PRESENTATION TO U.S. NRC

PERFORMANCE OF L GRADE STAINLESS STEEL RECIRCULATION OUTLET SAFE ENDS AT PEACH BOTTOM-3

OCTOBER 1, 1985

[redacted]

OUTLINE

- EXAMINATION SUMMARY
- UT EXAMINATION RESULTS FOR OUTLET SAFE ENDS
- LOW CARBON STAINLESS STEEL EXPERIENCE
- EVALUATION OF PEACH BOTTOM-3 OUTLET SAFE ENDS
  - MATERIAL VERIFICATION
  - FABRICATION CONTROLS
  - FABRICATION HISTORY
  - CRACK GROWTH EVALUATION
- SUMMARY

EXAMINATION SUMMARY

WELDED STAINLESS STEEL PIPING AND SAFE ENDS
PEACH BOTTOM-2 AND -3

- UNIT 2 (MEETING WITH NRC HELD AUGUST 30, 1984)

  126 WELDS INSPECTED
  26 CRACKED (21%)
  24 L GRADE INSPECTED } D.M welds
  0 CRACKED *

- UNIT 3 (MEETING WITH NRC HELD SEPTEMBER 5, 1985)

  131 WELDS INSPECTED
  39 CRACKED (30%)
  17 L GRADE INSPECTED
  2 CRACKED (UNDER EVALUATION) } D.M welds

- TODAY'S MEETING FOCUS

OUTLET SAFE END PIPE WELD CRACKING STATUS

* 2 outlets P.T (not UT)

PEACH BOTTOM-3 1985 SUMMARY

INSPECTION STATUS (1985 OUTAGE)

- TOTAL NUMBER OF WELDS - 151
- TOTAL NUMBER REQUIRING EXAMINATION - 132
  - -- PIPING WELDS - 125
  - -- 1983 OVERLAYS - 7
- NUMBER OF EXAMS COMPLETE - 131
- TOTAL NUMBER OF NEW CRACK INDICATIONS - 39
  - -- PIPING - 29
  - -- SAFE END THERMAL SLEEVES - 10

REPAIR STATUS

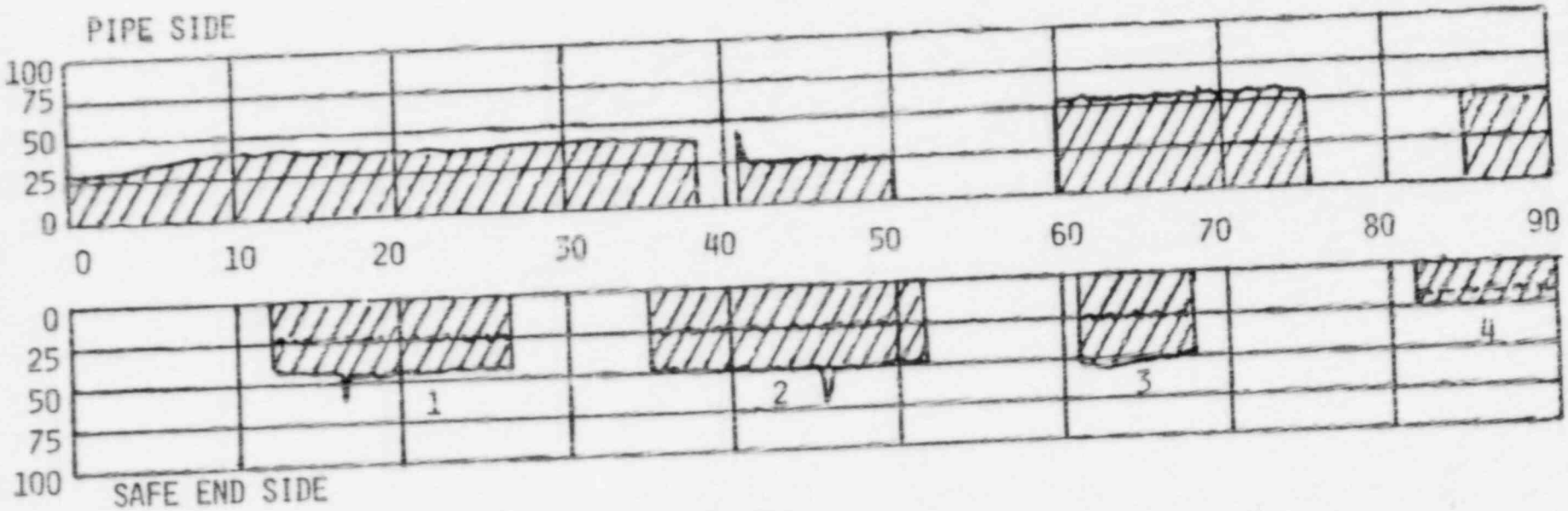
	# CRACKED JOINTS	# OF 1983 OVERLAY EXAMS	# OF NEW OVERLAYS	# OF OPERATE AS-IS	EXAMS REMAINING
28" PIPE/SAFE END	2 (2)	-	2	0	0
28" PIPE	11 (9)	-	9*	2	1
24" RHR	8 (6)	-	2	6	0
22" HEADER	0	-	0	0	0
20" RHR	4 (4)	5**	2	2	0
12" RECIRC	4 (4)	-	3	1	0
12" SAFE END T.S.	10	-	0	10	0
4" JET PUMP INST. SE	-	2**	-	-	-
	39	7	18	21	1

* MAY BE MORE OPERATE AS-IS WHEN FINAL UT DATA IS RECEIVED

**NO CRACK GROWTH DETECTED IN 1983 WELD OVERLAYED JOINTS

() = NUMBER OF WELDS IHSI TREATED IN 1983

PEACH BOTTOM UNIT 3
UT OF RECIRCULATION OUTLET SAFE END TO PIPE WELD
2BS2



1. 14" LONG-AVERAGE 25%, MAX 40%, CUSP 60%
2. 15" LONG AVERAGE 25%, MAX 50%, CUSP 70%
3. 10" LONG AVERAGE 25%, MAX 50-57%
4. 8" LONG AVERAGE 15% MAX 25%

47" TOTAL LENGTH

~~~~~ SMART UT AVERAGE
~~~~~

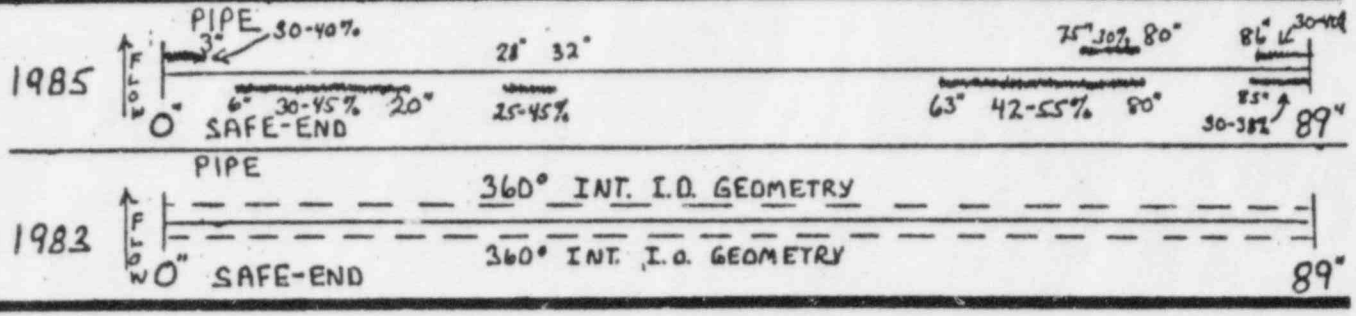
NDE OF PEACH BOTTOM 3 RECIRCULATION OUTLET SAFE END TO PIPE WELDS

J. P. CLARK

SEPT. 1985

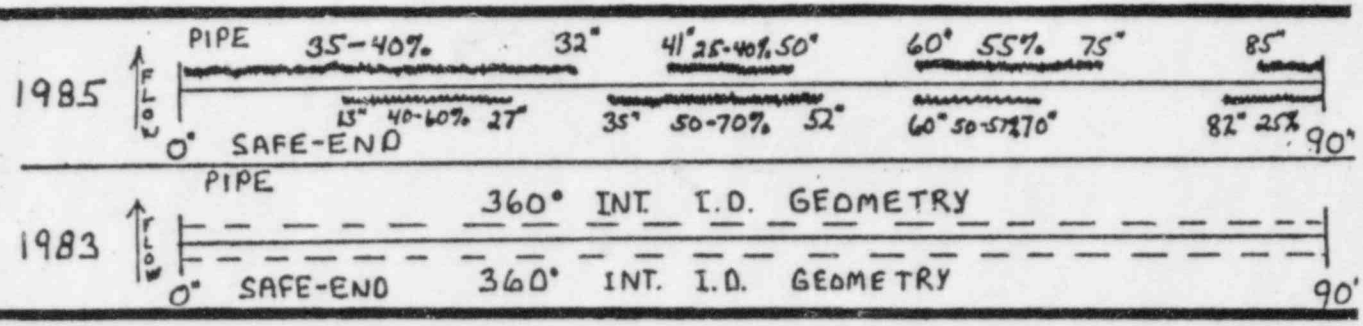
2-AS-2

(28" DIA.)

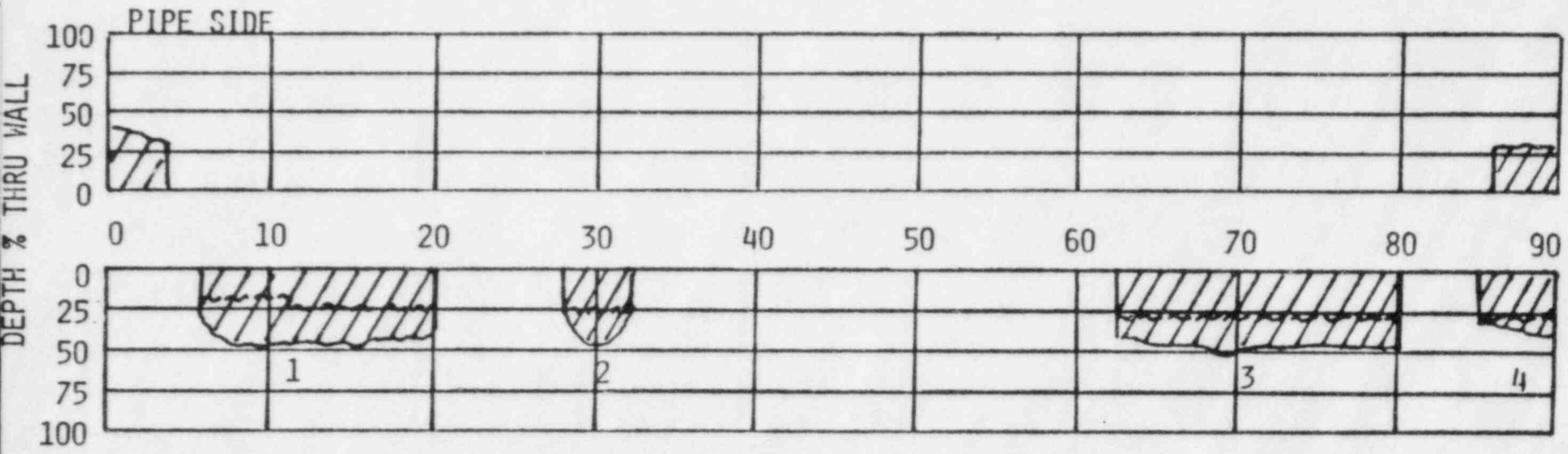


2-BS-2

(28" DIA)



PEACH BOTTOM UNIT 3
UT OF RECIRCULATION OUTLET SAFE END TO PIPE WELD
2AS2



SAFE END SIDE

1. 14" LONG-AVERAGE 15-25% MAX 30-45%
2. 4" LONG-AVERAGE 25% MAX 45%
3. 17" LONG-AVERAGE 25% MAX 42-55%
4. 4" LONG-AVERAGE 25% MAX 30-38%

39" TOTAL LENGTH

~~~~~ SMART UT AVERAGE
~~~~~

RADIOGRAPHY

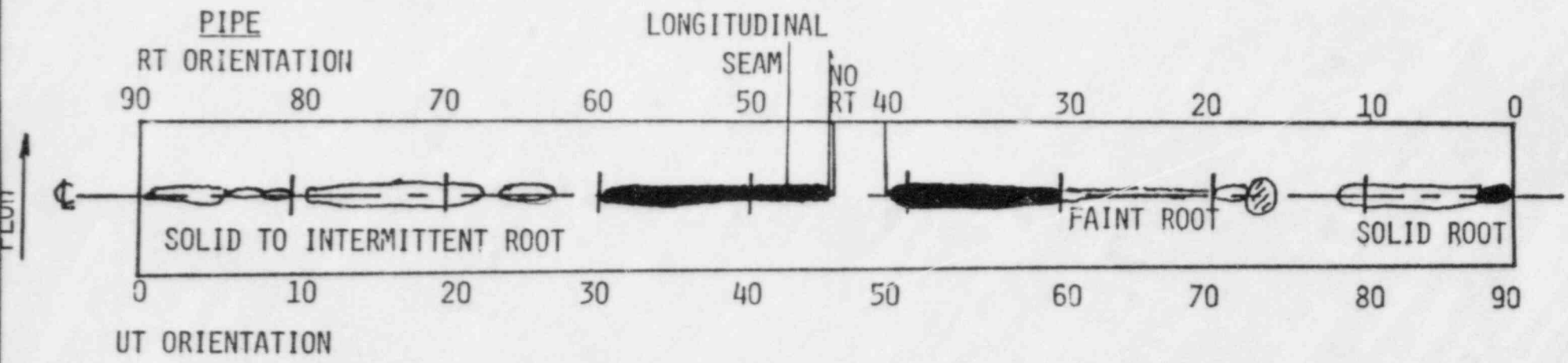
- FABRICATION RADIOGRAPHS DO SHOW GRINDING ON BOTH SAFE ENDS
  - LOCALIZED HEAVY IN SOME AREAS - TO INTERMITTENT 360° SPOTTY GRIND
  - 4 LEVEL IIIs IN AGREEMENT
  - 2BS2 SHOWS EVIDENCE OF HEAVIER GRINDING THAN 2AS2 AND IT HAS MORE EXTENSIVE CRACKING
  - SOME AREAS WHERE UT SIGNALS HAD BEEN EVALUATED AS INTERMITTENT ID GEOMETRY IN 1983 HAS NO ID GEOMETRY - COUNTERBORE AND ROOT WERE REMOVED BY GRINDING

<u>THEREFORE</u>

- CRACK INITIATION MAY BE RELATED TO GRINDING
- CRACKS WERE PRESENT IN 1983 AND EVALUATED AS GEOMETRY

FABRICATION RADIOGRAPHS
OF PEACH BOTTOM UNIT 3 RECIRCULATION OUTLET
SAFE END TO PIPE WELD NO. 2AS-2

COMPOSITE EVALUATION BY 1 PECO LEVEL III
2 GE - DAESO LEVEL III
1 GE - NEBO LEVEL III



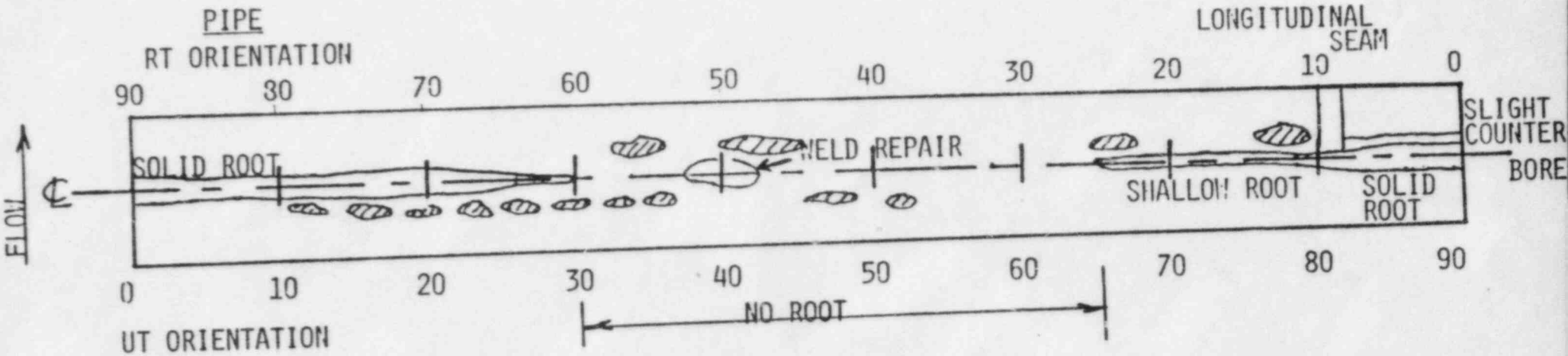
SAFE END

NOTES 1. SOME GRINDING OR INTERMITTENT FLAPPERING 360°
2. SOME SMALL AREAS OF INCOMPLETE FUSION AT 24.5" (RT ORIENTATION)

CONCAVITY OR SUCKBACK
DEEPER GRINDING

FABRICATION RADIOGRAPHS
OF PEACH BOTTOM 3 RECIRCULATION OUTLET SAFE END TO PIPE
WELD NO 2BS2

COMPOSITE EVALUATION BY 1 PECO LEVEL III
2 GE - DAESO LEVEL III
1 GE - NEBO LEVEL III



NOTES 1. SOME GRINDING INTERMITTENT 360°
2. SOME MISMATCH ON PIPE SIDE NEAR SEAM
3. SOME SMALL AREAS OF INCOMPLETE FUSION AT 84" ON SAFE END SIDE (RT ORIENTATION)

DEEPER GRINDING

UT OF PEACH BOTTOM 3 RECIRCULATION OUTLET SAFE END TO PIPE WELDS 2AS2 & 2BS2

- CRACK DETECTION
  - SMART UT - 45° SHEAR WAVE DETECTED CRACKS ON BOTH SIDES OF BOTH WELDS
- CRACK SIZING
  - MANUAL UT, REFRACTED LONGITUDINAL WAVES USED TO VERIFY AND SIZE DEEPER AREAS
- CONFIRMATION
  - SWRI CONFIRMED ALL INDICATIONS WITH ONLY SLIGHT VARIATIONS IN SIZING
- EXAMINATION AND SIZING PERSONNEL
  - ALL PERSONNEL TRAINED AND QUALIFIED AT EPRI UNDER IE83-02

IE8302 REQUIREMENTS WORKED

SUMMARY OF UT RESULTS
PEACH BOTTOM 3

CIRCULATION OUTLET SAFE END TO PIPE WELDS

1985 EXAMINATION REVEALED CRACKS ON BOTH SIDES OF BOTH WELDS

WELDS EXAMINED IN 1983 FOUND INDICATIONS WHICH WERE EVALUATED AS 360° INTERMITTENT ID GEOMETRY

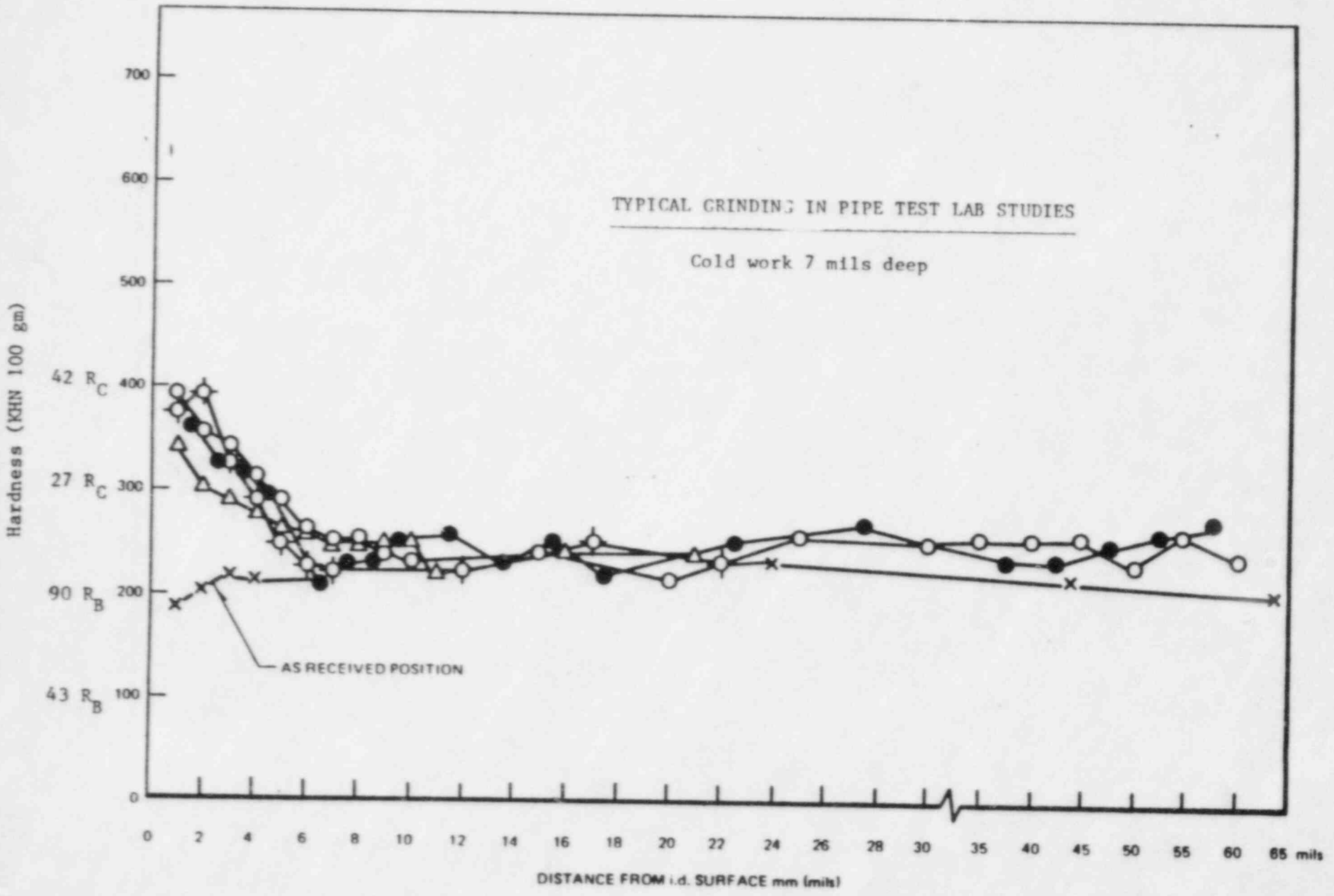
INITIAL FABRICATION RADIOGRAPHS SHOW EVIDENCE OF EXTENSIVE GRINDING

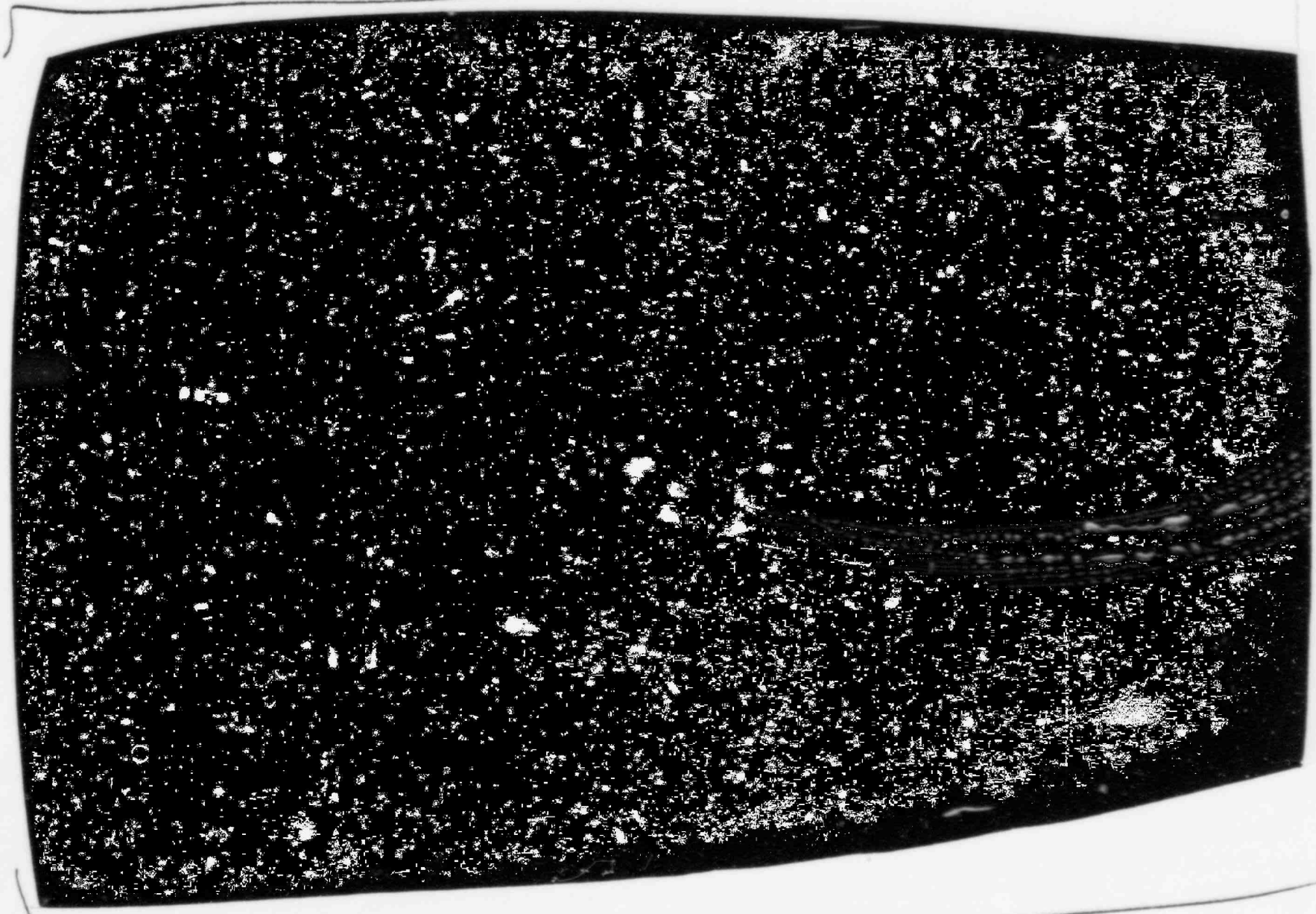
- AREAS OF TOTAL ROOT AND COUNTERBORE REMOVAL - NO ID GEOMETRY

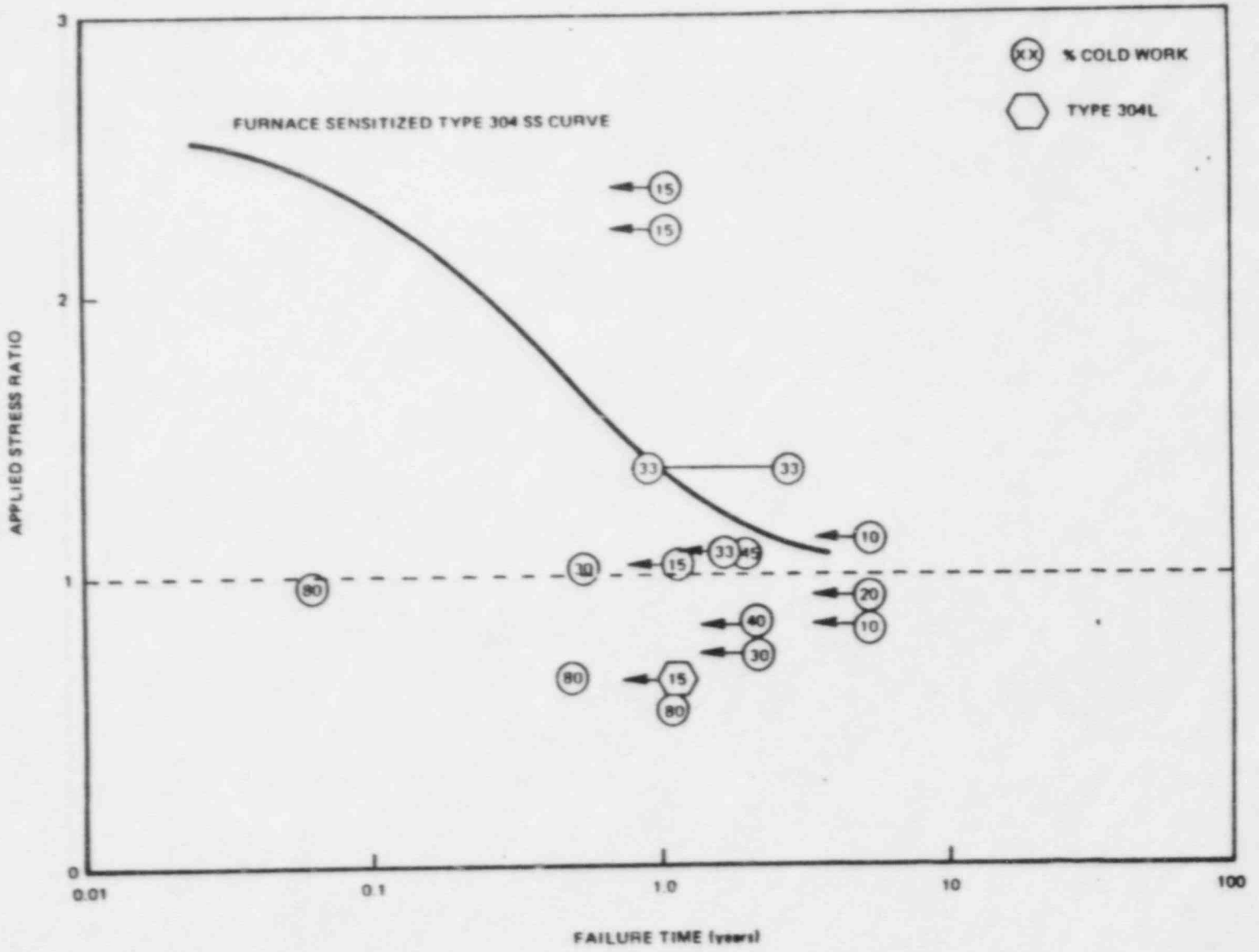
CURRENT UT PERSONNEL, PROCEDURES AND EQUIPMENT CAPABLE OF DETECTING AND SIZING IGSCC

- QUALIFIED IN ACCORDANCE WITH IE83-02
- 1983 EXAMINATIONS WERE IN ACCORDANCE WITH IE82-03

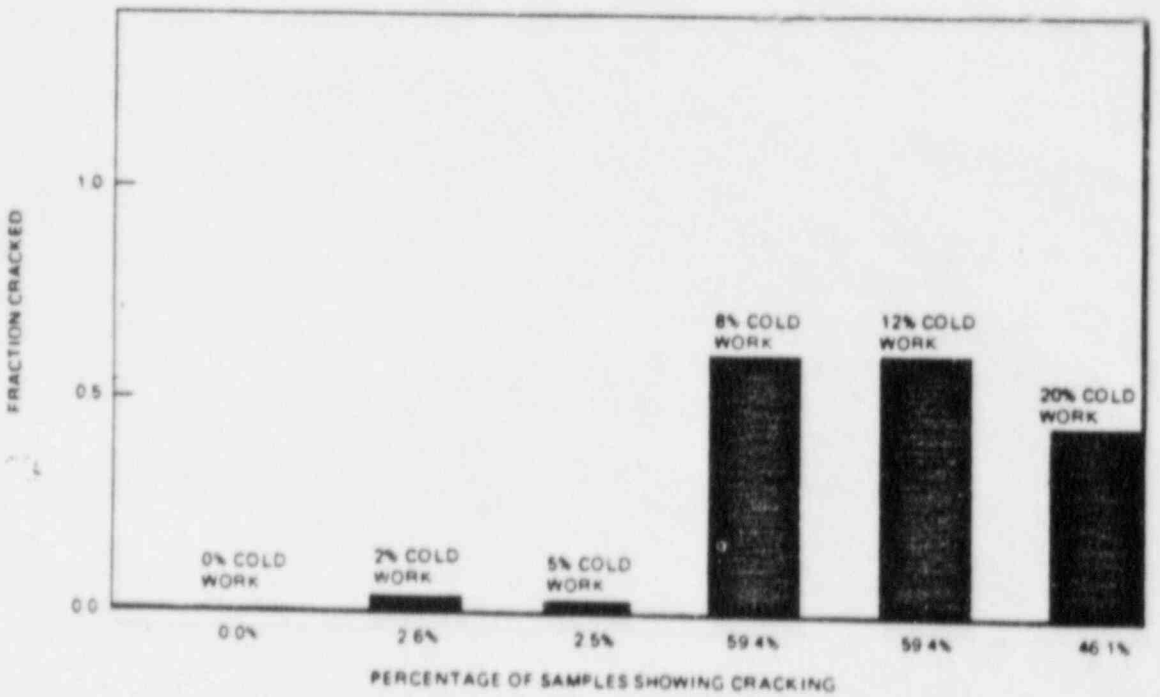
QUALIFICATION OF PERSONNEL, PROCEDURES & EQUIPMENT IN ACCORDANCE WITH IE83-02 SHOWN TO BE SUITABLE


TYPICAL GRINDING IN PIPE TEST LAB STUDIES
Cold work 7 mils deep
Hardness (KHN 100 gm)
700
600
500
42 R_C
400
27 R_C
300
90 R_B
200
43 R_B
100
0
AS RECEIVED POSITION
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 35 40 45 50 55 60 65 mils
DISTANCE FROM i.d. SURFACE mm (mils)





SCC of Cold Worked Type-304 Stainless Steel at 288°C



CREVICED BENT BEAMS - TYPE 316 NG SS

8 ppm oxygen, 1% strain

METALLURGICAL FACTORS INHERENT IN COLD WORK EFFECTS ON STRESS CORROSION CRACKING

- COLD WORK INCREASES THE DISLOCATION DENSITY AND CHEMICAL REACTIVITY

- LOCALIZED COLD WORK SUCH AS GRINDING PRODUCES HARD SURFACE LAYER

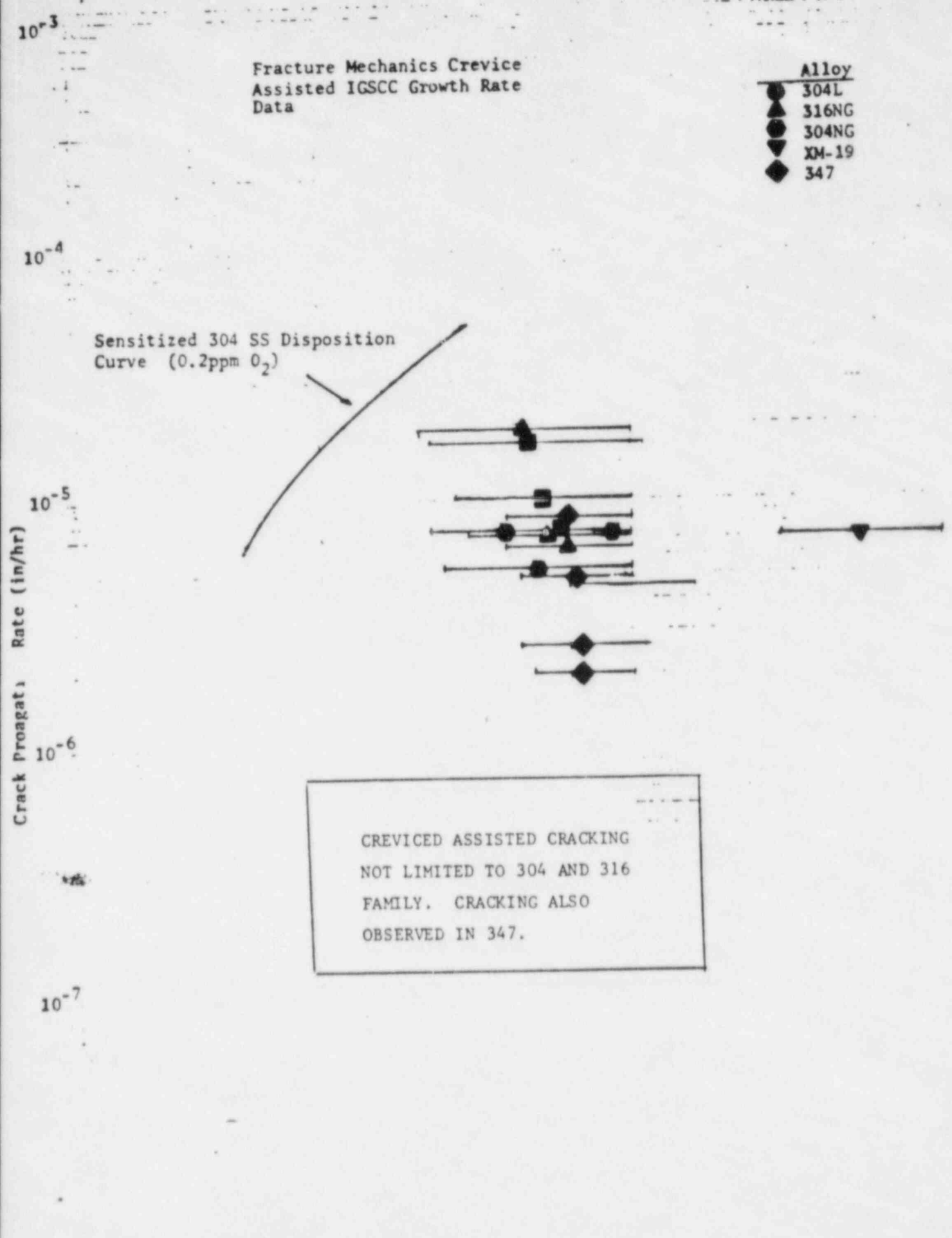
  - LOCAL STRAIN TOLERANCE IS DECREASED
  - ALSO, GROUND LAYER IS MARTENSITIC IN 304 FAMILY

- SEVERE COLD WORK CAN RESULTS IN CRACK INITIATION

  - IF COLD WORKED LAYER IS DEEP, CREVICE CAN FORM WITH RESULTANT GROWTH INTO ANNEALED MATERIAL

LOCALIZED COLD WORK CAN PRODUCE CRACK INITIATION IN ALL AUSTENITIC STAINLESS STEELS

Fracture Mechanics Crevice Assisted IGSCC Growth Rate Data



CREVICED ASSISTED CRACKING NOT LIMITED TO 304 AND 316 FAMILY. CRACKING ALSO OBSERVED IN 347.

- PEACH BOTTOM-2 AND -3 SAFE END TO PIPE WELD MADE IN 1973

  - NO SPECIAL GRINDING SPECIFICATIONS OR CONTROLS TO LIMIT COLD WORK

- GRINDING CONTROLS IMPLEMENTED 1979

  - IN PLACE FOR BACKLOG PLANT 316 NG CHANGEOVER

  - IMPLEMENTED FOR OPERATING PLANT PIPE REPLACEMENT

LABORATORY DATA ON COLD WORK AND CREVICE EFFECTS

- SEVERE GRINDING AND/OR CREVICES CAN LEAD TO CRACKING

- NOT RESTRICTED TO SENSITIZED STAINLESS STEEL - CAN OCCUR IN L GRADE OR STABILIZED STEELS

MATERIAL CHEMISTRY VERIFICATION

	TEST CERT	ANAMET VERIFICATION*
CARBON	0.019	0.016**
CHROMIUM	17.05	17.20***
NICKEL	13.49	13.72***
MOLYBDENUM	2.19	2.19***
SILICON	0.80	0.28
SULFUR	0.020	0.019
PHOSPHORUS	0.031	0.028
MANGANESE	1.67	1.79
COBALT	---	0.11
COLUMBIUM	---	0.02
COPPER	---	0.33
TITANIUM	---	0.005
VANADIUM	---	0.04
BORON	---	0.005
NITROGEN	---	0.60-0.100

* BY EMISSION SPECTROSCOPIC METHOD

** 0.024% BY COMBUSTION METHOD

*** BY X-RAY FLOURESENCE METHOD

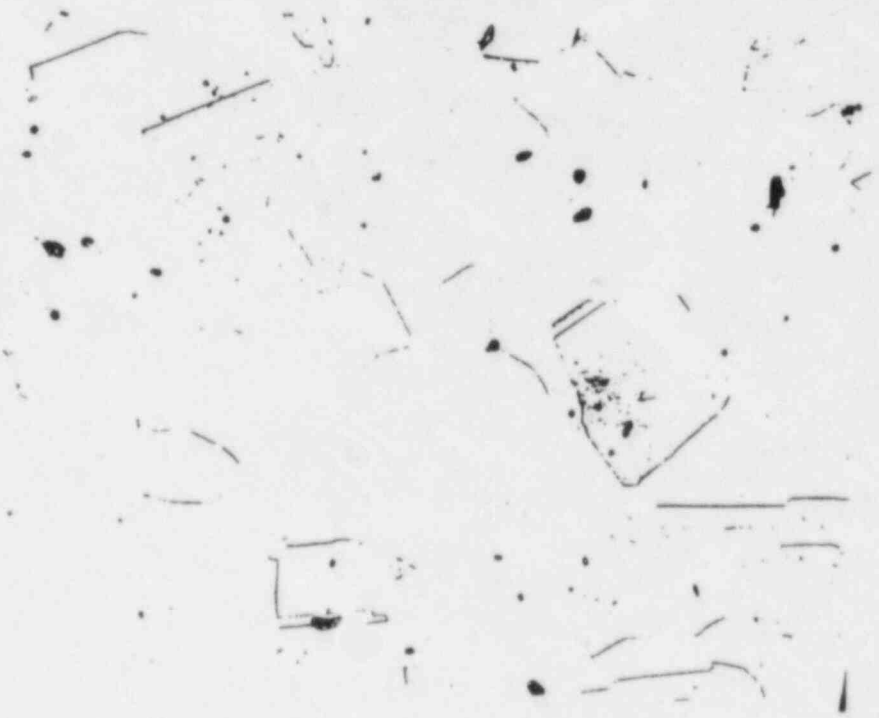
PEACH BOTTOM-3 MATERIAL VERIFICATION

- BOAT SAMPLE REMOVED FROM O.D. OF B LOOP OUTLET SAFE END
  - SAMPLE REMOVED AT ABOUT 2 O'CLOCK POSITION
  - SAMPLE WAS 1/8 INCH DEEP x 1 1/4 INCH LONG 1/4 INCH WIDE AND COVERED 316 L AND WELD
- EVALUATED FOR
  - EPR
  - MICROSTRUCTURE/SENSITIZATION
  - CHEMISTRY
  - HARDNESS

OVERALL RESULTS

O.D. BOAT SAMPLE EVALUATION

- MATERIAL NOT SENSITIZED
  - DUAL SCAN EPR
  - ETCHED MICROSTRUCTURE
- MICROSTRUCTURE SHOWS NO EVIDENCE OF IMPROPER FABRICATION
  - ANNEALED
  - MODERATE GRAIN SIZE (ASTM 3.5)
  - NORMAL HARDNESS (R_B - 71)
- CHEMISTRY CONFIRMED TO MEET SPECIFICATION
- YIELD AND ULTIMATE STRENGTHS MEET CODE
  - 33 KSI YIELD STRENGTH
  - 75 KSI ULTIMATE STRENGTH



125x

MICROSTRUCTURE FOR O.D. BOAT SAMPLE
SAFE END SIDE OF WELD 2-BS-2
(ETCHED WITH AMMONIUM PERSUFATE)

0 NO SENSITIZATION, TYPICAL GRAIN SIZE OF ASTM 3.5

PEACH BOTTOM-3
SAFE END FABRICATION

- ORIGINAL FABRICATION BY B&W INCLUDED FURNACE SENSITIZED (F.S.) 304 SAFE ENDS

- UNIT-3 VESSEL SHELL COURSE SUB-ASSEMBLIES SENT TO CB&I FOR COMPLETION

- CB&I VESSEL COMPLETION

  - MACHINE TO REMOVE F.S. SAFE ENDS AND ORIGINAL 308 BUTT WELD MATERIAL

  - RE-BUTTER WITH Ni-Cr-Fe ALLOY 182 AND POSTWELD HEAT TREAT (PWHT)

  - PERFORM ADDITIONAL PWHT FOR COMPLETION OF VESSEL SHELL COURSE ASSEMBLY

  - INSTALL NEW LOW CARBON 316 SAFE ENDS

VESSEL AND SAFE END
FABRICATION/PROCESSING
APPEARS NORMAL

PEACH BOTTOM-3
PIPE TO SAFE END WELD INSTALLATION
(2-AS-2, 2-BS-2)

- THESE ARE CLOSURE WELDS FOR THE 28-INCH DISCHARGE PIPING
  - INSTALL TEMPLATE TO OBTAIN ORIENTATION
  - MACHINE SPOOL TO MATCH TEMPLATE (WITH ALLOWANCE FOR WELD SHRINKAGE)
  - FIT-UP SPOOL AND START VERTICAL WELD, WATCHING ALIGNMENT OF HORIZONTAL WELD
  - WHEN ALIGNMENT ACHIEVED, PERFORM HORIZONTAL WELD

- WELDING PROCEDURE AND INSTALLER
  - BECHTEL OPEN-BUTT TECHNIQUE
  - TYPE 308 ROOT AND OTHER PASSES UNTIL 3/16" THICKNESS
  - TYPE 308 STICK ELECTRODE FOR COMPLETION

PEACH BOTTOM-3
PIPE TO SAFE END WELD RECORDS REVIEW

- 2-AS-2
  - WELDED 4-2-73 THROUGH 4-5-73
  - FINAL RADIOGRAPH 4-30-73
  - WELDER "A & B" DREW 40 LBS. OF STICK ELECTRODE (3/32", 1/8" ONLY)

- 2-BS-2
  - WELDED 1-22-73 THROUGH 1-27-73
  - WELDER "A, C, AND D" DREW 40 LBS. OF STICK ELECTRODE (3/32", 1/8", 5/32")
  - RADIOGRAPHED AND REJECTED ONE ZONE 2-8-73
  - RELEASED FOR REPAIR 2-14-73, WELDER "D" DREW 2 LBS. OF 3/32", 1/8" ELECTRODE
  - REPAIR RADIOGRAPHED AND ACCEPTED 2-16-73

- WELDING APPEARS NORMAL FIELD PRACTICE
- 2-BS-2 COMPLETED WITH LARGER ELECTRODE, WHICH COULD HAVE INFLUENCED STRESS PATTERN

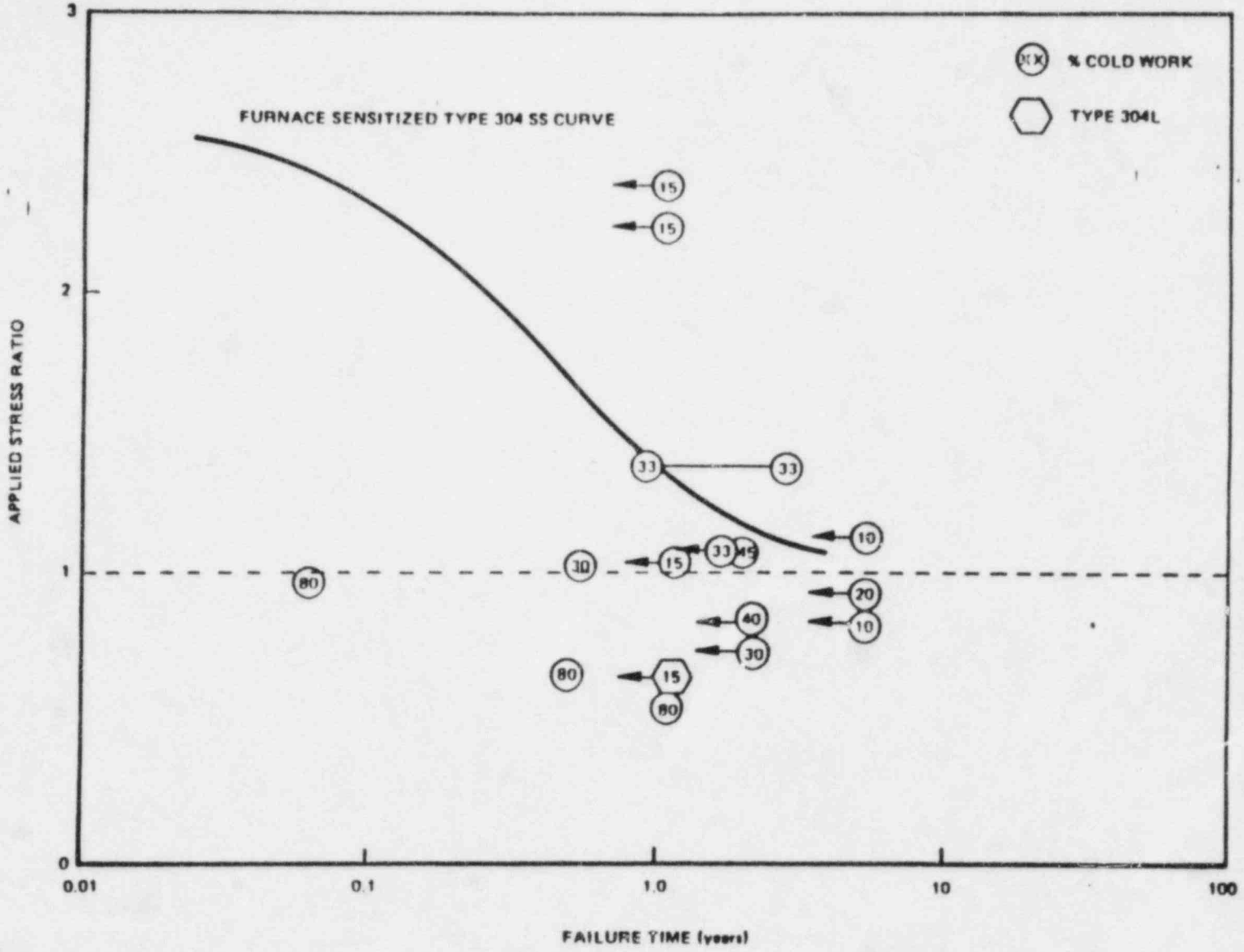
PEACH BOTTOM-3
WELD 2-AS-2 AND 2-BS-2

- FIELD WELD FABRICATION CONSIDERATIONS
  - CLOSURE WELD JOINT FIT-UP FOR ROOT PASS TYPICALLY WORSE THAN NORMAL WELDS
  - TYPE 316 MATERIAL ON ONE SIDE COULD HAVE MADE ROOT PASS MORE DIFFICULT TO WELD
  - EASY ACCESS TO PIPE I.D. FROM VESSEL FACILITATES I.D. GRINDING
- I.D. GRINDING IN LARGE BORE PIPING COMMON PRACTICE IN OLDER PLANTS
- RADIOGRAPHIC REVIEW SHOWS
  - EVIDENCE OF EXTENSIVE I.D. GRINDING
  - WELD 2-BS-2 WORSE THAN 2-AS-2
  - ROOT APPEARANCE (WHERE NOT GROUND FLUSH) IS NOT UNIFORM, CONFIRMING NEED FOR GRINDING TO CLEAN-UP FOR RADIOGRAPHY

RADIOGRAPHS CONFIRM EXPECTATIONS AND PIPE INSTALLATION PRACTICES FOR 28-INCH CLOSURE SPOOL WELDS

REPORTED CRACKING EVALUATION
REQUIRED CONDITIONS

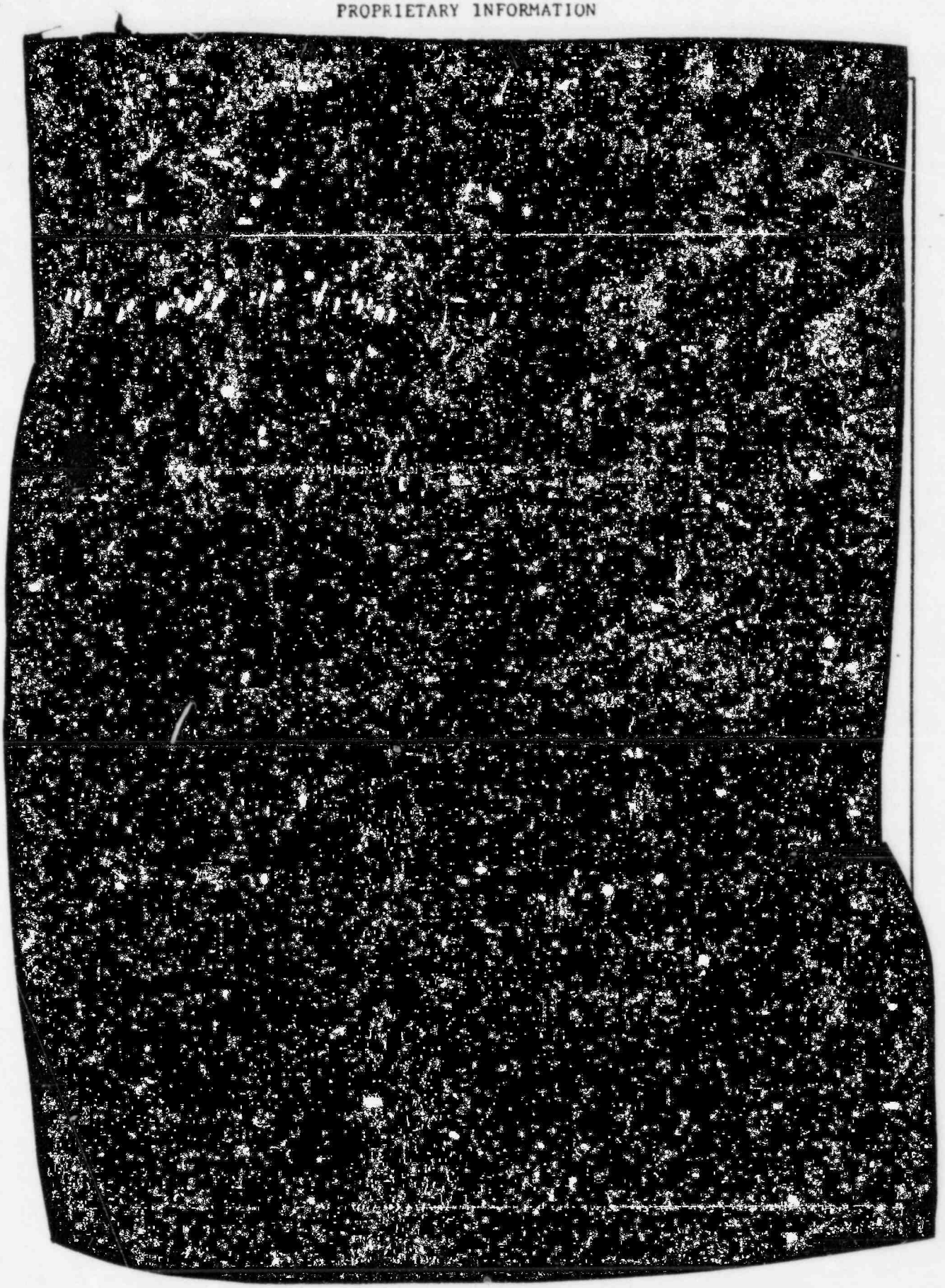
- CRACK INITIATION
  - COLD WORKING
- WATER CHEMISTRY HISTORY EFFECT ON CRACK GROWTH RATES
- APPLIED OPERATIONAL STRESSES
- WELD RESIDUAL STRESS EFFECTS ON CRACK PROPAGATION



SCC of Cold Worked Type-304 Stainless Steel at 288°C

CRACK GROWTH RATES

- GROWTH RATE BASED ON LIFE TIME WATER CHEMISTRY AT PEACH BOTTOM UNIT 3 FOR 316 L GRADE STAINLESS STEEL
- ASSUMED CRACK GROWTH RATE IDENTICAL TO THAT USED IN THE RECIRC INLET SAFE END ASSESSMENT
- CONSISTENT WITH LABORATORY DATA AND FIELD EXPERIENCE AT PEACH BOTTOM UNIT 2

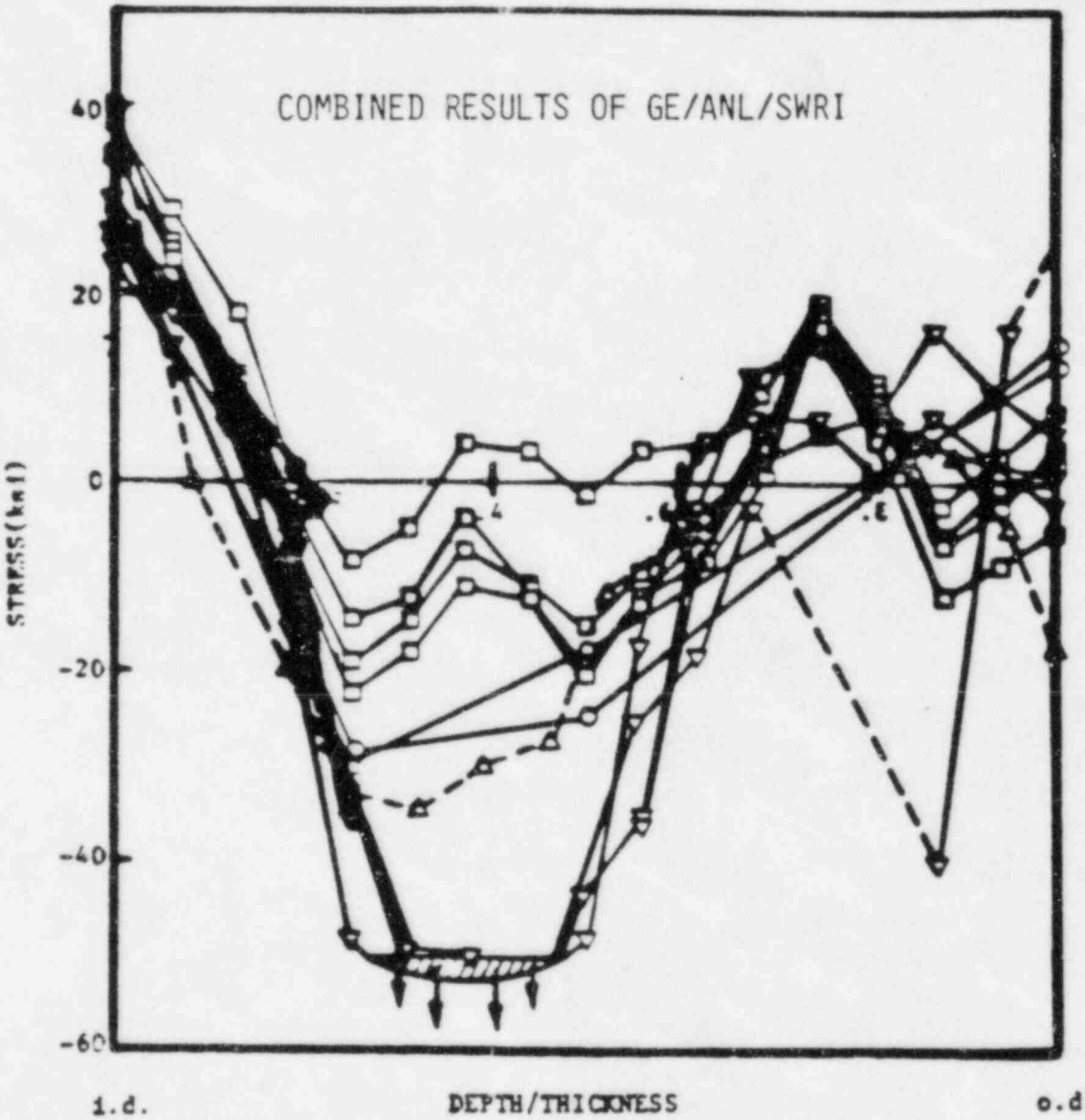


APPLIED OPERATING STRESSES

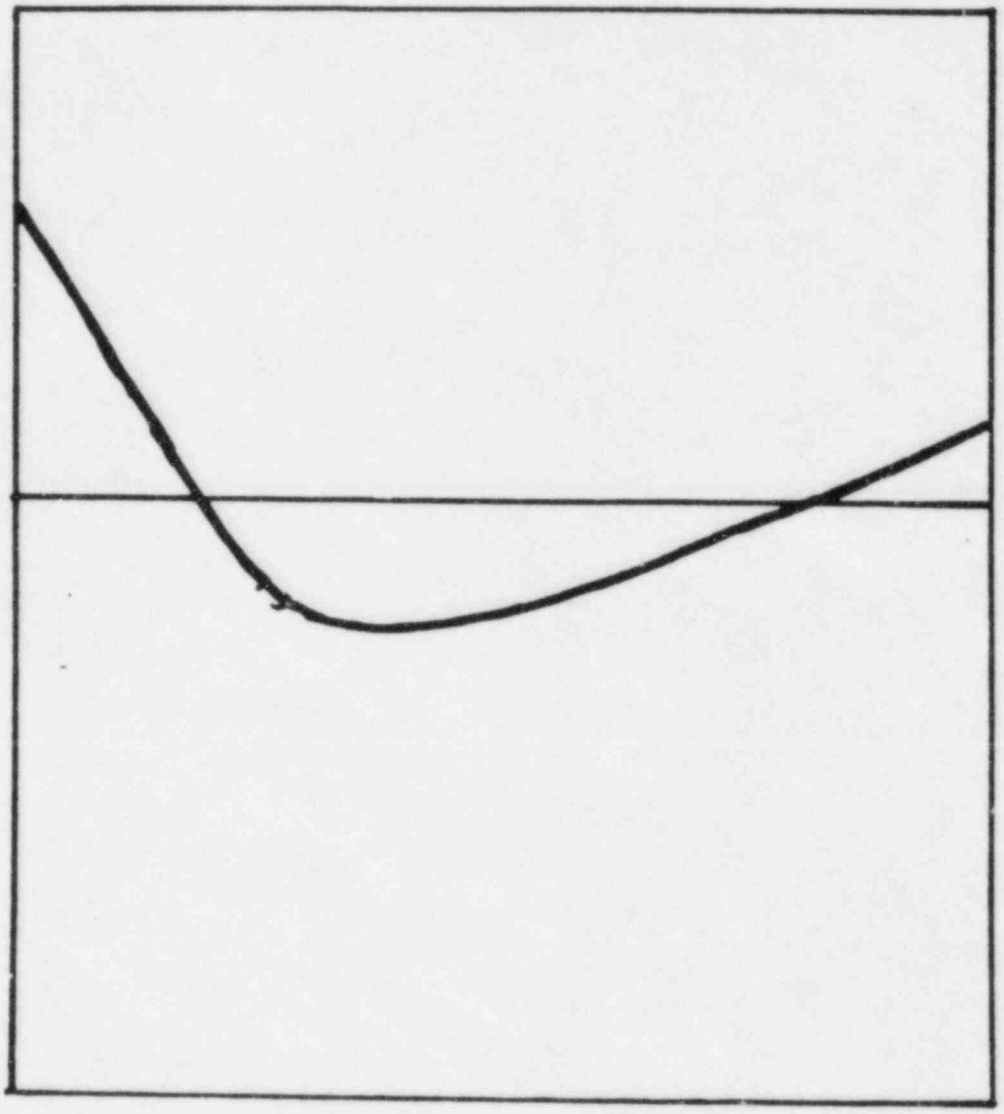
	STRESS(KSI)
PRESSURE	5.9
DEADWEIGHT	.91
THERMAL	3.65
TOTAL	10.5

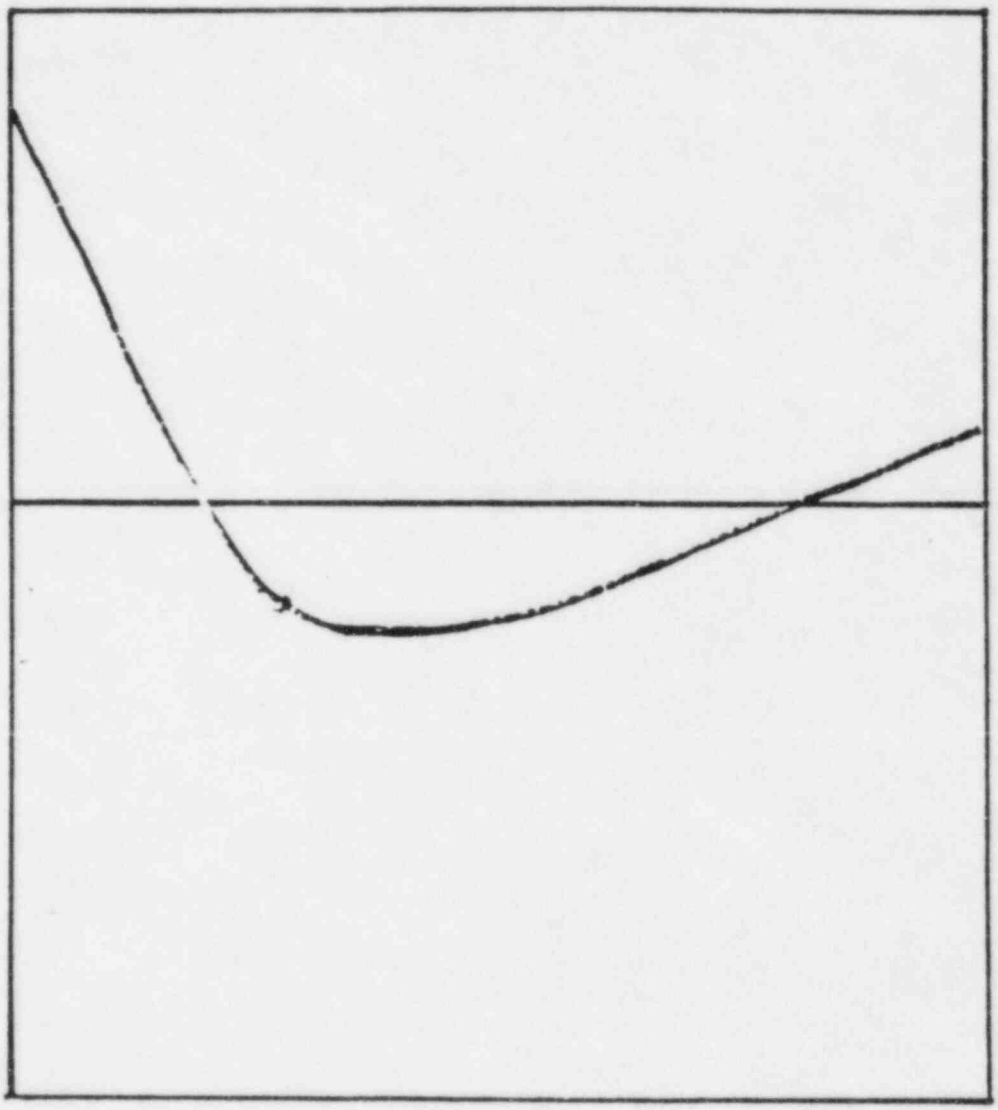
WELD RESIDUAL STRESS
PARAMETRIC STUDY

- CRACK GROWTH IS STRONGLY DEPENDENT ON APPLIED AND WELD RESIDUAL STRESS
- LARGE DIAMETER PIPING WELD RESIDUAL STRESS SHOWS WIDESPREAD SCATTER, AND TYPICAL SINUSOIDAL SHAPE
- VARIATIONS FROM "NRC" CURVE CONSIDERED
- ANALYSIS PERFORMED TO DETERMINE WHETHER ATYPICAL RESIDUAL STRESS DISTRIBUTION CAN EXPLAIN REPORTED CRACK DEPTHS

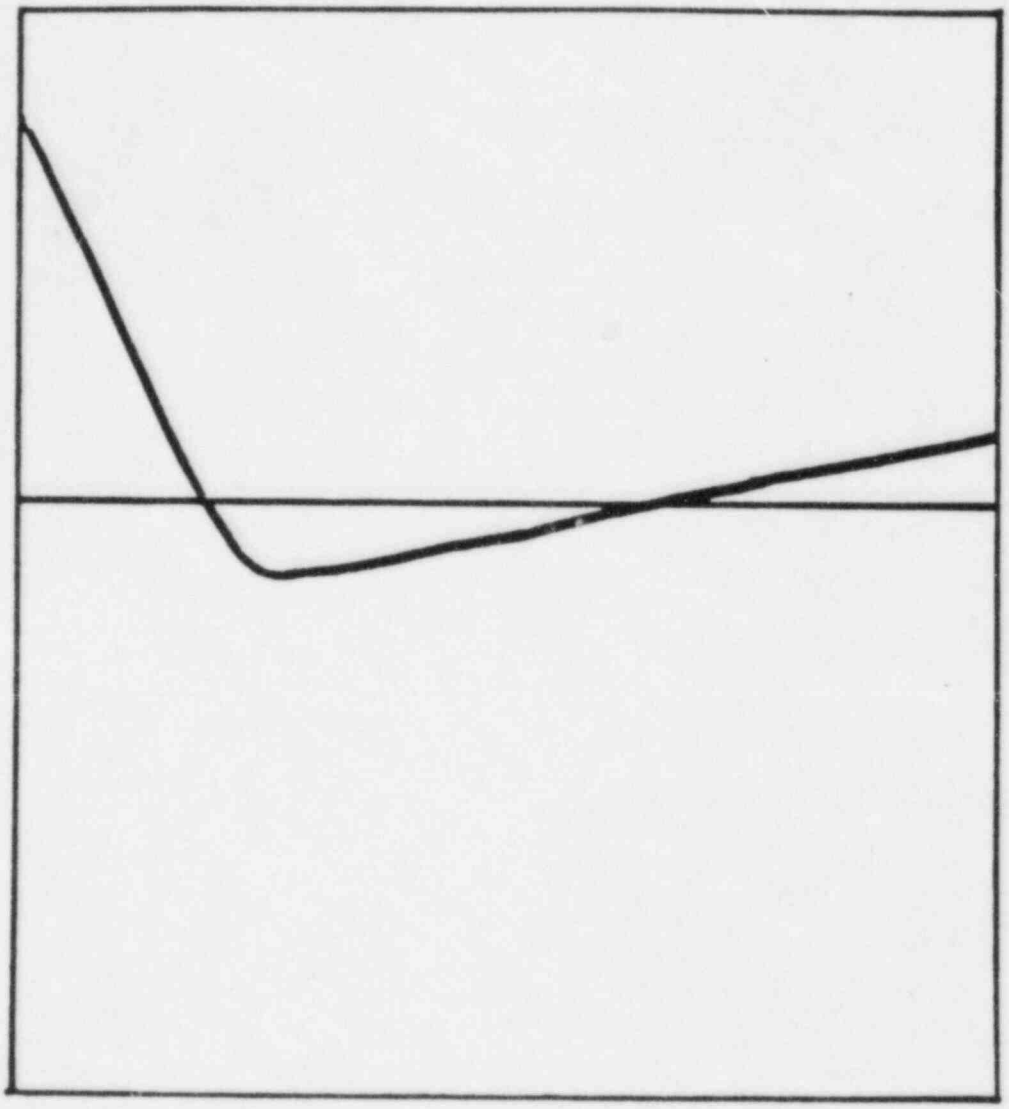


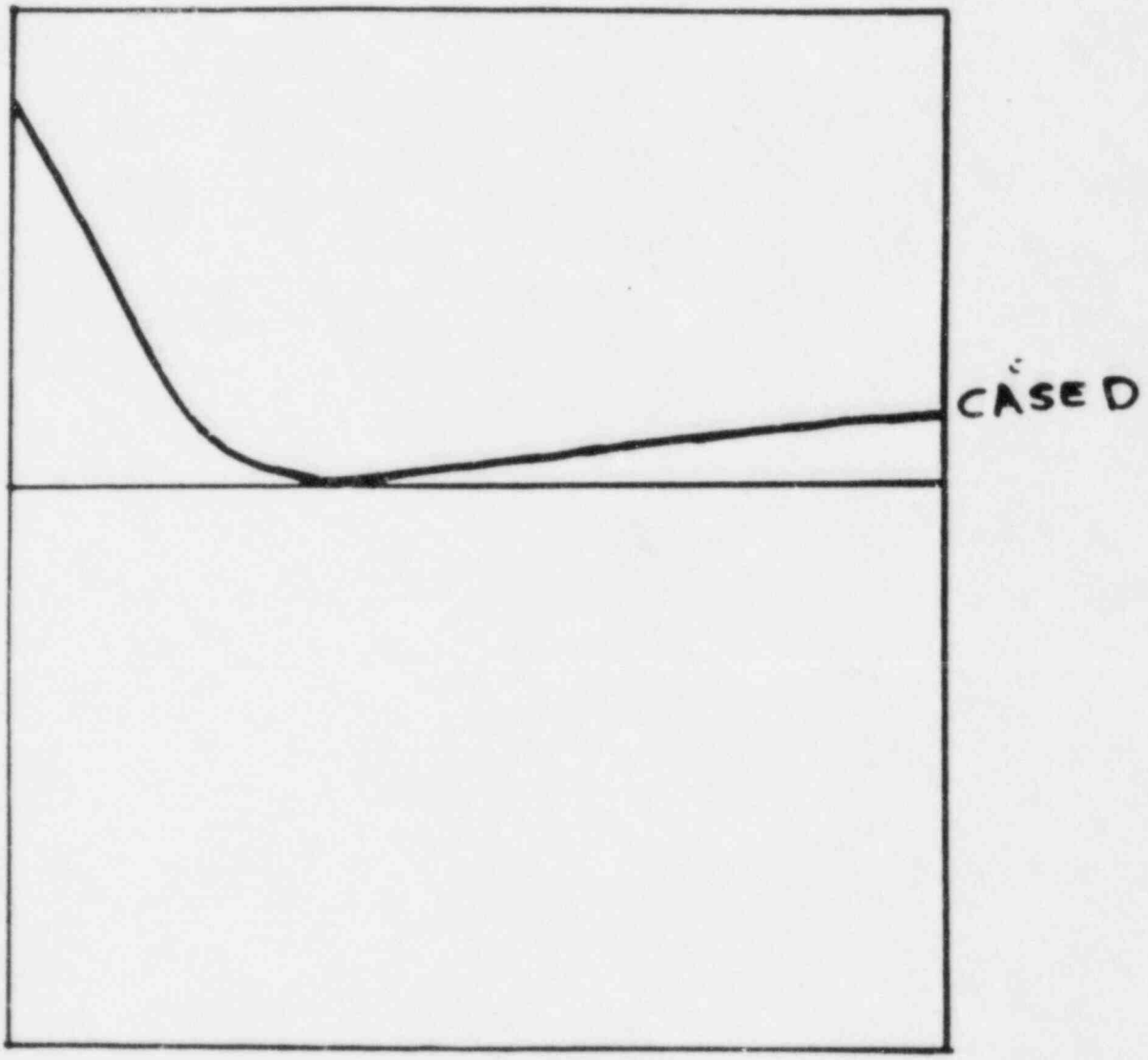
THROUGH WALL AXIAL WELD RESIDUAL STRESS
MEASUREMENTS ON LARGE DIAMETER PIPES.


CASE A



CASE B


CASE C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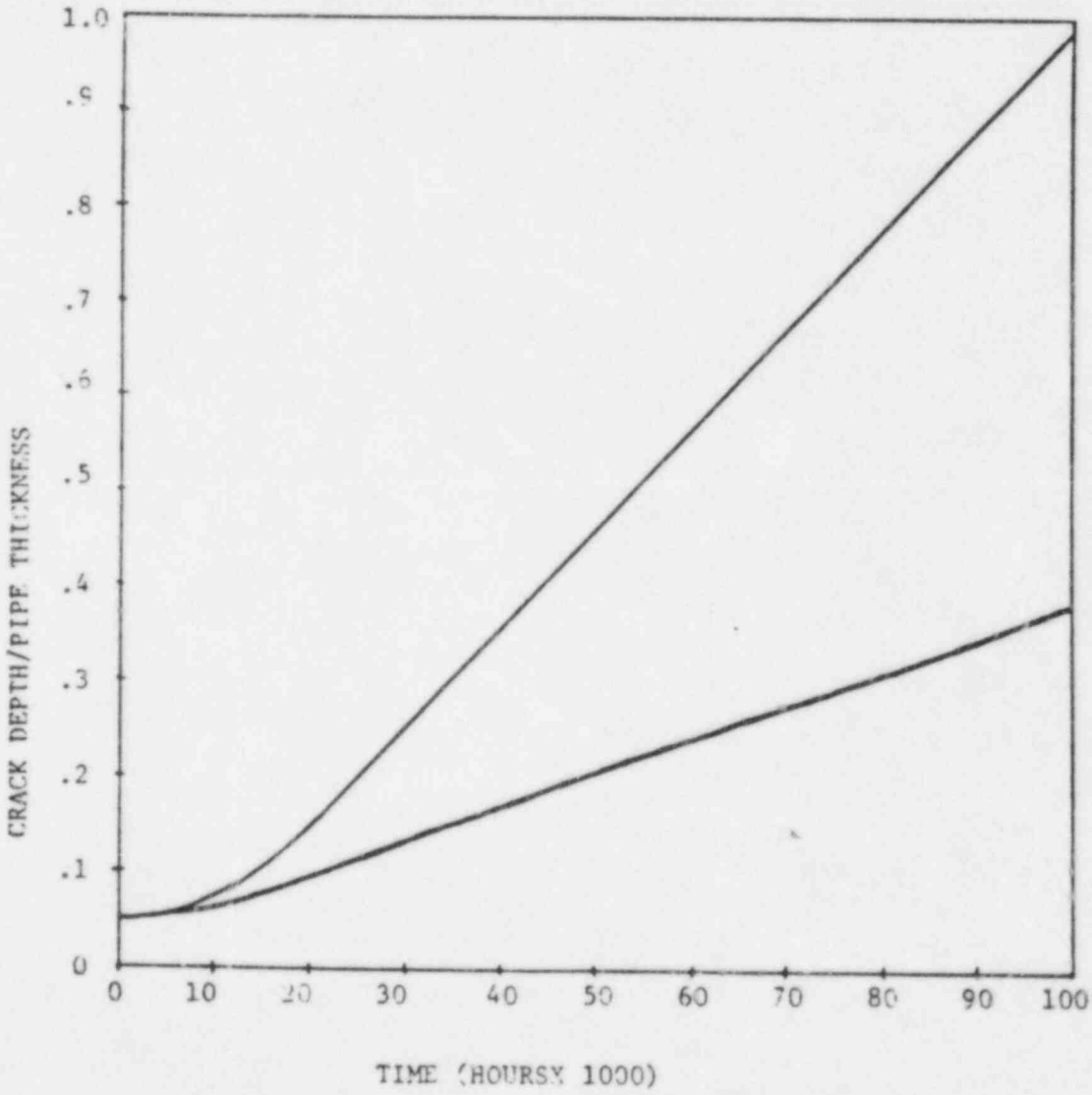
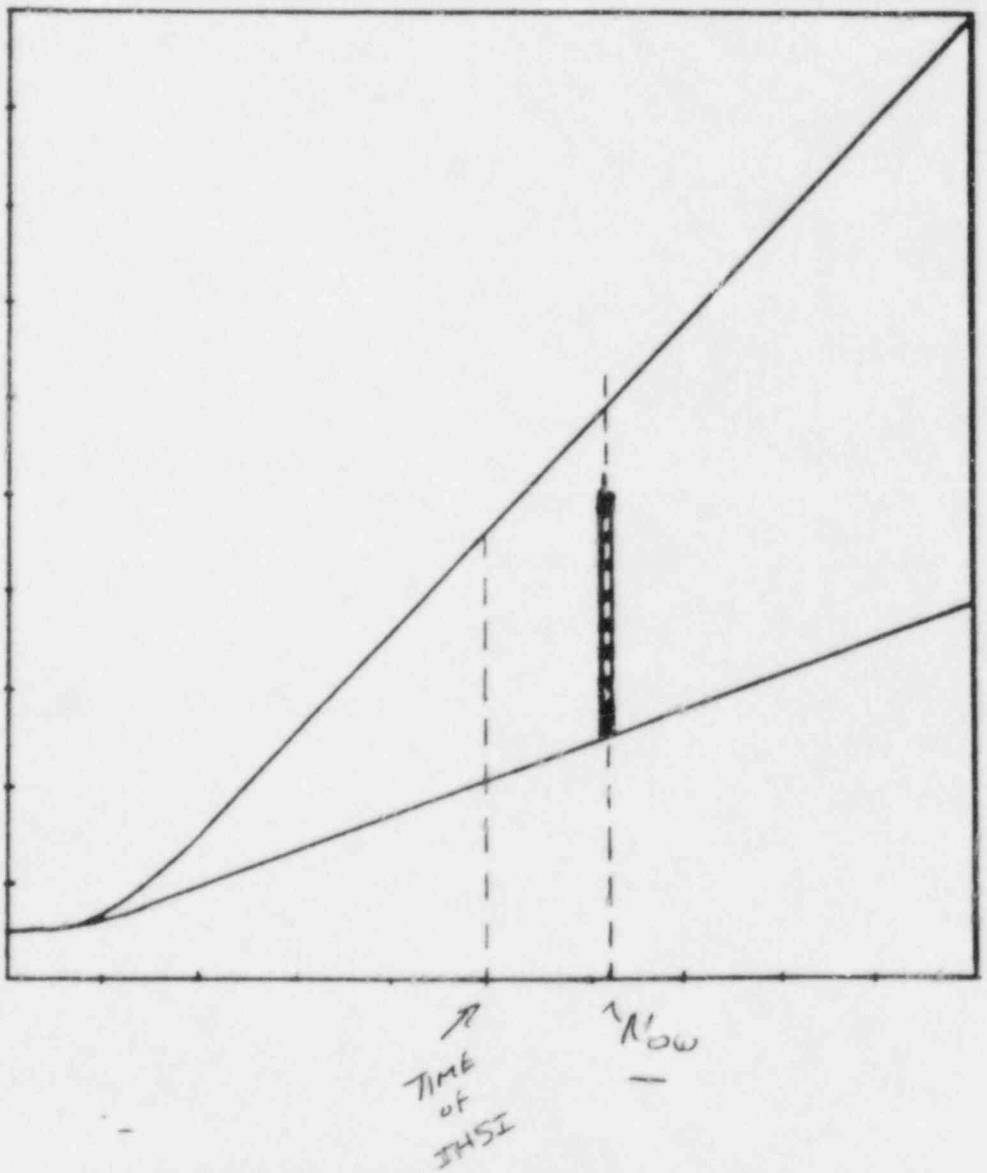
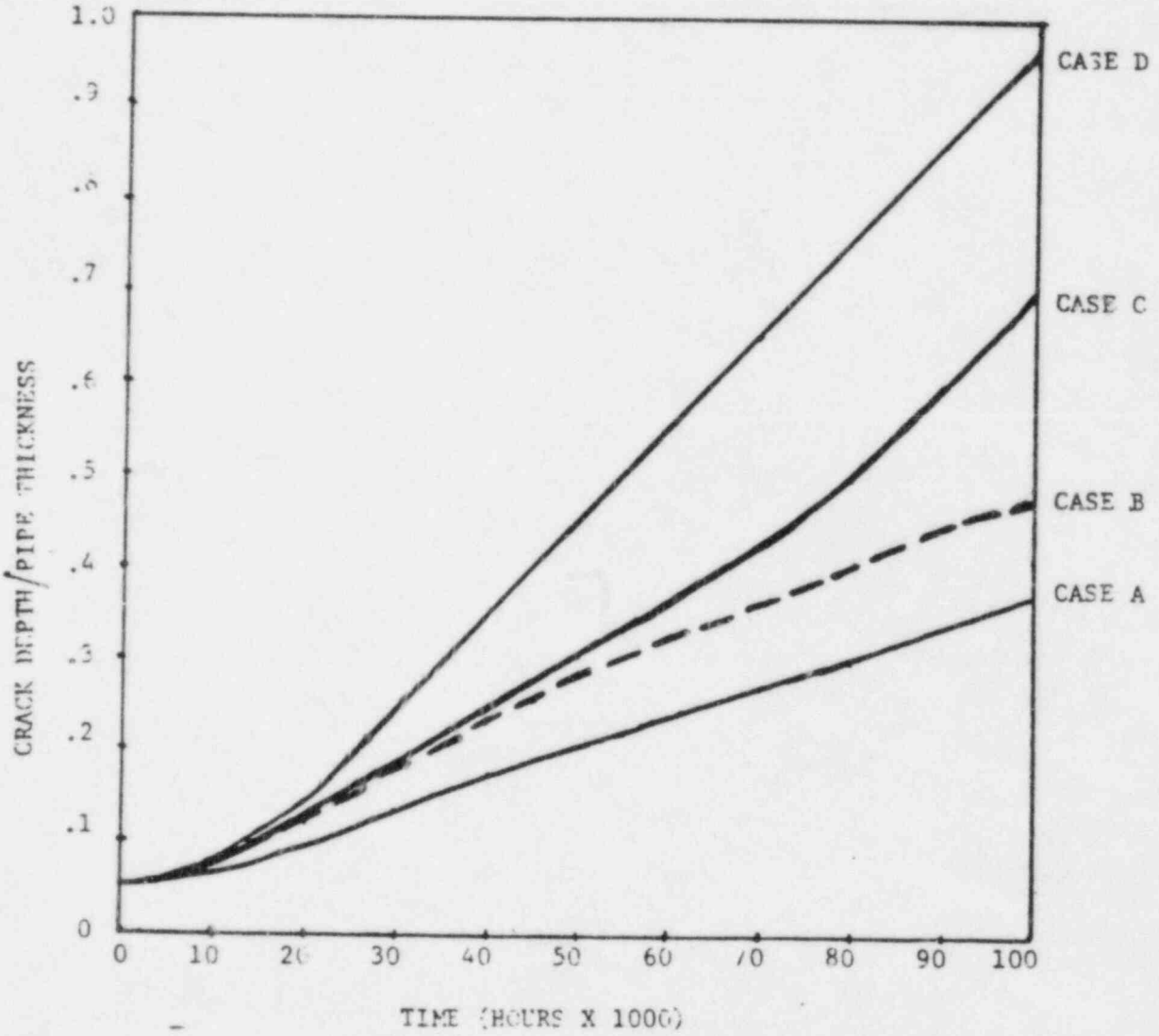


CRACK GROWTH VERSUS TIME FOR BOUNDING CASES

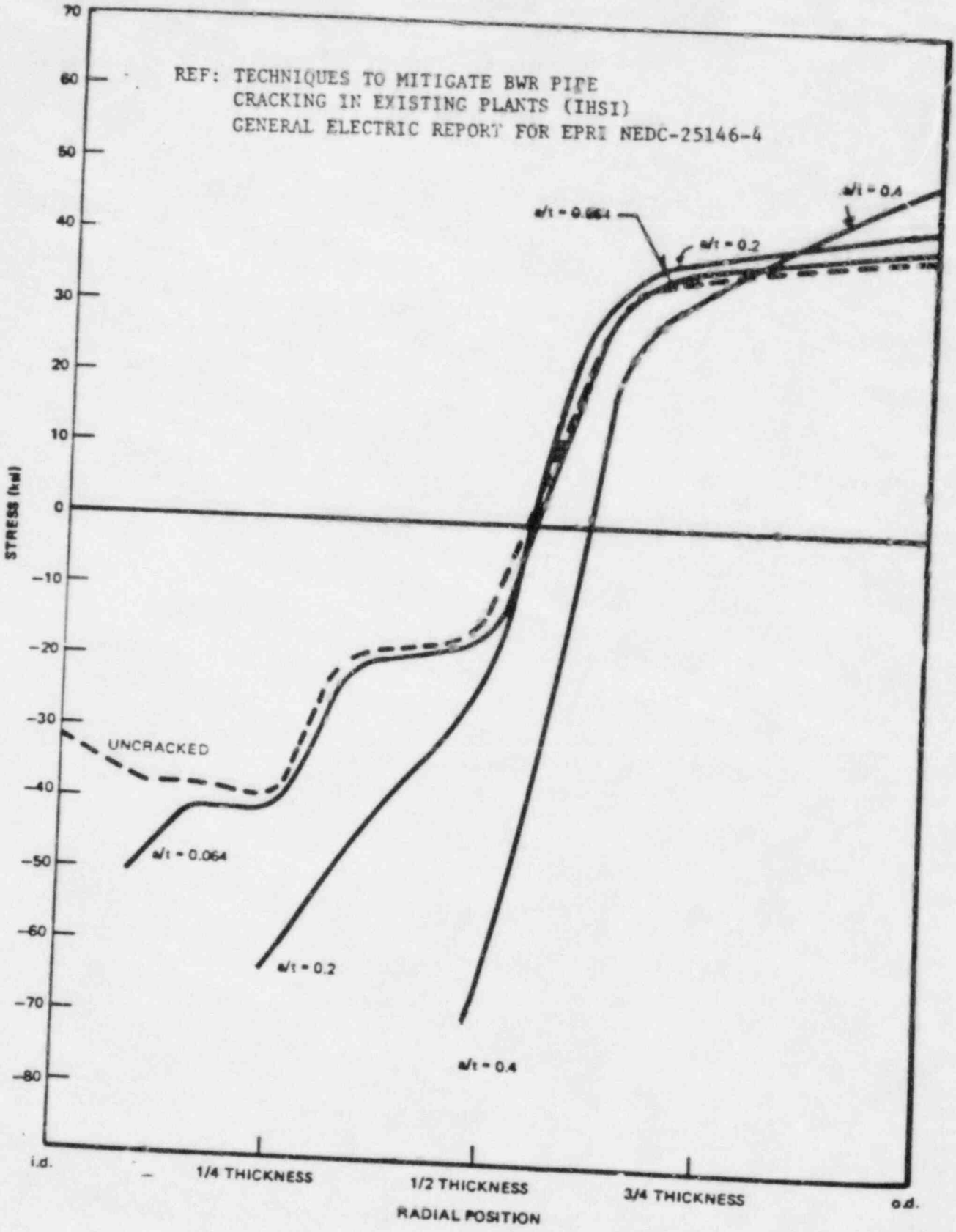

TIME of IHSI



CRACK GROWTH VERSUS TIME FOR ALL CASES

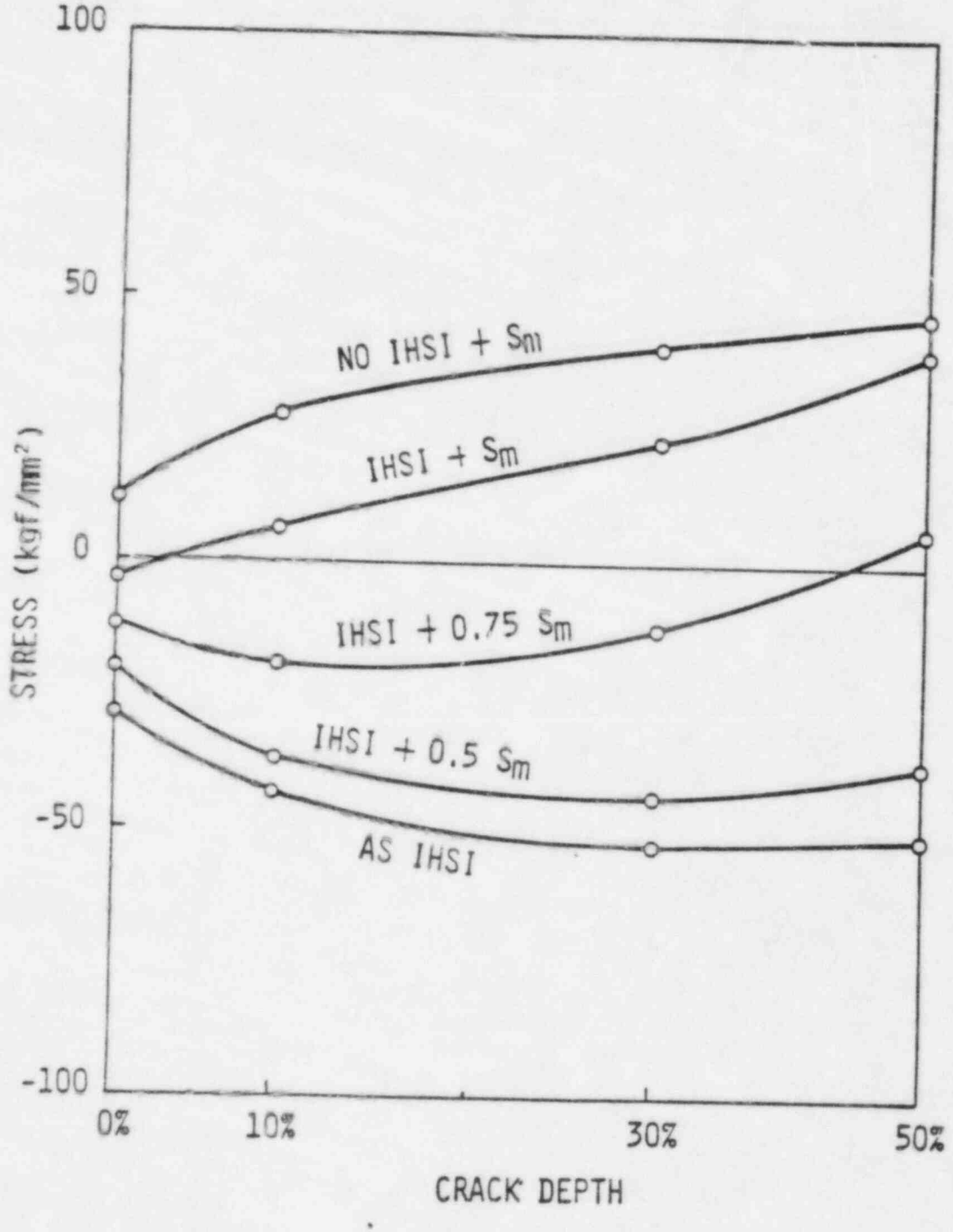
POSSIBLE ROLE OF IHSI

- ANALYTICAL STUDIES SHOW BENEFIT OF IHSI FOR CRACKED PIPES TO $\approx$ 50% WALL.
- ANALYTICAL STUDIES ALSO SHOW HIGH APPLIED STRESSES CAN REDUCE COMPRESSION FOR DEEP CRACKS $>$ 30% WALL.
- PB-3 OPERATED $\approx$ 12000 HRS FOLLOWING IHSI + MAXIMUM GROWTH FOLLOWING IHSI $\approx$ 13% WALL.
- NEGATIVE EFFECT OF IHSI AT PB-3 IS PLAUSIBLE BUT NOT CONCLUSIVE.



IHSI Through-Wall Axial Stress Distribution at Weld Center Line for Preexisting Cracks

REF: IHSI APPLICATION TO THE WELD
JUNCTION WITH SMALL CRACKS
A. OKAMOTO, H. WADA, T. UMEMOTO
AUGUST, 1985, SMIRT POST CONFERENCE
ISPRA, ITALY



AXIAL STRESS AT THE CRACK TIP.

RECIRCULATION OUTLET
NOZZLE SAFE END CRACKING SUMMARY

- REPORTED CRACKING IS GREATER THAN EXPECTED
- RESIDUAL STRESS VARIATIONS COULD CAUSE THE DEEPER CRACKS
- WELD OVERLAY RECOMMENDED

INLET SAFE END CRACK GROWTH ASSESSMENT

- INLET SAFE END CRACK GROWTH RATES BASED ON LIFE TIME PEACH BOTTOM UNIT 3 WATER CHEMISTRY DATA.
- CRACK GROWTH ESTIMATE BASED ON BOUNDING PLATEAU CRACK.
- MOST UNFAVORABLE RESIDUAL STRESS DISTRIBUTION USED FOR GROWTH PREDICTION.
- 360° CIRCUMFERENTIAL CRACK WITH PEAK CRACK DEPTH FOR THE WORST SAFE END ASSUMED.
- 2/3 MARGIN APPLIED OVER CODE ALLOWABLE FLAW SIZE.

CRACK GROWTH PREDICTIONS
FOR INLET SAFE END
CONSERVATIVE EVEN CONSIDERING
OUTLET SAFE END EXPERIENCE

SUMMARY

- L-GRADE SS WELDS HIGHLY RESISTANT TO IGSCC, BUT
  - * CRACKING CAN INITIATE IN NORMAL STRESSED, CREVICED AND/OR SEVERELY COLD WORKED REGIONS
- ONCE INITIATED CRACK GROWTH CAN OCCUR IN NON-SENSITIZED SS, BUT
  - * GROWTH RATES LOWER THAN SENSITIZED SS
  - * WATER CONDUCTIVITY AN IMPORTANT FACTOR
- EXTENT OF CRACKING IN PB-3 OUTLET SAFE ENDS NOT YET FULLY UNDERSTOOD
  - * VERIFICATION OF CRACKING MODE, I.D. SURFACE COLD WORK AND CRACK DEPTHS WILL BE OBTAINED BY PLUG SAMPLE
- NRC IE 83-02 UT QUALIFICATION REQUIREMENTS UTILIZED FOR PB SAFE END EXAMS
  - * ARE SUITABLE FOR DETECTING AND SIZING IGSCC

SUMMARY (CONT'D)

- EVALUATION OF PB-3 INLET SAFE ENDS FOR 18 MONTHS OPERATION REMAINS CONSERVATIVE

- FABRICATION AND INSTALLATION CONTROLS TO LIMIT COLD WORK OF ALL WELDED SS MATERIAL REQUIRED TO ASSURE HIGH RESISTANCE TO IGSCC

  * BEING UTILIZED FOR PIPE REPLACEMENTS

- PB-3 OUTLET SAFE END CRACKING OCCURRENCE CONSISTENT WITH "LEAK-BEFORE-BREAK" REQUIREMENTS

  * OUTLET SAFE ENDS WILL BE OVERLAYED

  * PB-3 ACCEPTABLE FOR 18 MONTHS OPERATION

Philadelphia Electric Company

cc w/enclosure(s):

Eugene J. Bradley
Philadelphia Electric Company
Assistant General Counsel
2301 Market Street
Philadelphia, Pennsylvania 19101

Troy B. Conner, Jr.
1747 Pennsylvania Avenue, N.W.
Washington, D. C. 20006

Thomas A. Deming, Esq.
Assistant Attorney General
Department of Natural Resources
Annapolis, Maryland 21401

Philadelphia Electric Company
ATTN: Mr. R. Fleishmann
Peach Bottom Atomic
Power Station
Delta, Pennsylvania 17314

Albert R. Steel, Chairman
Board of Supervisors
Peach Bottom Township
R. D. #1
Delta, Pennsylvania 17314

Hers J. Williams
U.S. Nuclear Regulatory Commission
Office of Inspection and Enforcement
Peach Bottom Atomic Power Station
P. O. Box 399
Delta, Pennsylvania 17314

Regional Radiation Representative
EPA Region III
Curtis Building (Sixth Floor)
6th and Walnut Streets
Philadelphia, Pennsylvania 19106

M. J. Cooney, Superintendent
Generation Division - Nuclear
Philadelphia Electric Company
2301 Market Street
Philadelphia, Pennsylvania 19101

Mr. Edward G. Bauer, Jr.
Vice President and General Counsel
Philadelphia Electric Company
2301 Market Street
Philadelphia, Pennsylvania 19101

Mr. R. A. Heiss, Coordinator
Pennsylvania State Clearinghouse
Governor's Office of State Planning
and Development
P. O. Box 1323
Harrisburg, Pennsylvania 17120

Thomas M. Gerusky, Director
Bureau of Radiation Protection
Pennsylvania Department of
Environmental Resources
P. O. Box 2063
Harrisburg, Pennsylvania 17120

Mr. Thomas E. Murley, Regional Administrator
U. S. Nuclear Regulatory Commission, Region I
Office of Inspection and Enforcement
631 Park Avenue
King of Prussia, Pennsylvania 19406

ENCLOSURE 1

ATTENDANCE LIST FOR OCTOBER 1, 1985 MEETING

RE: PEACH BOTTOM UNIT 3 SAFE END CRACKING

Name	Affiliation
R. A. Hermann	NRR/DL
E. Kiss	GE
E. C. Kistner	PECo
W. M. Alden	PECo
R. H. Zong	PECo
S. Ranganath	GE, San Jose
J. Kass	GE
G. C. Lainas	NRR/DL
W. S. Hazelton	NRR/DE
A. Taboada	NRR/DE
W. Johnston	NRR/DE
G. Gears	NRR/DL
D. B. Vassallo	NRR/DL
A. W. Dromerick	IE/EGCB
R. J. Tamminga	CECo
W. Koo	NRR/DE
C. Y. Cheng	NRR/DE
J. P. Clark	GE
D. W. Diefeuderfer	GE
E. F. Reczek	GE
R. M. Horn	GE
M. R. Hum	NRR/DE
S. Lee	NRR/DE
T. C. Hinkle	PECo
J. F. O'Rourke	PECo
T. L. Chapman	GE
K. J. Wilson	PECo
A. P. Bazzani	PECo
R. L. Lebre	GE
S. F. Klapproth	GE
V. Benaroya	NRR/DE
J. Wiggins	NRC/Reg I
S. Reynolds	NRC/Reg I