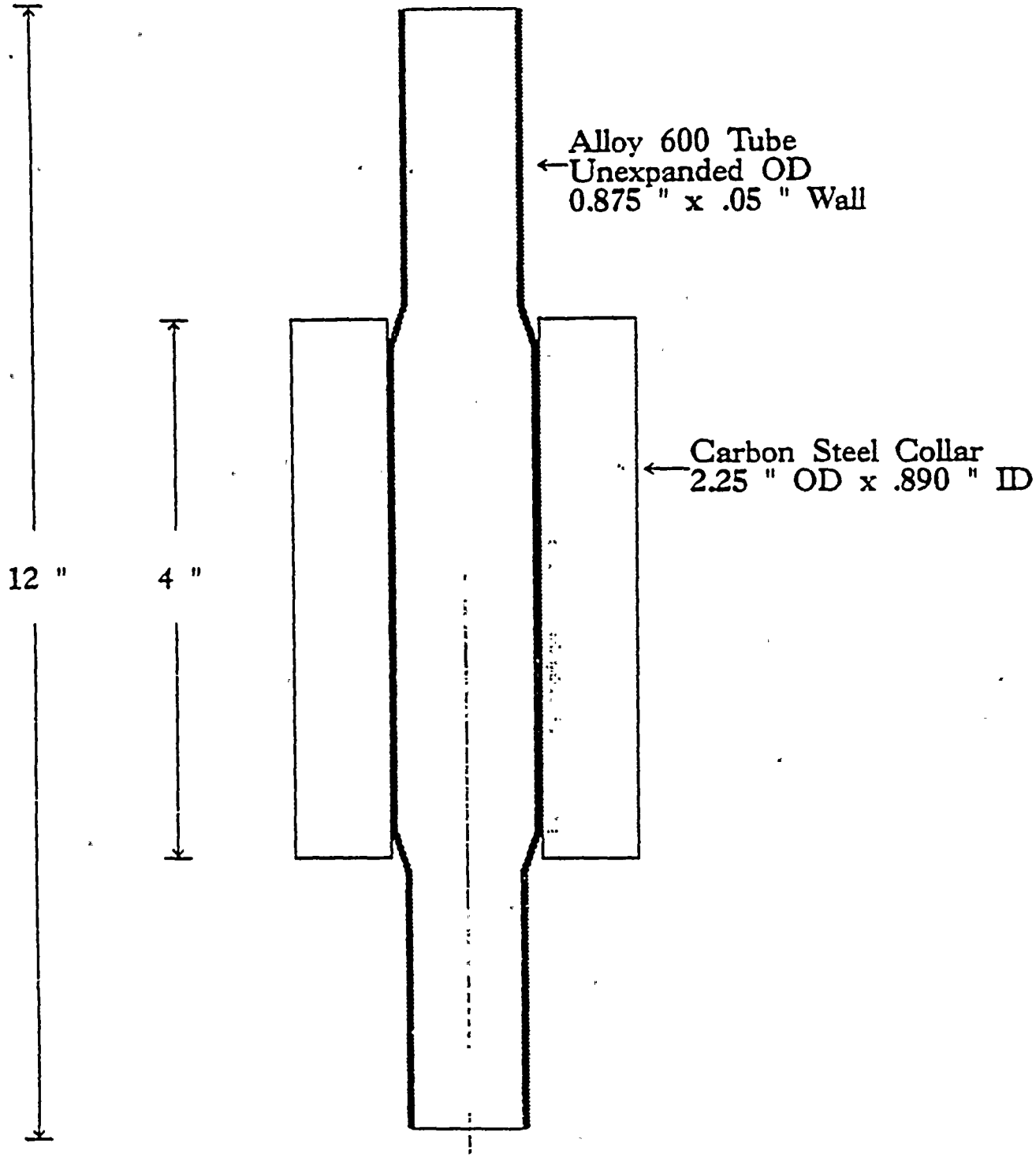
Objective:
To determine the coefficient of friction between the tube and tubesheet collar and the nominal radial interference pressure due to WEXTEX expansion

Specimen Preparation:

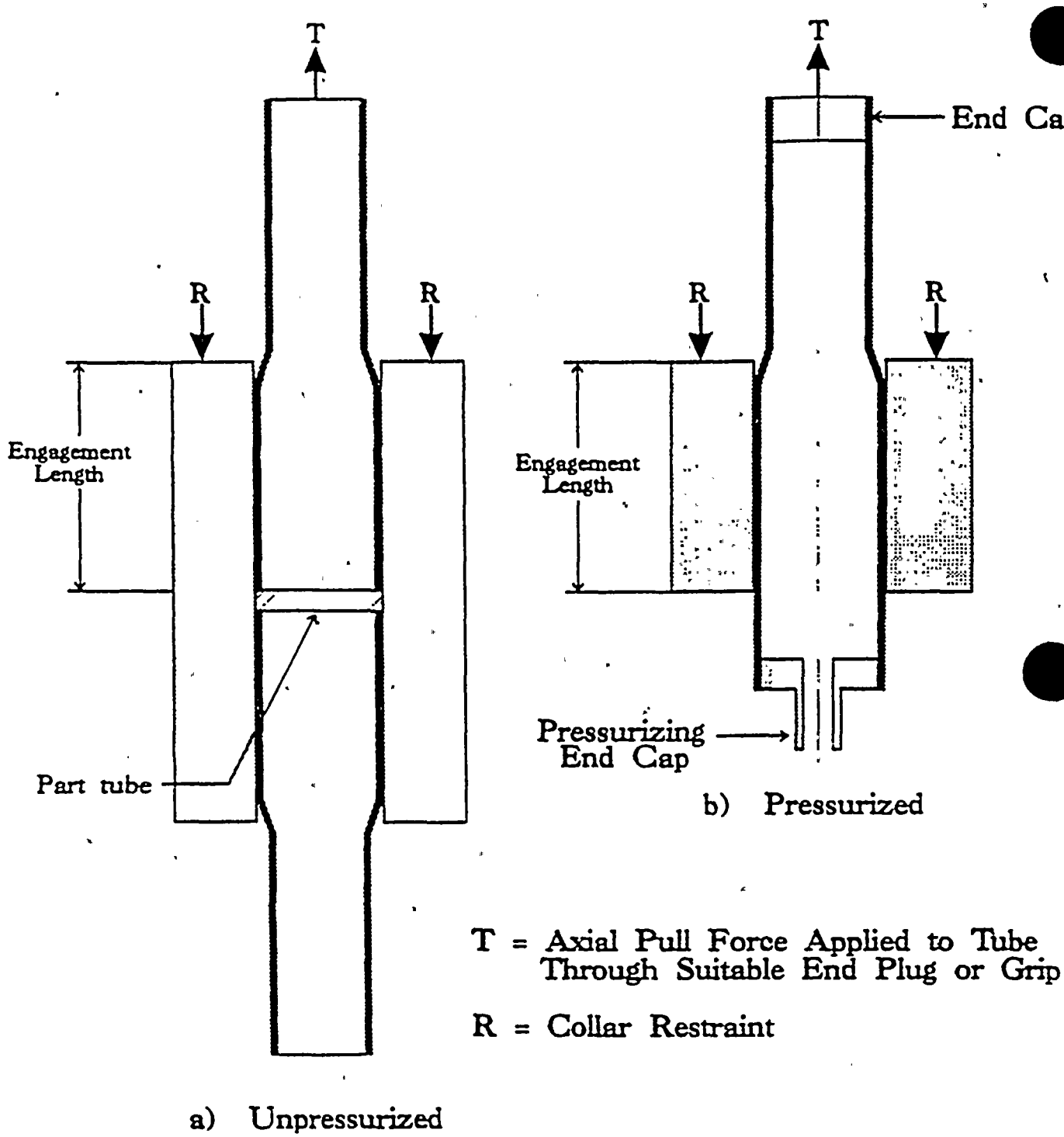
- Tubes expanded with nominal WEXTEX conditions
- Average sample length approx. 4"
- 0.875" x 0.050" Alloy 600 tubes
- Expanded into 1018 CR collars sized to simulate the radial stiffness of the tubesheet
- Typical collar ID surface finish of 100 to 250 rms

Testing:

- Each specimen tested at four conditions:
  - Room temperature
  - 400°F, Zero ID pressure
  - 600°F, Zero ID pressure
  - 600°F, 1635 ID pressure
- Pull forces obtained for each test condition



As-Fabricated WEXTEX Samples for Pull Tests



Pull Force Sample Configurations Tested

WEXTEX EXPANSION JOINT PULL FORCE TEST RESULTS

Sample	--- Design Test Cond'ns ---		---------- Actual Test Conditions ----------				Pull
No.	Temp.,°F	ID Pressure, psi	L[1]	L_{eff}[2]	Temp.,°F	ID Pressure, psi	Force, Lb.

b,c,e

Pull Force Testing

Test Results

Linear Regression Fit of 4 Data Points for Each Sample:

Sample No.	μ, Friction Coefficient	SrW, WEXTEX Radial Contact Pressure

b,c,e

Limiting Condition:

- WEXTEX average friction coefficient = [ ] b,c,e
- WEXTEX average expansion pressure = [ ]

Pull Force Testing

Pullout Load Reaction Length Calculation

- Pullout Load Reaction Length (PLRL)

$$PLRL = \frac{\text{Applied Axial Load}}{(\text{Integrated Contact Pressure} * \pi * D * \mu)}$$

where,

μ = average tube-to-tubesheet friction coefficient

D = expanded tube outside diameter

and Contact Pressure = Operating Contact Pressure + WEXTEX Contact Pressure

Tubesheet Structural Analysis

Overview

Purpose of Analysis:

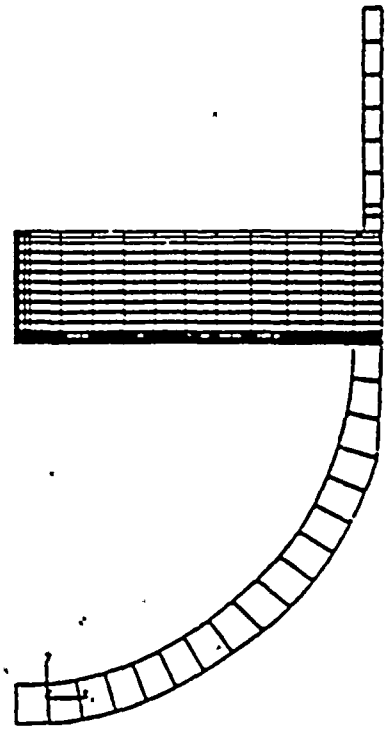
Provide a model to represent changes in tube/tubesheet contact pressure for variations in:

- Operating conditions (temperature, pressure)
- Radius from tubesheet centerline axis
- Depth below secondary face of tubesheet

Results used in conjuction with test to determine radial contact pressure at each location of tubesheet.

Model Configuration:

- Model 51 FEM
- 2-D, Axisymmetric
- Unit Loadings
- Results for analysis conditions determined by scaling

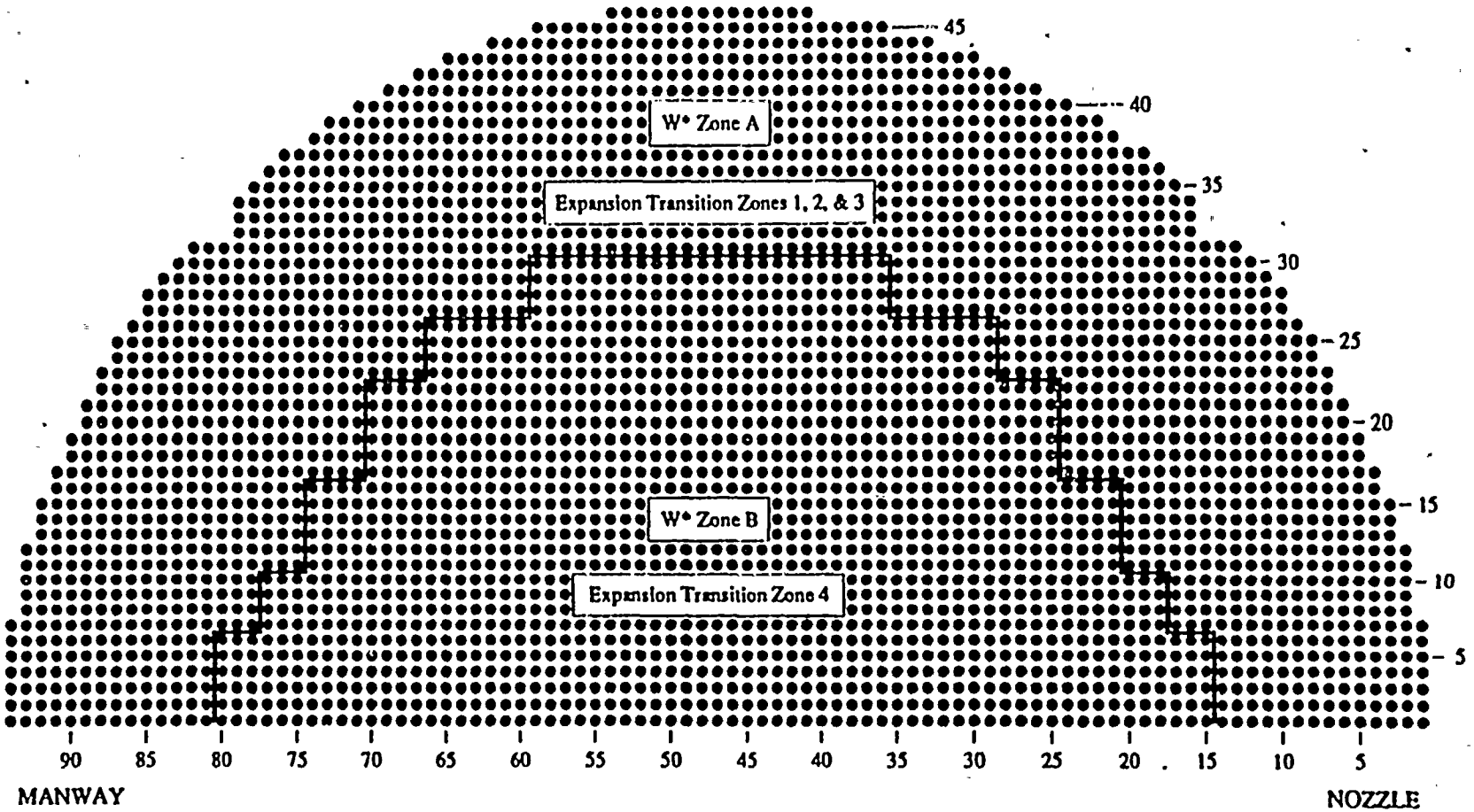


Tubesheet Structural Analysis

Observations for W* Conditions

- Radial contact pressure increases with distance (depth) from top of tubesheet
- Radial contact pressure is lower near tubesheet centerline axis, higher at periphery
- Radial contact pressures are lower on cold leg than on hot leg

W* Zone A and Zone B Boundaries



W* Length Calculation for Normal Conditions - Hot Leg

Depth from TTS	Total Contact Pressure R=2.28" (Zone B)	Total Contact Pressure R=37.7" (Zone A)	Incremental Load R=2.28" (Zone B)	Incremental Load R=37.7" (Zone A)	Cumulative Load R=2.28" (Zone B)	Cumulative Load R=37.7" (Zone A)
[						] c,e

W* Length [ ] c,e

W* Length Summary

Condition	Location	Radial Distance from Tubesheet Centerline	
		R= 2.28" (W* Zone B)	R= 37.7" (W* Zone A)
Normal	HL	6.4	5.0
Normal	CL	6.9	5.2
Faulted	HL	5.0	3.0
Faulted	CL	5.2	3.1

Conservatisms in W* Length Calculations

- Lower value of μ and WEXTEX radial pressure used
- "Clean" crevice conditions used in test; significantly higher pullout loads observed in samples exposed to doped steam
- Crevice deposits expected to increase radial contact pressures
- No pullout load resistance assumed over entire axial extent of an axial crack

---

- The potential for burst-type leakage is essentially eliminated by the presence of adjacent U-bends (interior tubes) and lockup at tube support plates

W* ARC
SLB Leak Rate Methodology

Meeting with NRC

November 20, 1996

Presented by

G. P. Lilly
Westinghouse, NSD

Purpose

Develop and Apply Model for Calculating Leakage from Cracks within a WEXTEX Crevice

Summary

- Background - Previous Modeling
- Model Changes, Leak Tests with Constrained Crack Opening
- Model Test Data Bases and Results

Background - Previous Modeling

- Developed Leak Rates for Cracks in Series with WEXTEX Crevices

- Basis

  - Free Span Crack Opening Assumed

  - Crevice Loss Coefficient Based on Crevice Leak Tests, Correlated with Contact Pressure

  - Calculated Contact Pressure for Field Application

- Results: Leak Rates vs Geometry and Operating Condition Factors

  - Normal / Faulted Operating Conditions

  - Tube Position on Tubesheet

  - Crack Length and Depth

Model Changes

Integrate New Data Base for Constrained Crack Opening Leak Tests into Leak Rate Model

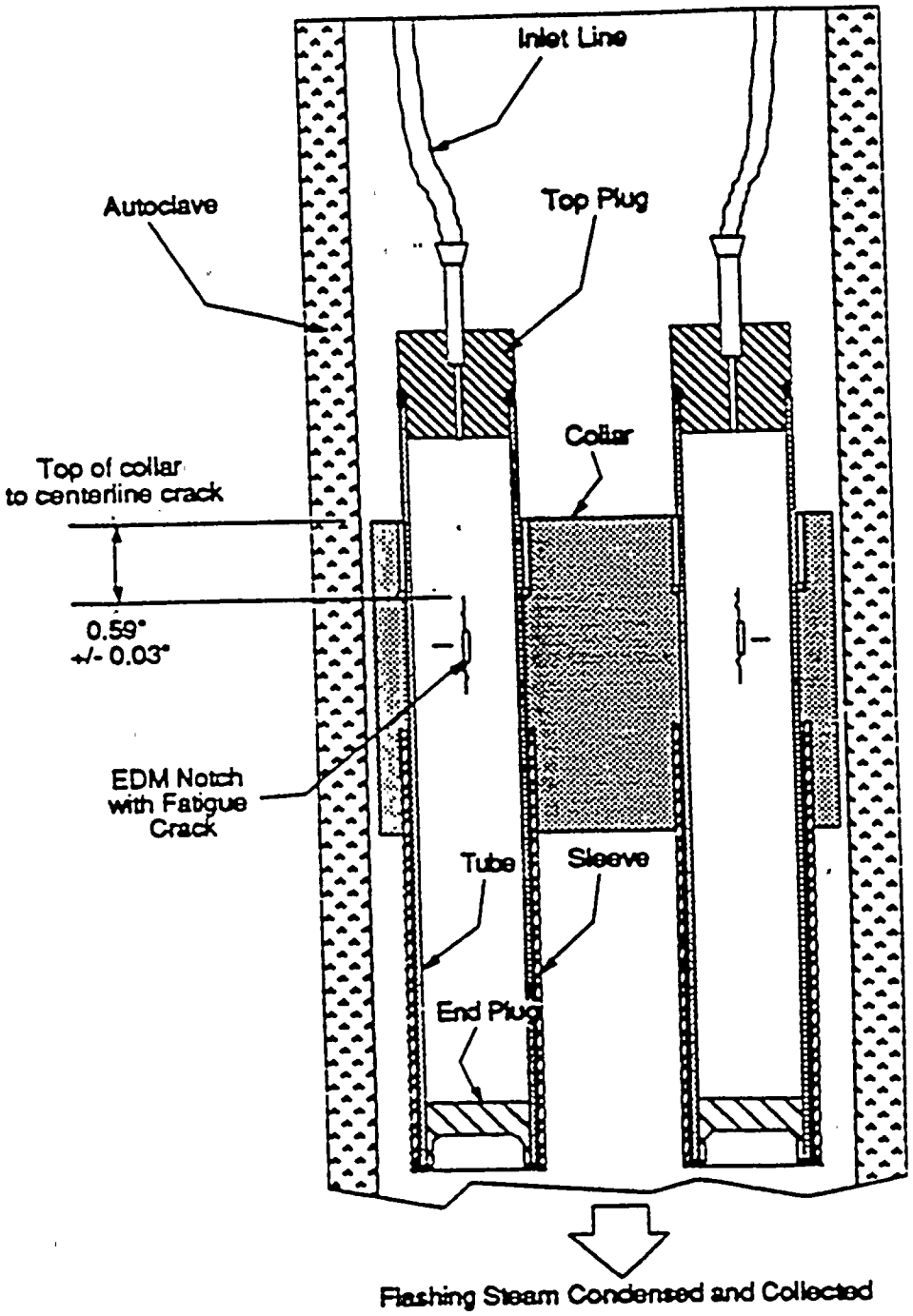
Leak Tests with Constrained Crack Opening

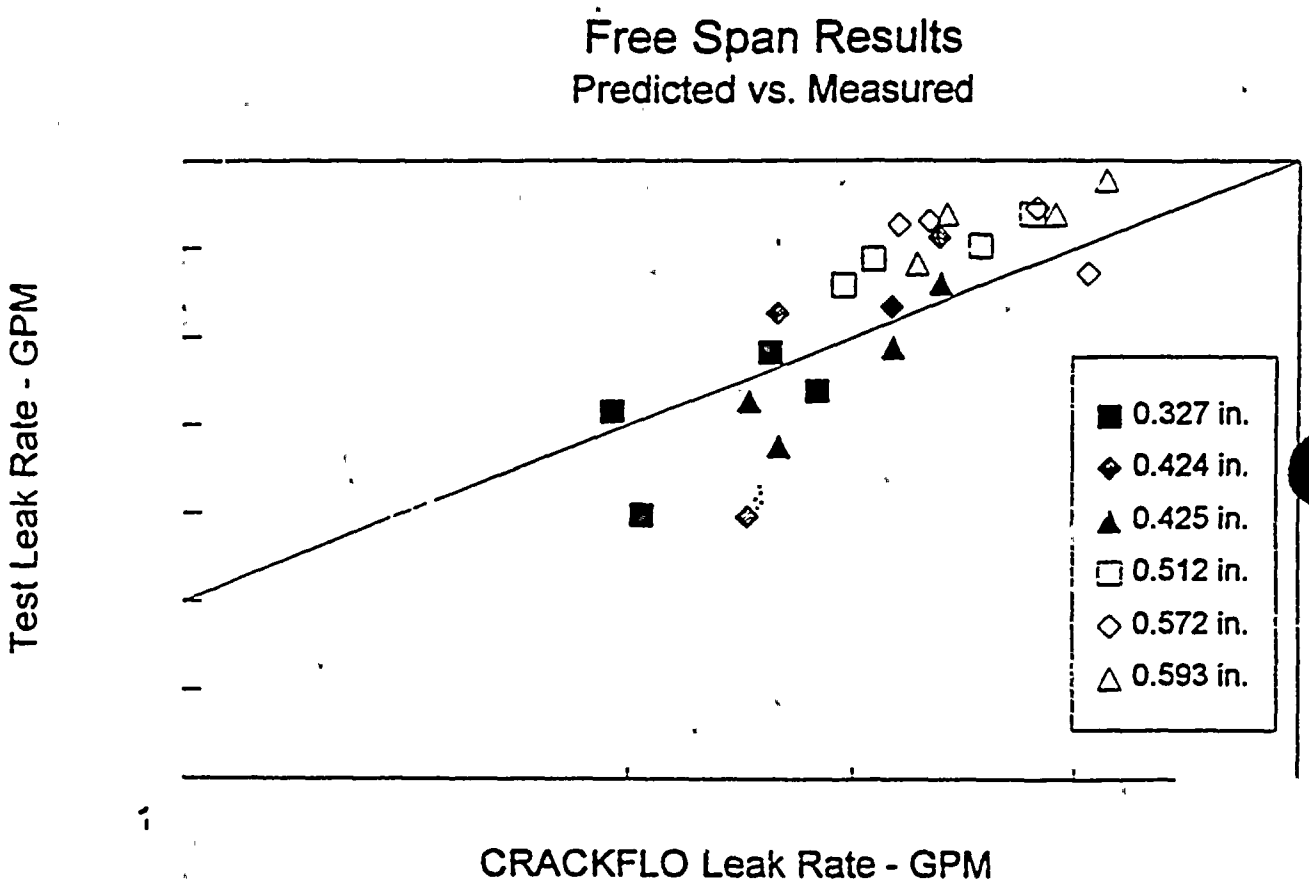
- Cracks Leak Tested at Free Span and in Constraining Collar with Controlled Gap/ Interference Fit
- Tests Designed to Eliminate Crevice Resistance Effect

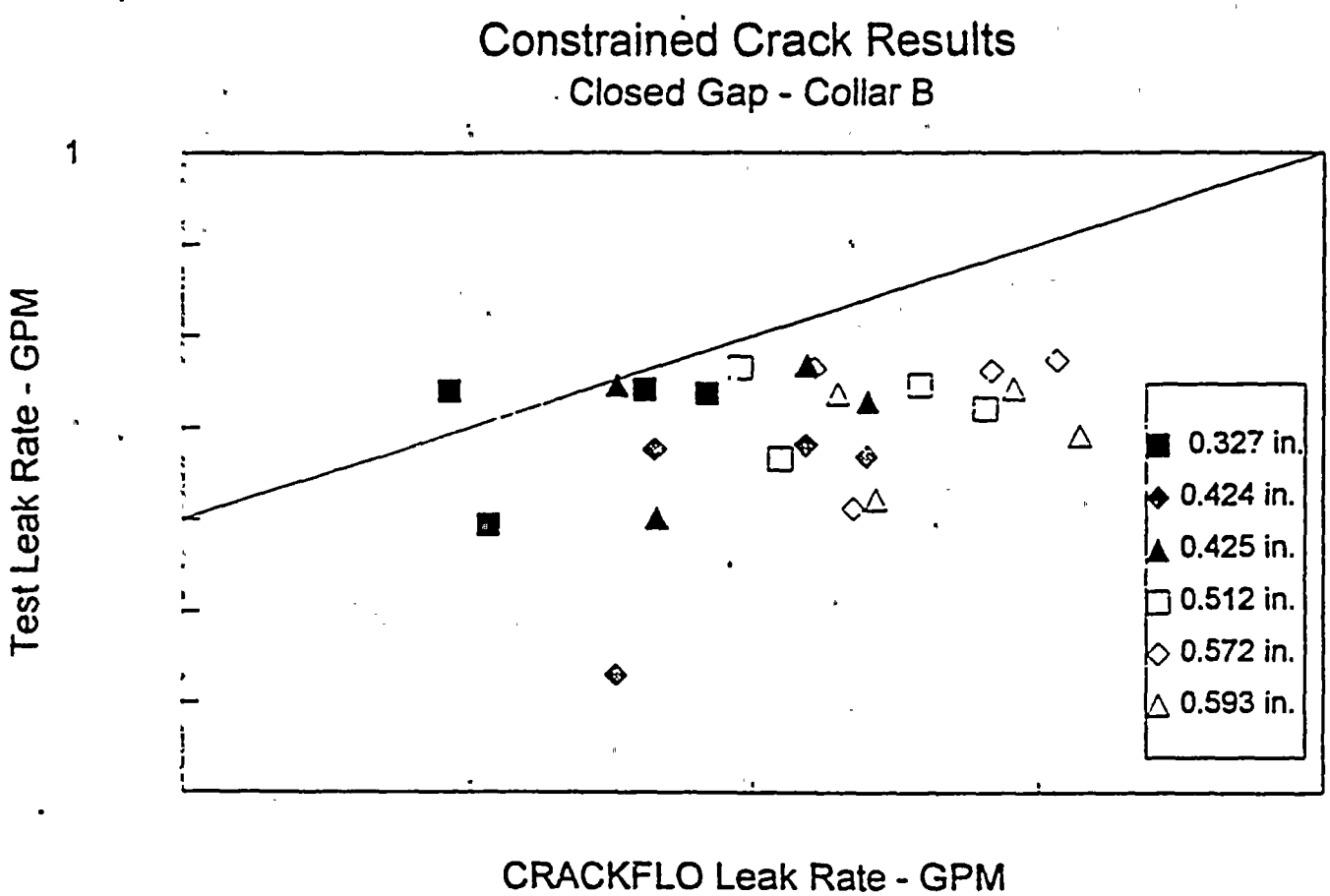
Constrained Crack Leak Test Results

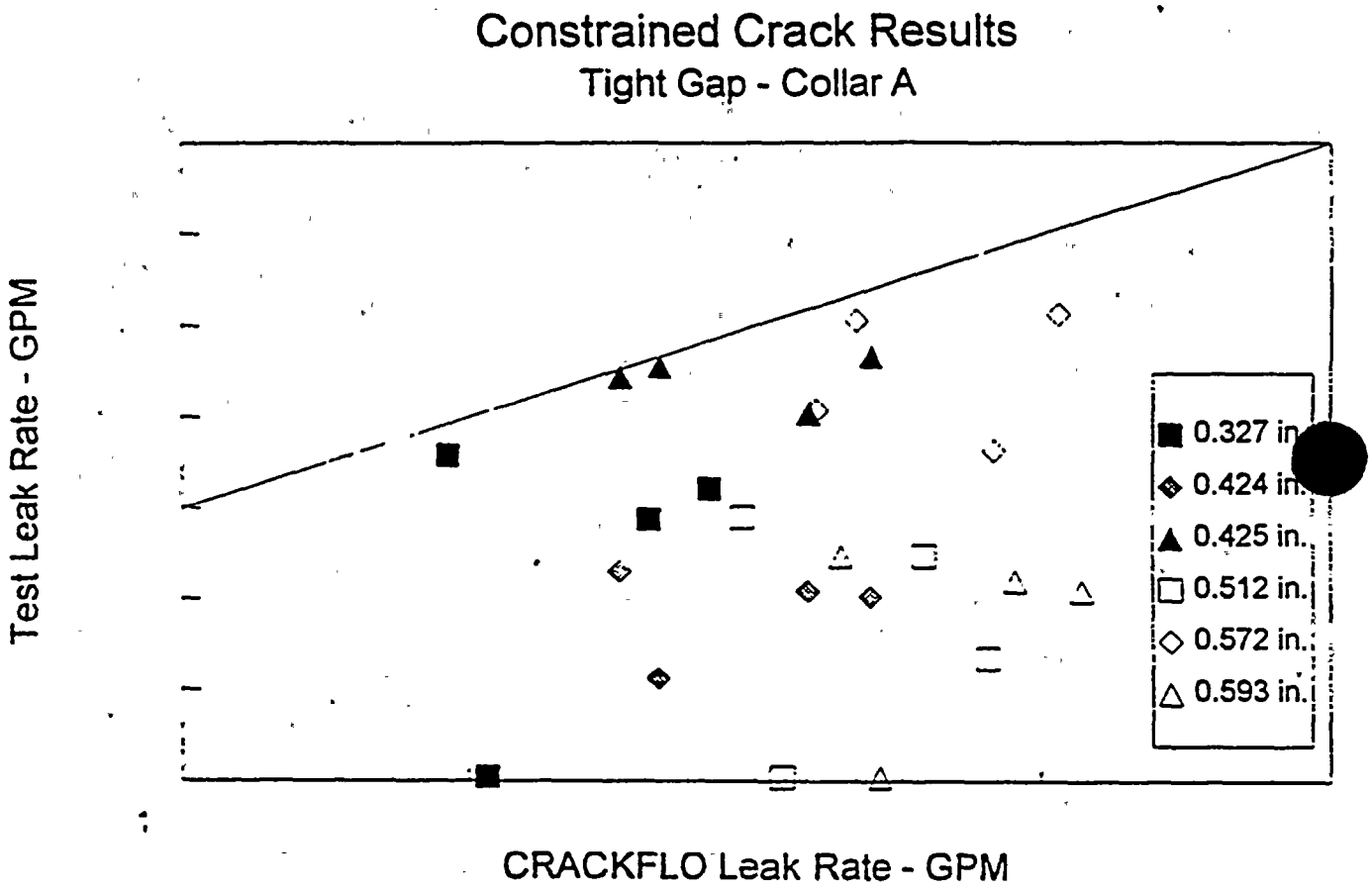
- Comparison with CRACKFLO, Code for Calculating Free Span Crack Leak Rates
  - Free Span Tests
  - "Closed Gap" Collar Tests
  - "Tight Gap" Collar Tests
- Determination of an "Effective Crack Length"
  - Effective length of a crack is the length of a free span crack which leaks at the measured rate
  - The correlating parameter is tube/tubesheet contact pressure

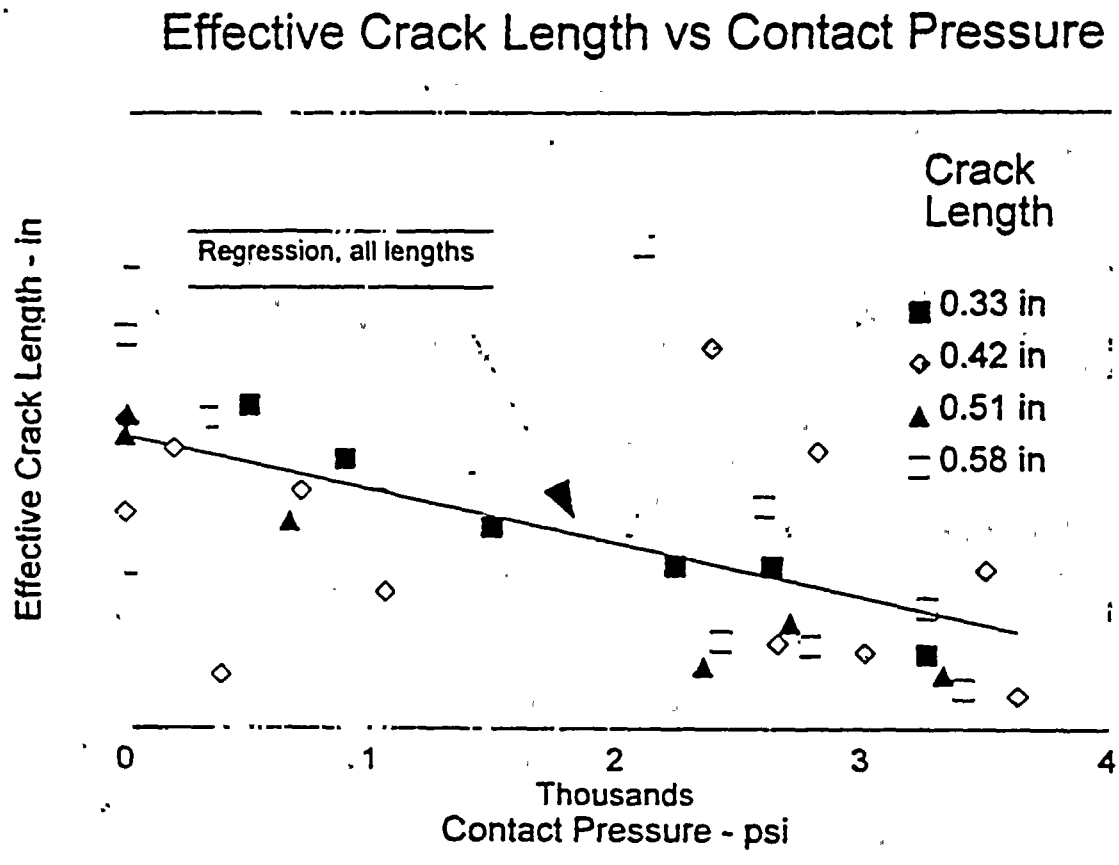
W* Leak Rate Modeling




Free Span Results
Predicted vs. Measured
Test Leak Rate - GPM
CRACKFLO Leak Rate - GPM
0.327 in.
0.424 in.
0.425 in.
0.512 in.
0.572 in.
0.593 in.


Constrained Crack Results
Closed Gap - Collar B
1
Test Leak Rate - GPM
CRACKFLO Leak Rate - GPM
0.327 in.
0.424 in.
0.425 in.
0.512 in.
0.572 in.
0.593 in.


Constrained Crack Results
Tight Gap - Collar A
Test Leak Rate - GPM
CRACKFLO Leak Rate - GPM
0.327 in.
0.424 in.
0.425 in.
0.512 in.
0.572 in.
0.593 in.



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Leak Rate Model

- Uses the DENTFLO Code which solves for leakage of a tube crack in series with a crevice resistance.

  - The crack element of the leakage path assumes an effective length derived from the constrained crack data. Effective length is a function of contact pressure and independent of crack length.

  - The crevice element of the leakage path uses a crevice loss coefficient derived from leak rate tests through WEXTEX crevices. Loss coefficient is a function of contact pressure.

Leak Rate Calculations

Parameters which determine leak rate are:

- Primary and secondary side fluid conditions - SLB assumed

- Crack depth and tubesheet radial position. These two parameters define contact pressure:

  - At the crack depth ⇒ Effective crack length

  - Along the crevice ⇒ Crevice loss coefficient

Analysis results are subject to completion of final checking process

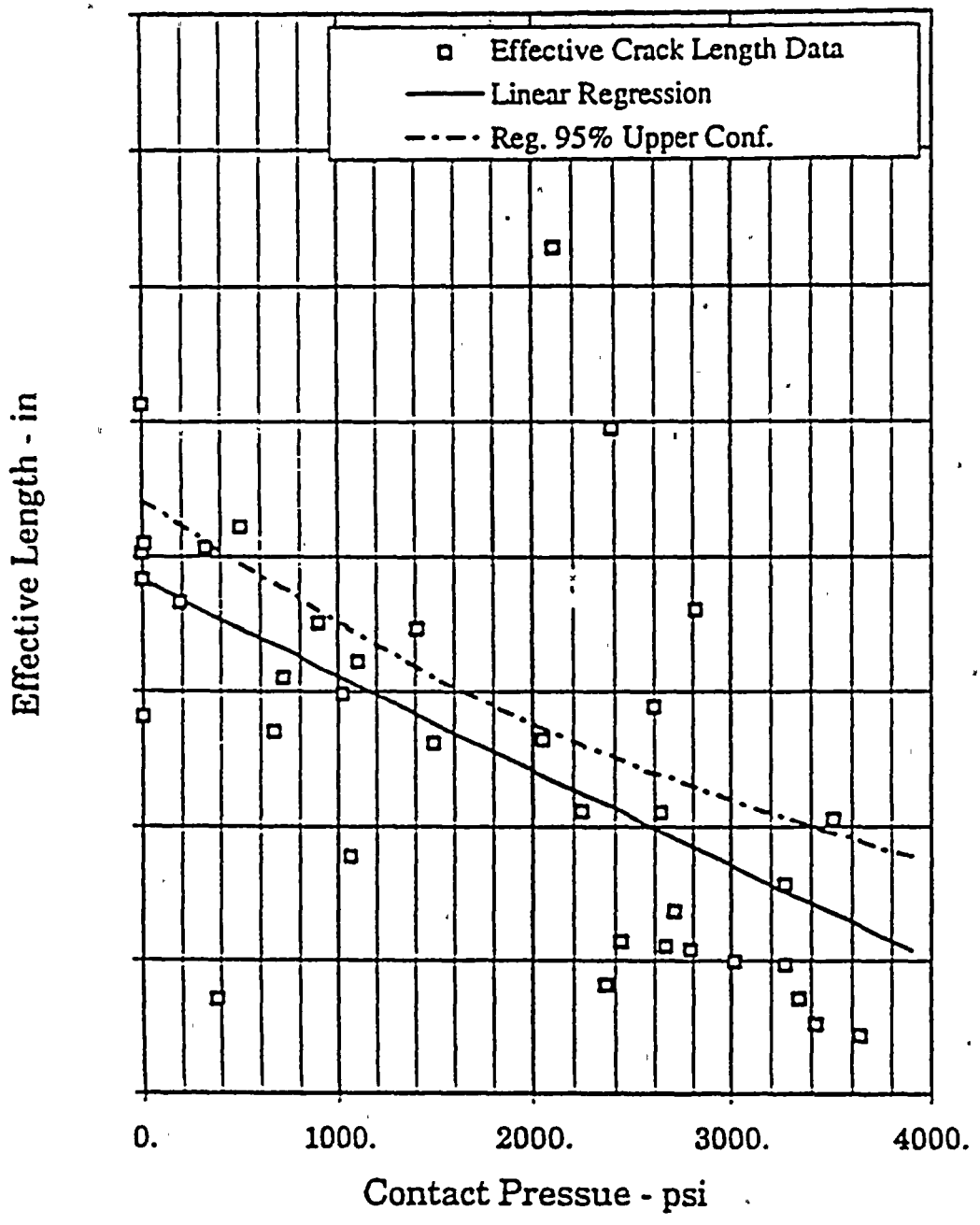
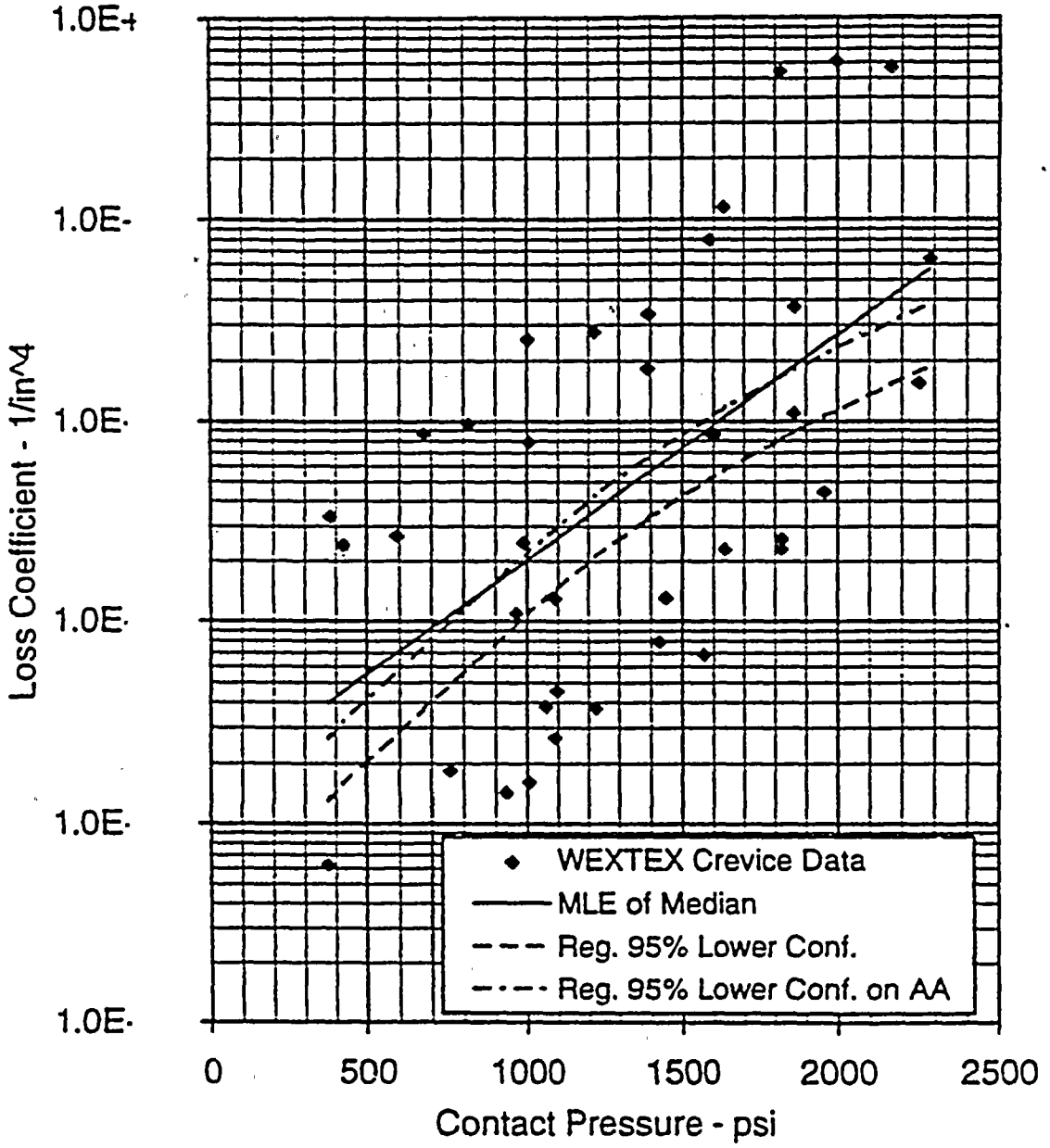
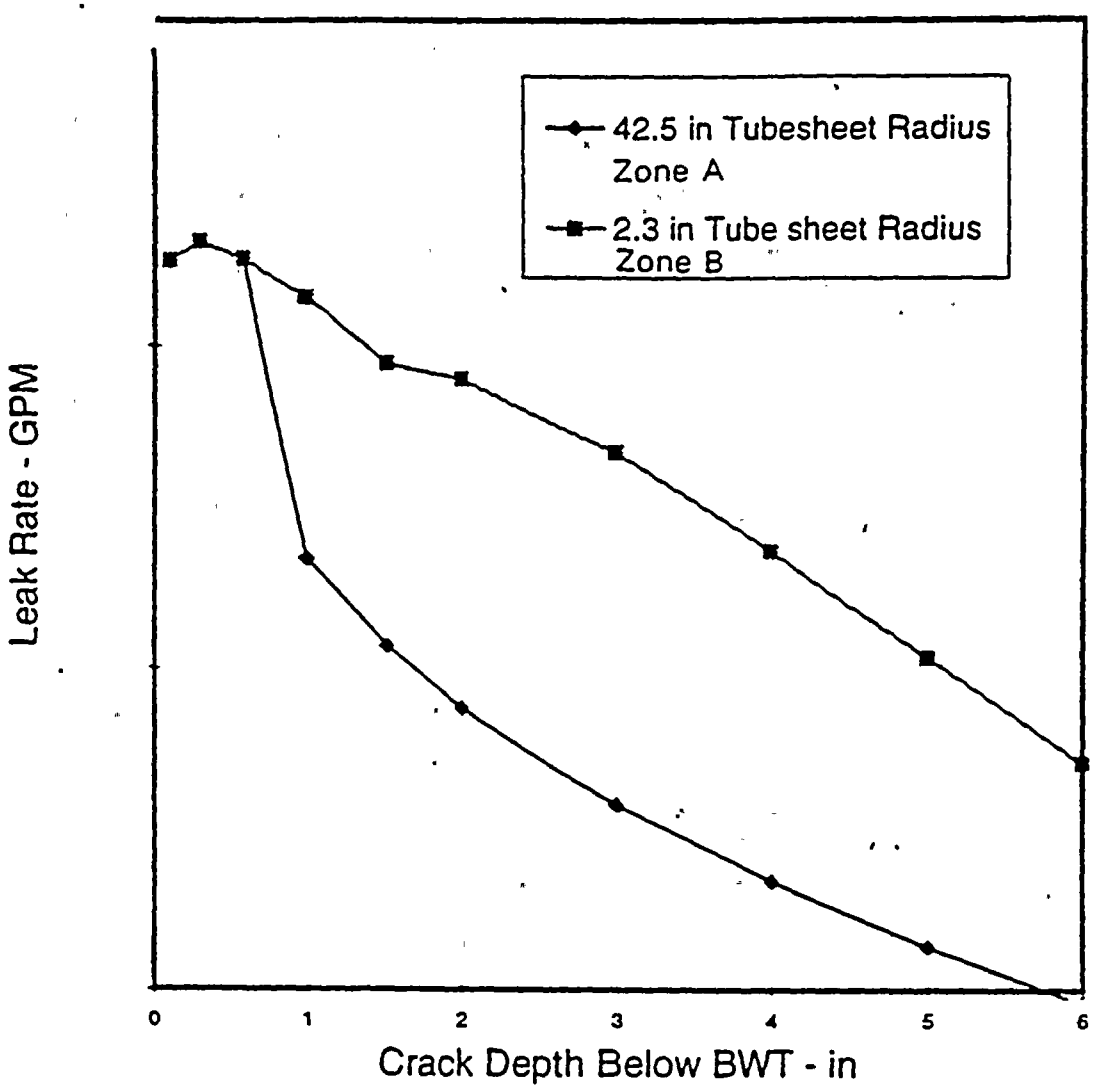


Figure 6.4-1 Effective Crack Length Versus Tube-to-Tubesheet Contact Pressure

WEXTEX Crevice Loss Coefficients vs Contact Pressure



WEXTEX Crack/ Crevice Leak Rate
Hot Leg



Model 51 SG Limited SLB TSP Displacement
Summary of WCAP-14707

NRC/Utility Meeting

November 20, 1996

Presented By:

T. A. Pitterle

Nuclear Services Division

Westinghouse Electric Corp.

WCAP-14707: Model 51 SG Limited TSP Displacement Analyses for Dented or Packed Tube to TSP Crevices

Axial Pull Forces to Determine Loads Required to Displace TSPs Relative to Tube for Packed or Dented Intersections

Leakage Tests with Packed or Dented Intersections

Hydraulic SLB Loads on TSPs (RELAP5, TRANFLO)

Dynamic Structural Analyses for TSP Displacements

Assessment for SLB TSP Displacements with Dented or Packed Crevices

Revision to WCAP-14707 in Process

- Local TSP structural analyses for Hot to Cold Condition

Tube/TSP Displacement Force Tests

Laboratory Pull Force Tests

- TSP displacement forces of 80 to 4200 lbs for laboratory induced dented specimens

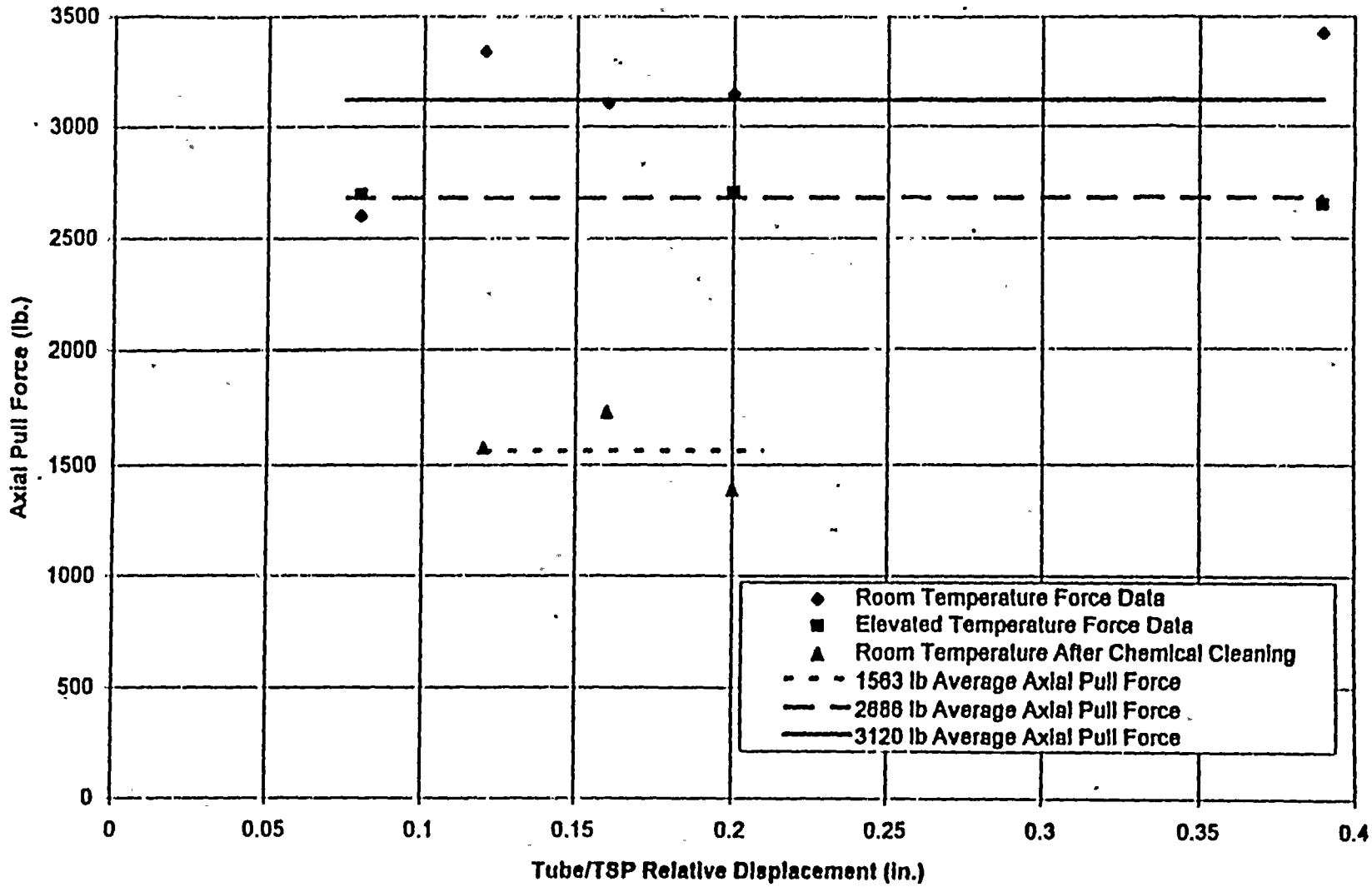
Pulled Tubes

- Tube breakaway forces of 925 to 2650 lbs

French Dampierre-1 Tubes Removed from SG with TSP

- Non-dented tube/TSP intersections
- Average of 23 measurements yields 3120 lbs to move tube at room temperature and 2686 lbs at operating temperatures
  - Forces at lower 90% confidence are 2106 at room temperature and 1635 at operating temperature
- Forces approximately independent of TSP displacements up to 0.4"

Tube/Tsp Axial Pull Force vs. Displacement
Dampierre-1 Removed Tubes and TSP with Crevice Deposits



Leakage for Indications at Packed and Dented TSPs

Laboratory Leak Rate Tests

- Essentially no leakage for throughwall cracks up to 0.7" at SLB conditions

Dampierre-1 Leak Rate Tests for Tubes/TSP Removed from SG

- Crevice deposits limit leakage to negligible levels (< 0.004 gpm for TW hole in tube)
- Leakage essentially independent of TSP displacements up to about 0.16"

Conclusion

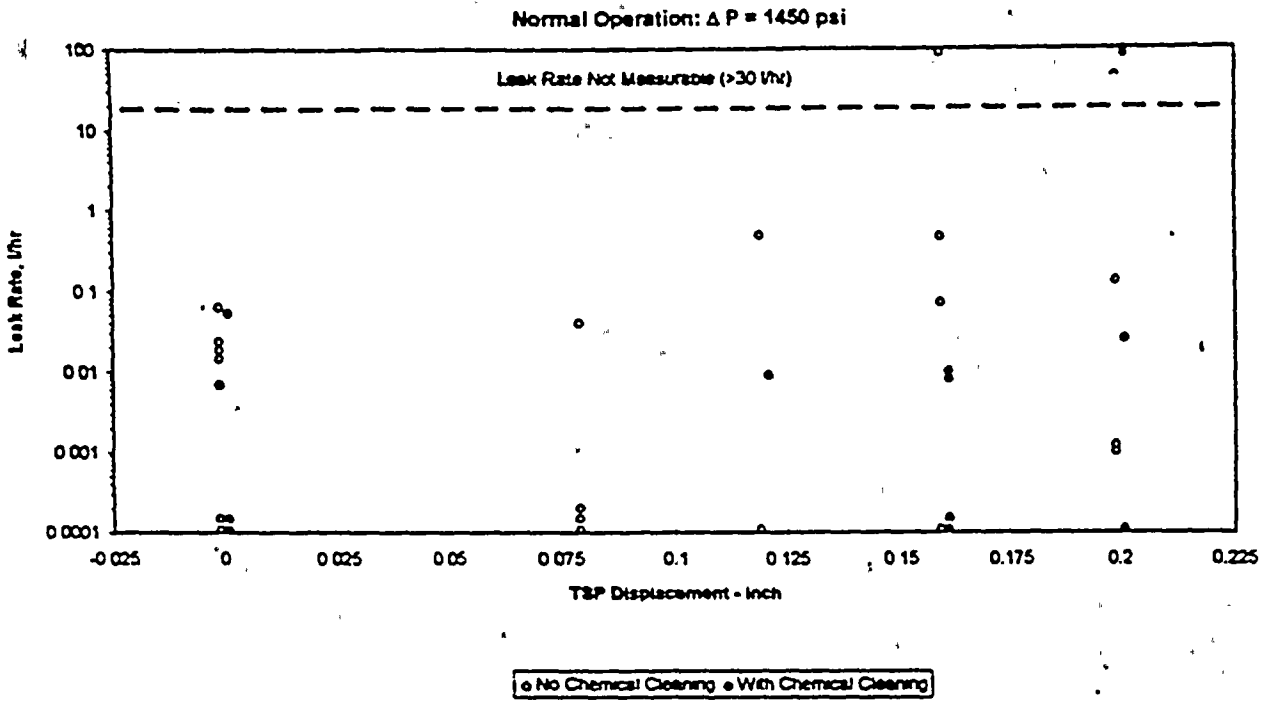
- Leakage from indications within packed or dented TSPs result in negligible leakage

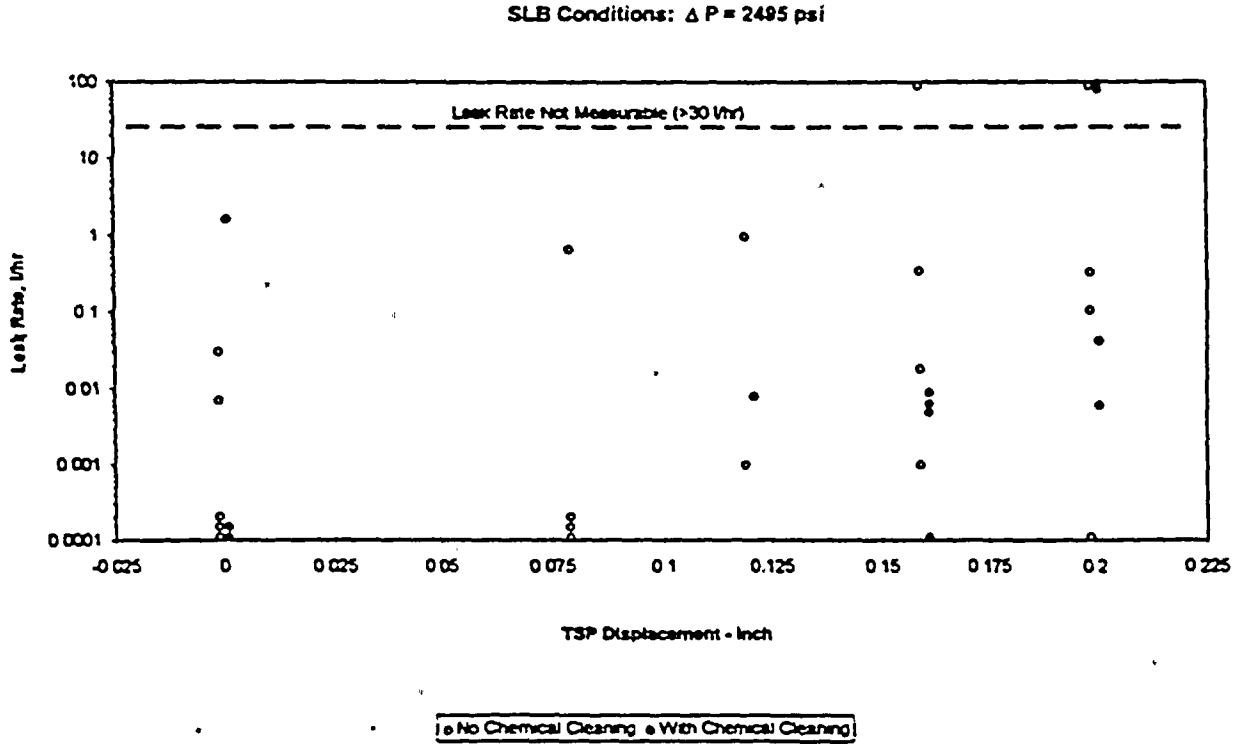
Summary of Laboratory Leak Rate and Pull Force Test Results for Dented TSP Intersections				
Specimen	Dent Volts	TW Crack Length, in.	SLB Leak Rate, gpm	TSP Pull Force, lbs
FAT-1	7.4	0.500	0.0	-
FAT-2	6.1	0.299	0.0	4,200
FAT-3	12.1	0.300	0.0	3,220
FAT-4	12.0	0.697	0.0	-
FAT-5	4.6	0.300	-	475
FAT-6	0.0	0.302	-	700
FAT-7	9.4	0.509	0.0	-
FAT-8	17.4	0.707	0.0	-
FAT-9	3.4	0.513	-	85
FAT-10	2.5	0.701	-	85
FAT-11	2.8	0.499	0.0002	80
BW-3	6.3	0.78[1]	0.0	-
BW-9	6.4	0.65[1]	0.0	-

Notes:

1. Corrosion crack specimens. Lengths given are total corrosion crack length of known TW cracks. TW lengths were not measured.

Leak Rates (Dampierre-1 Data) from 20 mil Diameter Hole with Packed Crevice





SLB TSP Displacement Analysis Results

SLB Forces on TSP to Cause Displacement

- Maximum force on TSP < 60 lbs even for SLB upstream of flow restrictor

Conclusions

- SLB forces acting on TSPs are much smaller than the forces required to displace the TSP with packed crevices
- 0.1 to 1.3 tubes with packed crevices within tube groups of 13 to 60 tubes are adequate to prevent SLB TSP displacement
- 0.2 to 2.5 tubes per tube group are adequate to prevent TSP displacement even following chemical cleaning

Overall Conclusions

TSPs With Packed Crevices Will Not Displace Relative to the Tube in a SLB Event

Tube Integrity Analyses Should be Based Upon:

- Only crack length outside TSP contributes to the potential for tube burst
- Only the throughwall crack length outside the TSP or near the edge of the TSP contributes to potential SLB leakage
  - Even with crack extending outside the TSP, crack opening is restricted by the packed crevice, particularly for dented TSP intersections
- Adequate TSP integrity is retained to prevent tube rupture as long as there is not a loss of a section of TSP at an indication
  - Limited cracking of the TSP ligament at an indication is acceptable provided there is not a loss of a TSP section
  - Acceptable TSP integrity would include one crack at a tube indication or two or more cracks if the adjacent tube intersection has only one crack
- Some denting presence in a SG provides a basis for the TSP corrosion and packed crevices to develop high forces resisting SLB TSP displacement and resulting in negligible leakage for indications within the TSP

Overall Conclusions

Alternate Repair Criteria for Indications at Dented TSP Intersections

- Based on TSP preventing tube burst even at SLB conditions for indications within the TSP or negligible (about < 0.2") extension outside of the TSP
- Limiting SLB leakage within acceptable limits would be the basis for tube repair for indications at dented TSP intersections within or negligibly outside the TSP
- ARCs for cracks (PWSCC) extending significantly outside the TSP would be based upon the length of crack outside the TSP relative to achieving structural and leakage integrity

TSP Displacement Analysis for Series 51 Steam Generators with Packed Crevices

Local TSP Structural Analyses

Hot - to - Cold Condition

Richard E. Smith

November 20, 1996

DISK 250 - DIABLO\NRC01 - 11/15/96

TSP Displacement Analysis
Presentation Outline

- Introduction
- TSP Support Configuration
- Review of Global (Dynamic) Model / Results for Hot-to-Cold Condition
- General Methodology for Detailed Evaluation
- Development of Tube / Plate Equivalent Properties
- Finite Element Model
- Initial Matrix of Boundary Conditions To Be Considered
- Analysis Status
- Tube / TSP Interaction: Tubes Exceeding Breakaway Force
- TSP Stress Results
- Remaining Work
- Analysis Conclusions

INTRODUCTION

- ANALYSIS PURPOSE - EVALUATE LOCKED TUBE CONDITION FOR SERIES 51 STEAM GENERATORS SUBJECT TO DIFFERENTIAL THERMAL EXPANSION FROM FULL POWER TO COLD SHUTDOWN

- ANALYSIS OBJECTIVES
  - DETERMINE NUMBER AND LOCATION OF TUBES THAT EXCEED BREAKAWAY FORCE
  - CALCULATE PLATE STRESSES FOR THE PRESCRIBED LOADING
  - CALCULATE STRESSES FOR WELDS JOINING WEDGES AND SUPPORT BARS TO TSP AND WRAPPER

TSP SUPPORT CONFIGURATION

- TSP SUPPORTED BY WEDGES, SUPPORT BARS, AND TIERODS / SPACERS
- SIX WEDGES SPACED EVERY 60° AROUND PLATE CIRCUMFERENCE
- WEDGE WIDTH OF 6" FOR TSP 1 - 6, 10" FOR TSP 7
- TWO VERTICAL BAR SUPPORTS LOCATED 180° APART
- ONE CENTRAL TIEROD / SPACER, 4 PERIPHERAL TIERODS / SPACERS
- WEDGES AND VERTICAL BARS WELDED TO BOTH TSP AND WRAPPER
- TIERODS THREADED INTO TUBESHEET, WITH NUT ON TOP OF UPPERMOST TSP
- SPACERS LOCATED BETWEEN TSP - NON-LINEAR INTERACTION

a,c

[ ]

Figure 8-2. Wrapper / TSP / Wedge Interface

a.c

Figure 8-4. TSP Support Locations
TSP 2 - 7

REVIEW OF GLOBAL (DYNAMIC) MODEL / RESULTS FOR HOT-TO-COLD LOAD CONDITION

- DYNAMIC MODEL LUMPED TUBES INTO 30 GROUPS
- NUMBER OF TUBES / GROUP BASED ON PLATE AREA RATIO
- FINITE ELEMENT MODEL CONSIDERED 7 TSP, CHANNEL HEAD, TUBESHEET, SHELL, TIERODS / SPACERS, AND TUBE GROUPS
- ANALYSIS SHOWED TUBE / PLATE INTERACTION FORCES THAT RANGED FROM 56 LBS. TO 419 LBS.
- MAX FORCES ISOLATED TO AREAS ADJACENT TO WEDGES
- DISPLACEMENT PLOTS SHOW HIGH LOCALIZED DISPLACEMENTS
- DUE TO TUBE GROUPING, DYNAMIC MODEL DID NOT GIVE SUFFICIENT DETAIL IN WEDGE REGIONS
- DETAILED MODELS OF WEDGE REGIONS NEEDED TO CALCULATE TUBE / PLATE INTERACTION FORCES, AND PLATE AND WELD STRESSES

a,c

Figure 8-5. Overall Finite Element Model

a,c

Figure 8-7. Location of Tube Groups and Number of Tubes Per Group

Table 10-2

Summary of Maximum Tube / Plate Interface Forces
Full Power to Cold Shutdown Conditions

a.c

[ ]

a,c

Figure 10-6. Distribution of Tube / Plate Forces
Full Power to Cold Shutdown - Plate 6
Quadrant 1,3 Support Locations

a,c

Figure 10-7. Distribution of Tube / Plate Forces
Full Power to Cold Shutdown - Plate 7
Quadrant 1,3 Support Locations

a,c

Figure 10-13. Distribution of Tube / Plate Forces
Full Power to Cold Shutdown - Plate 6
Quadrant 2,4 Support Locations

a,c

Figure 10-14. Distribution of Tube / Plate Forces
Full Power to Cold Shutdown - Plate 7
Quadrant 2,4 Support Locations

a,c

Figure 10-15. Displaced Geometry Plot
Full Power to Cold Shutdown
Quadrant 1,3 Support Locations

a,c

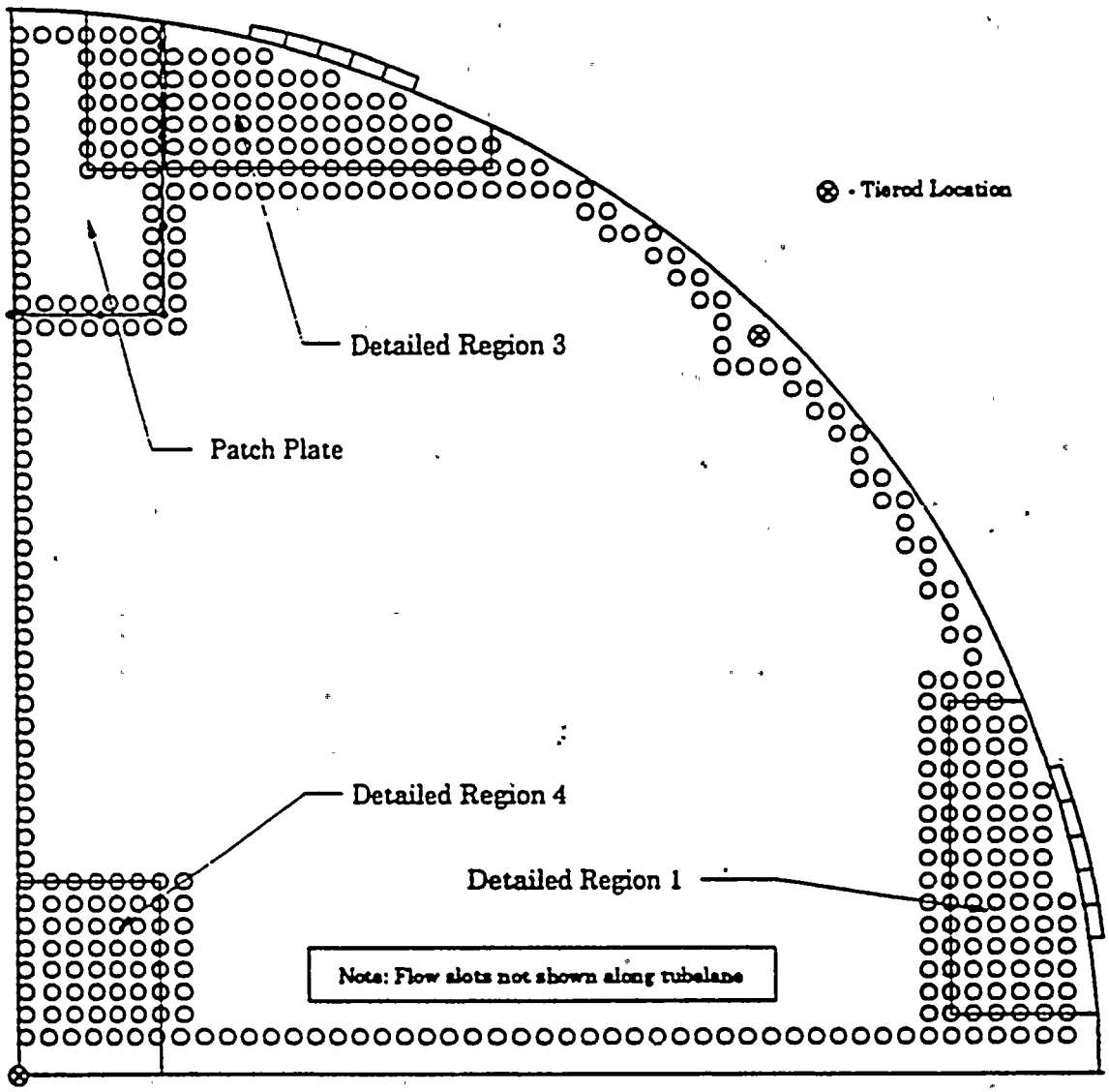
Figure 10-16. Displaced Geometry Plot
Full Power to Cold Shutdown
Quadrant 2,4 Support Locations

General Methodology for Detailed Evaluation

- Develop Detailed Models of Three wedge Regions and Central Region Adjacent to Tierod
- Develop Plate Equivalent Plate Properties for Local Wedge Regions Using Detailed Models
- Modify Dynamic Model to Include More Detailed Modeling of Wedge Regions and Central Tierod Area
- Apply Temperature Gradients to Model
- Calculate Tube / Plate Interaction Forces
- For Any Tube Where Breakaway Force is Exceeded, Decouple Tube / Plate Interface, and Rerun Thermal Solution Until Converged Solution Results
- Once Converged Solution is Obtained, Calculate Weld Stresses
- Consider Various Boundary Conditions to Account for TSP Support Arrangement, Fixed / Pinned TSP / Wrapper Interface, and Min / Max Breakaway Force

DEVELOPMENT OF TUBE / PLATE EQUIVALENT PROPERTIES

- DEVELOP DETAILED MODELS OF THREE WEDGE REGIONS AND CENTRAL REGION ADJACENT TO TIEROD
- DEVELOP CORRESPONDING EQUIVALENT PLATE MODEL OF EACH REGION
- INCLUDE TUBES WITH PACKED INTERSECTIONS IN EACH MODEL
- APPLY DIFFERENTIAL TEMPERATURE TO TUBES
- ADJUST TUBE / PLATE PROPERTIES TO ACHIEVE SAME (OR AS CLOSE AS POSSIBLE) AXIAL STRESS DISTRIBUTION IN TUBES



Model 51 Tube Support Plate
Location and Size of Detailed Plate Regions

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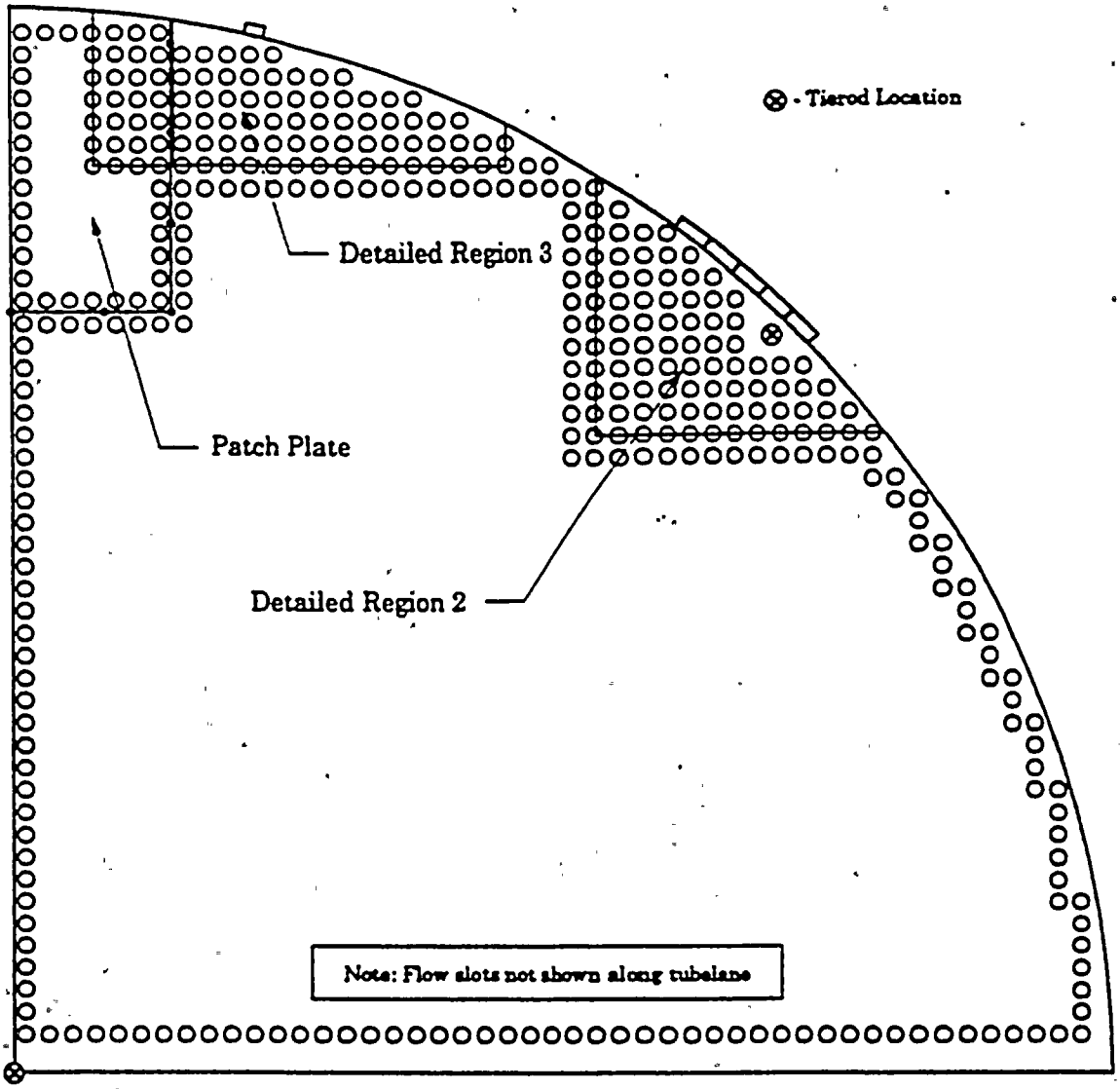
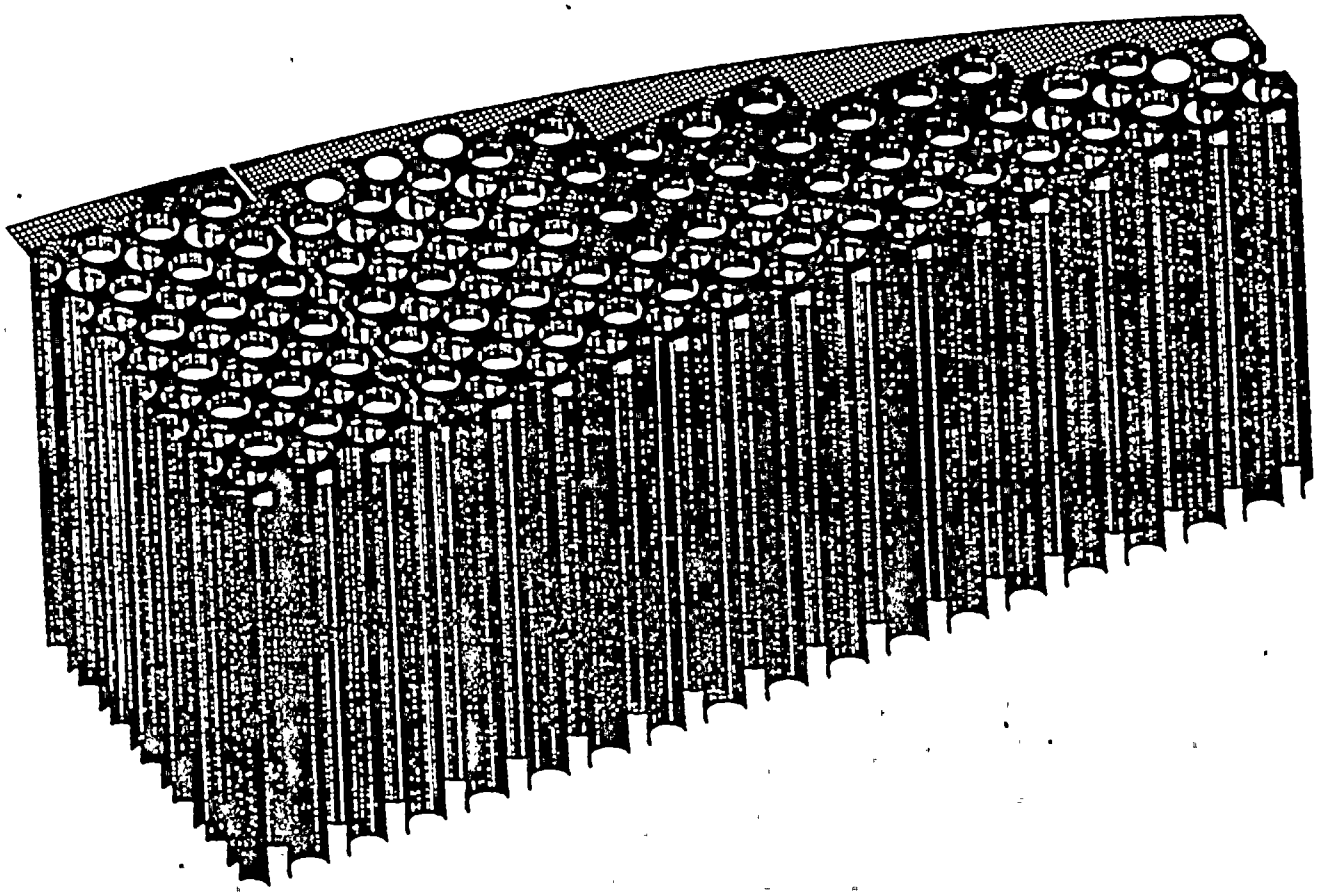


Model 51 Tube Support Plate
Location and Size of Detailed Plate Regions



DETAILED REGION 3 / PATCH PLATE
FINITE ELEMENT MODEL

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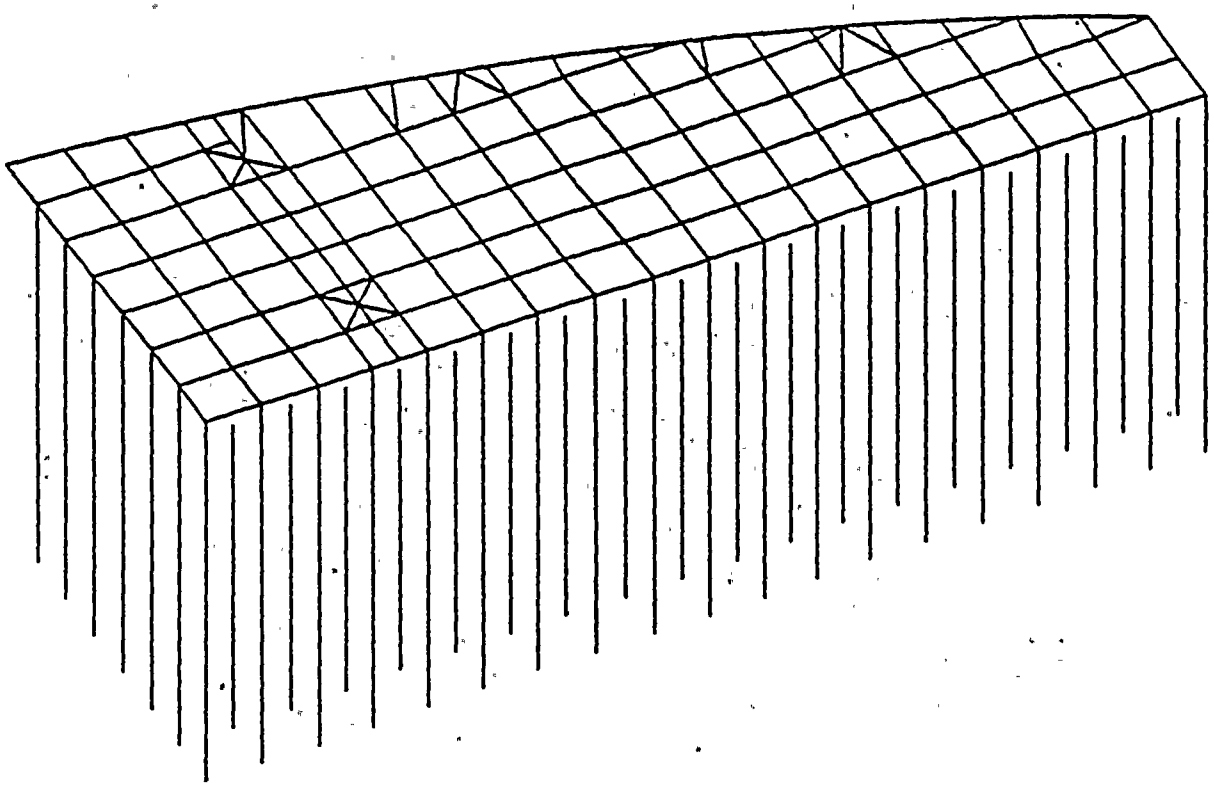

DETAILED REGION 3 / PATCH PLATE
EQUIVALENT PLATE MODEL

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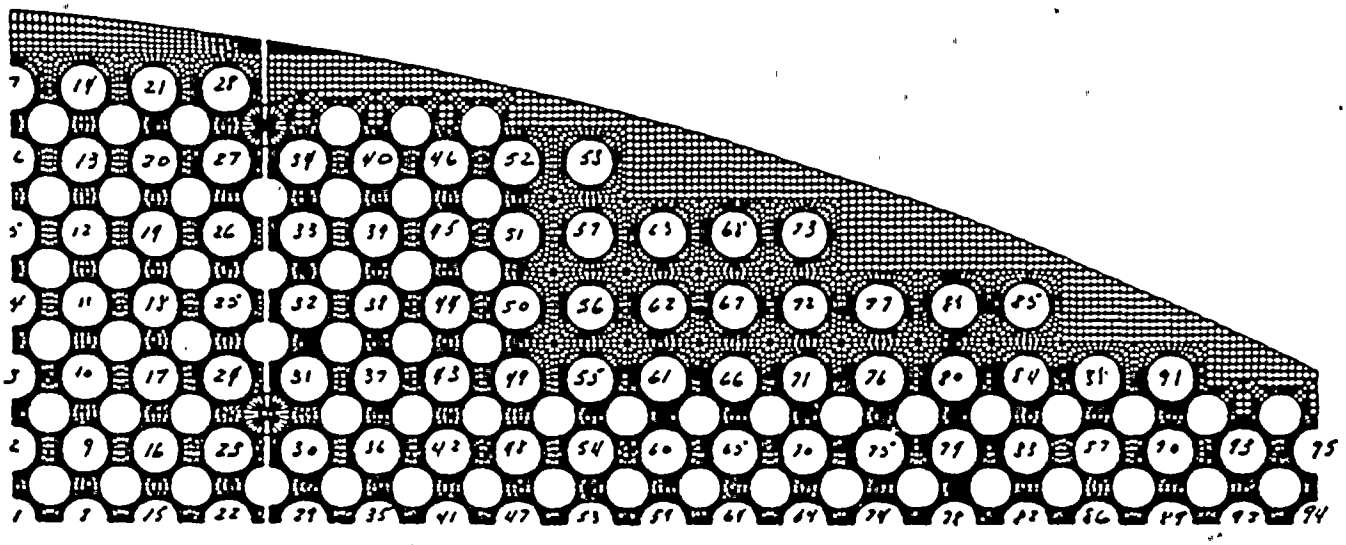
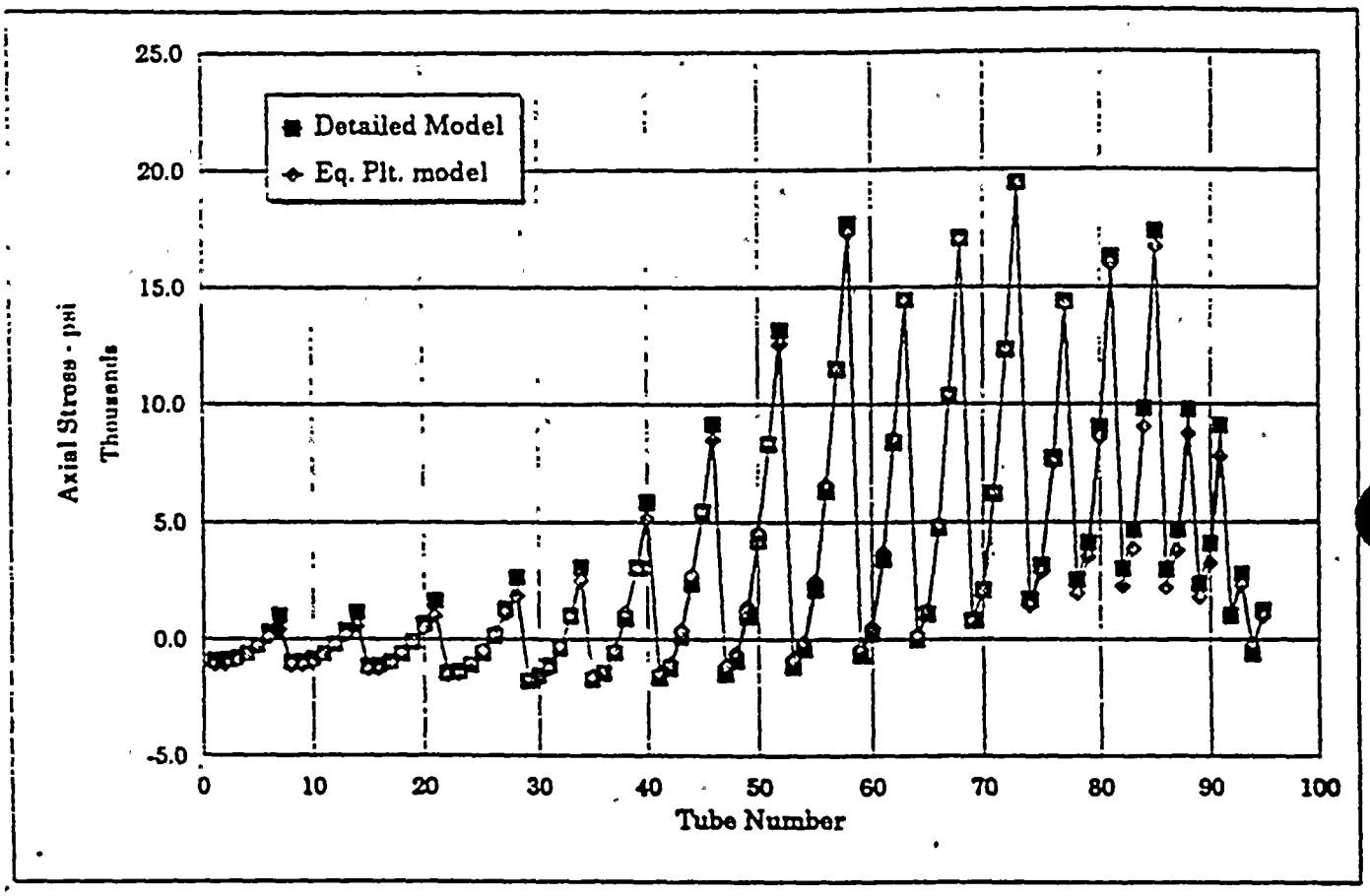


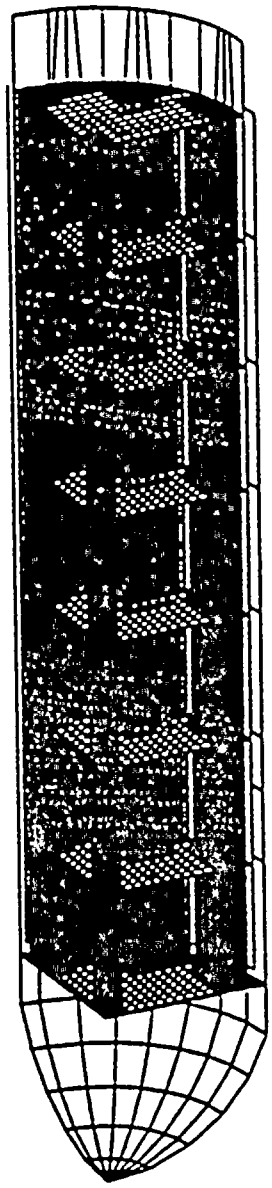
DETAILED REGION 3 / PATCH PLATE
TUBE NUMBERING SCHEME

Comparison of Tube Axial Stress
Detailed Region 3
Six Inch Wedge Width

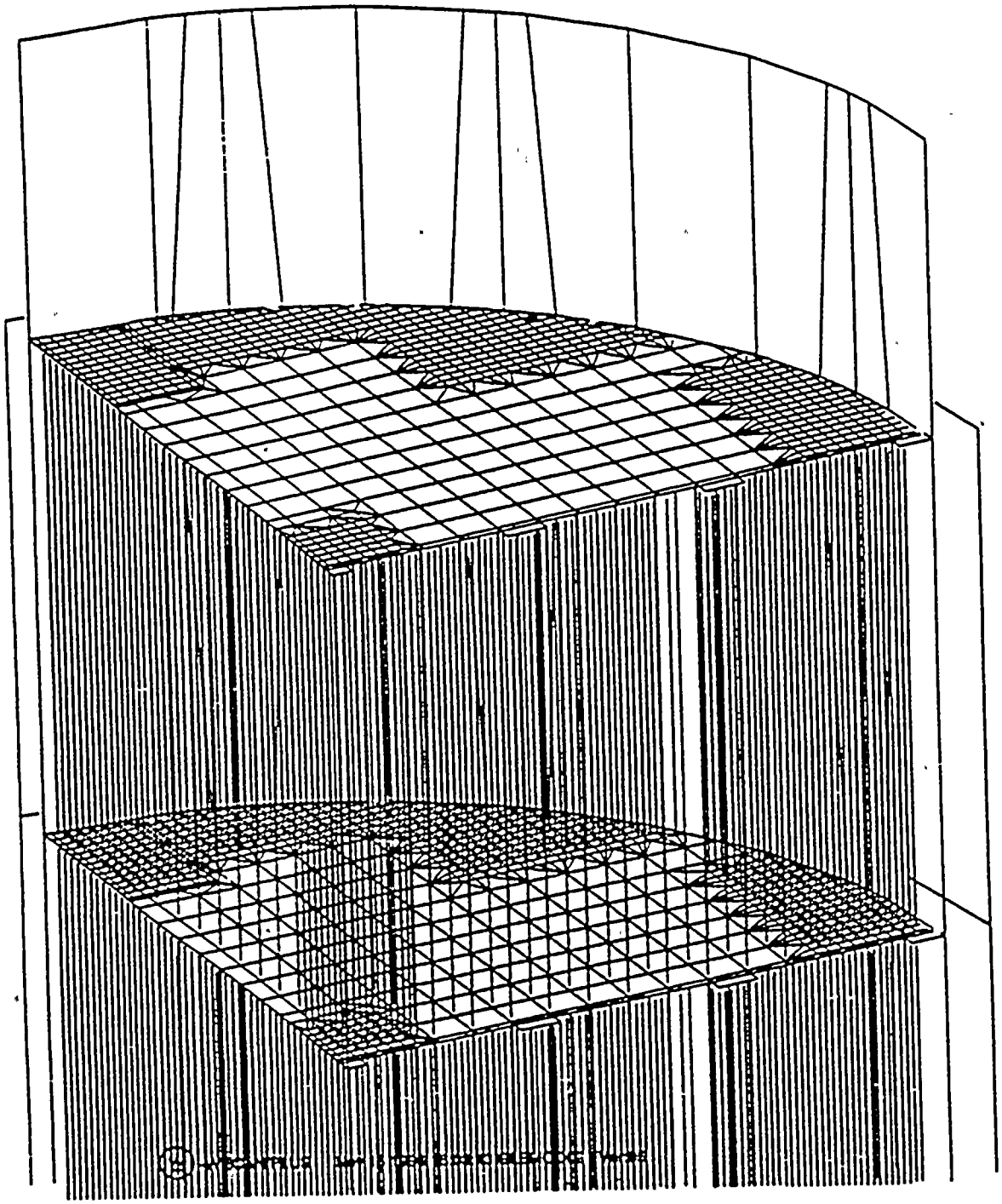


FINITE ELEMENT MODEL

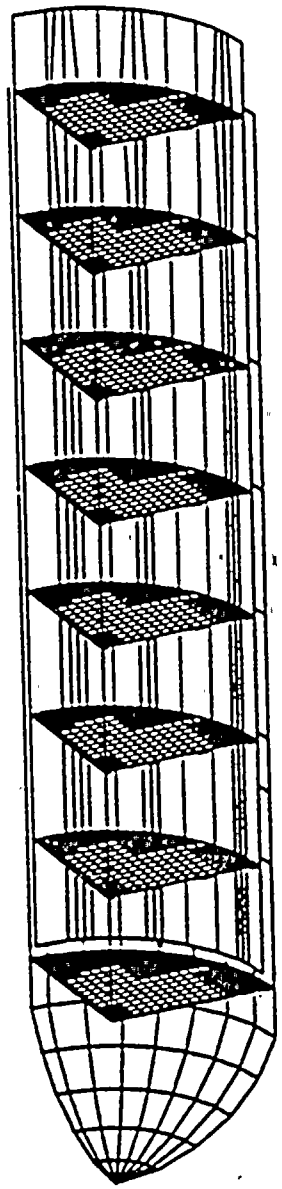
- FINITE ELEMENT MODEL SAME AS DYNAMIC MODEL WITH MODIFIED PLATE REPRESENTATION AND SHELL EXTENDED TO TOP TSP
- SINGLE TUBES MODELED - 567
- TUBE GROUPS MODELED - 119
- TOTAL NUMBER OF ELEMENTS IN MODEL EXCEEDS 31,000



FINITE ELEMENT MODEL

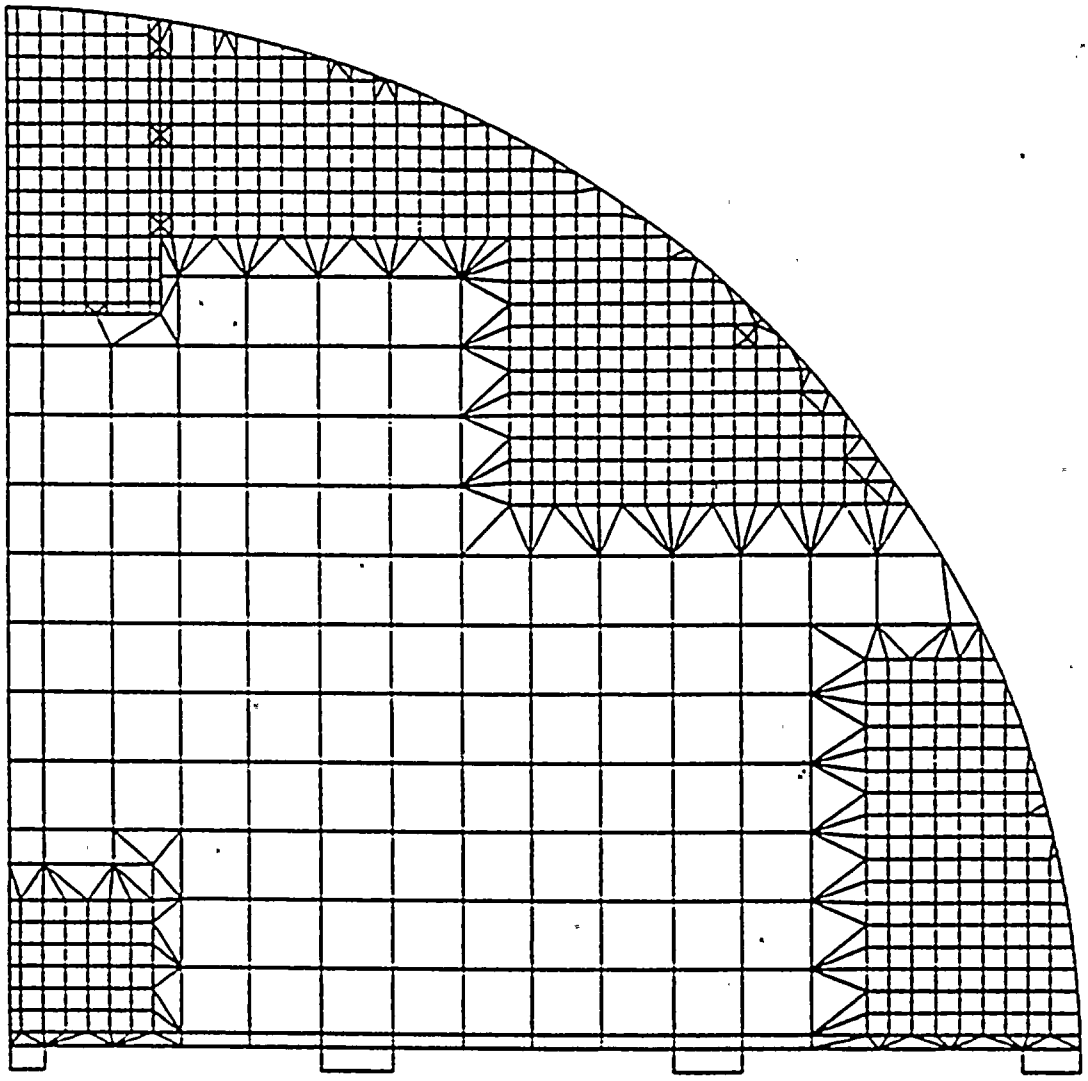


FINITE ELEMENT MODEL
ENLARGED VIEWS OF PLATES 6 AND 7



FINITE ELEMENT MODEL
TUBE ELEMENTS NOT SHOWN

DISK 250 - DIABLO\NRC01 - 11/15/96



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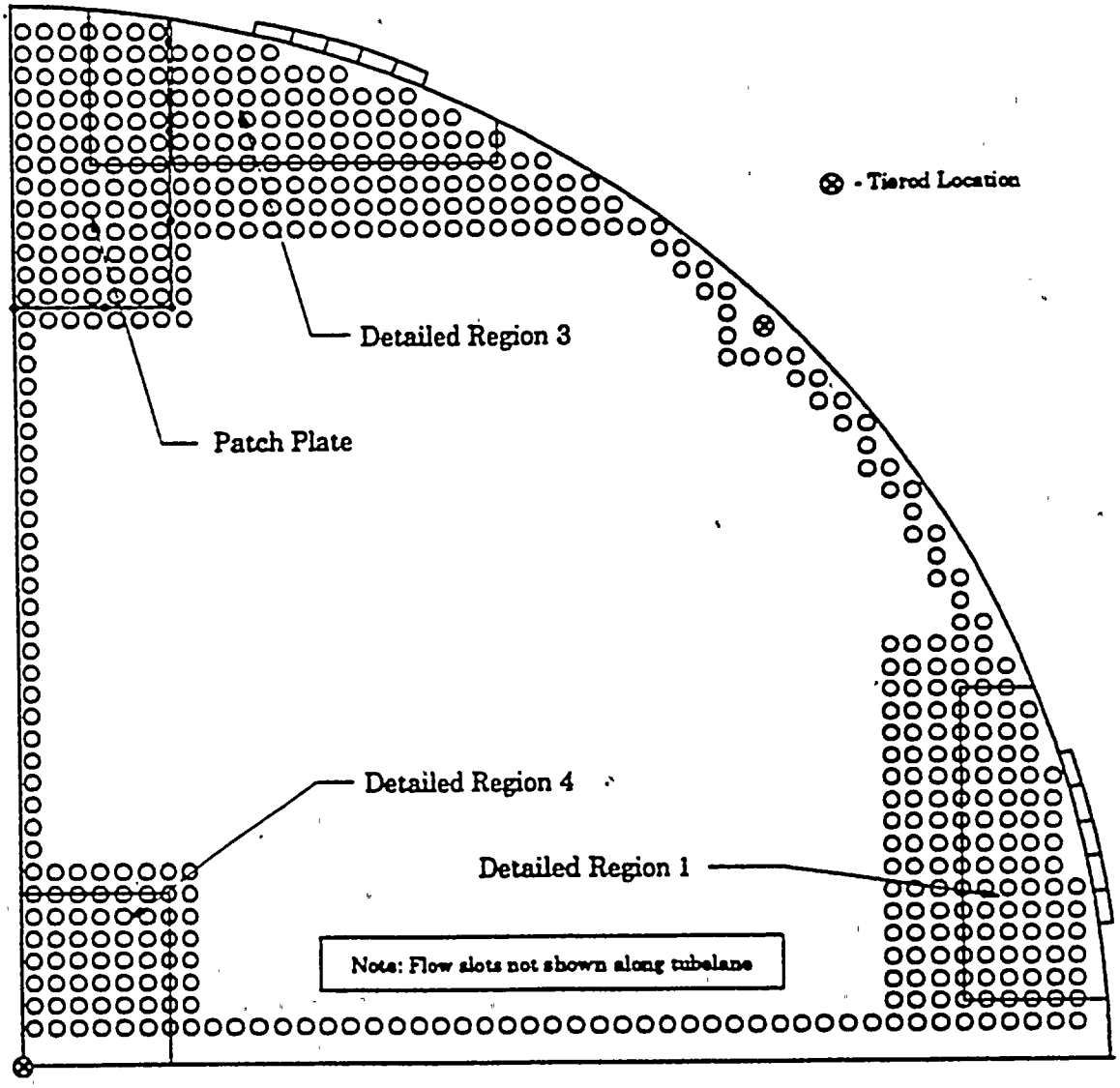
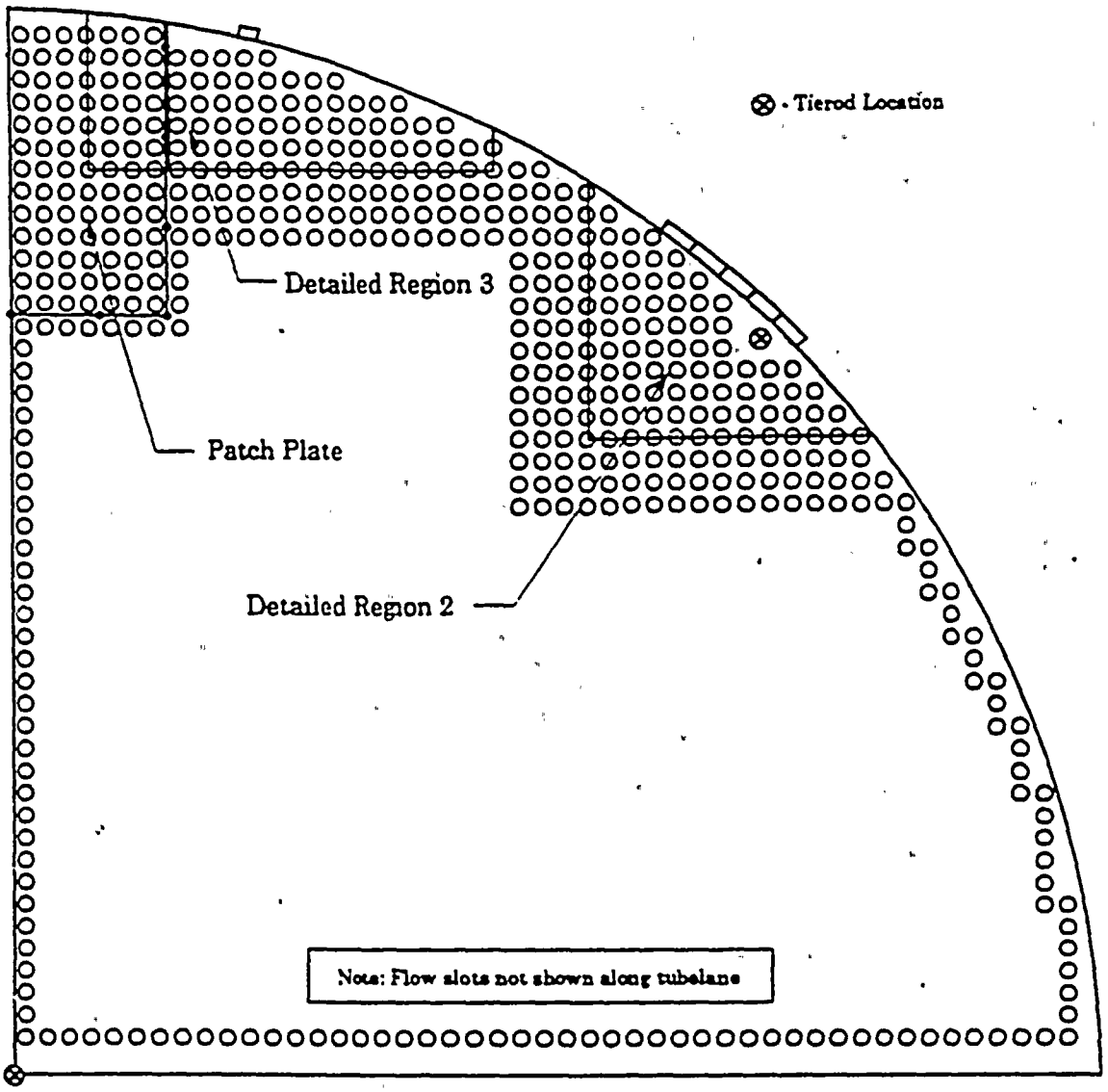
TOP PLATE ELEMENTS
PLAN VIEW



Model 51 Tube Support Plate
Location and Size of Detailed Plate Regions
Global Model

DISK 250 - DIABLO\NRC01 - 11/15/96



Model 51 Tube Support Plate
Location and Size of Detailed Plate Regions
Global Model

DISK 248 - MOD360-FIG03 - 11/18/1996

INITIAL MATRIX OF BOUNDARY CONDITIONS CONSIDERED

- NUMBER OF TSP SUPPORT CONFIGURATIONS: 2
  - QUADRANT 1, 3
  - QUADRANT 2, 4

- NUMBER OF PLATE / WRAPPER SUPPORT CONDITIONS: 2
  - FIXED AND PINNED

- NUMBER OF BREAKAWAY FORCES CONSIDERED: 2
  - MINIMUM ($-\sigma$) : 1630 LBS.
  - MAXIMUM ($+\sigma$) : 3740 LBS.

- TOTAL NUMBER OF CASES TO BE CONSIDERED: 8

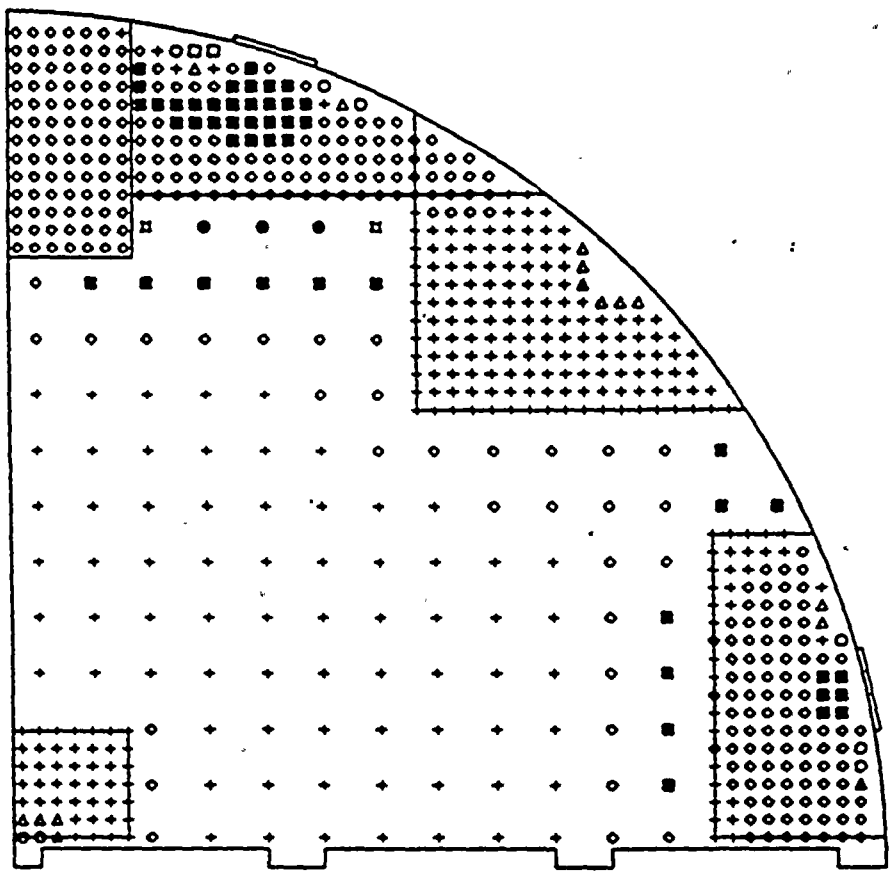
ANALYSIS STATUS

- FOUR CASES CURRENTLY IN PROGRESS
  - QUADRANT 1,3; FIXED TSP / WRAPPER; MIN FORCE
  - QUADRANT 1,3; PINNED TSP / WRAPPER; MIN FORCE
  - QUADRANT 2,4; FIXED TSP / WRAPPER; MIN FORCE
  - QUADRANT 2,4; PINNED TSP / WRAPPER; MIN FORCE

Distribution of Interface Forces
Quadrant 1, 3 Boundary Conditions
Plate / Wrapper - All DOF Coupled
All Elements Active

		Min / Max Force Values For Each Range									
Plate	Region	-1078 -1000	-1000 -500	-500 -100	-100 100	100 400	400 800	800 1200	1200 1630	1630 2543	Inactive
1	Interior	0	0	0	994	133	0	0	0	0	0
	Detail 1	0	0	7	134	0	0	0	0	0	0
	Detail 2	0	0	0	115	38	10	5	31	3	0
	Detail 3	0	3	29	80	0	0	0	0	0	0
	Patch Plate	0	0	1	89	1	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	3	37	1461	172	10	5	3	3	0
2	Interior	0	0	0	881	246	0	0	0	0	0
	Detail 1	0	0	13	128	0	0	0	0	0	0
	Detail 2	0	3	7	137	27	0	0	0	0	0
	Detail 3	0	0	0	109	3	0	0	0	0	0
	Patch Plate	0	0	0	85	6	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	3	20	1389	282	0	0	0	0	0
3	Interior	0	0	0	748	331	47	0	0	0	0
	Detail 1	0	0	4	137	0	0	0	0	0	0
	Detail 2	0	0	0	174	0	0	0	0	0	0
	Detail 3	0	0	6	106	0	0	0	0	0	0
	Patch Plate	0	0	0	91	0	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	10	1305	331	47	0	0	0	0
4	Interior	0	0	0	720	313	95	0	0	0	0
	Detail 1	0	0	0	136	5	0	0	0	0	0
	Detail 2	0	0	0	174	0	0	0	0	0	0
	Detail 3	0	0	0	112	0	0	0	0	0	0
	Patch Plate	0	0	0	86	5	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	0	1277	323	95	0	0	0	0
5	Interior	0	0	0	691	303	85	47	0	0	0
	Detail 1	0	0	5	94	42	0	0	0	0	0
	Detail 2	0	0	0	174	0	0	0	0	0	0
	Detail 3	0	0	8	41	63	0	0	0	0	0
	Patch Plate	0	0	0	17	74	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	13	1066	482	85	47	0	0	0
6	Interior	0	0	0	663	284	133	19	28	0	0
	Detail 1	0	3	3	31	98	6	0	0	0	0
	Detail 2	0	0	6	146	22	0	0	0	0	0
	Detail 3	2	3	2	4	72	29	0	0	0	0
	Patch Plate	0	0	0	1	90	0	0	0	0	0
	Detail 4	0	2	4	43	0	0	0	0	0	0
	TOTAL	2	8	15	888	566	168	19	28	0	0
7	Interior	0	0	0	786	218	76	19	28	0	0
	Detail 1	0	0	0	31	81	19	5	2	3	0
	Detail 2	0	0	0	118	50	6	0	0	0	0
	Detail 3	0	0	0	0	68	23	8	10	3	0
	Patch Plate	0	0	0	36	55	0	0	0	0	0
	Detail 4	0	0	0	36	9	3	1	0	0	0
	TOTAL	0	0	0	1007	481	127	33	40	61	0

DISTRIBUTION OF INTERFACE FORCES
QUADRANT 1 & 3 SUPPORT LOCATIONS
PLATE / WRAPPER - ALL DOF COUPLED
PLATE 6 - ALL ELEMENTS ACTIVE



FORCE LEGEND

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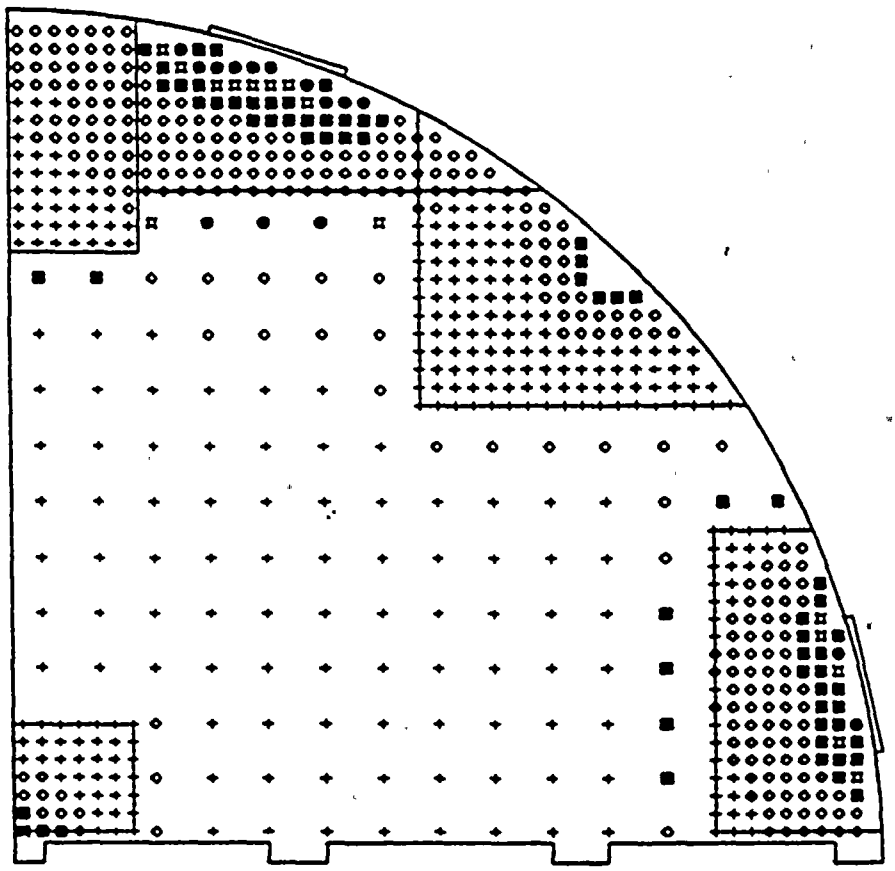
- ○ -1000. < F < -500.
- △ -500. < F < -100.
- + -100. < F < 100.
- ◇ 100. < F < 400.
- ■ 400. < F < 800.
- ⌑ 800. < F < 1200.
- ● 1200. < F < 1630.
- ⊞ 1630. < F < 2543.

● INTERFACE ELEMENT DEACTIVATED

DISTRIBUTION OF INTERFACE FORCES
QUADRANT 1 & 3 SUPPORT LOCATIONS
PLATE / WRAPPER - ALL DOF COUPLED
PLATE 7 - ALL ELEMENTS ACTIVE



FORCE LEGEND

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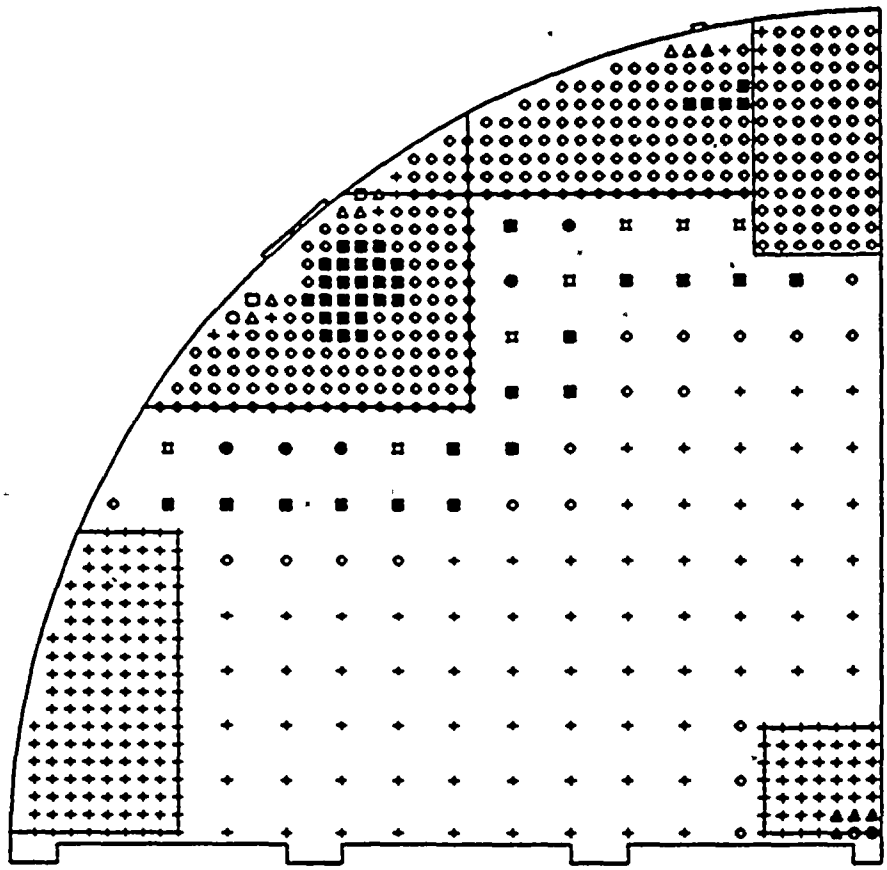
- ○ -1000. < F < -500.
- △ -500. < F < -100.
- + -100. < F < 100.
- ◇ 100. < F < 400.
- ■ 400. < F < 800.
- ⌑ 800. < F < 1200.
- ● 1200. < F < 1630.
- ⊞ 1630 < F < 2543.

● INTERFACE ELEMENT DEACTIVATED

Distribution of Interface Forces
Quadrant 2, 4 Boundary Conditions
Plate / Wrapper - All DOF Coupled
All Elements Active

		Min / Max Force Values For Each Range									
Plate	Region	-1410 -1000	-1000 -500	-500 -100	-100 100	100 400	400 800	800 1200	1200 1630	1630 2657	Inactive
1	Interior	0	0	0	938	189	0	0	0	0	0
	Detail 1	0	0	0	116	13	6	2	2	2	0
	Detail 2	0	0	16	158	0	0	0	0	0	0
	Detail 3	0	0	2	60	31	10	4	3	2	0
	Patch Plate	0	0	0	90	1	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	18	1411	234	16	6	5	4	0
2	Interior	0	0	0	833	265	28	0	0	0	0
	Detail 1	0	1	4	135	1	0	0	0	0	0
	Detail 2	0	0	0	156	18	0	0	0	0	0
	Detail 3	0	1	7	77	25	2	0	0	0	0
	Patch Plate	0	0	0	80	11	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	2	11	1330	320	30	0	0	0	0
3	Interior	0	0	0	739	256	133	0	0	0	0
	Detail 1	0	0	1	140	0	0	0	0	0	0
	Detail 2	0	0	0	174	0	0	0	0	0	0
	Detail 3	0	0	0	110	2	0	0	0	0	0
	Patch Plate	0	0	0	91	0	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	1	1303	258	133	0	0	0	0
4	Interior	0	0	0	729	208	133	57	0	0	0
	Detail 1	0	0	0	141	0	0	0	0	0	0
	Detail 2	0	0	1	59	114	0	0	0	0	0
	Detail 3	0	0	0	60	52	0	0	0	0	0
	Patch Plate	0	0	0	83	8	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	1	1121	382	133	57	0	0	0
5	Interior	0	0	0	720	161	133	104	9	0	0
	Detail 1	0	0	0	141	0	0	0	0	0	0
	Detail 2	0	0	3	28	143	0	0	0	0	0
	Detail 3	0	0	2	21	89	0	0	0	0	0
	Patch Plate	0	0	0	29	62	0	0	0	0	0
	Detail 4	0	0	0	49	0	0	0	0	0	0
	TOTAL	0	0	5	988	455	133	104	9	0	0
6	Interior	0	0	0	682	180	142	66	47	9	0
	Detail 1	0	0	0	141	0	0	0	0	0	0
	Detail 2	2	1	5	6	134	26	0	0	0	0
	Detail 3	0	0	3	1	103	5	0	0	0	0
	Patch Plate	0	0	0	3	88	0	0	0	0	0
	Detail 4	0	2	4	43	0	0	0	0	0	0
	TOTAL	2	3	12	876	505	173	66	47	9	0
7	Interior	0	0	0	748	218	28	76	57	0	0
	Detail 1	0	0	0	141	0	0	0	0	0	0
	Detail 2	0	0	0	4	122	27	11	7	3	0
	Detail 3	0	0	0	5	92	11	2	2	0	0
	Patch Plate	0	0	0	42	48	1	0	0	0	0
	Detail 4	0	0	0	36	9	3	1	0	0	0
	TOTAL	0	0	0	976	489	70	90	66	3	0

DISTRIBUTION OF INTERFACE FORCES
QUADRANT 2 & 4 SUPPORT LOCATIONS
PLATE / WRAPPER - ALL DOF COUPLED
PLATE 6 - ALL ELEMENTS ACTIVE

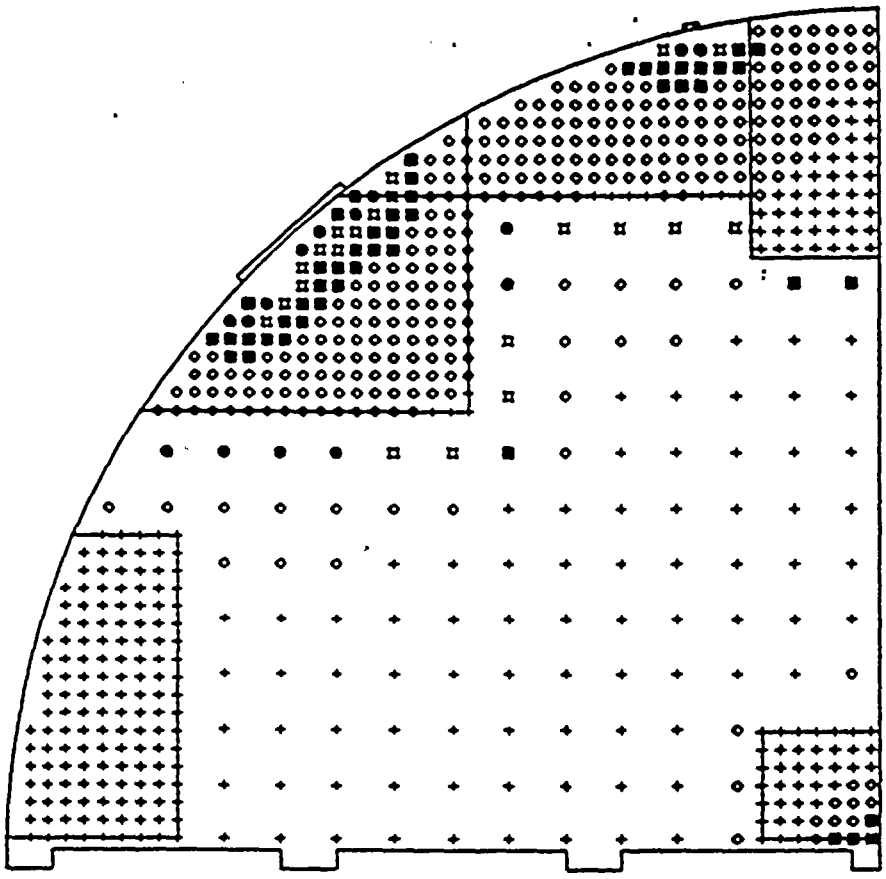


FORCE LEGEND

- □ -1410. < F < -1000.
- ○ -1000. < F < -500.
- △ -500. < F < -100.
- + -100. < F < 100.
- ◇ 100. < F < 400.
- ■ 400. < F < 800.
- ⌑ 800. < F < 1200.
- ● 1200. < F < 1630.
- ⊞ 1630. < F < 2657.

● INTERFACE ELEMENT DEACTIVATED

DISTRIBUTION OF INTERFACE FORCES
QUADRANT 2 & 4 SUPPORT LOCATIONS
PLATE / WRAPPER - ALL DOF COUPLED
PLATE 7 - ALL ELEMENTS ACTIVE



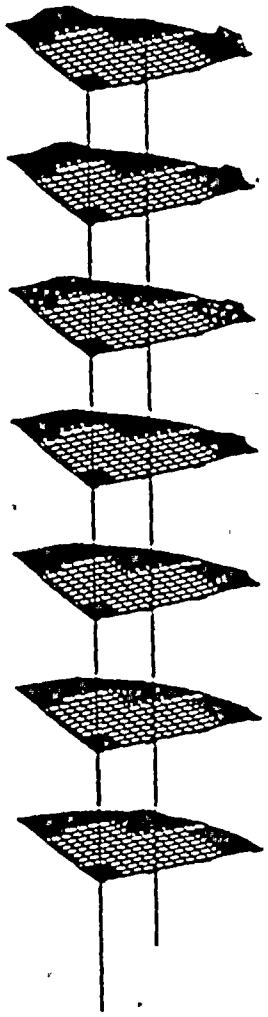
FORCE LEGEND

- □ -1410. < F < -1000.
- ○ -1000. < F < -500.
- △ -500. < F < -100.
- + -100. < F < 100.
- ◇ 100. < F < 400.
- ■ 400. < F < 800.
- ⌑ 800. < F < 1200.
- ● 1200. < F < 1630.
- ⊞ 1630. < F < 2657.

● INTERFACE ELEMENT DEACTIVATED

TSP Stress Results

- Maximum Stresses Concentrated at Wedges Near the Plate Edge
- General Plate Stresses Less Than Yield Two to Three Tube Pitches Away from Support Location
- Peak Stresses Less Than Yield Four to Five Tube Pitches Away from Support Location



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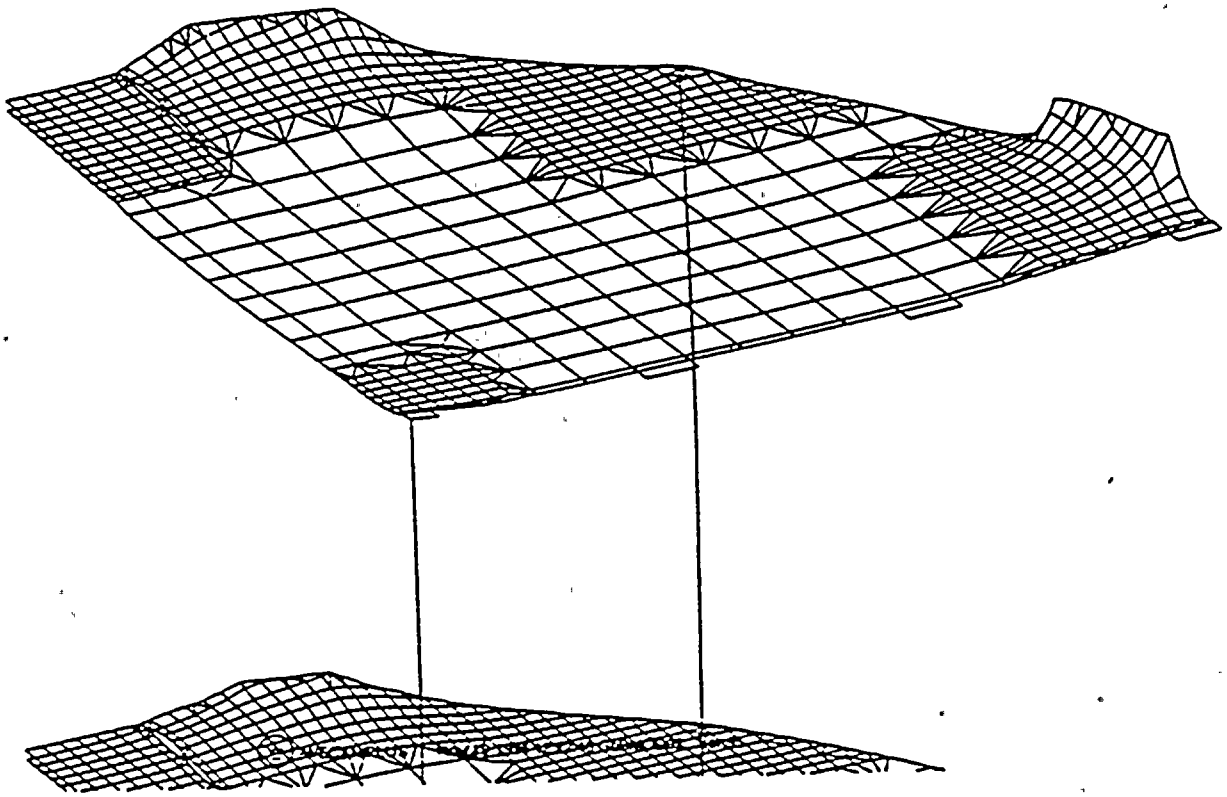
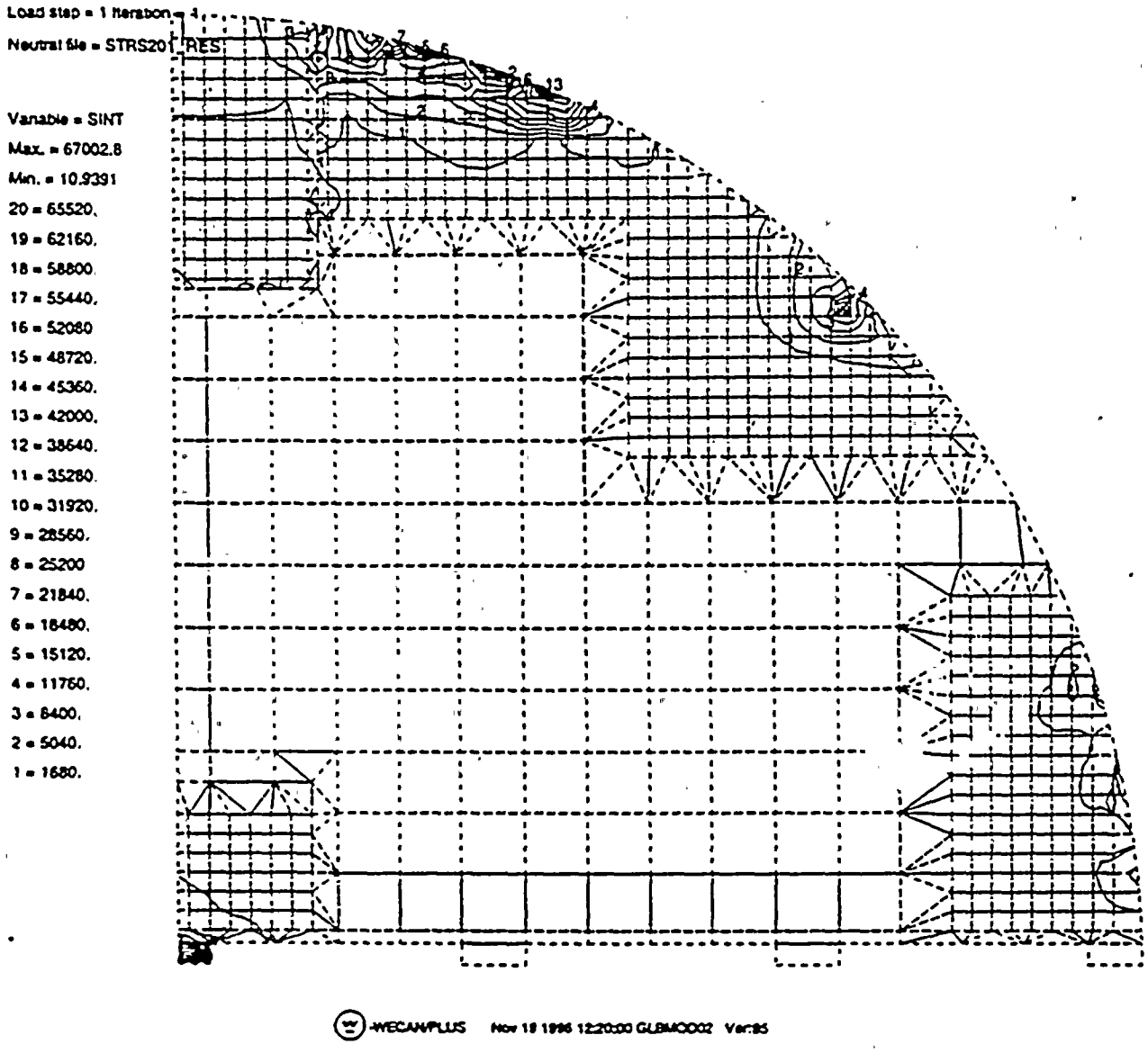
DISPLACED GEOMETRY
QUADRANT 1,3 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



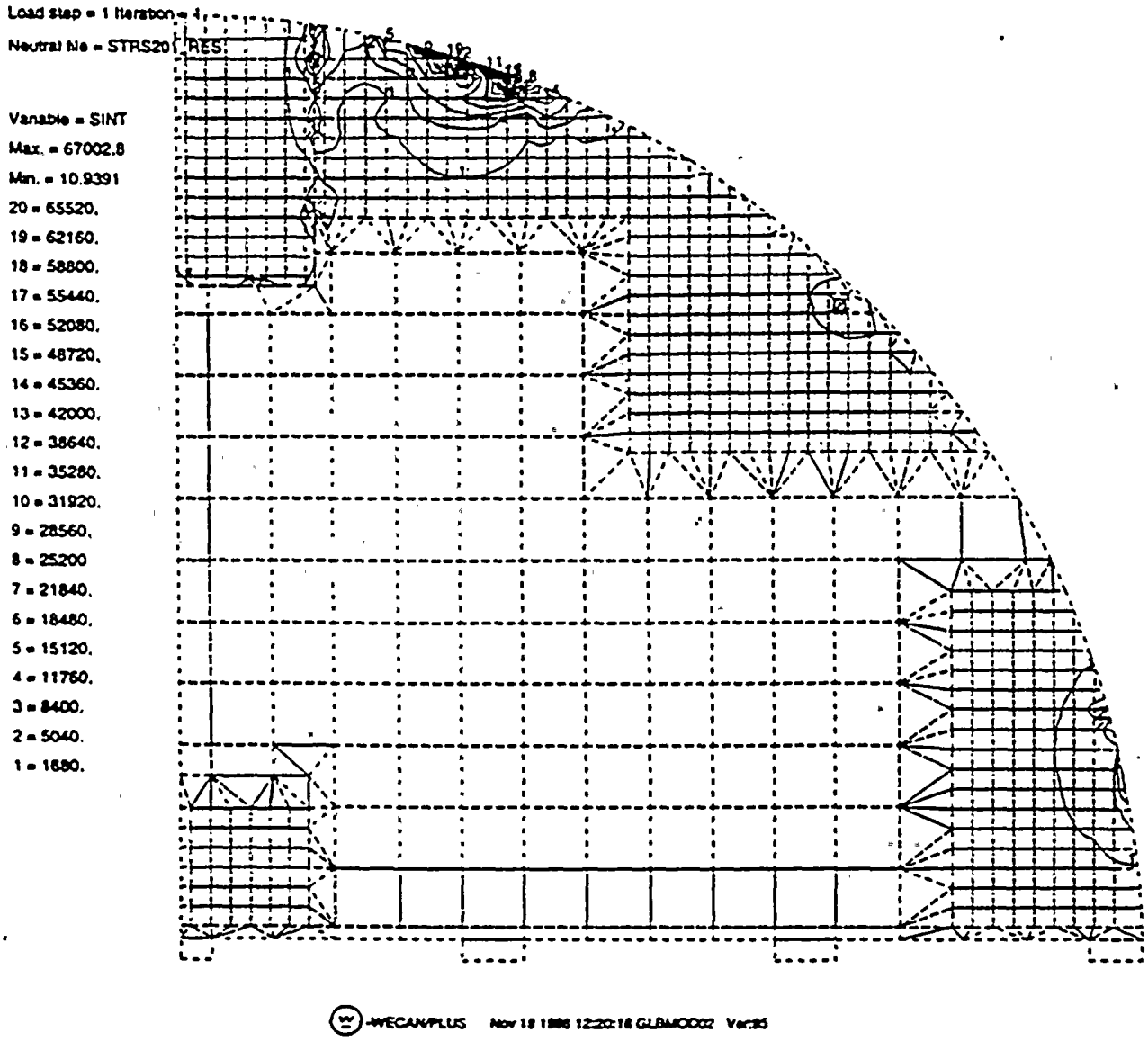
DISPLACED GEOMETRY - PLATE 7
QUADRANT 1,3 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/90



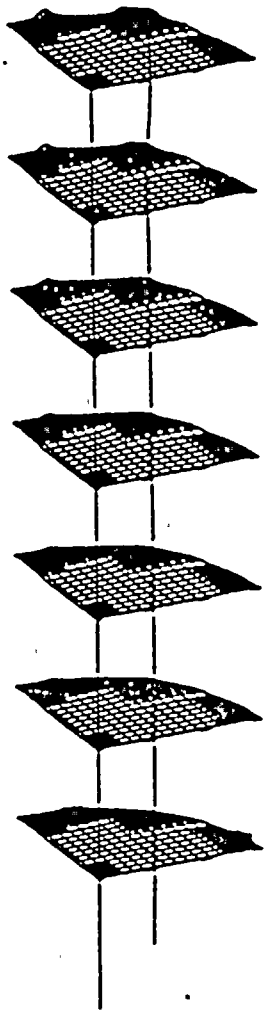
STRESS CONTOUR PLOT - PLATE 7
QUADRANT 1,3 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



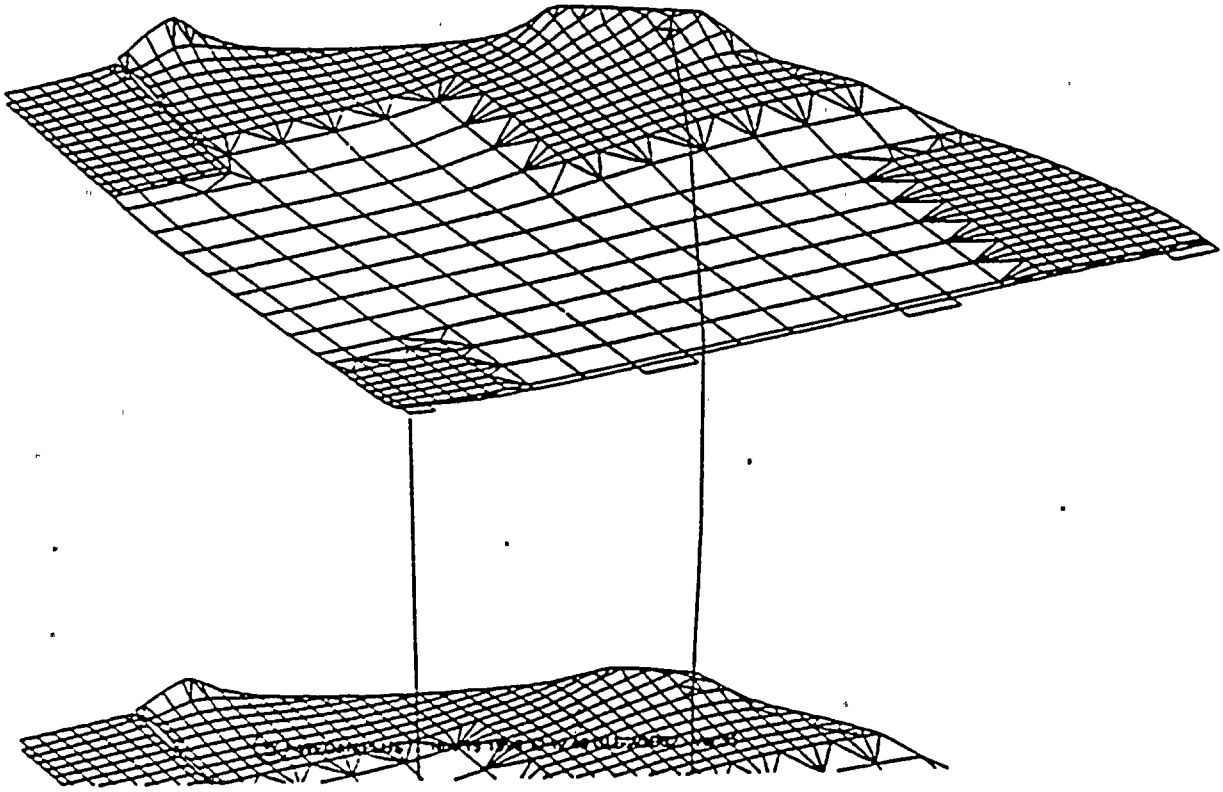
STRESS CONTOUR PLOT - PLATE 6
QUADRANT 1,3 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



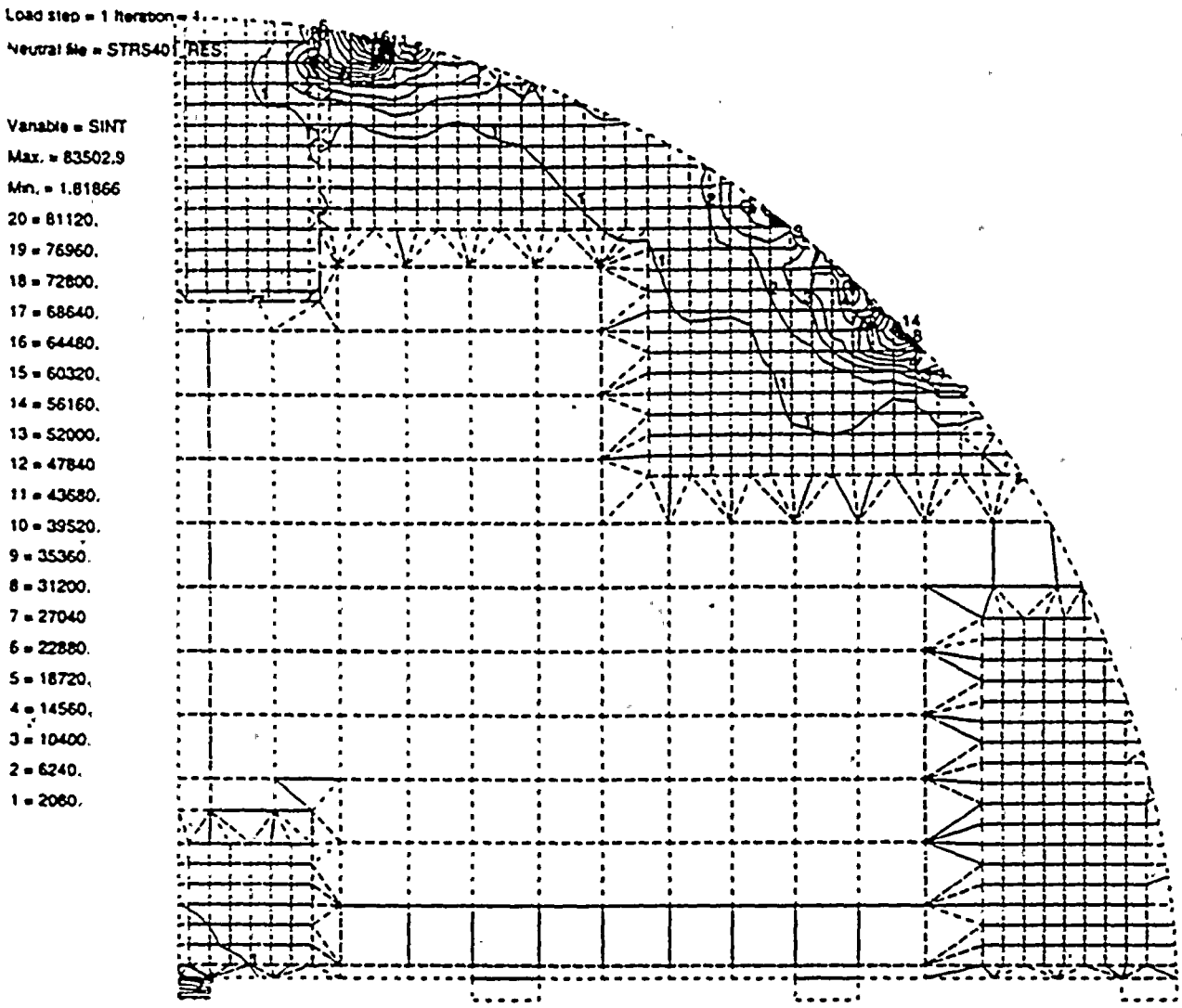
DISPLACED GEOMETRY
QUADRANT 2,4 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



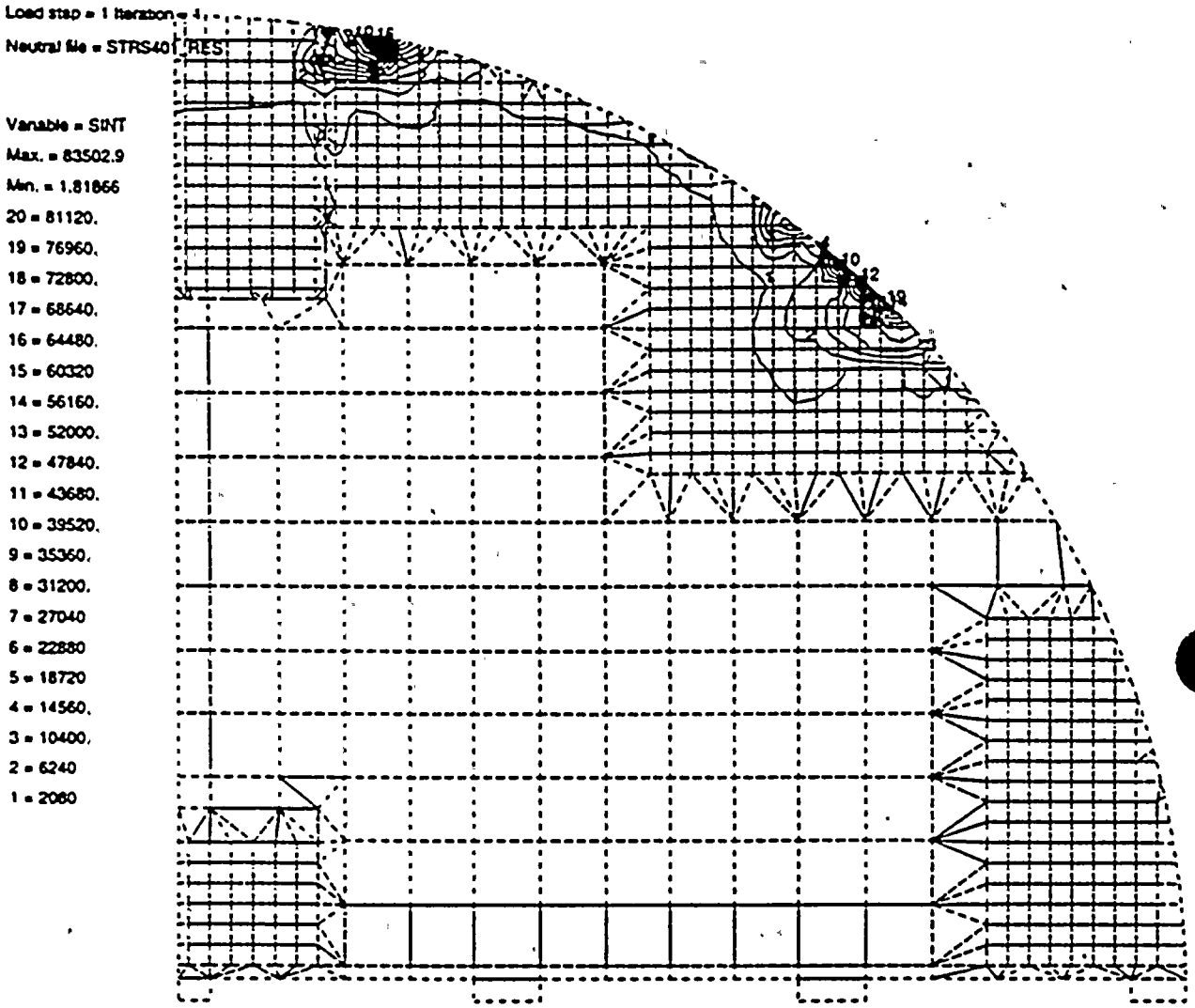
DISPLACED GEOMETRY - PLATE 7
QUADRANT 2,4 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



STRESS CONTOUR PLOT - PLATE 7
QUADRANT 2,4 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96



STRESS CONTOUR PLOT - PLATE 6
QUADRANT 2,4 SUPPORT CONDITION
PLATE / WRAPPER - ALL DOF COUPLED

DISK 250 - DIABLO\NRC01 - 11/19/96

REMAINING WORK

- COMPLETE MATRIX OF CASES TO CONVERGENCE
- CALCULATE WELD STRESSES
- PREPARE REPORT
- COMPLETE DOCUMENTATION

ANALYSIS CONCLUSIONS

- LIMITED NUMBER OF TUBES WILL EXCEED MINIMUM BREAKAWAY FORCE
- HOT-TO-COLD DISPLACEMENT AT TOP TSP IS 0.1 INCH. TUBE BREAKAWAY WILL NOT RESULT IN SIGNIFICANT DISPLACEMENT
- BREAKAWAY OF LIMITED NUMBER OF TUBES ADJACENT TO WEDGES WILL NOT RESULT IN SIGNIFICANT INCREASE IN PLATE DISPLACEMENT UNDER SLB
- PLATE STRESSES ARE LOCALIZED AT PLATE WEDGE REGION
- PLATES SUPPORTED BY BOTH WEDGES AND TUBES:
  LOSS OF WEDGE SUPPORT WOULD NOT RESULT IN PLATE MOTION
- AXIAL STRESS IN TUBES FOR HOT-TO-COLD CONDITION LESS THAN YIELD

NDE Sizing for Axial PWSCC at Dented TSPs

NRC/Utility Meeting

November 20, 1996

Presented By:

T. A. Pitterle

Nuclear Services Division

Westinghouse Electric Corp.

Discussion Topics

Pulled Tube and Laboratory Specimen Database

Coil Lead-in and Lead-out Crack Edge Effects

- Length adjustment guidelines

Depth Adjustments for Uncorroded Ligaments

General Comparisons of NDE and Destructive Exam

NDE Uncertainties

Conclusions

NDE Sizing for Axial PWSCC

Objective

- Qualify + Point sizing for PWSCC axial cracks at dented TSPs
  - Average depth
  - Maximum depth
  - Length

Database

- 4 pulled tube axial PWSCC indications from dented TSP intersections
  - Lengths = 0.12" to 0.99"
  - 4 cracks in 3 intersections

- 14 laboratory cracks in dented specimens
  - Lengths = 0.13" to 2.56"
  - 14 cracks in 6 specimens
  - Additional specimen with 2 cracks being processed

NDE Analyses are "Blind"

- Completed prior to destructive examination

- Only 1 pulled tube has NDE following tube exam

Coils Evaluated

- + Point mid-range - principal emphasis

- Also + Point high frequency, mag bias and gimbaled

Laboratory Specimen Preparation

Mechanically dented

Cracked in doped steam

TSP with packed magnetite crevice placed on tube

NDE data collected

Specimens burst

- 3 with TSP and 3 freespan

Specimens destructively examined

Fractography to obtain depth vs length profiles

- Uncorroded ligaments identified and sized

Crack Morphology of Pulled Tubes and Lab Specimens

Pulled Tube PWSCC Shows Relatively Simple Morphology

- Generally single cracks
  - May be two cracks about 180° apart
- Typical initiation as microcracks
- Only a few remaining uncorroded ligaments
- Cracks nearly linear with small (typically < 10 mil) ligaments joining microcracks

Laboratory PWSCC Morphology

- No identifiable differences from pulled tubes

No Identifiable Difference in Sizing Lab Specimens vs Pulled Tubes

- Shallower lab and pulled tube ind. show comparable NDE
- Deeper lab ind. easier to size as would pulled tubes if available

Lab Specimen Preparation Emphasized Deeper Indications

- Desire to demonstrate capability to size indications challenging structural integrity
- Smaller indications also obtained with larger indications

Coil Lead-in, Lead-out Crack Edge Effects

Edge Effects

- Demonstrated on EDM notches
- Effects somewhat larger for + Point coil than for pancake coils
  - Larger + point field of > 0.2"

Effects Found on EDM Notch and Laboratory Specimens

- Lengths overestimated within coil field of end of crack
- Phase angles increase within coil field of edge of crack
  - Causes ID depths to be overestimated
  - OD phase angles frequently occur at edges of crack
- Increased phase angles occur with low voltage response
  - Typically depths > 85% with < 1 volt

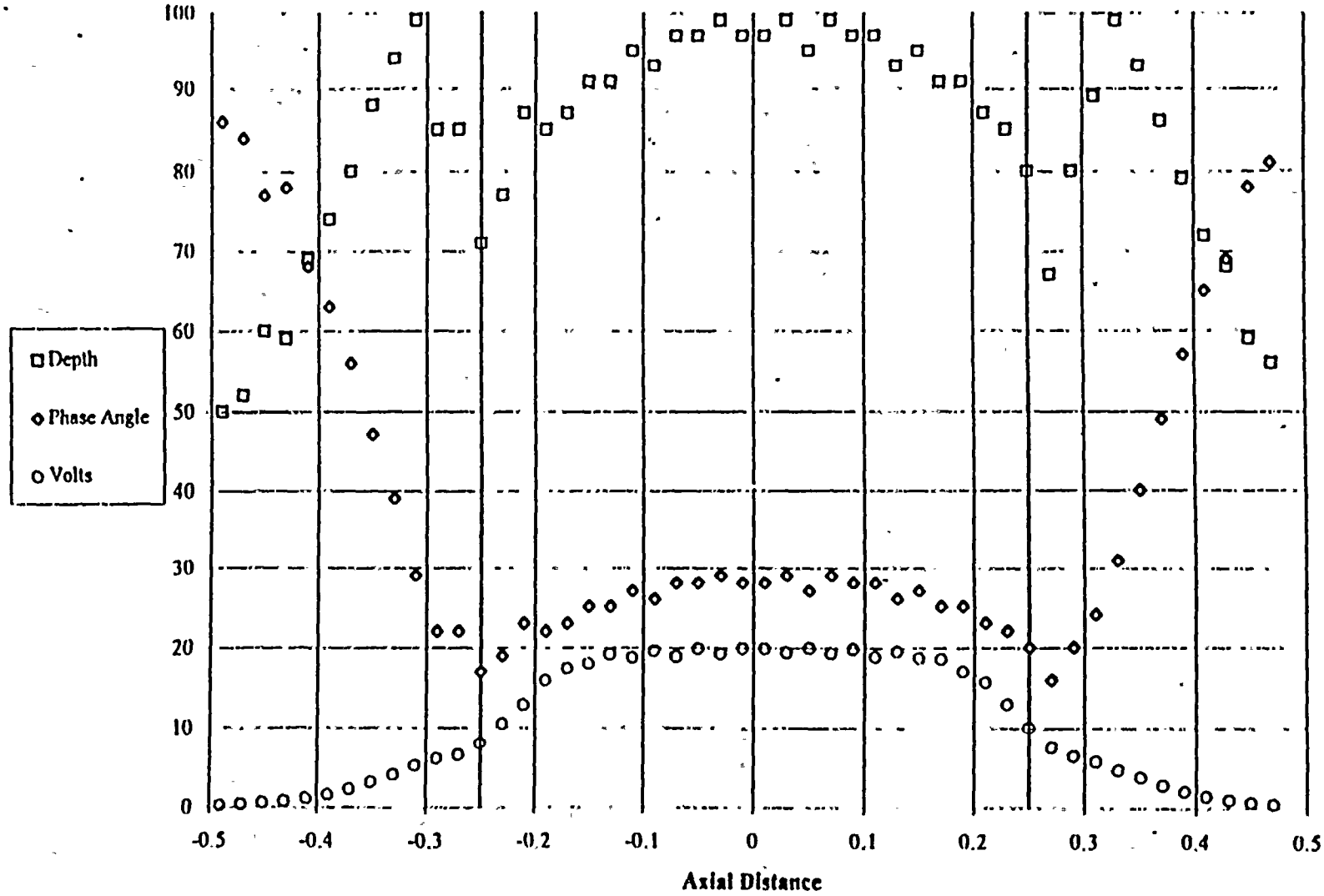
Edge Effects Significantly Reduce Detection of Large (.1-0.3") Ligaments Within Macrocrack

- Effects tend to result in deep NDE calls at ligaments

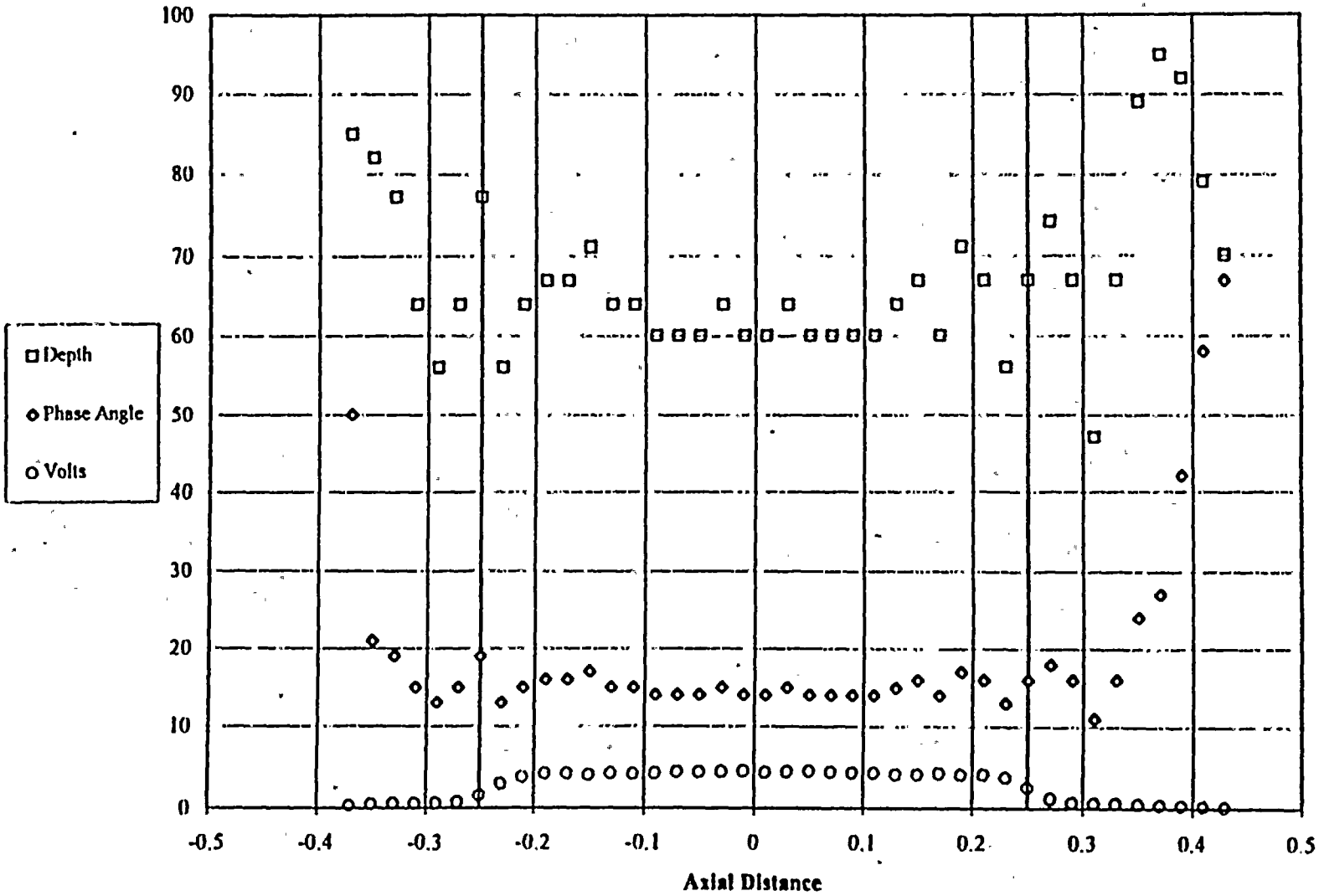
Length Adjustment Guideline Defined

- Length adjustment applied to NDE for development of NDE uncertainties

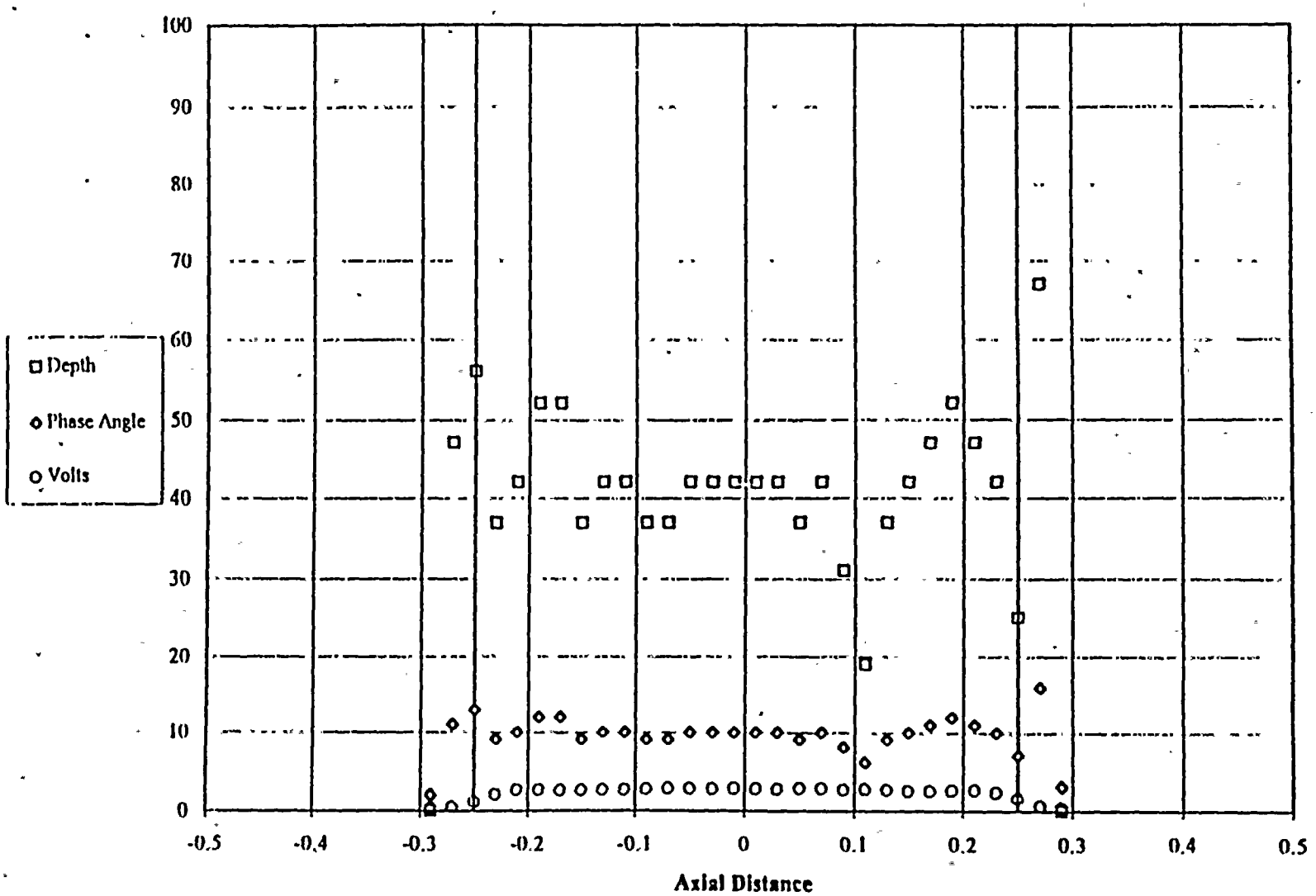
100% TW Slot - Eddynet, + Point



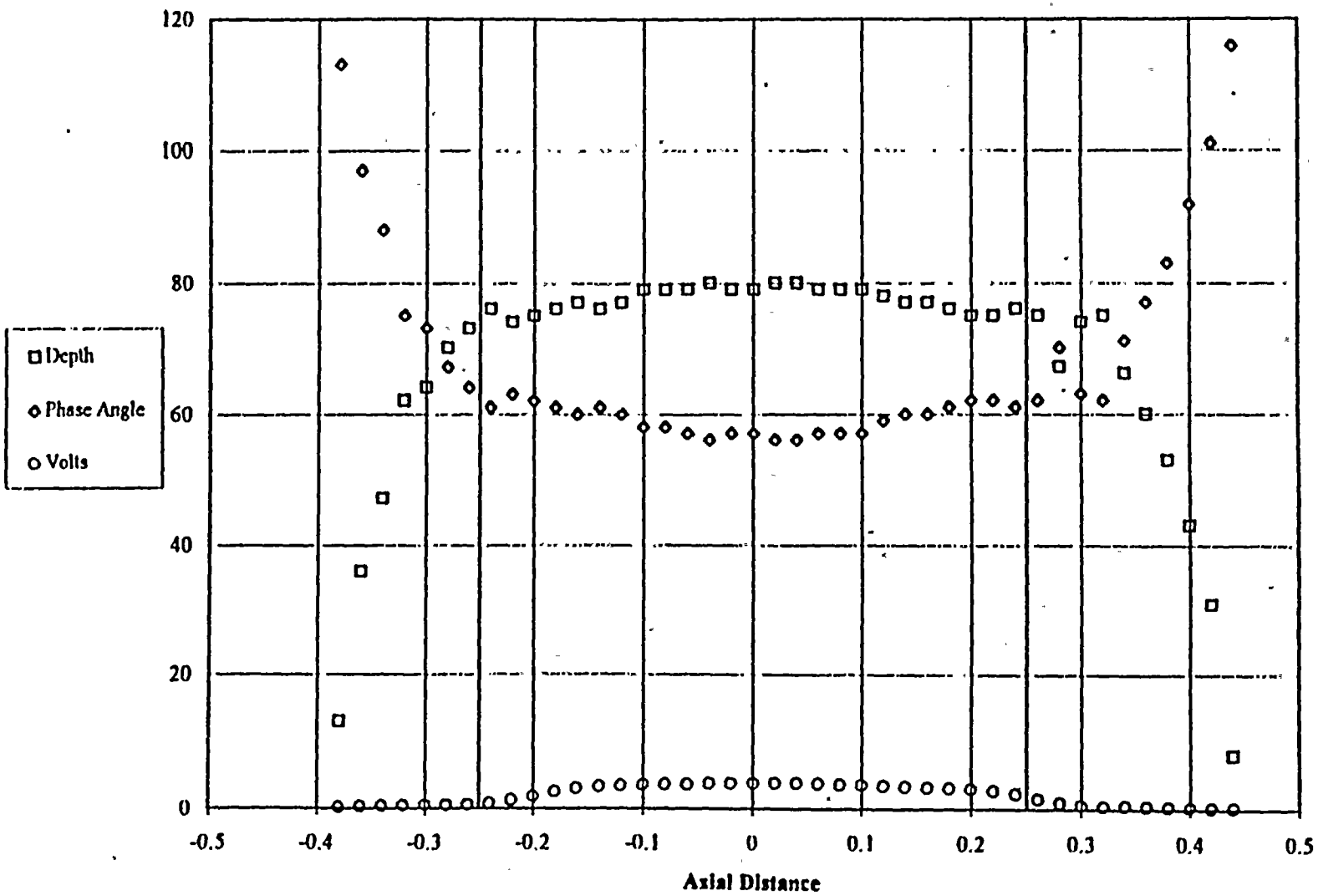
60% TW ID Slot - Eddynet + Point



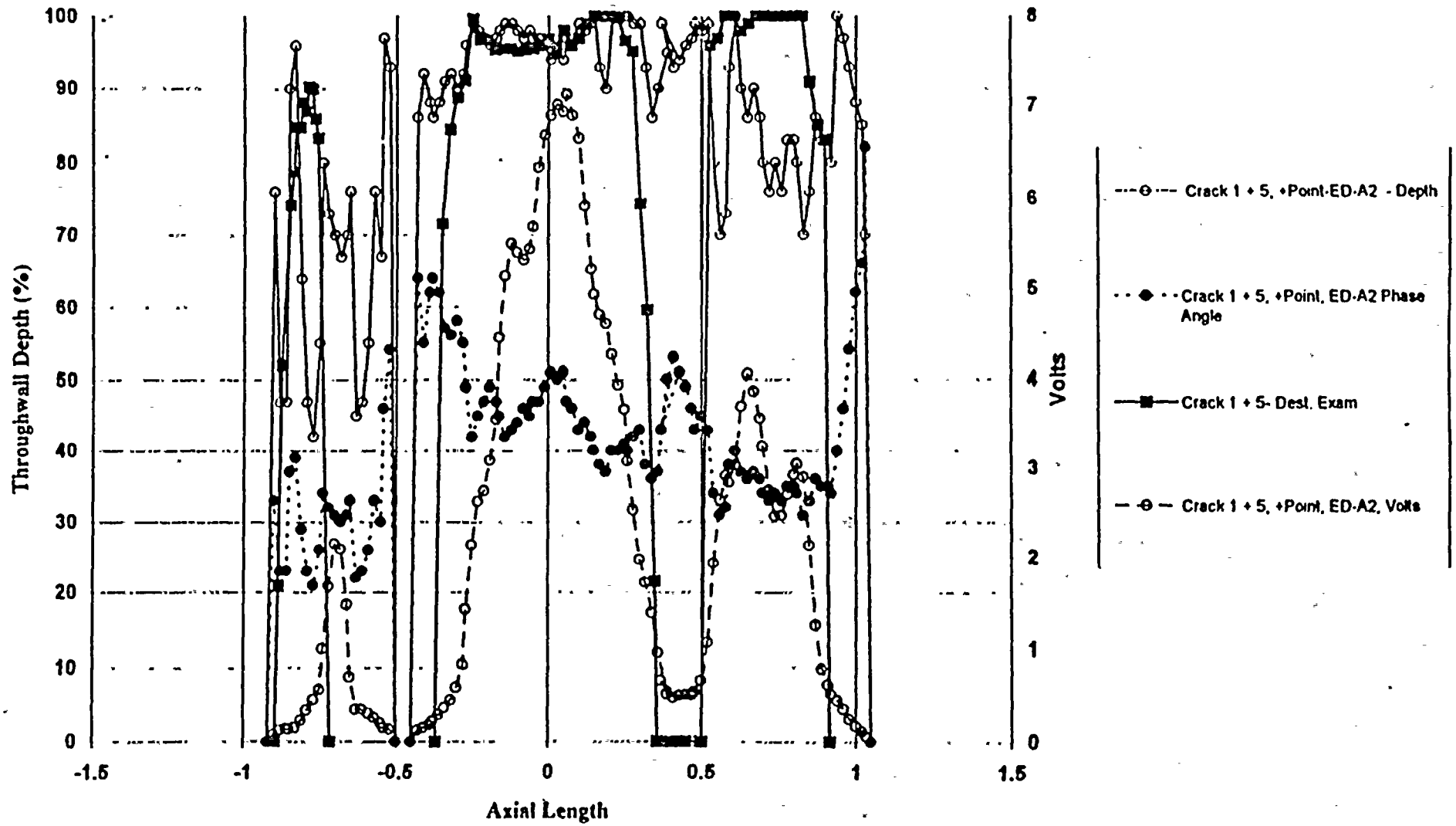
40% TW ID Slot - Eddynet, + Point



80% TW OD Slot - Eddynet, + Point



Sample 12 - Cracks 1 and 5
Destructive Exam Depth vs. NDE +Pt Depth, Volts and Phase Angle



Dnllab12 Chart A 11/15/98

Adjustment Guidelines for PWSCC Crack Lengths

OD Phase Angles Near Ends of Crack

- Data points with OD phase angles from the start of OD to the end of the crack are ignored in defining the crack length as long as within 0.2" of the indicated end of the crack. The end of the crack shall be defined as ≤ 0.03" beyond the last accepted (without points with OD phase) data point if points are deleted at the end of the crack.

Near Throughwall ID Phase Angles Near Ends of Crack

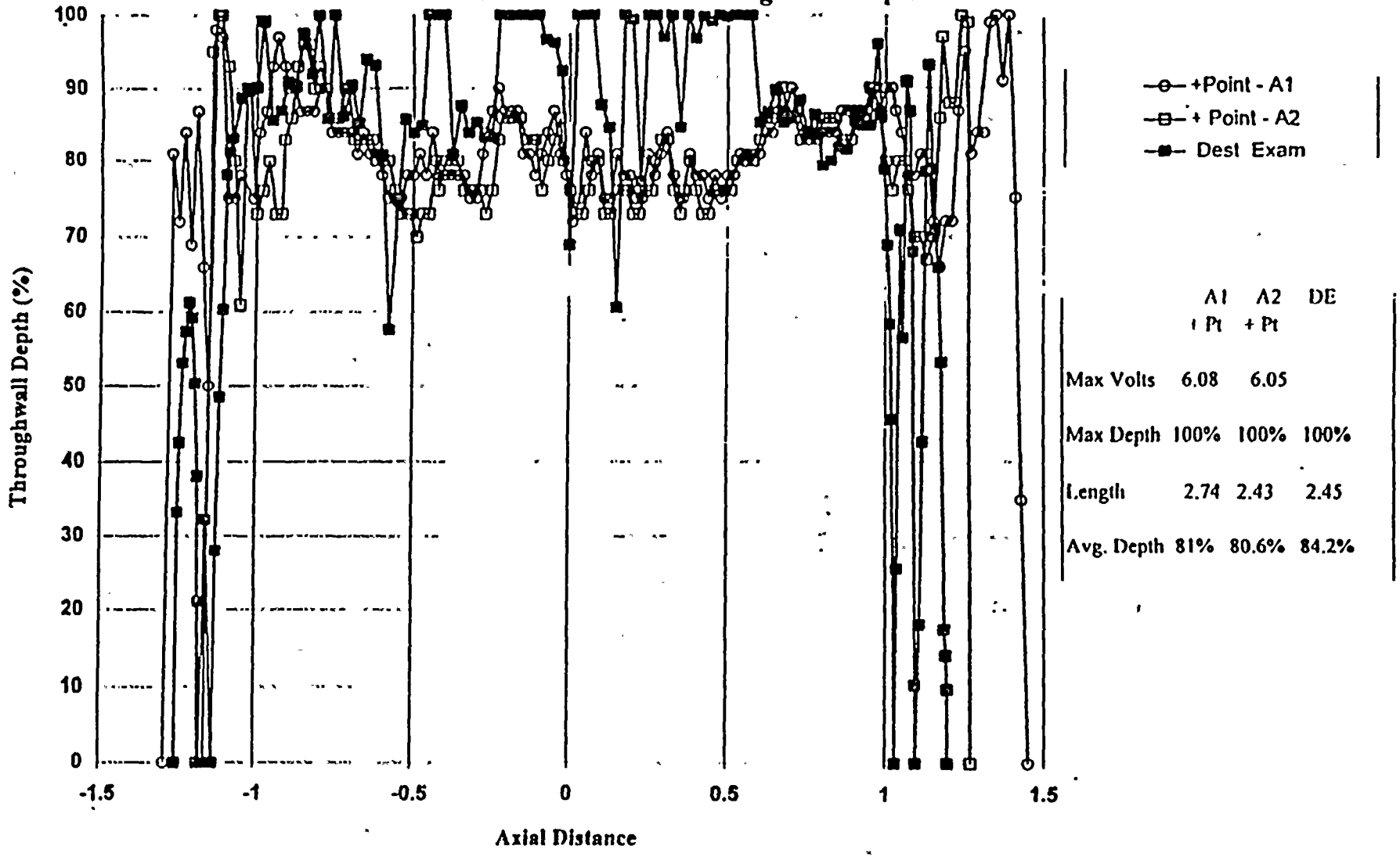
- Near throughwall ID phase depths (≥ 85 %) with voltages < 1 volt are ignored in defining the crack length as long as within 0.2" of the indicated end of the crack. The end of the crack shall be defined as ≤ 0.03" beyond the last accepted data point if points are deleted at the end of the crack.

ID Depths Increase Near Ends of Crack

- If ID depths at points near the end of the crack show depth increases of > 10% over about 0.05" spans and voltages < 1 volt, the data points shall be ignored in defining the crack length as long as within 0.2" of the indicated end of the crack. The end of the crack shall be defined as ≤ 0.03" beyond the last accepted data point if points are deleted at the end of the crack.

Sample 8 - Crack 2

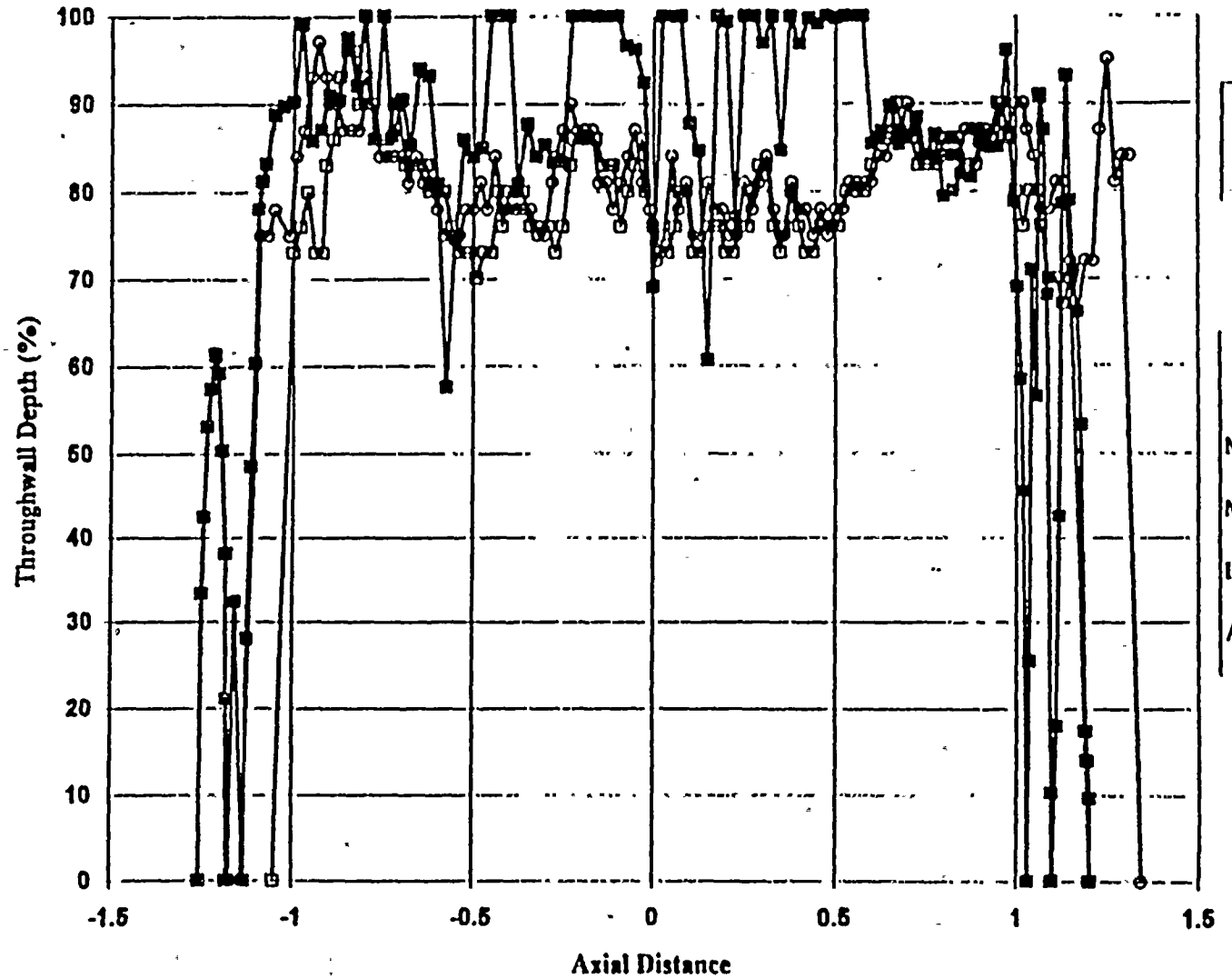
Axial Distance vs Throughwall Depth



	A1 + Pt	A2 + Pt	DE
Max Volts	6.08	6.05	
Max Depth	100%	100%	100%
Length	2.74	2.43	2.45
Avg. Depth	81%	80.6%	84.2%

DNTLAB08.XLS:Ch NDE_DE C2:10/28/96

Sample 8 - Crack 2 (MOD 3)
Axial Distance vs Throughwall Depth



	A1 + Pt	A2 + Pt	DE
Max Volts	6.08	6.05	
Max Depth	97%	96%	100%
Length	2.48	2.25	2.45
Avg. Dpth	80.0%	78.2%	84.2%

Dntlab08 xls:Ch NDE DE C2 (MOD 3):10/29/96

Depth Adjustments for Uncorroded Ligaments

General Considerations

- Uncorroded ligaments between microcracks much smaller for PWSCC at dents than for ODSCC indications
- Smaller ligaments result in less influence on NDE sizing accuracy

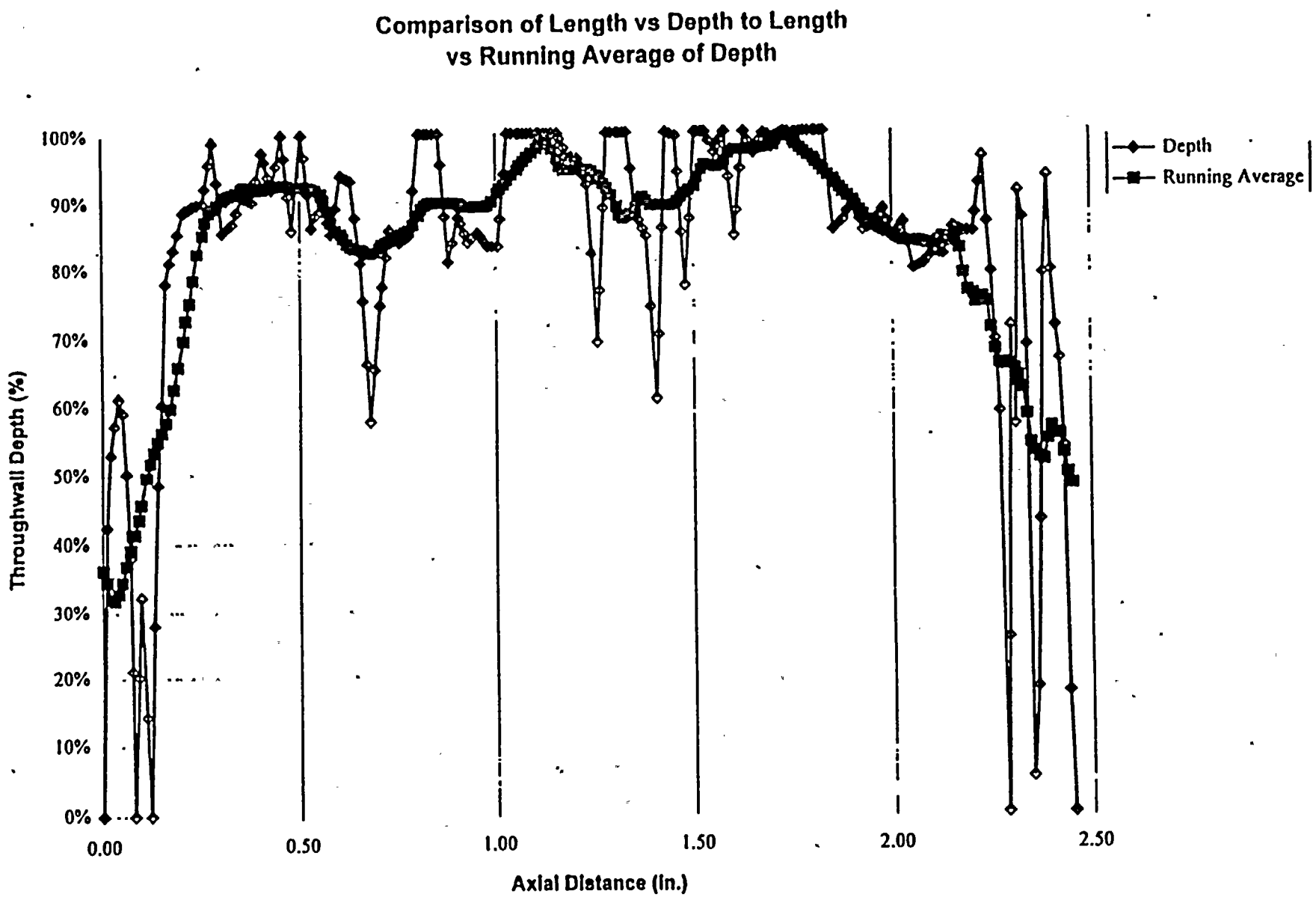
Ligament Area of Uncorroded Ligaments Measured in Destructive Exams

Crack Depths Can be Adjusted for Ligament Area

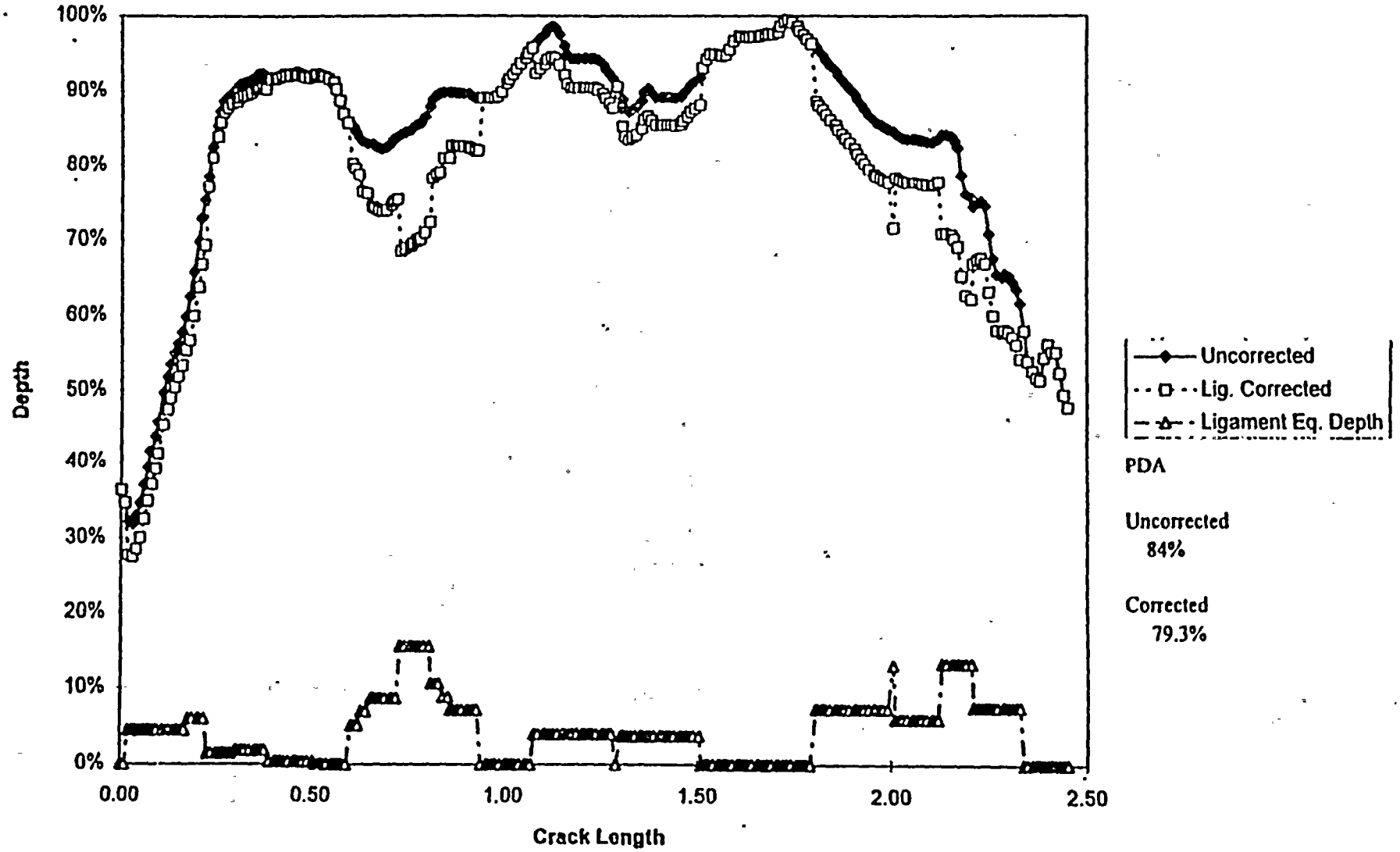
- Crack depths are reduced by effective ligament area
- Effective ligament area for burst considerations is 60% of total area
  - Ligaments perpendicular to plane of crack are in shear
- Application to depth profiling requires length averaging
  - Destructive exam depth profiles and ligament areas developed as running average over 0.2" coil field spread

Corrections for Ligaments

- Adjustments range from 1% to 5% on average depth
- Ligament corrections improve agreement with NDE


Comparison of Length vs Depth to Length
vs Running Average of Depth
Throughwall Depth (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.00
0.50
1.00
1.50
2.00
2.50
Axial Distance (in.)
Depth
Running Average

Sample 8 Crack 2, Ligament Correction

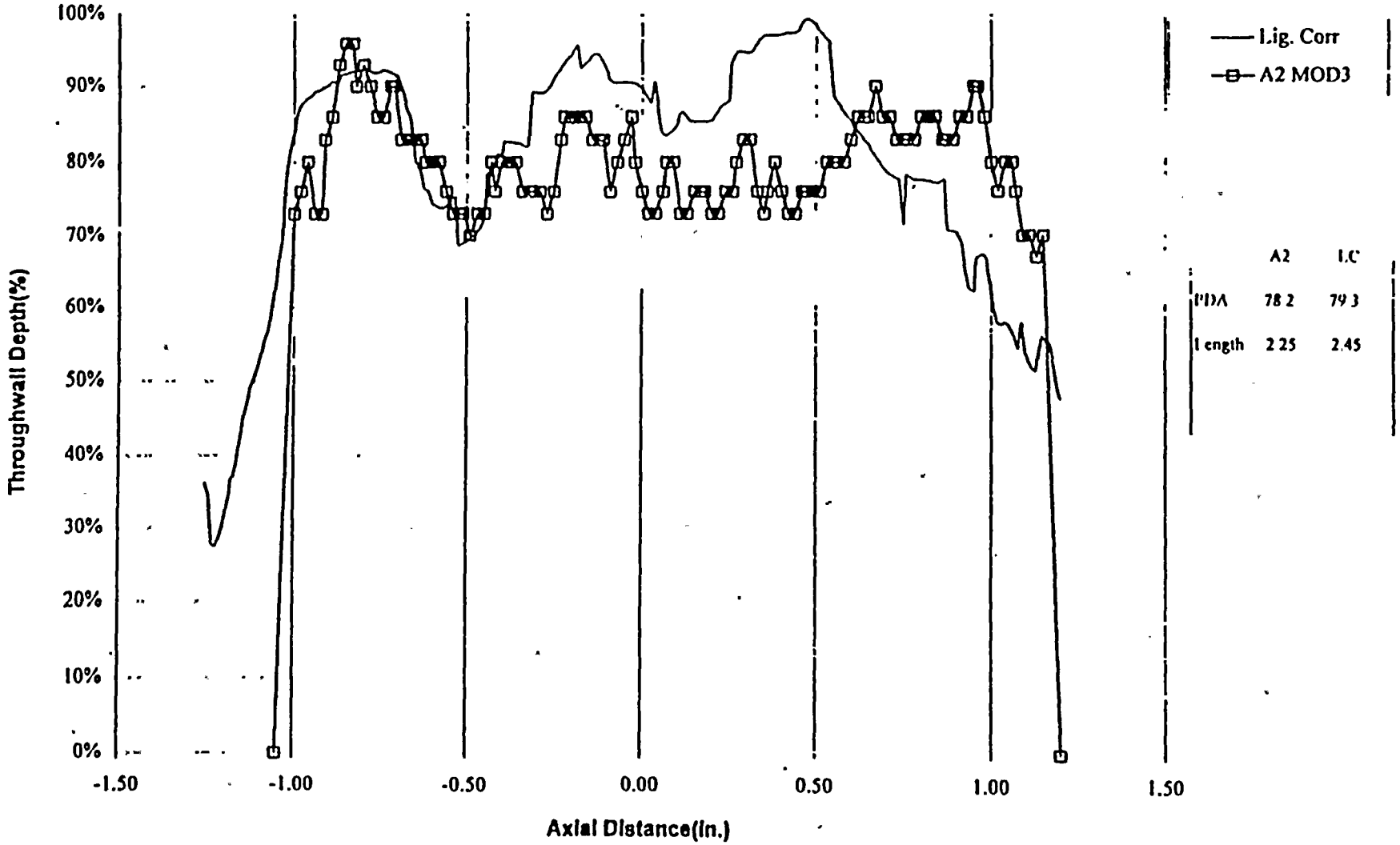


PDA

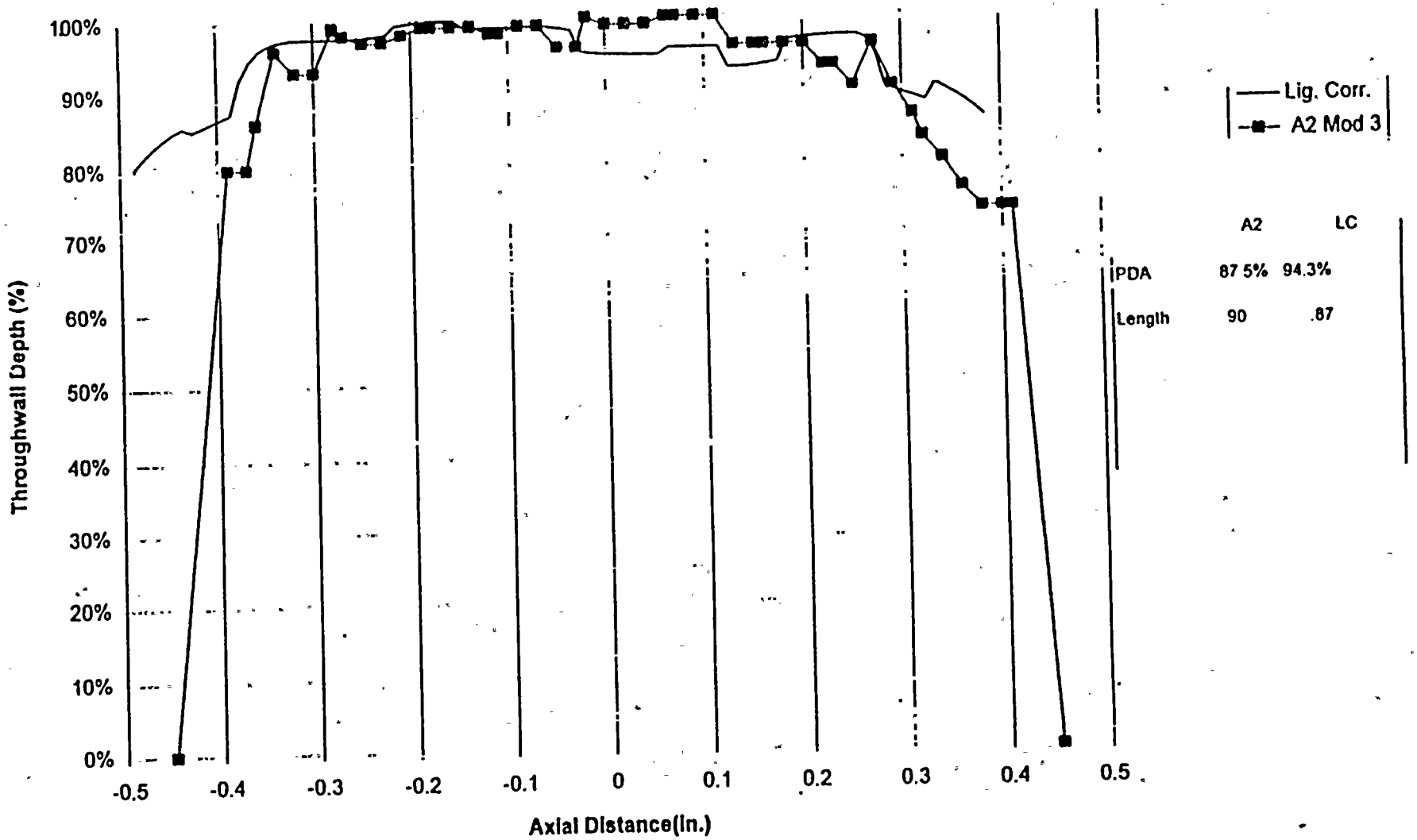
Uncorrected
84%

Corrected
79.3%

Sample 8 Lig Correction Compared to NDE
Crack 2



Sample 7 Lig Correction Compared to NDE Crack 1



General Comparisons of NDE and Destructive Exam

Comparisons Between Analysts

- Very good agreement between NDE analysts for significant indications
- Differences between analysts primarily in unadjusted length calls with some analysts terminating length at significant OD phase angles
- As would be expected, differences between analysts are more significant for small indications and in separating closely spaced, small indications

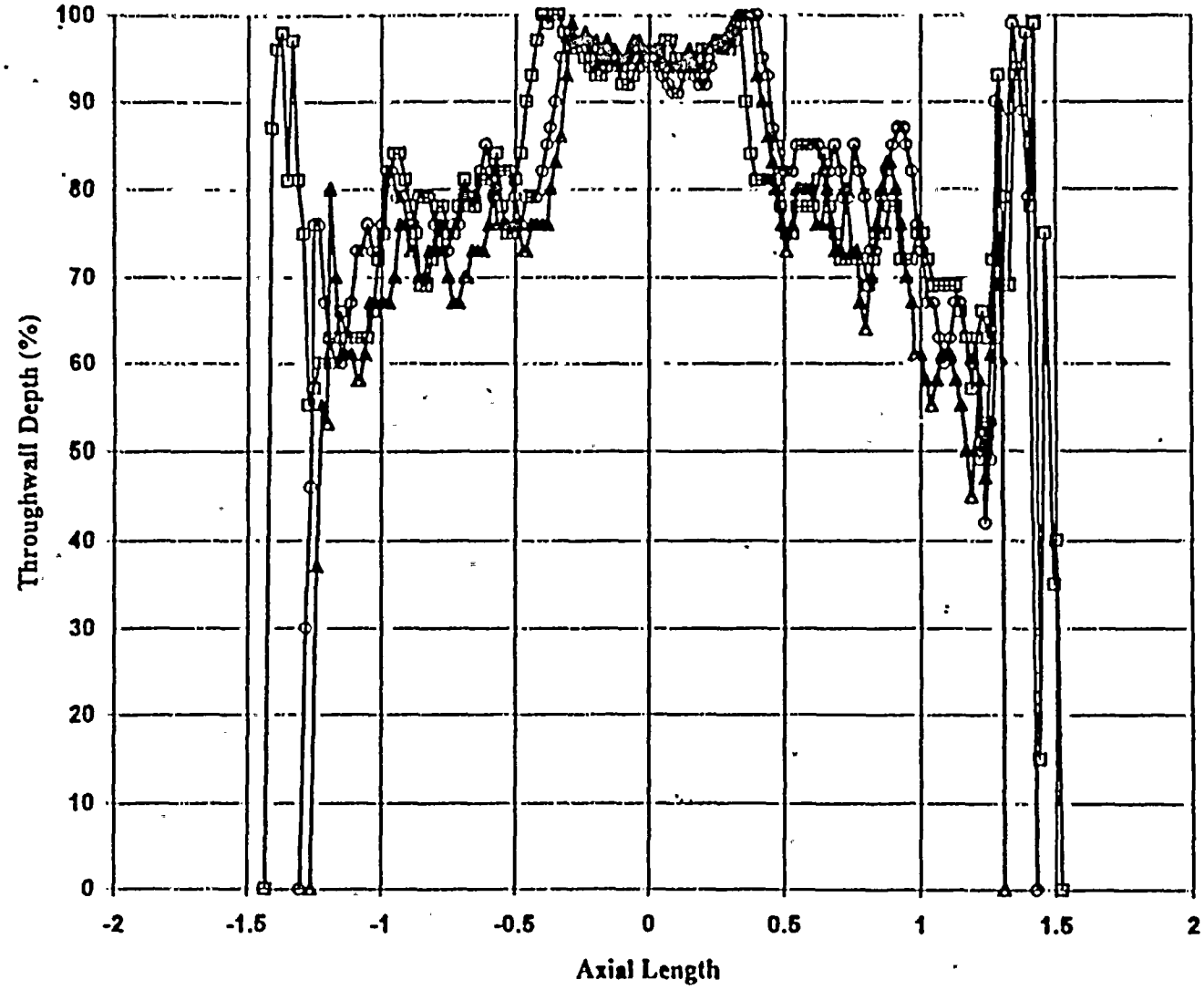
Length

- Unadjusted lengths consistently and significantly overestimate actual lengths
- Adjusted lengths remain slightly biased to overestimates of length but show generally good agreement with actual lengths

Average Depth

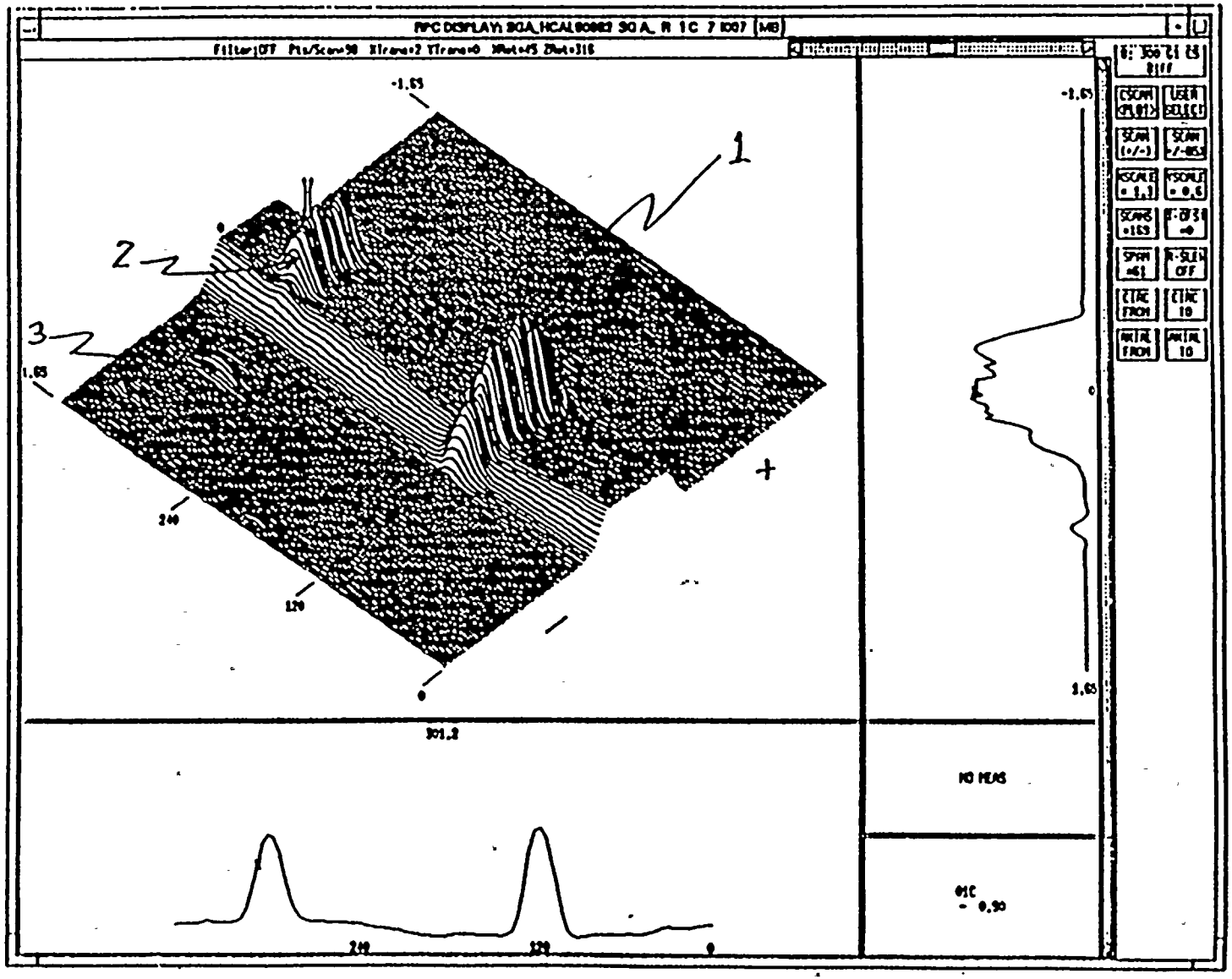
- General trend to overestimate average depths below about 80% depth and slightly underestimate above 80%
- Overall agreement of NDE with actuals is good
- Length adjustment leads to a modest improvement in average depth

Sample 10 Depth vs. Axial Length
+ Point Probe

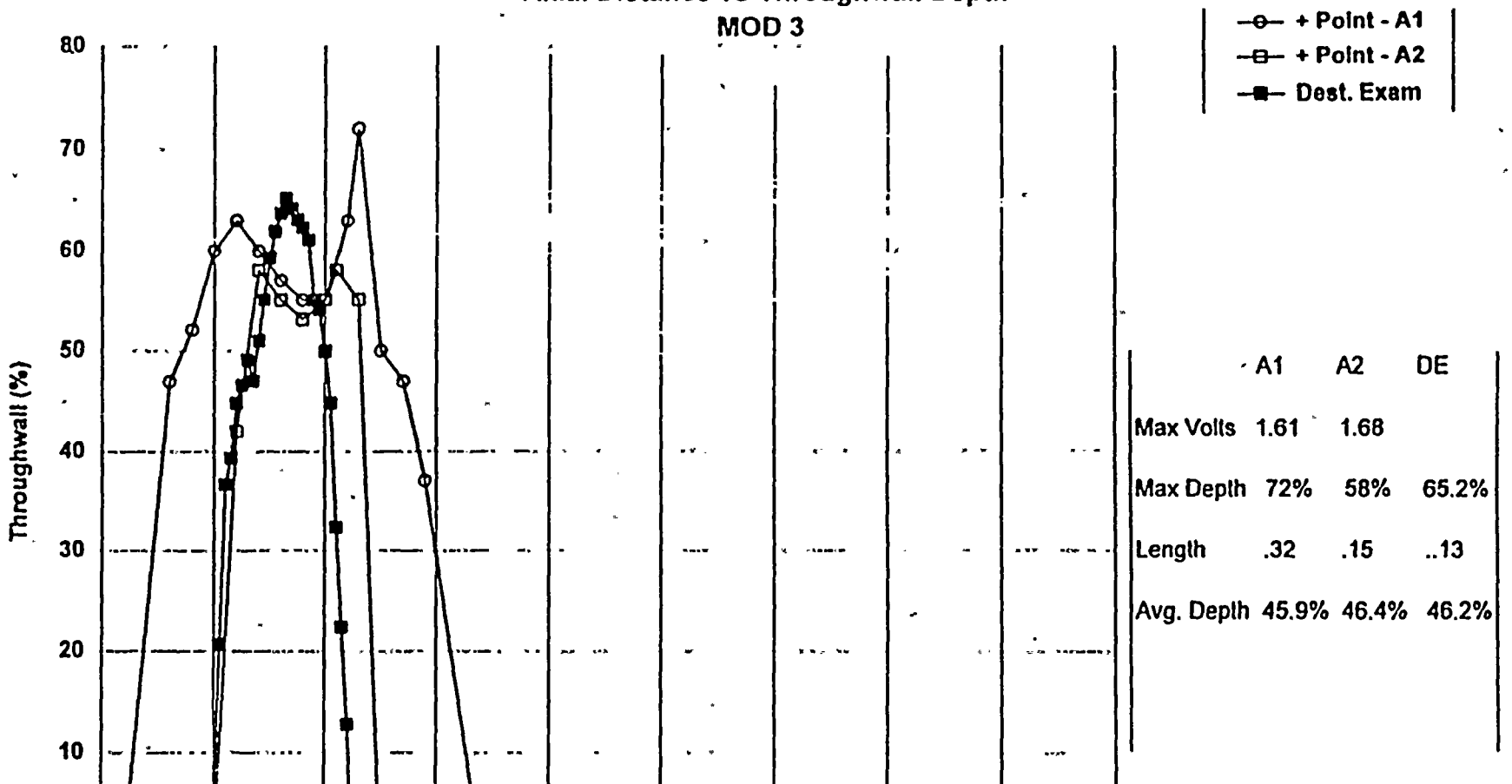


	A1 A+P	A2 E+P	A3 E+P
Max Volts	6.86	6.87	7.02
Max Depth	100%	100%	100%
Length	2.95	2.57	2.73
Avg. Depth	79.6%	77.2%	80.7%

DNTLAB10.XLS:Ch sample 10_C1,a1,a2,a3 :8/15/96

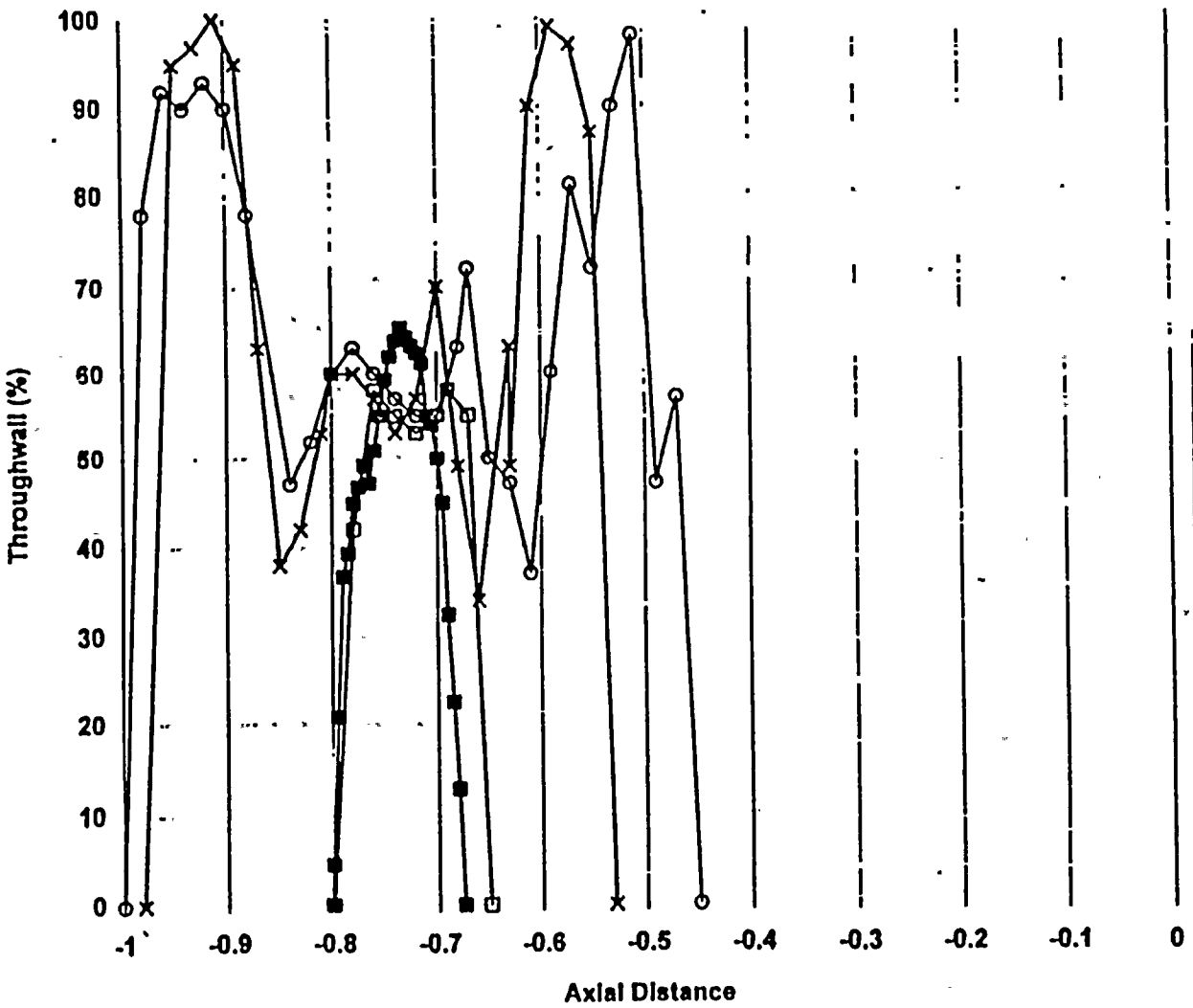

1
2
3
-1.65
1.65
240
120
0
+
NO MEAS

Sample 7 - Crack 3
Axial Distance vs Throughwall Depth
MOD 3



	A1	A2	DE
Max Volts	1.61	1.68	
Max Depth	72%	58%	65.2%
Length	.32	.15	..13
Avg. Depth	45.9%	46.4%	46.2%

Sample 7 - Crack 3
Axial Distance vs Throughwall Depth



	A1	A2	A3	DE
Max Volts	1.61	1.68	1.65	
Max Depth	98%	58%	100%	65.2%
Length	.55	.15	.45	.13
Avg. Depth	64.5%	46.4%	65.4%	46.2%

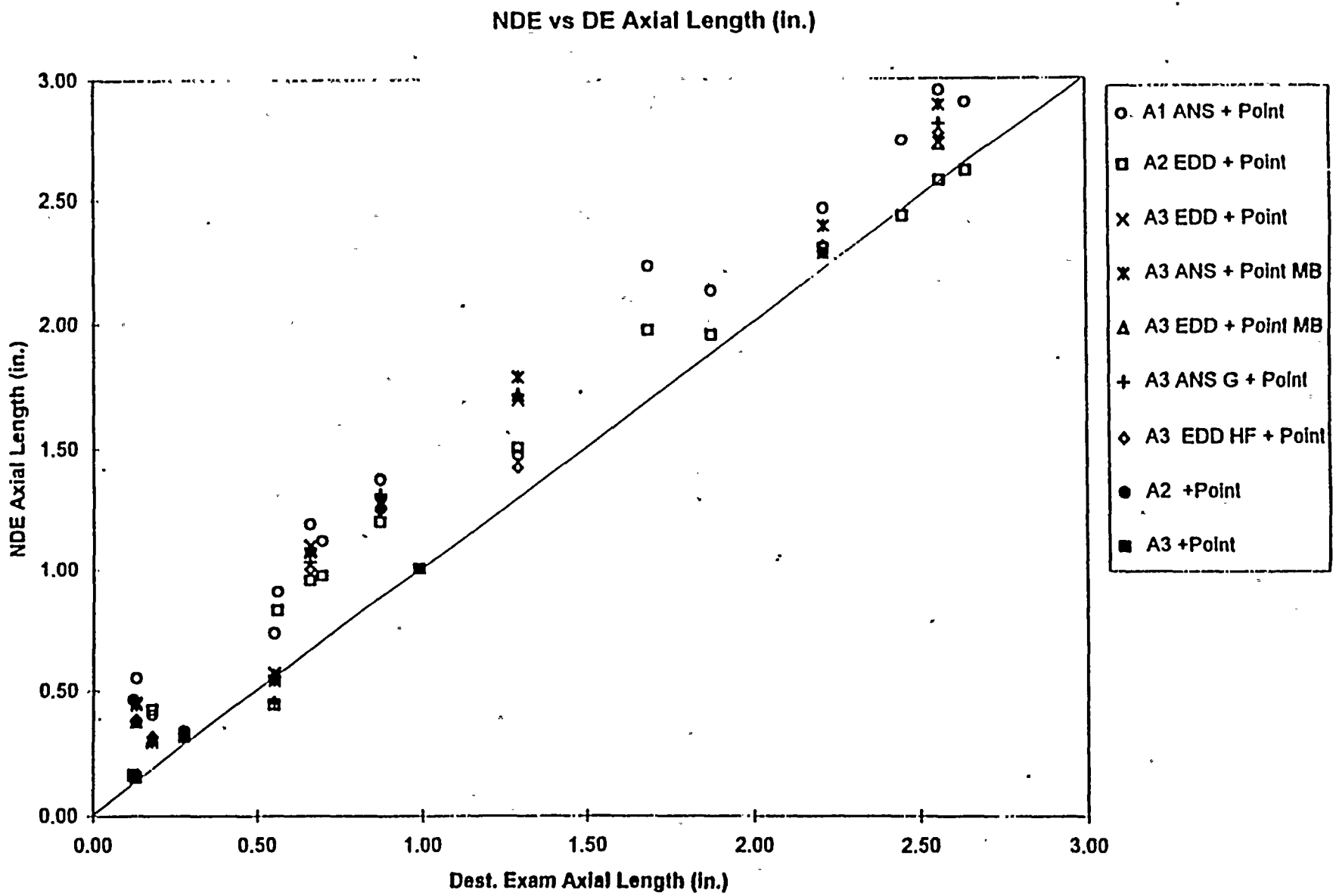
General Comparisons of NDE and Destructive Exam

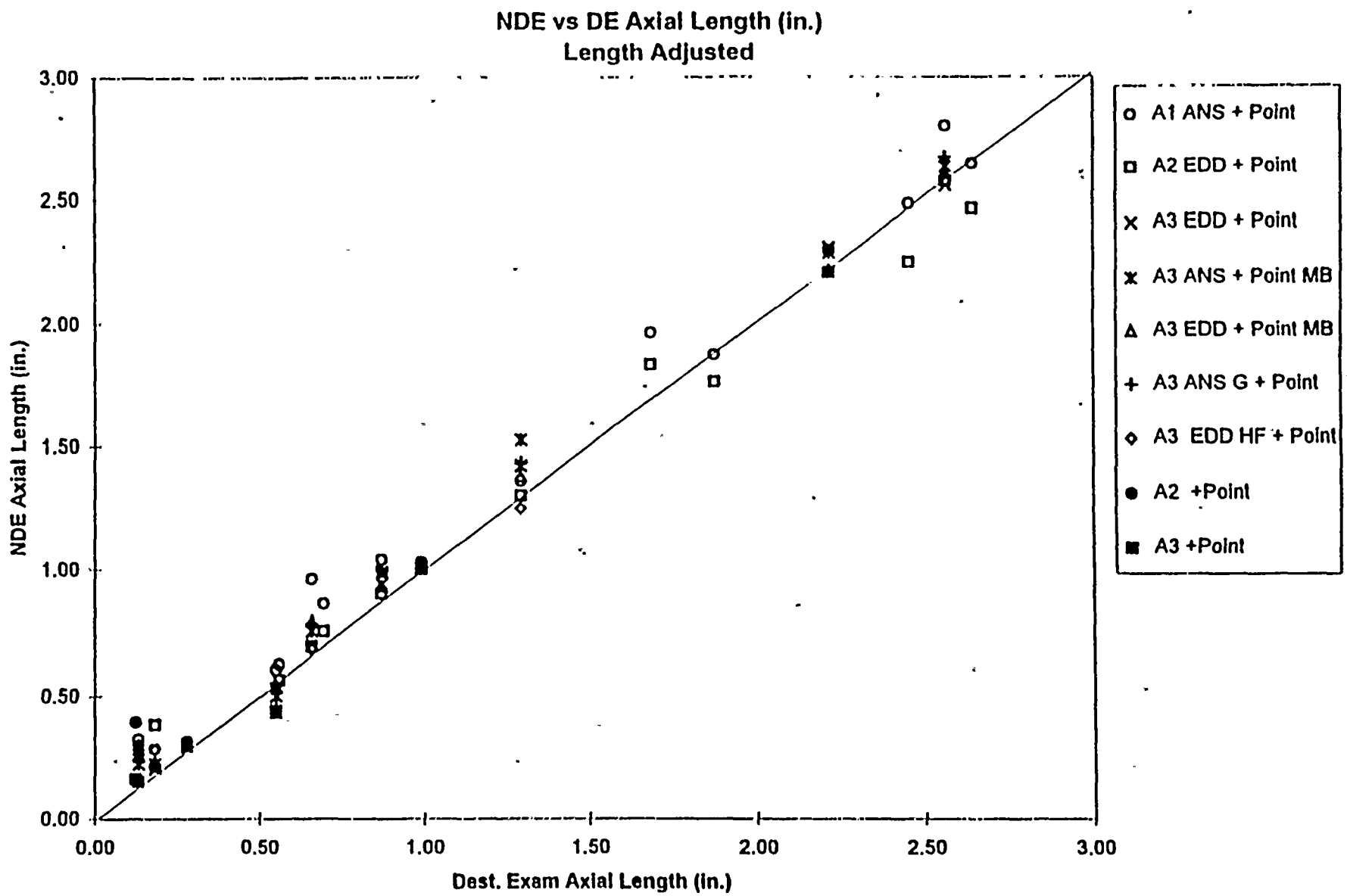
Maximum Depth

- As generally expected, agreement of NDE with actuals is not as good as for average depth and length
- Generally acceptable for predicting throughwall or near throughwall depths

Differences Between Coils

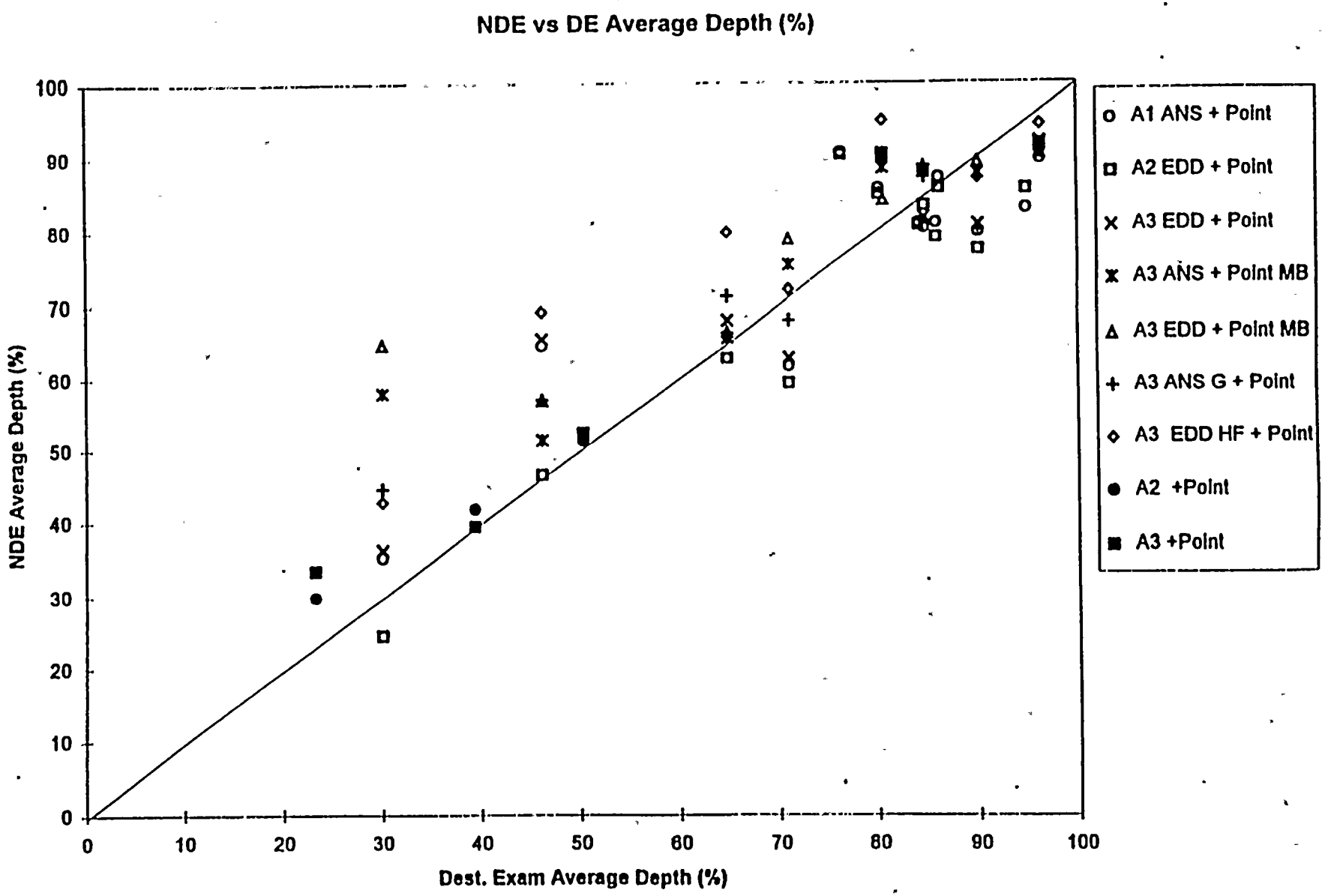
- Mid-range + Point coil yields an acceptable and consistent agreement with actuals
- Mag bias and high frequency + Point tend to overpredict average depths
- Mid-range + Point is preferred coil and used as basis to develop NDE uncertainties

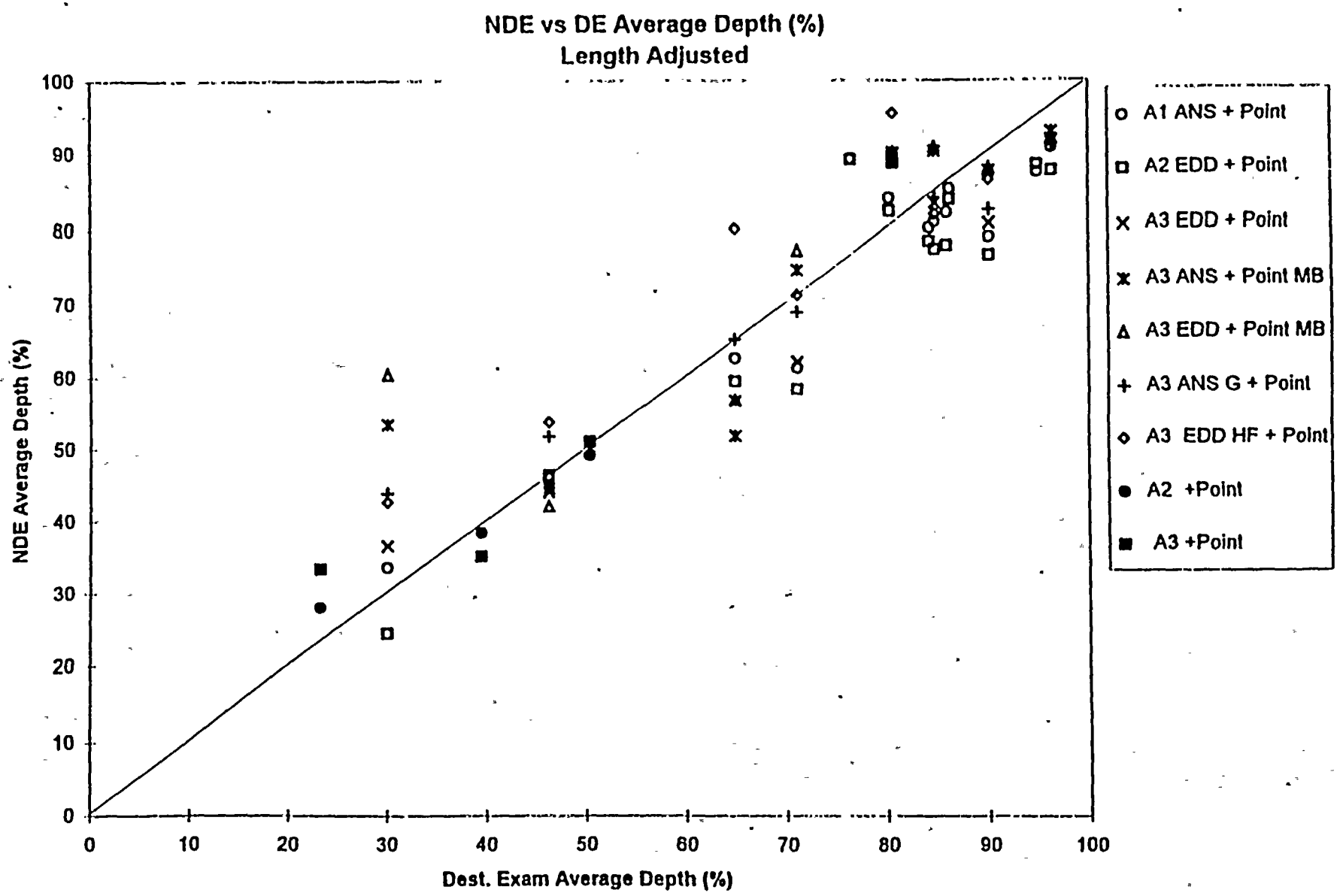

NDE vs DE Axial Length (in.)
NDE Axial Length (in.)
Dest. Exam Axial Length (in.)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
A1 ANS + Point
A2 EDD + Point
A3 EDD + Point
A3 ANS + Point MB
A3 EDD + Point MB
A3 ANS G + Point
A3 EDD HF + Point
A2 +Point
A3 +Point



Ch AX Lgth NDE vs DE (ADJ)

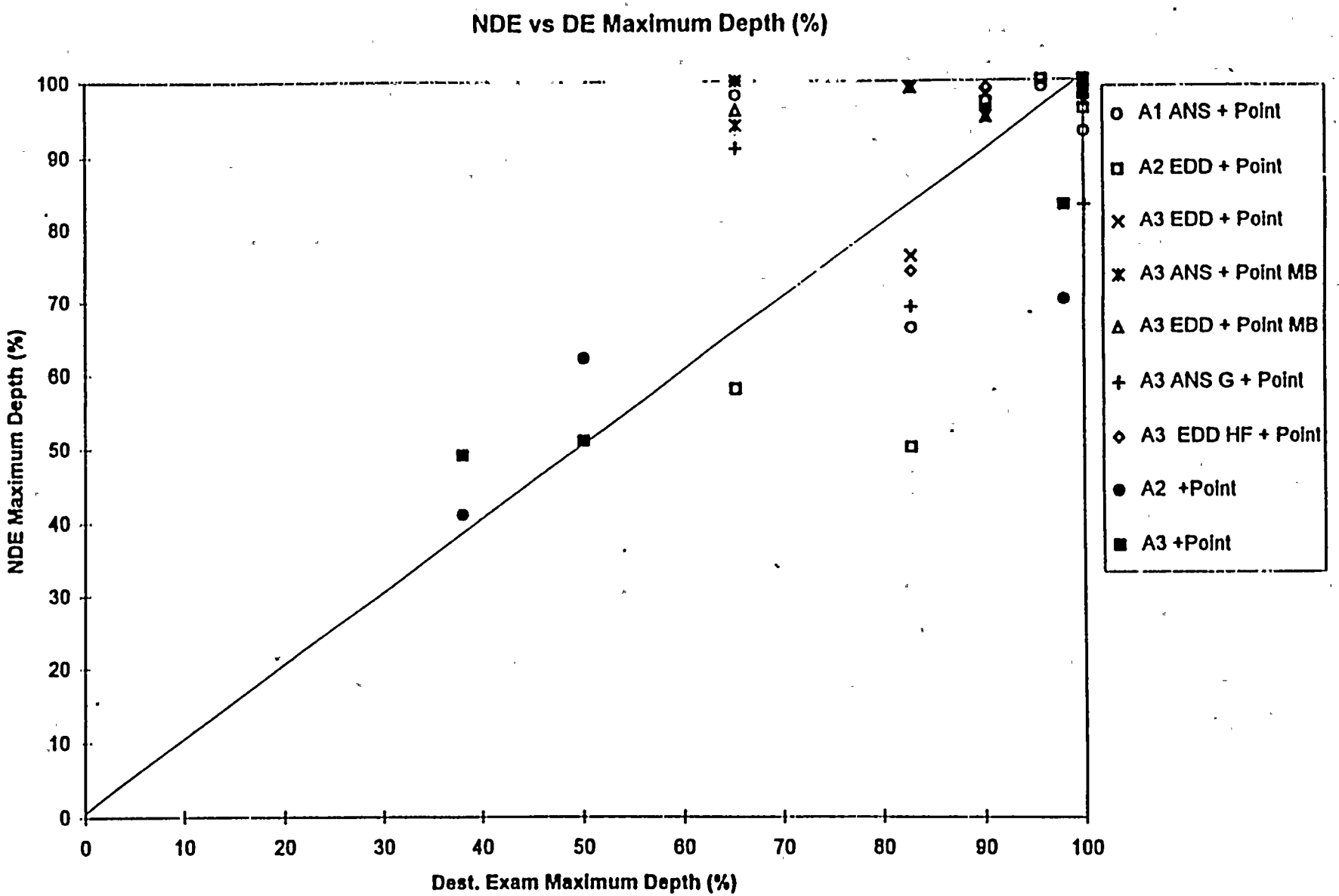
Dentanl1.skd:11/18/96

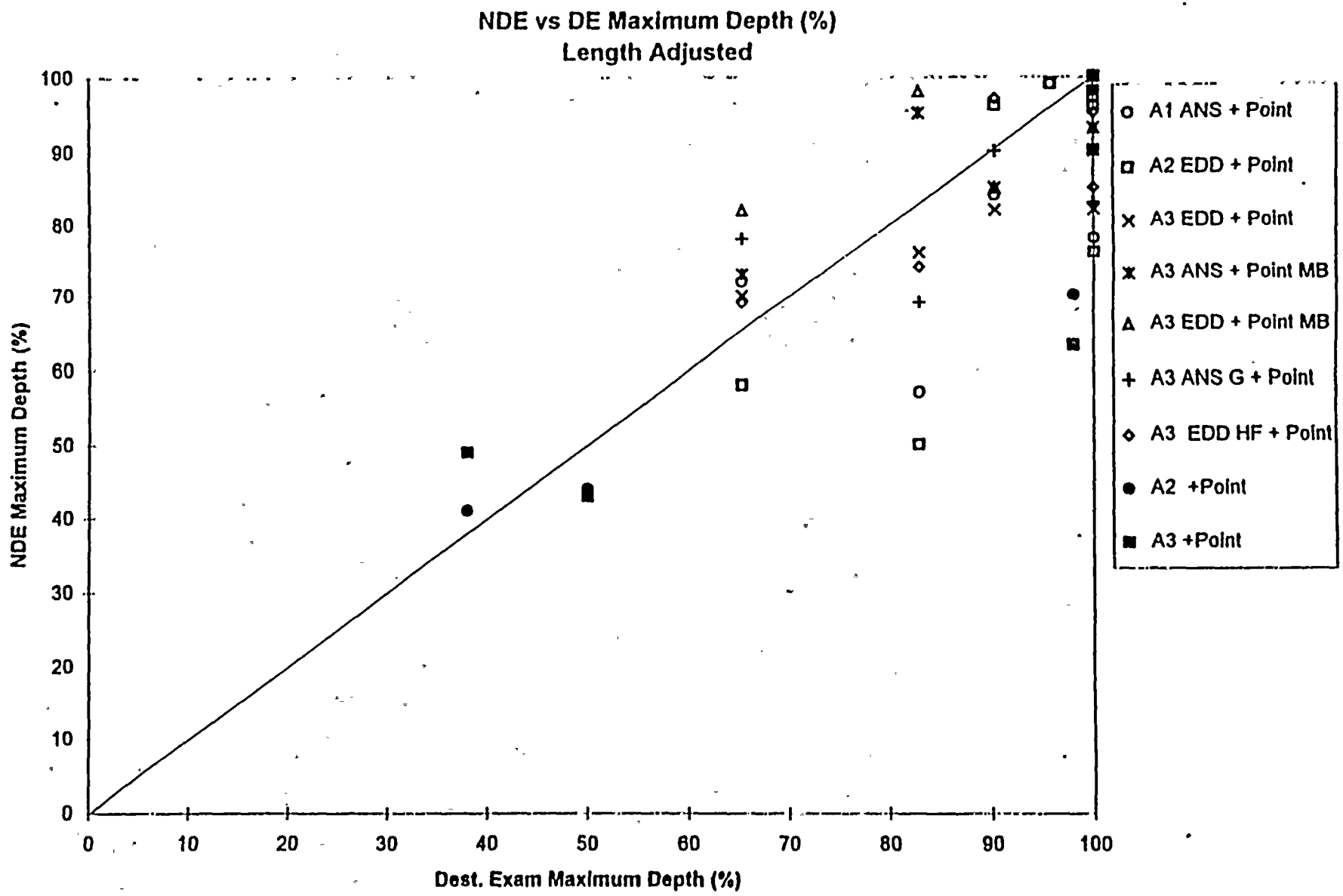

NDE vs DE Average Depth (%)
NDE Average Depth (%)
Dest. Exam Average Depth (%)
0
10
20
30
40
50
60
70
80
90
100
A1 ANS + Point
A2 EDD + Point
A3 EDD + Point
A3 ANS + Point MB
A3 EDD + Point MB
A3 ANS G + Point
A3 EDD HF + Point
A2 +Point
A3 +Point



Ch Avg. Depth NDE vs DE (ADJ)

Dentant1.sld:11/18/96


NDE vs DE Maximum Depth (%)
NDE Maximum Depth (%)
Dest. Exam Maximum Depth (%)
0
10
20
30
40
50
60
70
80
90
100
A1 ANS + Point
A2 EDD + Point
A3 EDD + Point
A3 ANS + Point MB
A3 EDD + Point MB
A3 ANS G + Point
A3 EDD HF + Point
A2 +Point
A3 +Point



Ch Max. Depth NDE vs DE (ADJ)

Dentanl1.sld:11/18/96

NDE Uncertainties

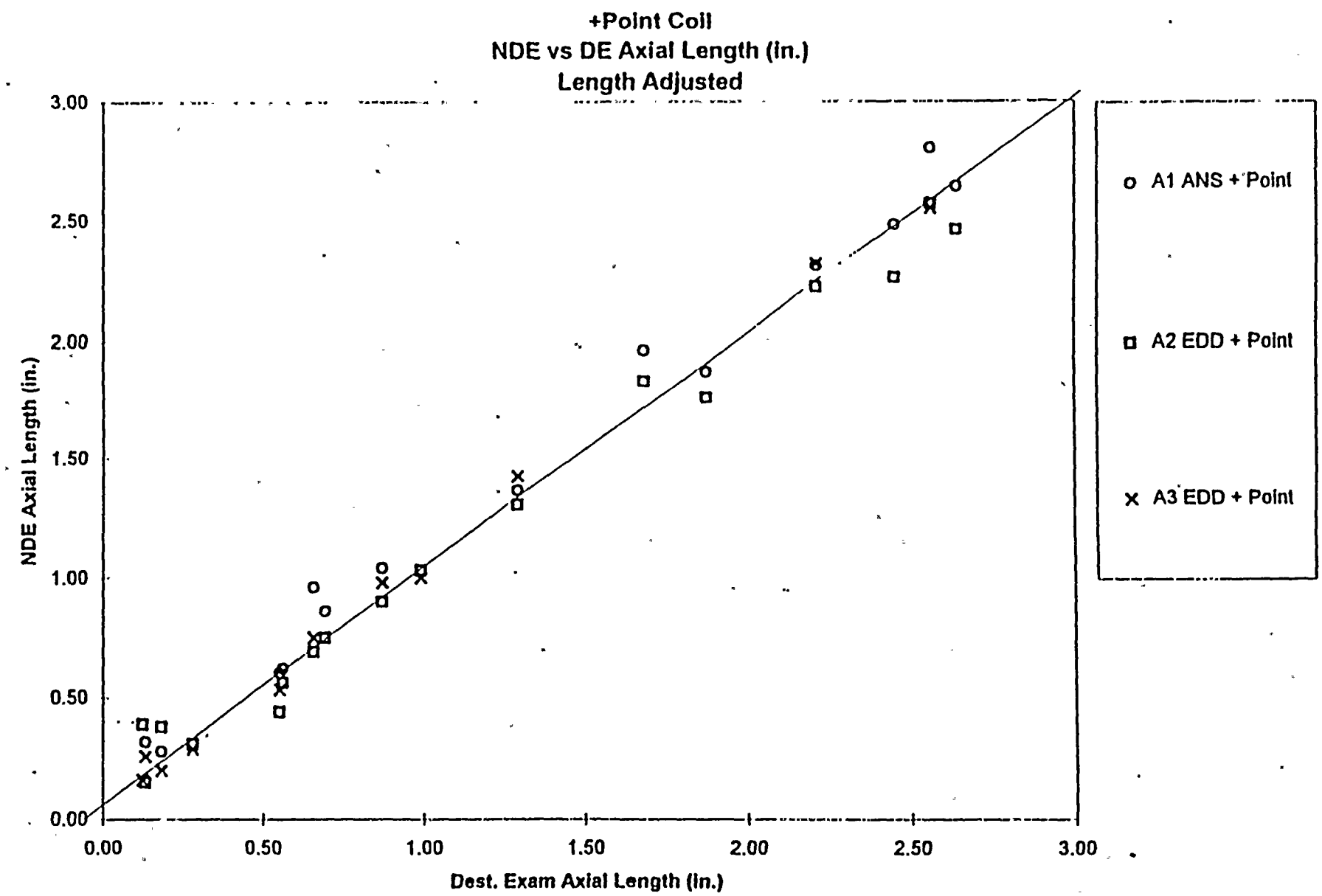
Data for Three Analysts Utilized

- Some indications only analyzed by two analysts
- One pulled tube with only one analyst
  - Data is 80 mil coil but included for completeness and conservatism

NDE Uncertainty Analysis Limited to Mid-range + Point Coil with Length Adjusted Data

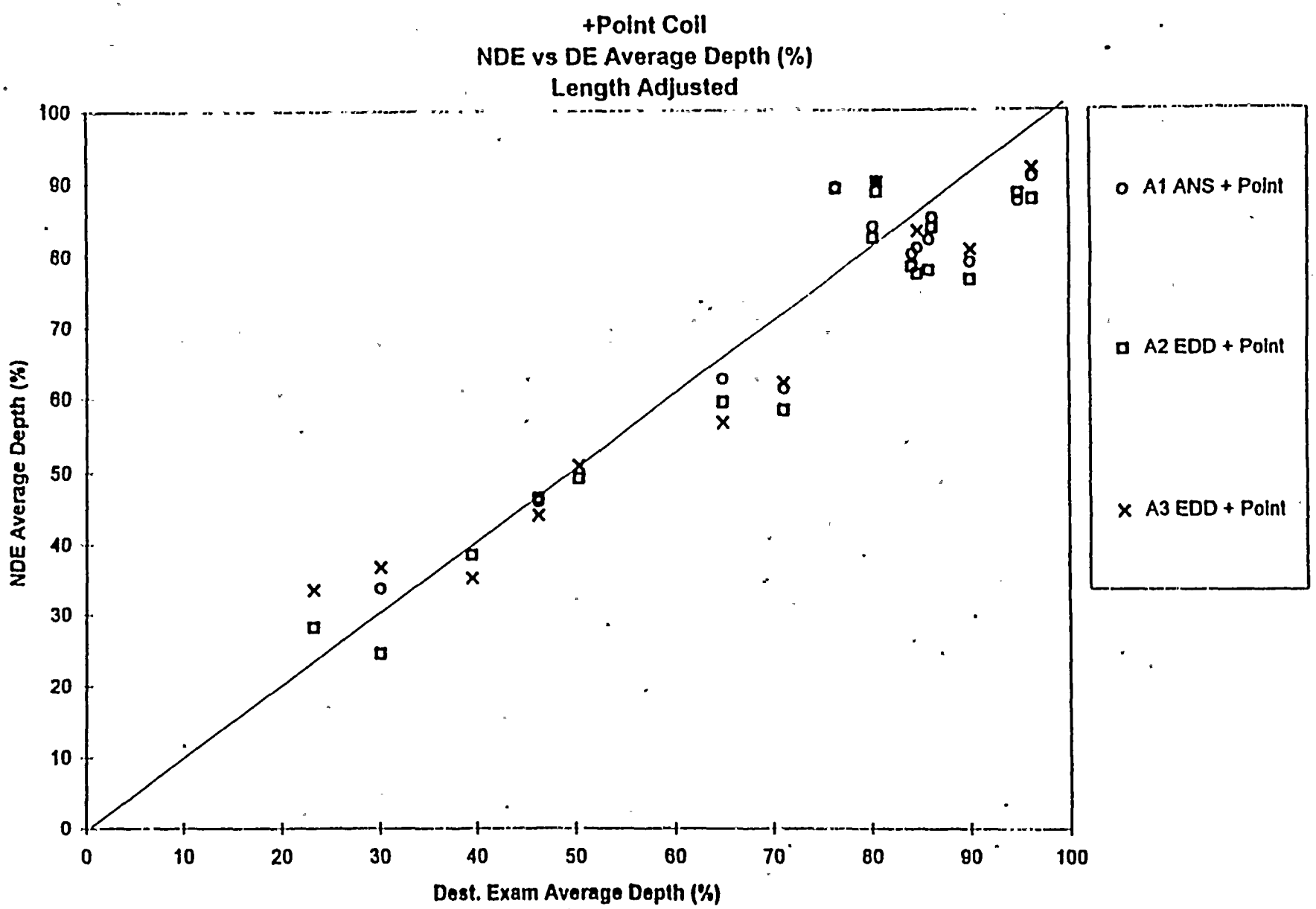
Analyses for NDE Uncertainties

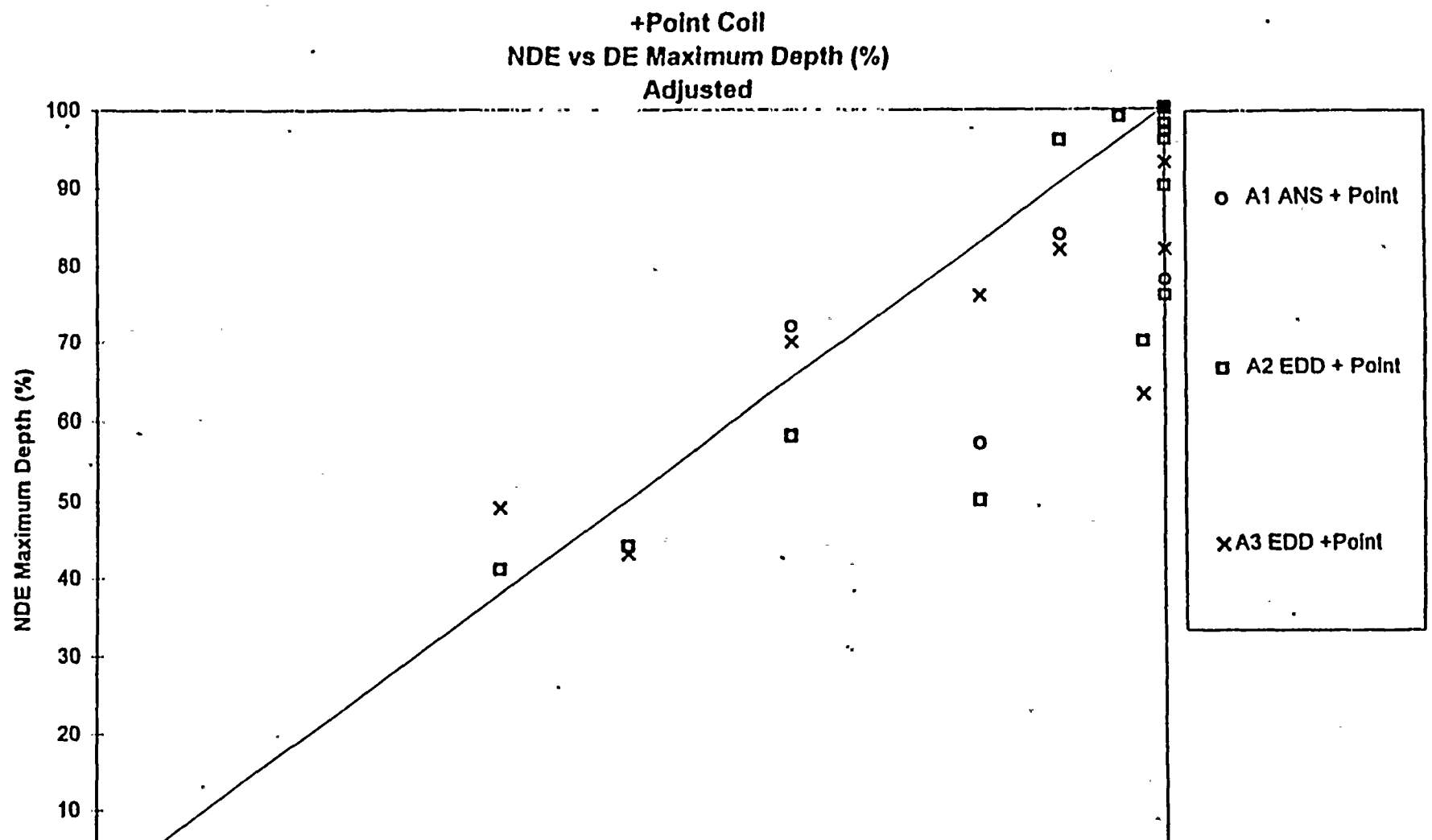
- Comparisons of NDE with Destructive Exam
- Regression analyses to compare slope to theoretical one-to-one slope
- Mean and standard deviation of differences between NDE and Destructive Exam
- Preliminary NDE uncertainty analyses given herein will be updated to include two additional indications and ligament corrections to the destructive exam average depths



Ch AX Lgth NDE vs DE(Adj)2)

Dentanlt.skd:11/18/96


+Point Coil
NDE vs DE Average Depth (%)
Length Adjusted
NDE Average Depth (%)
Dest. Exam Average Depth (%)
0
10
20
30
40
50
60
70
80
90
100
A1 ANS + Point
A2 EDD + Point
A3 EDD + Point



Ch Max. Depth NDE vs NE(Adj)(2)

Dentanl1.sld,11/18/96

DENTED TUBE SUPPORT PLATE
Adjusted NDE & DESTRUCTIVE EXAM EVALUATIONS
Comparison of Analysis Techniques, Software and Probes

Sample Number	Crack Number	Probe Type	Software	Analyst	Adjusted NDE			Destructive Exam			NDE-Destructive Exam		
					Length (inches)	Max Depth (%)	Avg Depth (%)	Length (inches)	Max Depth (%)	Avg Depth (%)	Length (inches)	Max Depth (%)	[illegible] (%)
7	1	+point	ANS	1	1.04	100	90.6	0.87	100	96.3	0.17	0.0	-5.
7	2	+point	ANS	1	0.96	100	80.8	0.66	100	84.7	0.30	0.0	-3.
7	3	+point	ANS	1	0.32	72	45.9	0.13	65.2	46.2	0.19	6.8	-0.
8	1	+point	ANS	1	2.64	100	85.0	2.64	100	86.2	0.00	0.0	-1.
8	2	+point	ANS	1	2.48	97	80.0	2.45	100	84.2	0.03	-3.0	-4.
9	1	+point	ANS	1	1.87	100	83.8	1.87	100	80.2	0.00	0.0	3.
9	2	+point	ANS	1	1.96	100	81.9	1.68	100	85.9	0.28	0.0	-4.
10	1	+point	ANS	1	2.80	100	78.8	2.56	100	90.1	0.24	0.0	-11.
10	2	+point	ANS	1	2.30	78	61.1	2.21	100	71.0	0.09	-22.0	-9.
11	1	+point	ANS	1	0.86	97	87.3	0.694	100	94.9	0.17	-3.0	-7.
11	2	+point	ANS	1	0.62	99	89.2	0.56	95.8	76.4	0.06	3.2	12.
12	1	+point	ANS	1	1.36	100	89.9	1.29	100	80.6	0.07	0.0	9.
12	2	+point	ANS	1	0.60	57	33.6	0.55	82.8	30.0	0.05	-25.8	3.
12	5	+point	ANS	1	0.28	84	62.4	0.18	90.3	64.8	0.10	-6.3	-2.
7	1	+point	EDD	2	0.90	100	87.5	0.87	100	96.3	0.03	0.0	-8.
7	2	+point	EDD	2	0.69	90	77.2	0.66	100	84.7	0.03	-10.0	-7.
7	3	+point	EDD	2	0.15	58	46.4	0.13	65.2	46.2	0.02	-7.2	0.
8	1	+point	EDD	2	2.46	100	83.6	2.64	100	86.2	-0.18	0.0	-2.
8	2	+point	EDD	2	2.25	96	78.2	2.45	100	84.2	-0.20	-4.0	-6.
9	1	+point	EDD	2	1.76	100	82.2	1.87	100	80.2	-0.11	0.0	2.
9	2	+point	EDD	2	1.83	100	77.7	1.68	100	85.9	0.15	0.0	-8.
10	1	+point	EDD	2	2.57	100	76.4	2.56	100	90.1	0.01	0.0	13.
10	2	+point	EDD	2	2.21	76	58.2	2.21	100	71.0	0.00	-24.0	[illegible]
11	1	+point	EDD	2	0.75	98	88.3	0.694	100	94.9	0.06	-2.0	-6.
11	2	+point	EDD	2	0.56	99	89.0	0.56	95.8	76.4	0.00	3.2	12.
12	1	+point	EDD	2	1.30	100	88.5	1.29	100	80.6	0.01	0.0	7.
12	2 (3+4)	+point	EDD	2	0.44	50	24.4	0.55	82.8	30.0	-0.11	-32.8	-5.
12	5	+point	EDD	2	0.38	96	59.3	0.18	90.3	64.8	0.20	5.7	-5.
21/43	1	+point		2	1.03	70	49.1	0.991	98	50.3	0.04	-28.0	-1.
21/43	2	+point		2	0.31	44	38.4	0.277	50	39.4	0.03	-6.0	-1.
10/22	1	+point		2	0.39	41	28.0	0.122	38	23.2	0.27	3.0	4.
7	1	+point	EDD	3	0.98	100	91.8	0.87	100	96.3	0.11	0.0	-4
7	2	+point	EDD	3	0.75	93	83.2	0.66	100	84.7	0.09	-7.0	-1
7	3	+point	EDD	3	0.26	70	44.0	0.13	65.2	46.2	0.13	4.8	-2
10	1	+point	EDD	3	2.55	100	80.6	2.56	100	90.1	-0.01	0.0	-9
10	2	+point	EDD	3	2.31	82	61.9	2.21	100	71.0	0.10	-18.0	-9
12	1	+point	EDD	3	1.42	100	89.9	1.29	100	80.6	0.13	0.0	9
12	2 (3+4)	+point	EDD	3	0.53	76	36.6	0.55	82.8	30.0	-0.02	-6.8	6
12	5	+point	EDD	3	0.20	82	56.6	0.18	90.3	64.8	0.02	-8.3	-8
21/43	1	+point		3	1.00	63	50.9	0.991	98	50.3	0.01	-35.0	0
21/43	2	+point		3	0.29	43	35.1	0.277	50	39.4	0.01	-7.0	-4
10/22	1	+point		3	0.16	49	33.4	0.122	38	23.2	0.04	11.0	10
										Mean	0.06	-5.2	-2
										Standard Deviation	0.11	10.61	6.

Preliminary NDE Uncertainties

Length

- Mean = 0.06", Std. Dev. = 0.11"

Average Depth

- Mean = -2.0%, Std. Dev. = 6.8%

Maximum Depth

- Mean = -5.2%, Std. Dev. = 10.6%

NDE Sizing for Axial PWSCC at Dented Tube, TSP Intersections

Conclusions

+ Point Coil Provides Acceptable Crack Sizing for Tube Integrity and Potential Future ARC Applications

- Uncertainty on length < 0.1" and average depth about 7 %:

+ Point Coil Meets EPRI Appendix H Requirements for Sizing

- Formal Appendix H qualification to be performed with final report of sizing qualification efforts.

ARC Concepts for Indications at Dented TSPs

NRC/Utility Meeting

November 20, 1996

Presented By:

T. A. Pitterle

Nuclear Services Division

Westinghouse Electric Corp.

ARCs to be Developed

ARCs Based on Negligible SLB TSP Displacement

- WCAP-14707
  - Packed crevices prevent SLB TSP Displacement
  - Presence of denting demonstrates packed tube to TSP crevices

ARC for Axial Indications at Dented TSP Intersections

- Near-term ARC
  - Axial ID or OD cracks within dented tube TSP intersection
- Longer term ARC
  - Axial cracks extending outside TSP

Longer Term ARC for Circumferential Indications at Dented TSP Intersections

- Small ID or OD circumferential cracks detected by + Point but not confirmed second coil
- Confirmed circumferential cracks left in service

ARC for Axial Cracks Within Dented TSPs

Tube Burst Prevented by TSP for Crack Length Within TSP

- Normal operation and SLB conditions (WCAP-14707)

Potential for Tube Burst Negligible and Limited to Crack Growth Outside TSP for PWSCC Indications

- Current growth data would indicate growth outside TSP limited to about 0.2"
- Further growth studies to be performed
  - Sizing qualified for PWSCC axial indications
- Freespan burst probability for about 0.2" outside TSP is negligible
  - Estimated at $< 10^{-8}$ for a very large number of indications

Tube Repair Based on Limiting SLB Leakage to Within Allowable Limits

- Low leakage rates for cracks within TSP
- More significant leakage for crack tips near edge of TSP and outside of TSP
- Leakage must be combined with that from other ARCs when comparing to allowable limit

Indications Extending Outside the TSP Would be Repaired

SLB Leakage Model for Axial Cracks at Dented TSPs

Utilization of W* Leakage Model

- Effective crack length for length within TSP
  - Crack opening limited by hard magnetite resulting from denting
  - Contact pressure is high enough to deform tube
    - Analyses required to develop lower bound of contact pressure

- Crevice loss coefficient
  - Develop from leak tests performed on tubes/TSP removed from retired Dampierre-1 SG and EPRI tests for throughwall cracks at dented TSPs

  - Dampierre-1 tests show very low leak rates for throughwall hole in packed crevices

  - EPRI tests show essentially no leakage for throughwall cracks within dented tube at TSP intersection

Free Span Leakage Expected to be Applied for Length of Crack Outside TSP

- Short lengths due to limited crack growth rates

Anticipate Monte Carlo Analyses for Projected EOC Leak Rate

- Operational Assessment

- Statistically account for crack growth in length and depth as well as NDE uncertainties

Longer Term ARC Including Axial Cracks Extending Outside TSP

Implementation of ARC for cracks within TSP permits development of more accurate growth rates for crack length and depth

- Principle need to develop ARC including lengths outside TSP

Repair Basis

- Allowable length outside TSP as required to limit tube burst probability to acceptance limit
  - Burst probability must be combined with other implemented ARCs such as GL 95-05 ARC for ODSCC at non-dented TSP intersections
- As required to limit leakage to acceptable limit

Tube Burst Considerations

- Burst potential limited to length outside TSP
- Based on length and depth of crack outside TSP
- Monte Carlo analyses for operational assessment burst probability

SLB Leakage

- Modeling similar to ARC for cracks within TSP
- Plan to assess leakage for cracks outside TSP based on projected throughwall crack lengths
  - Requires growth rates for maximum depth and associated length as well as growth rates on total length and average depth
  - Could use number of length of deep crack sections in a model similar to that developed for circumferential indications
    - Number and length of deep sections developed from pulled tubes and NDE sizing analyses of field indications
    - Growth rate in depth applied first to deep sections until throughwall

ARC Concepts for Circumferential Indications

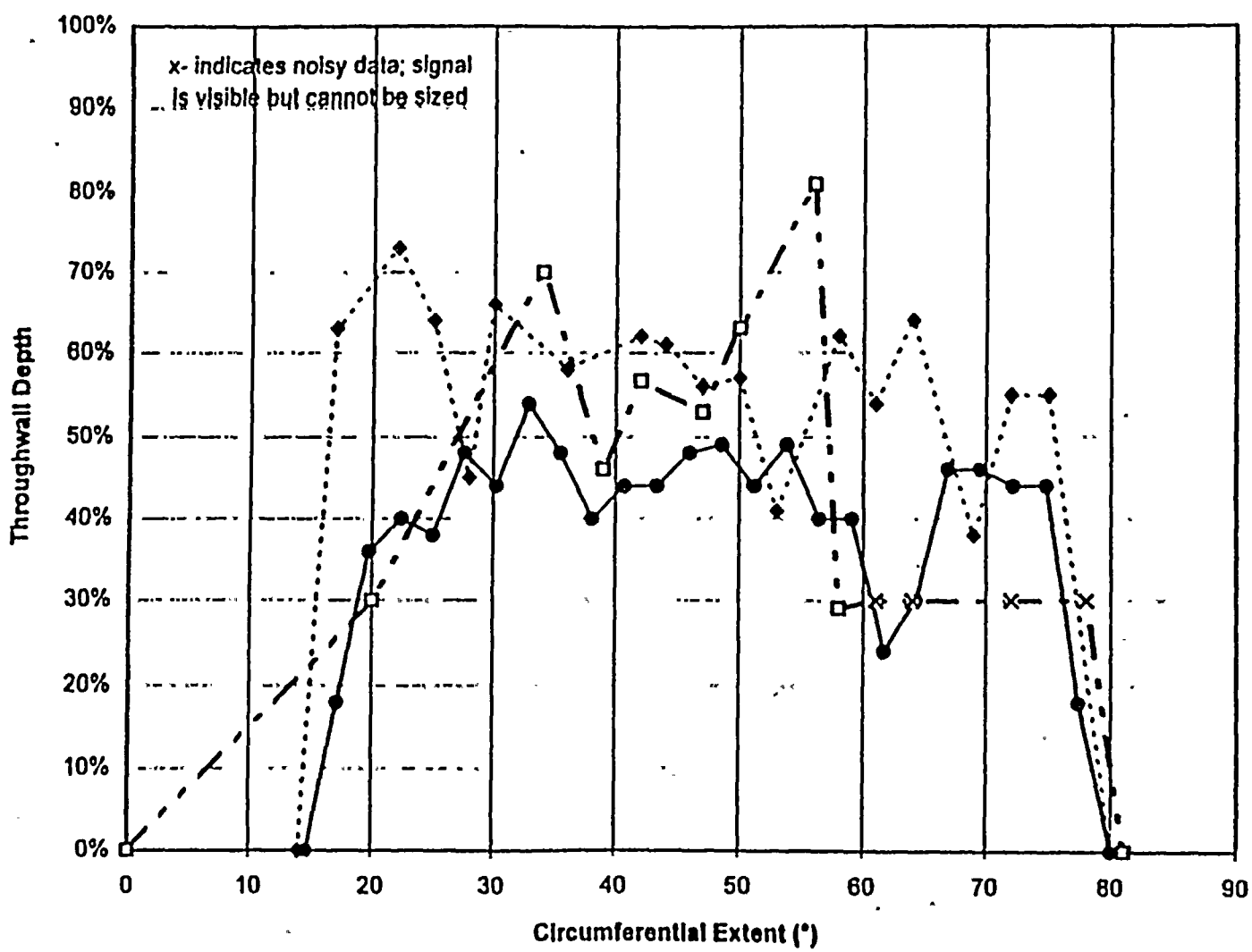
Option Based on + Point and UT Inspections

- Detection and sizing by + Point inspection
  - Sizing in angle and depth
  - Adequate sizing supported by two pulled tube exam results
- Confirm crack associated with local dent or major axis of ovality by UT examination
- In situ test largest indications to confirm structural and leakage integrity at EOC
- Repair largest indications in situ tested
  - For example, indications > 90° (TBD) or < 90° with PDA > 50% (TBD)
- Support next operating cycle using approximate growth rates (angle, PDA, volts) developed from current and prior cycle data
- Tube pull for largest indication

Second Option Based on + Point and Pancake Coil Inspection

- NDD by pancake coil as basis for defining short and shallow indications
  - Lack of flaw behavior as basis for NDD call
    - None or negligible C-scan indication with negligible implied depth from phase response and lack or phase rotation with frequency
- Pancake coil NDD replaces + Point sizing and UT inspection of Option 1
- Repair indications confirmed by pancake coil
- In situ testing of largest pancake coil confirmed indications, growth analyses and tube pull same as Option 1

Plant W, R11C61 - 1H; Circumferential Crack Profile Evaluation

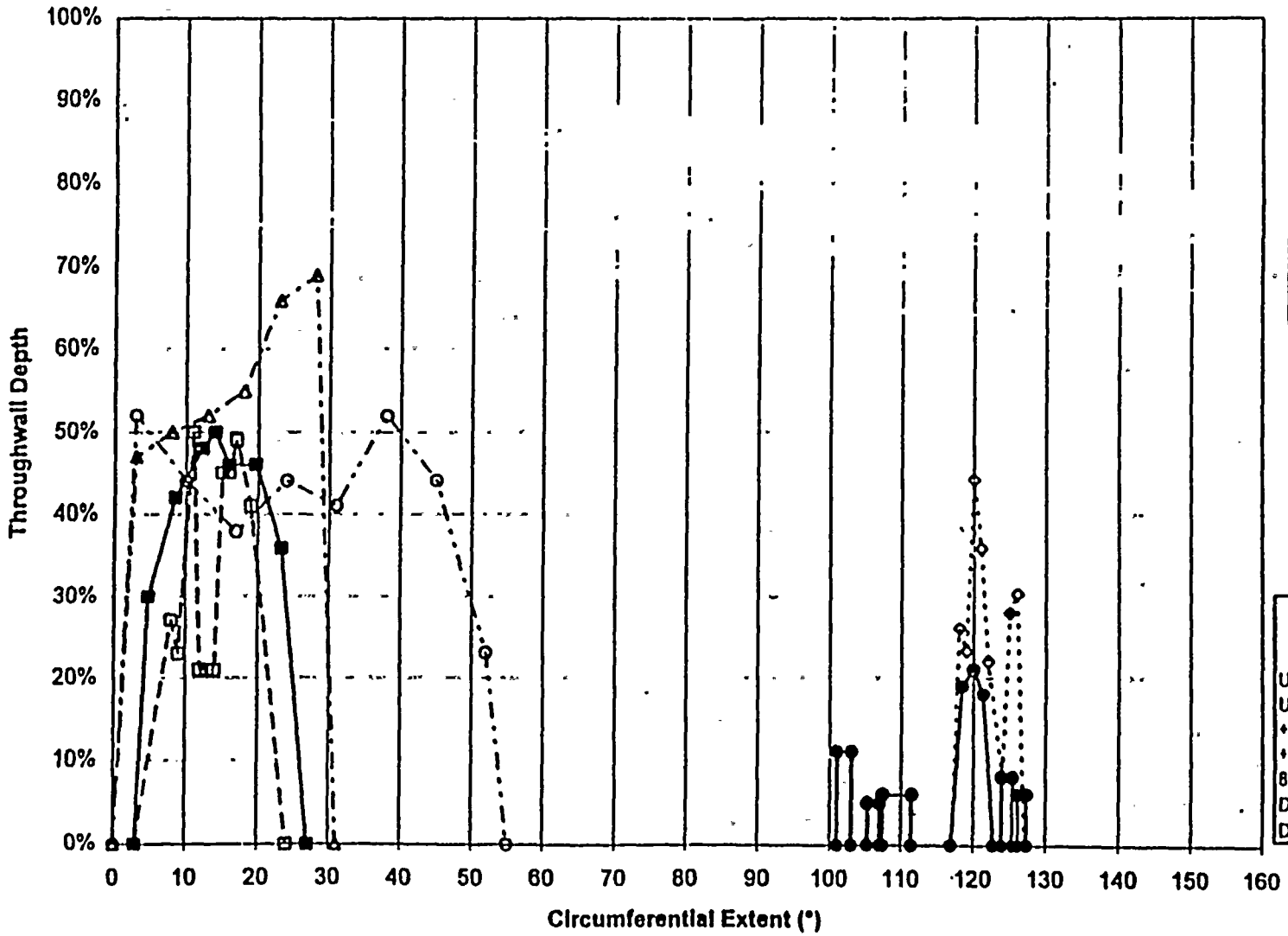


Destr. Exam
+Point
80 mil HF

Analysis
+Point Probe
300 KHz
80 mil HF coil
300 KHz
Calibration:
Based on field standard, all probes

Average Depths:
Destructive Exam:
360°: 7.3%
Crack: 40.5%
+Point Probe:
360°. 9.9%
Crack: 54.0%
80 mil HF coil
360°: 8.5%
Crack: 38.0%
Crack Length:
Destr Exam 65°
+Point Probe 66°
80 mil HF coil 81°

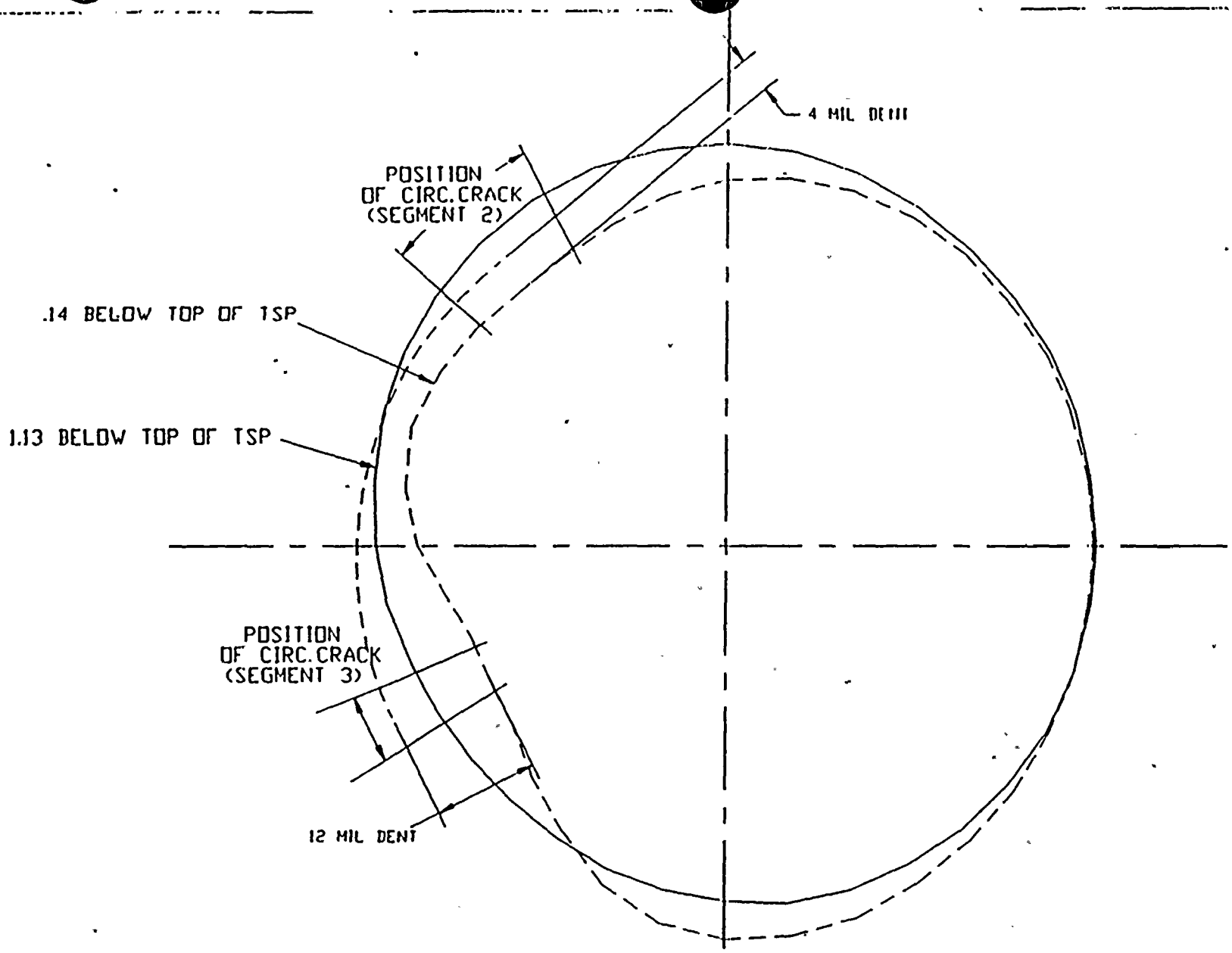
Plant Y-1 - Tube R14C69, TSP 1H



- UT - Crack 1
- UT - Crack 2
- +Point, Analyst C
- 80 mil HF, Analyst C
- Destructive Exam - Crack 1
- Destructive Exam - Crack 2

	Max Depths
UT-Crack 1:	50.0%
UT-Crack 2:	44.2%
+Point,-Crack 2:	69.0%
80 mil HF -Crack 2:	52.0%
DE-Crack 1:	50.0%
DE-Crack 2:	21.0%

	Avg. Depth	Degr. Area	Cr An
UT-Crack 1:	26.7%	1.5%	21
UT-Crack 2:	23.3%	0.6%	10
+Pt Gimbaled-Crk 2:	39.8%		2
+Point-Crack 2:	50.9%	4.2%	31
80 mil HF-Crack 2:	40.1%	5.8%	5
DE-Crack 1	37.3%	2.4%	24
DE-Crack 2:	6.0%%	0.4%	2



ROW 14 COL 69 1ST SUPPORT

PGE - S/G 12
OVALITY PLOT