July 13, 1984

Docket No. 50-293

LICENSEE: Boston Edison Company

FACILITY: Pilgrim Nuclear Power Station

SUBJECT: MEETING ON JUNE 15, 1984 WITH BOSTON EDISON COMPANY REGARDING CRACKS IN INCONEL WELD MATERIAL AT THE PILGRIM NUCLEAR POWER STATION

On June 15, 1984, a meeting was held with representatives of the Boston Edison Company (BECo) to discuss the resolution of crack indications found in Inconel weld material between the safe end and the nozzles of the recirculation system at Pilgrim Station. Enclosure 1 is a list of the meeting attendees. Enclosure 2 provides copies of viewgraphs shown by BECo and General Electric Company (GE) participants.

BECo confirmed that three of the ten reactor vessel inlet nozzles and one of the two outlet nozzles were found to have cracks in the Inconel-182 weld material (buttering) which is between the nozzle face and the safe end. As shown in the enclosed sketch of the 28-inch outlet nozzle-to-safe end weld, the cracks are predominantly axial. No cracks were found in the Inconel-82 root pass or the nozzle alloy steel. At least one crack extends from the Inconel-182 butter on the nozzle into buttering on the safe end.

The crack indications were recently identified by dye penetrant (PT) tests during preparations for recirculation system pipe replacements by the General Electric Company. Metallurgical evaluation of boat samples and surface replicas of the cracks is being conducted by GE to determine more fully the nature of the cracks. Preliminary metallography results indicate the cause to be stress corrosion. There are also some slag indications which are being removed during resurfacing of the nozzle butter (Inconel-182).

The new safe ends to be welded to the nozzles will have Inconel-82 butter, which has higher resistance to cracking than Inconel-182. GE proposes to make the rewelds as before if the Inconel-182 butter on the nozzles is at least 1/8-inch thick after being machined to remove the cracks. Otherwise, local post weld heat treatment or halfbead (temper bead) repair would probably be applied to restore the buttering.

As a final mitigation to limit cracking in the future, the licensee has decided to implement hydrogen water chemistry. Piping connections will be installed prior to startup and experiments will be conducted during the coming operating cycle to establish design parameters. Suitable equipment for this purpose would be installed during the next outage.

The NRC staff informed BECo at the conclusion of this meeting that we do not object to its proceeding with the repair plans described above. A comprehensive report is expected from BECo in 6 - 8 weeks regarding its piping repair/replacement program during this outage. That report will be reviewed by the staff prior to plant startup.

Original signed by RAHermann for/

Paul H. Leech, Project Manager
Operating Reactors Branch #2
Division of Licensing

Enclosures:
As stated

cc w/enclosures:
See next page

DISTRIBUTION
Docket File
NRC PDR
Local PDR
ORB#2 Reading
ORB#2 Mtg Summary File
DVassallo
PLeech
OELD
ELJordan
JNGrace
ACRS (10)
NRC Participants
NSIC

DL:ORB#2	DL:ORB#2
PLeech:ajs	DVassallo
07/13/84	07/13/84

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Boston Edison Company
Pilgrim Nuclear Power Station

cc:

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ENCLOSURE 1

JUNE 15, 1984 MEETING

ON INCONEL CRACKS AT PILGRIM STATION

Name	Affiliation
J. D. Keyes	Boston Edison Company
E. F. Kearney	Boston Edison Company
J. E. Howard	Boston Edison Company
R. A. Hermann	NRC/NRR/DL/ORB#2
D. B. Vassallo	NRC/NRR/DL/ORB#2
I. vanRooyer	Brookhaven National Laboratory
Harold Gray	NRC/Region I
J. R. Weeks	Brookhaven National Laboratory
T. Chapman	General Electric Company, San Jose
Sam Ranganath	General Electric Company, San Jose
G. M. Gordon	General Electric Company, San Jose
W. S. Hazelton	NRC/NRR/DE/MTEB
J. F. Klapproth	General Electric Company, San Jose
F. J. Witt	NRC/NRR/DE/ChEB
W. H. Koo	NRC/NRR/DE/MTEB
Paul Leech	NRC/NRR/DL/ORB#2

ENCLOSURE 2

NRC MEETING

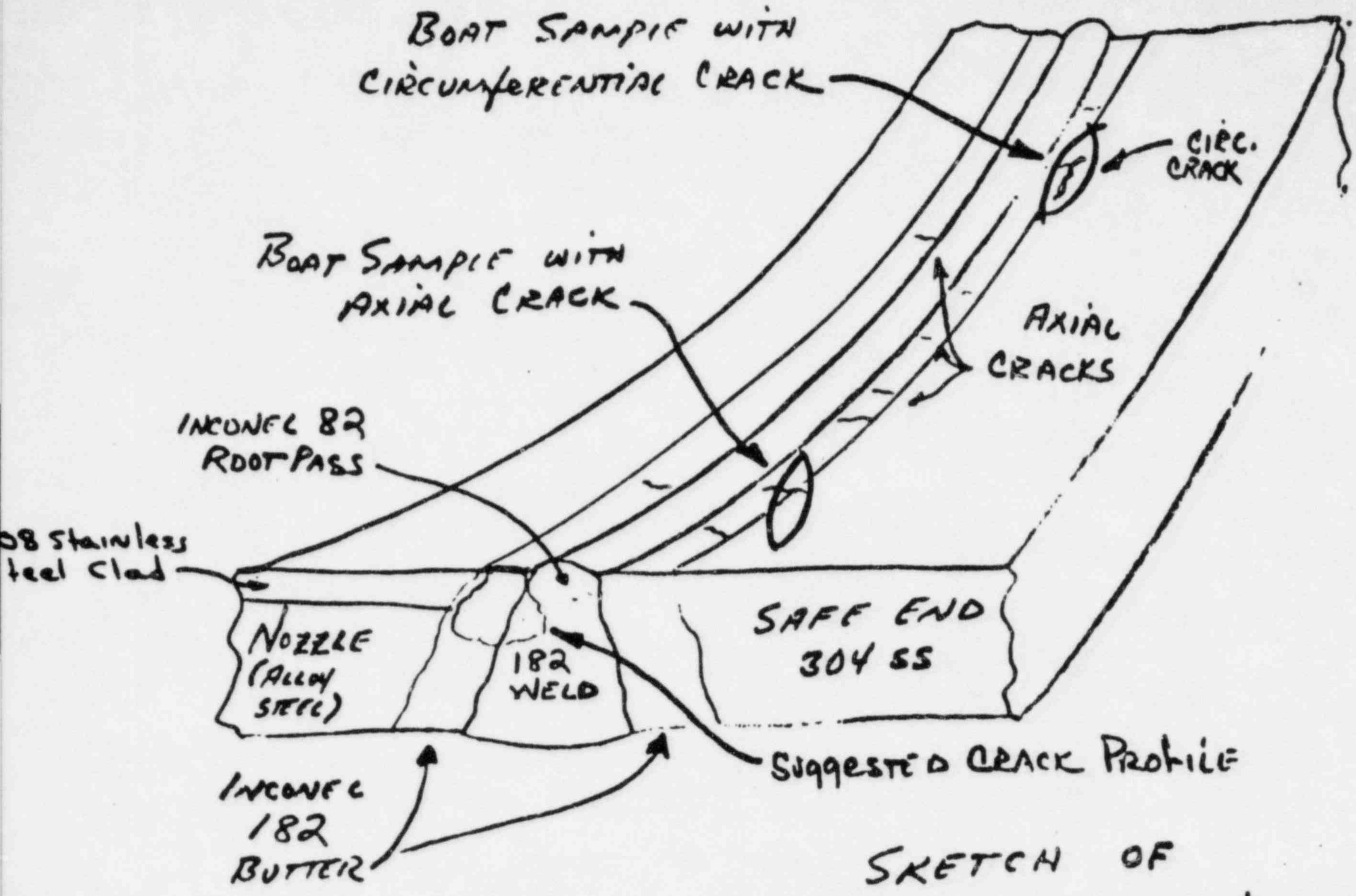
PILGRIM SAFE END REPAIRS

6/15/84

	PRESENTOR
o INTRODUCTION	BECO/ E. Kearney
o MATERIALS ISSUES	GE/ G. Gordon
o REPAIR PLAN	GE/ T. Chapman
o SERVICE PERFORMANCE	GE/ S. Ranganath
o SUMMARY	BECO/ E. Kearney

EVALUATIONS

- O BOAT SAMPLE TAKEN FROM RECIRCULATION OUTLET
  - THREE SAMPLES, ONE TO NRC
  - METALLOGRAPHY SHOWS INTERDENDRITIC CRACKING
    - + BOAT SAMPLE TAKEN FROM SAFE END SIDE
    - + INCONEL 182 CRACKING AXIALLY ORIENTED
      - o ONE SHORT CIRCUMFERENTIAL CRACK FOUND IN STAINLESS STEEL SAFE END
- O PENETRANT TESTS
  - REVEALED RADIAL CRACKING ON CUT FACE OF INLETS
    - + MULTIPLE CRACKS 30% OF WALL TO 70% OF WALL
  - REVEALED AXIAL CRACKING ON ID OF OUTLET
    - + INDICATIONS IN INCONEL 182 ON BOTH NOZZLE AND SAFE END SIDE OF WELD
    - + NO CRACKING IN INCONEL 82 ROOT PASS



Sketch of
28" Recirc Outlet Nozzle-To-
Safe End Weld N1-B

304 SS
SAFE END

INCONEL 182
BUTTER

PILGRIM NOZZLE N1-B

AXIAL INTERDENDRITIC CRACKING IN INCONEL 18 BUTTER WITH INTERGRANULAR PENETRATION INTO 304SS SAFE-END.

(PIPE INNER SURFACE IS PLANE OF POLISH)

33X

125X

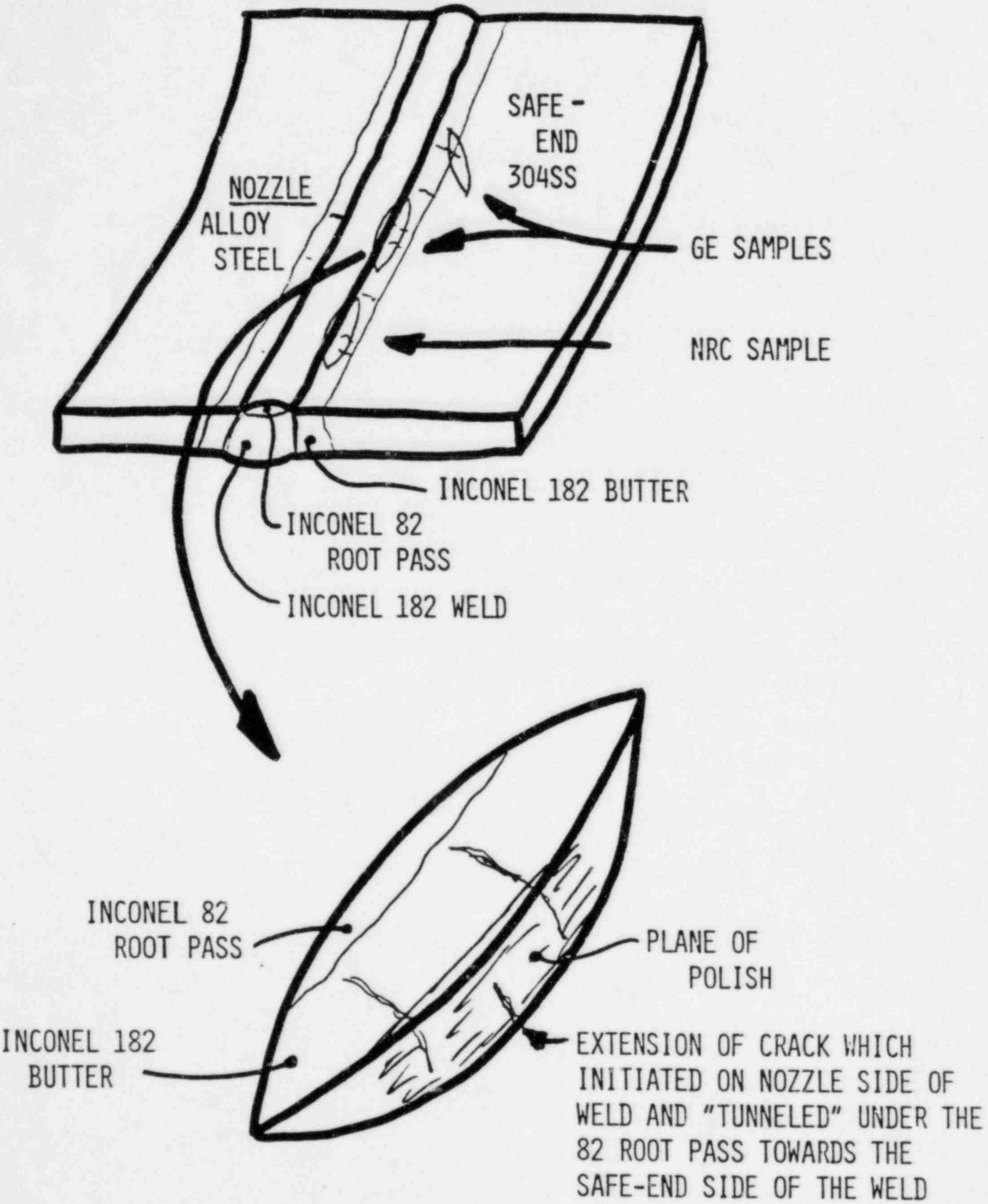
INTERGRANULAR CRACKING IN INCONEL 182 BUTTER

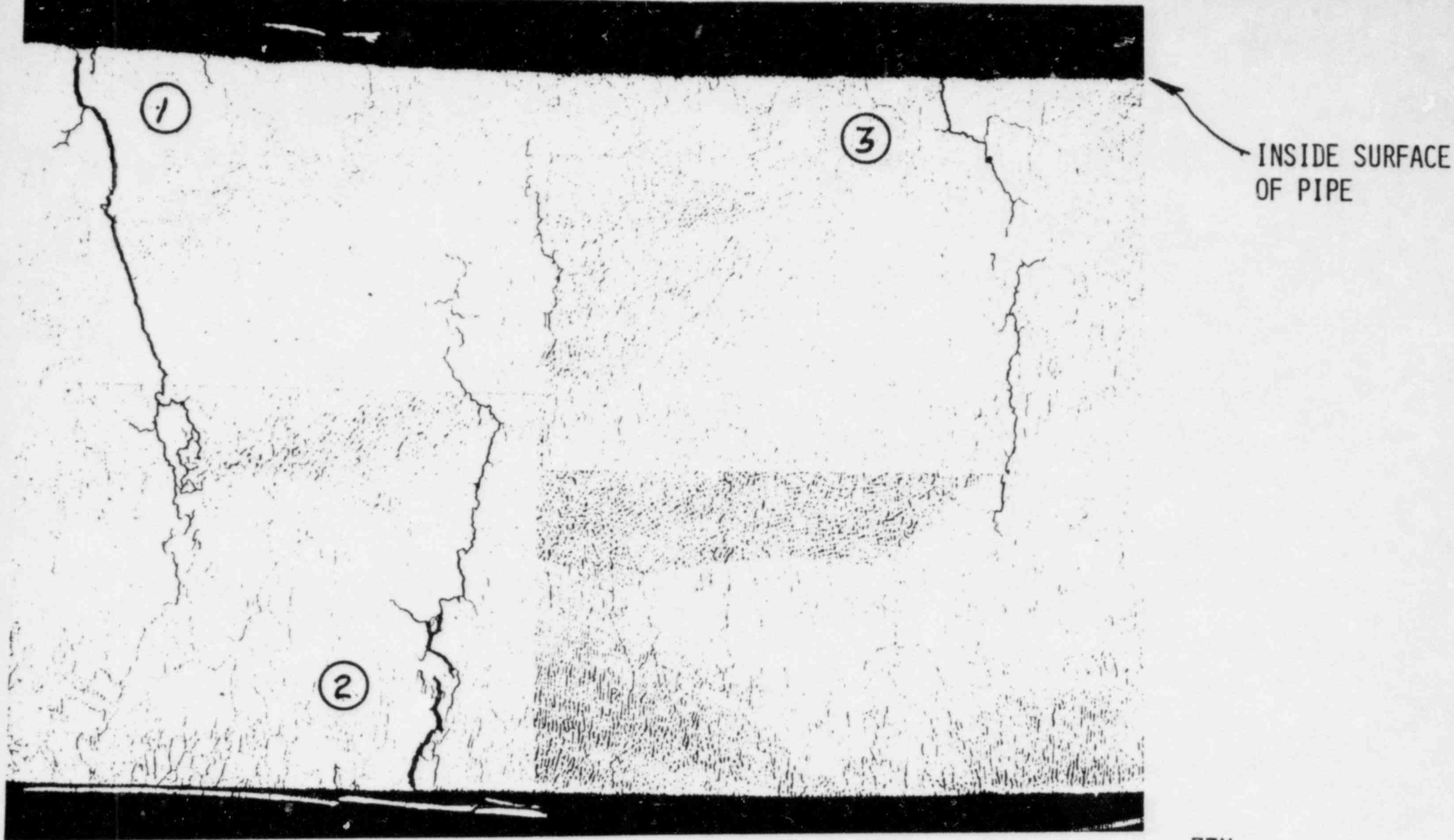
33X

125X

PILGRIM NOZZLE N1-B

CIRCUFERENTIAL INTERGRANULAR CRACKING AT INCONEL 182/304SS SAFE END INTERFACE

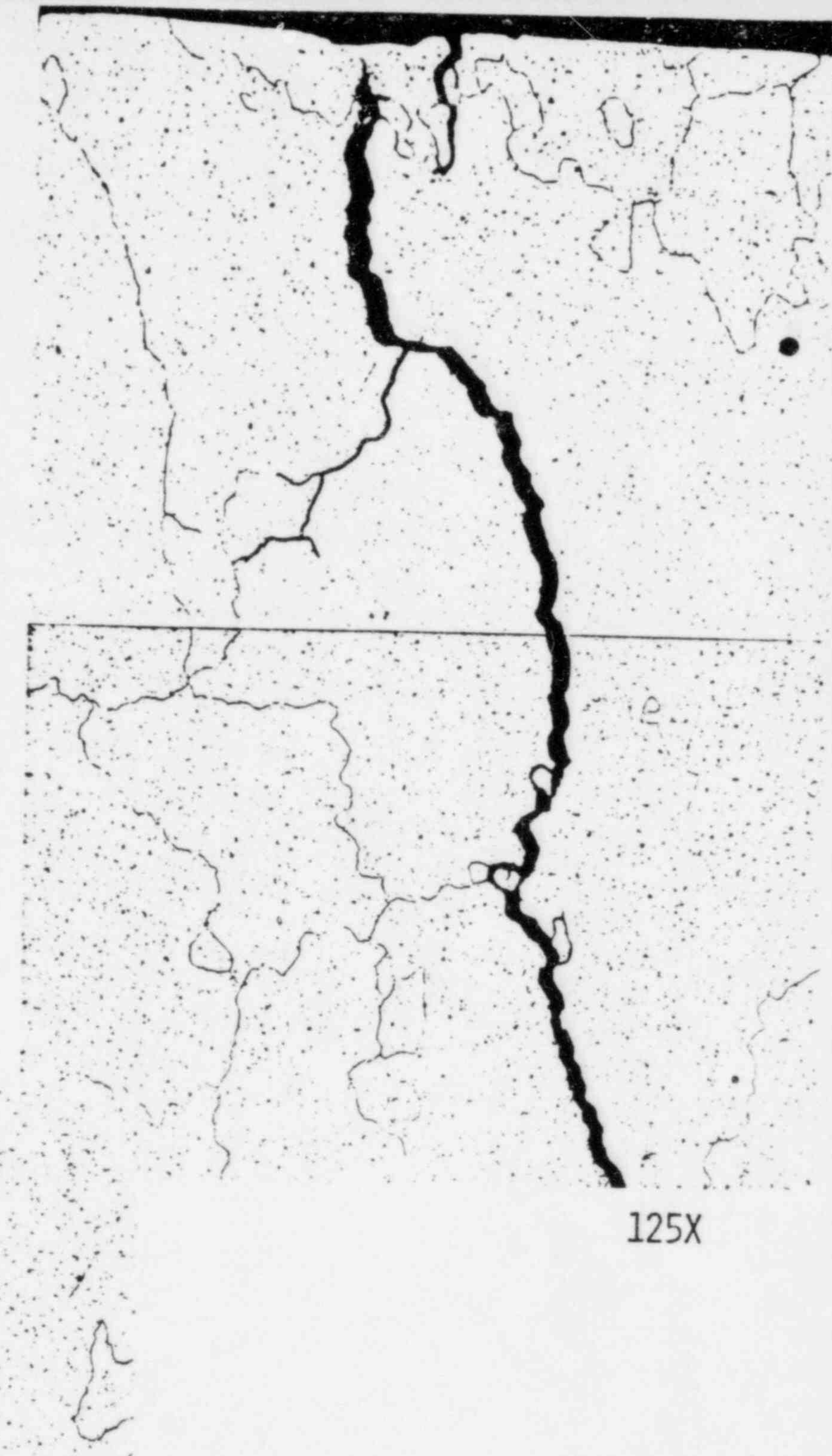

SAFE-END 304SS
NOZZLE ALLOY STEEL
GE SAMPLES
NRC SAMPLE
INCONEL 182 BUTTER
INCONEL 82 ROOT PASS
INCONEL 182 WELD
INCONEL 82 ROOT PASS
PLANE OF POLISH
INCONEL 182 BUTTER
EXTENSION OF CRACK WHICH INITIATED ON NOZZLE SIDE OF WELD AND "TUNNELED" UNDER THE 82 ROOT PASS TOWARDS THE SAFE-END SIDE OF THE WELD

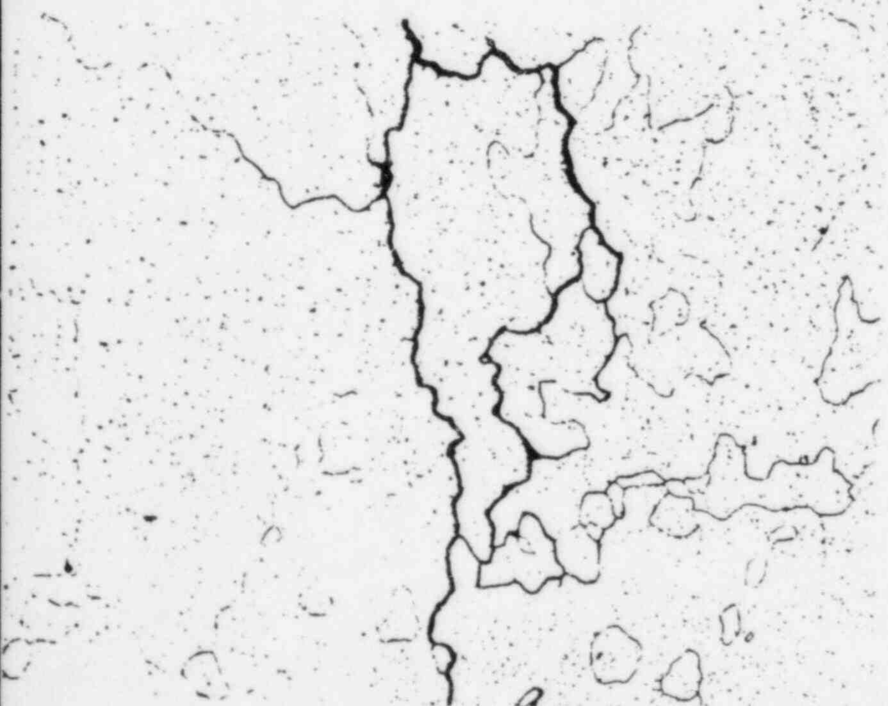


PILGRIM NOZZLE N1-B

AXIAL INTERDENDRITIC CRACKING IN INCONEL 182 BUTTER ADJACENT TO WELD ROOT ON SAFE END SIDE
CRACK IN CENTER OF PHOTO INITIATION IN INCONEL 182 BUTTER ON THE NOZZLE SIDE OF THE WELD.

PILGRIM NOZZLE N1-B



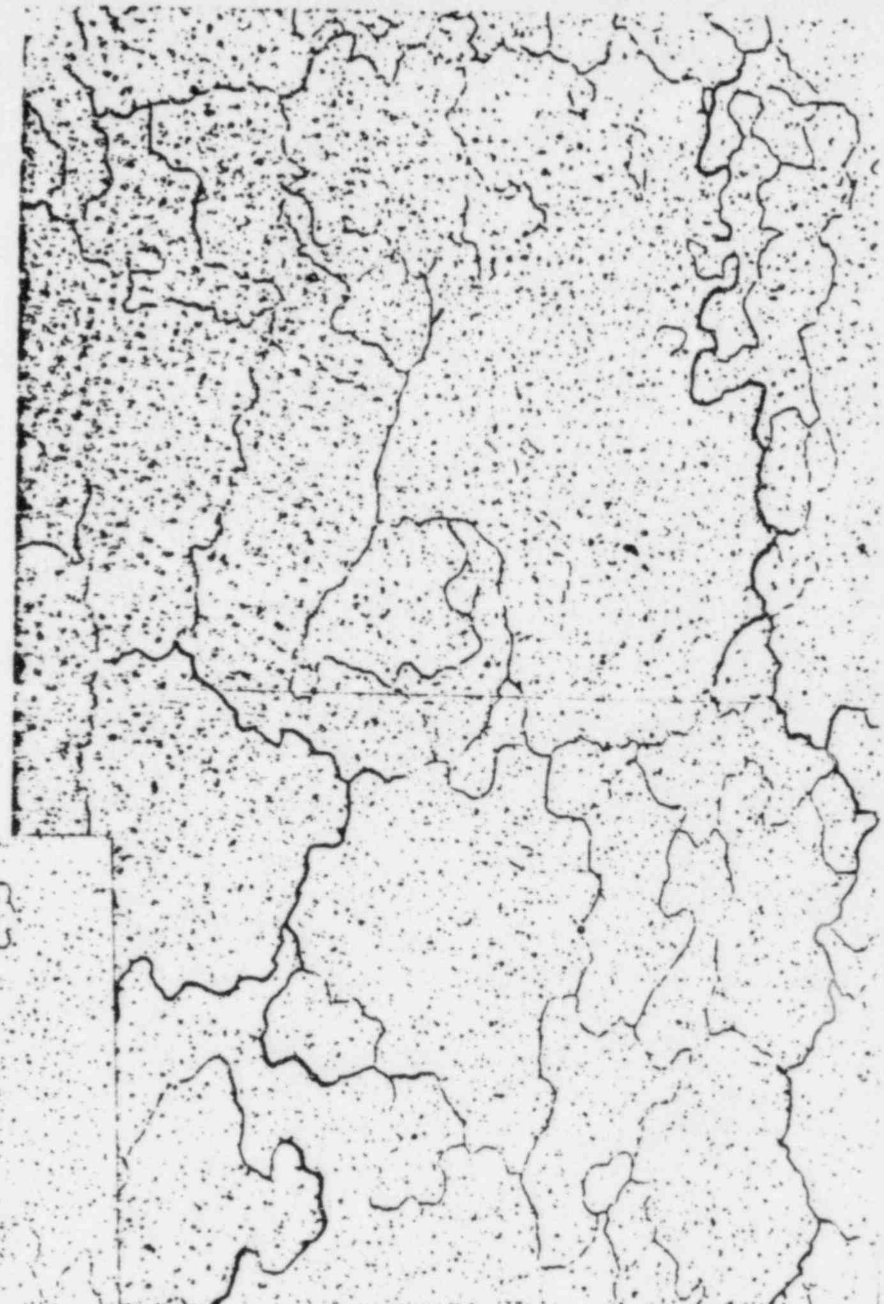


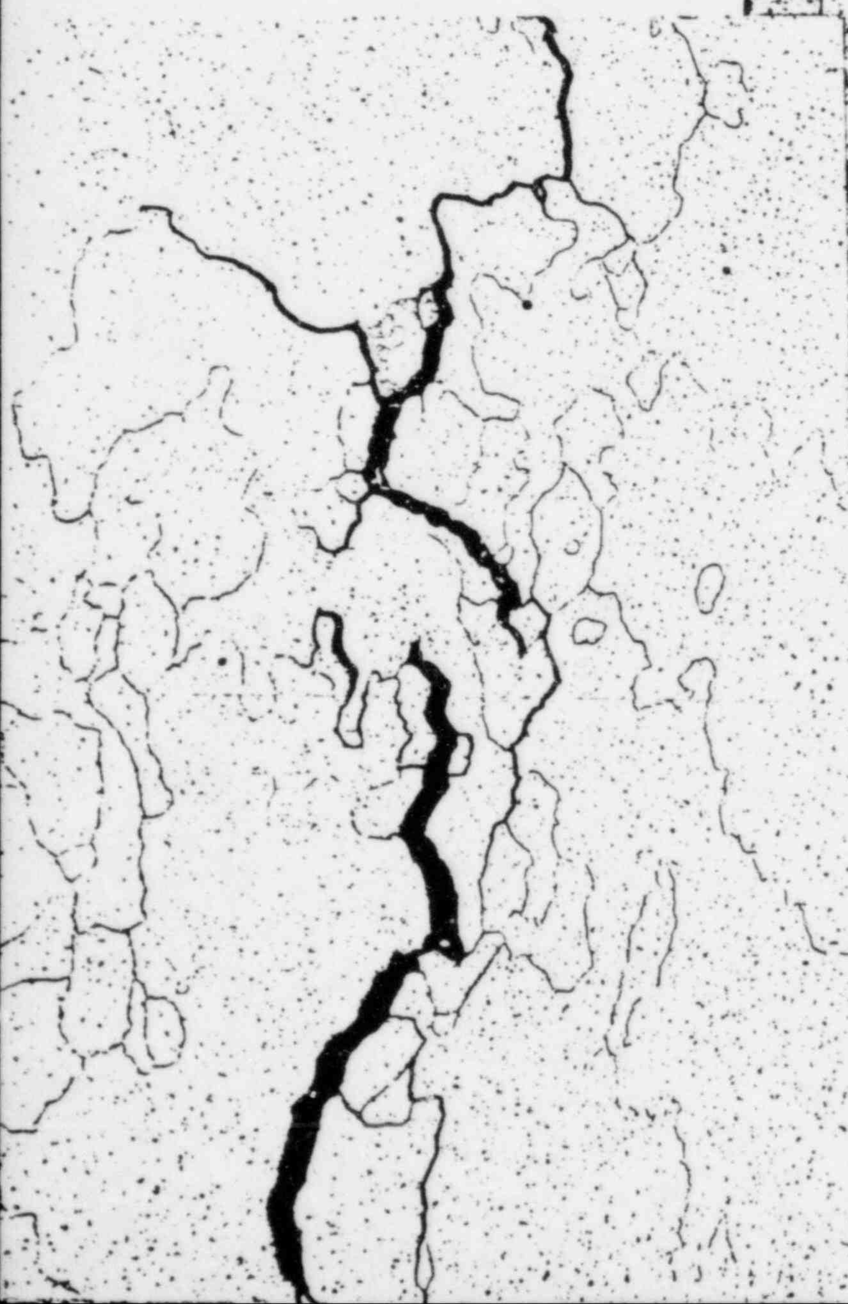
125X

HIGH MAGNIFICATION VIEW OF INTERDENDRITIC CRACK #1 OF 33X COMPOSITE - INCONEL 182 BUTTER

PILGRIM NOZZLE N1-B

CRACK #2





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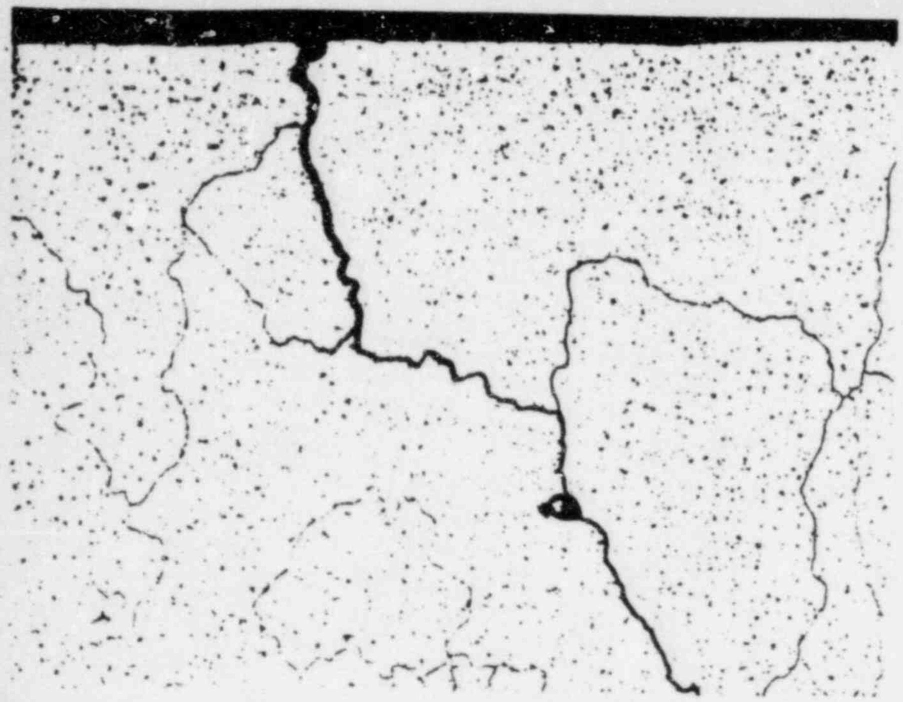
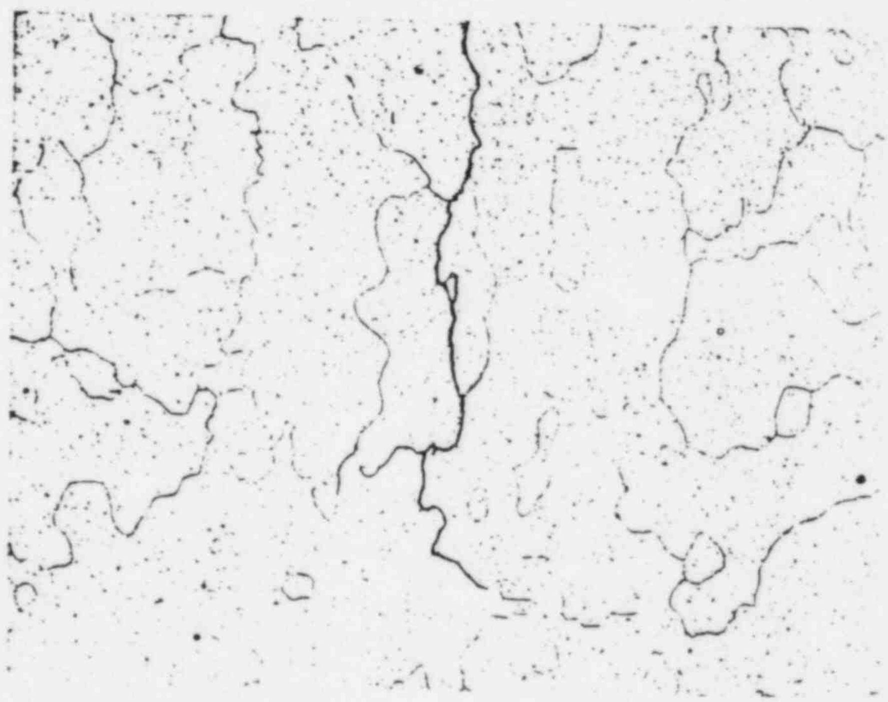
INTERDENDRITIC CRACKING IN INCONEL 182. THIS CRACK INITIATED ON NOZZLE SIDE OF WELD AND APPARENTLY TUNNELED TOWARDS THE SAFE END SIDE OF WELD



125X

CRACK ROOT

PILGRIM NOZZLE N1-B



CRACK TIP

HIGH MAGNIFICATION VIEW OF INTERDENDRITIC CRACK #3 OF 33X COMPOSITE - INCONEL 182 BUTTER.

RESULTS OF METALLOGRAPHIC EXAMINATION OF BOAT SAMPLES

(BOAT SAMPLES TAKEN FROM SAFE END SIDE)

- INCONEL 182 CRACKING AXIALLY ORIENTED
  - ONE SHORT CIRCUMFERENTIAL CRACK FOUND IN STAINLESS STEEL SAFE END NEAR 182 BUTTER INTERFACE.
- CRACKING INTERDENDRITIC, CHARACTERISTIC OF STRESS CORROSION CRACKING.
- NO CRACKING FOUND IN INCONEL 82 ROOT PASS
- POSSIBLE SUBSURFACE CRACK EXTENSION INTO INCONEL 82/182 DILUTION ZONE.

HEAT TO HEAT VARIABILITY

- O LAB DATA SHOWS
  - o HEAT TO HEAT VARIABILITY OF 182
  - o HIGH RESISTANCE OF 82 OVER 182
- O PILGRIM DATA SHOWS
  - o MANY 182 HEATS INVOLVED IN BUTTER AND FIELD WELDS
  - o 182 CHEMISTRY/CRACKING CORRELATION NOT IDENTIFIED
  - o NO CRACKING IN ALLOY 82 ROOT PASSES
- O CONCLUSIONS
  - o TRYING TO SPECIFY OR SELECT IMMUNE 182 NOT PRACTICAL
  - o ALL ALLOY 182 CONSIDERED SUSCEPTIBLE
  - o FURTHER SUPPORTS HWC IMPLEMENTATION

STEPS FOR HWC IMPLEMENTATION

- O INSTALLATION OF TAPS AND OTHER EQUIPMENT
  - INSTALL DURING OUTAGE

- O CONDUCT MINI TESTS TO DETERMINE SHIELDING REQUIRED
  - PLANT MUST BE OPERATIONAL
  - H_2 DELIVERY SYSTEM CAN BE USED FOR MANY MONTHS

- O INSTALL SHIELDING IF NECESSARY

- O CONVERT MINI TEST HYDROGEN DELIVERY SYSTEM TO PERMANENT INSTALLATION

- O RUN

NOZZLE REPAIR PROGRAM

- OVERVIEW -

- o EXISTING PROGRAM IN PLACE FOR SAFE END REPLACEMENT
  - IWB-7000 (REPLACEMENTS)
  - DESIGN DRAWINGS, SPEC.
  - INSTALLATION SPEC.
- o UNACCEPTABLE INDICATIONS ENCOUNTERED DURING SAFE END REMOVAL
  - SLAG INDICATIONS
  - STRESS CORROSION CRACKING
- o NOZZLE REPAIR PROGRAM IN PROCESS

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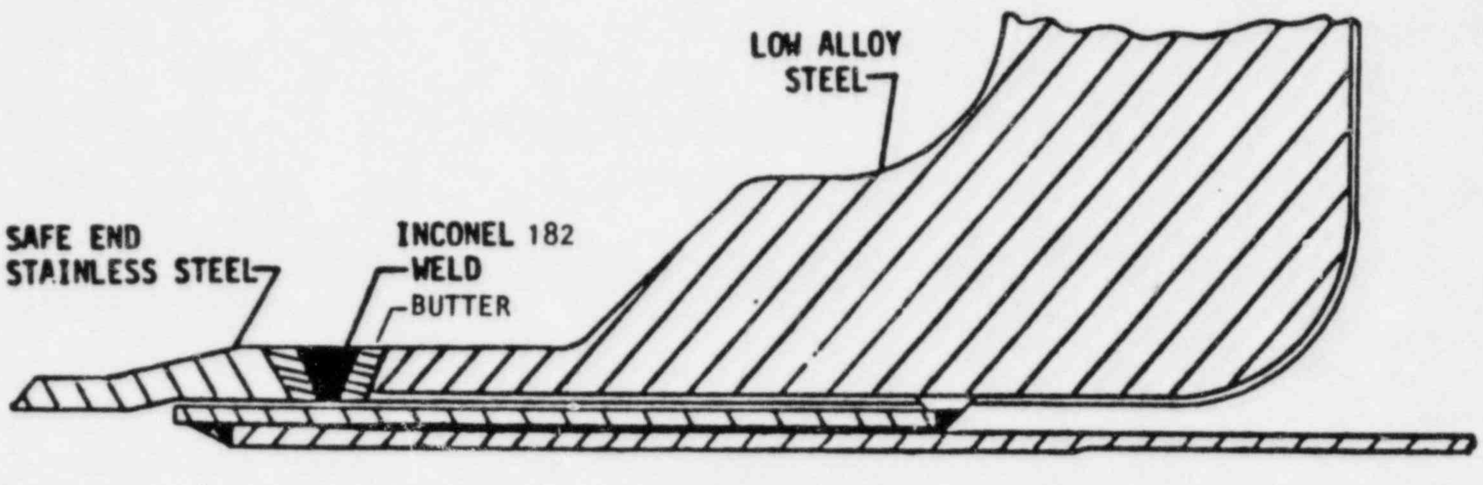
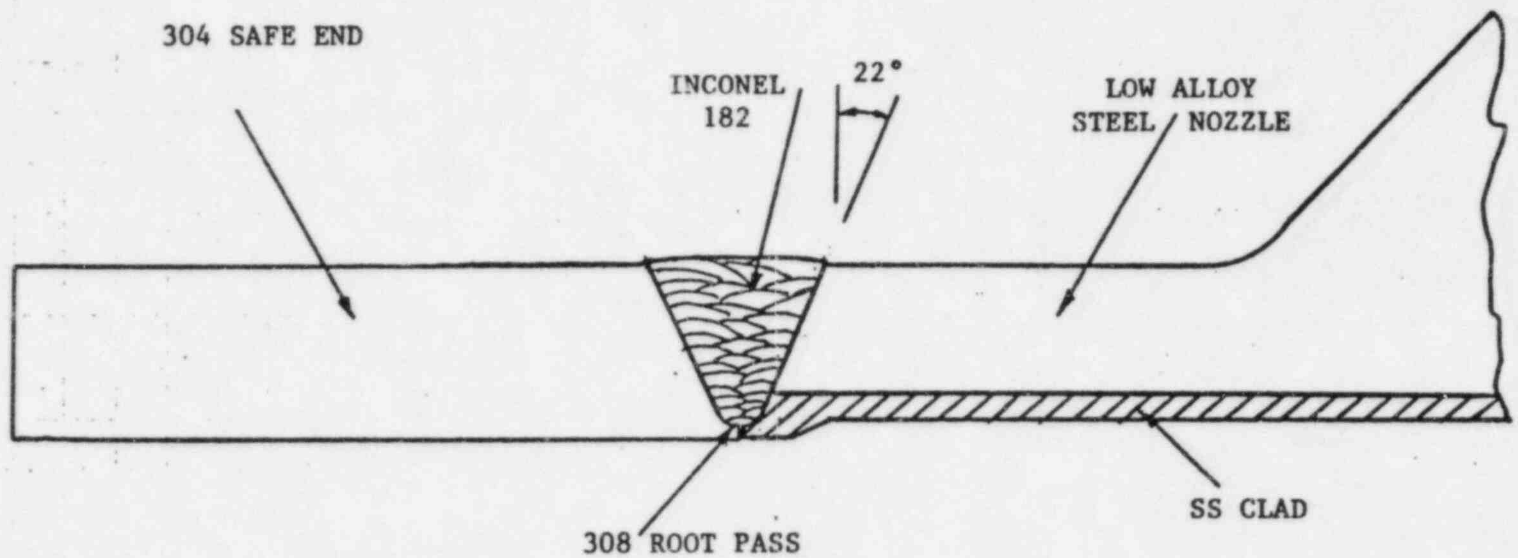
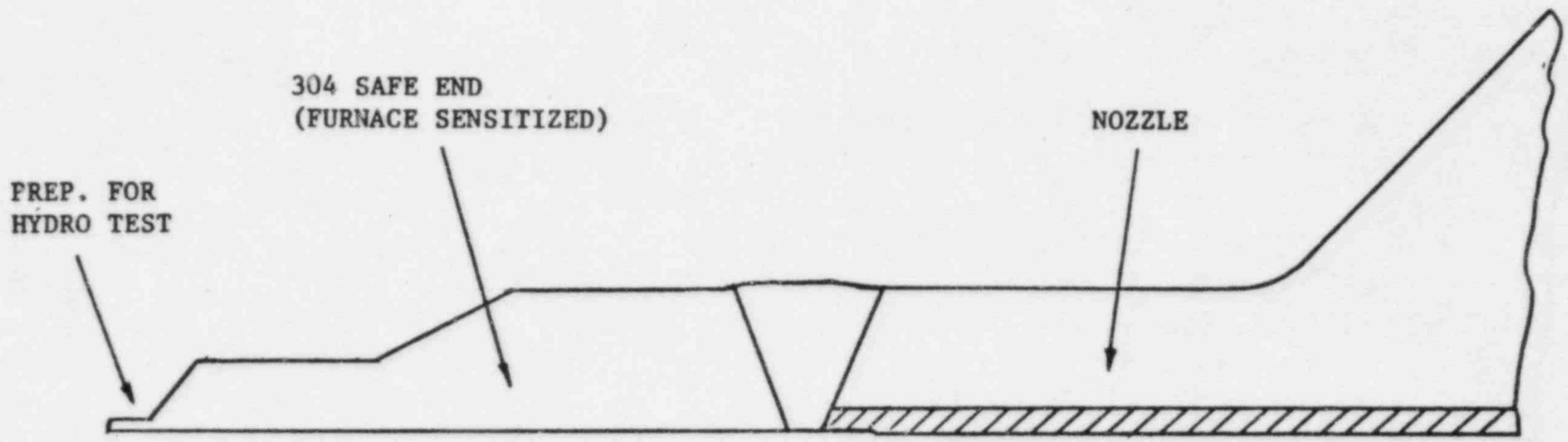


EXISTING PILGRIM RECIRC INLET NOZZLE

GAD
4/84

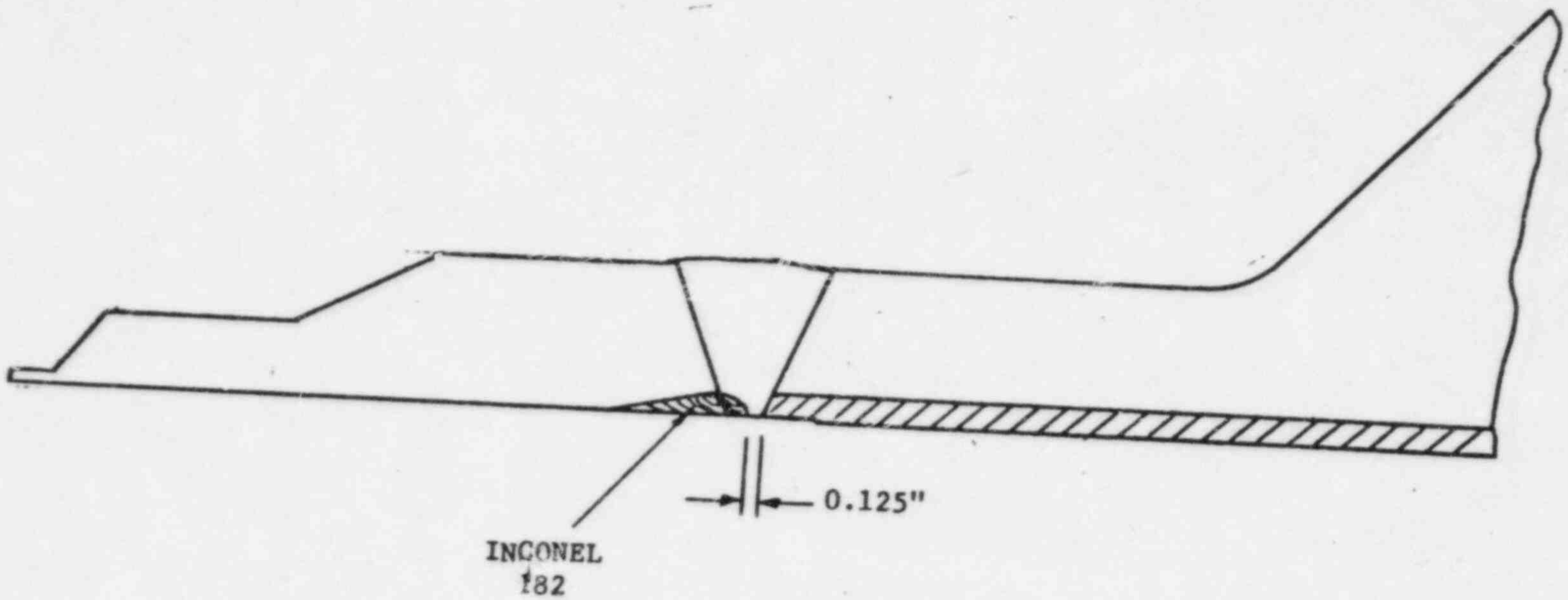


SHOP FABRICATION



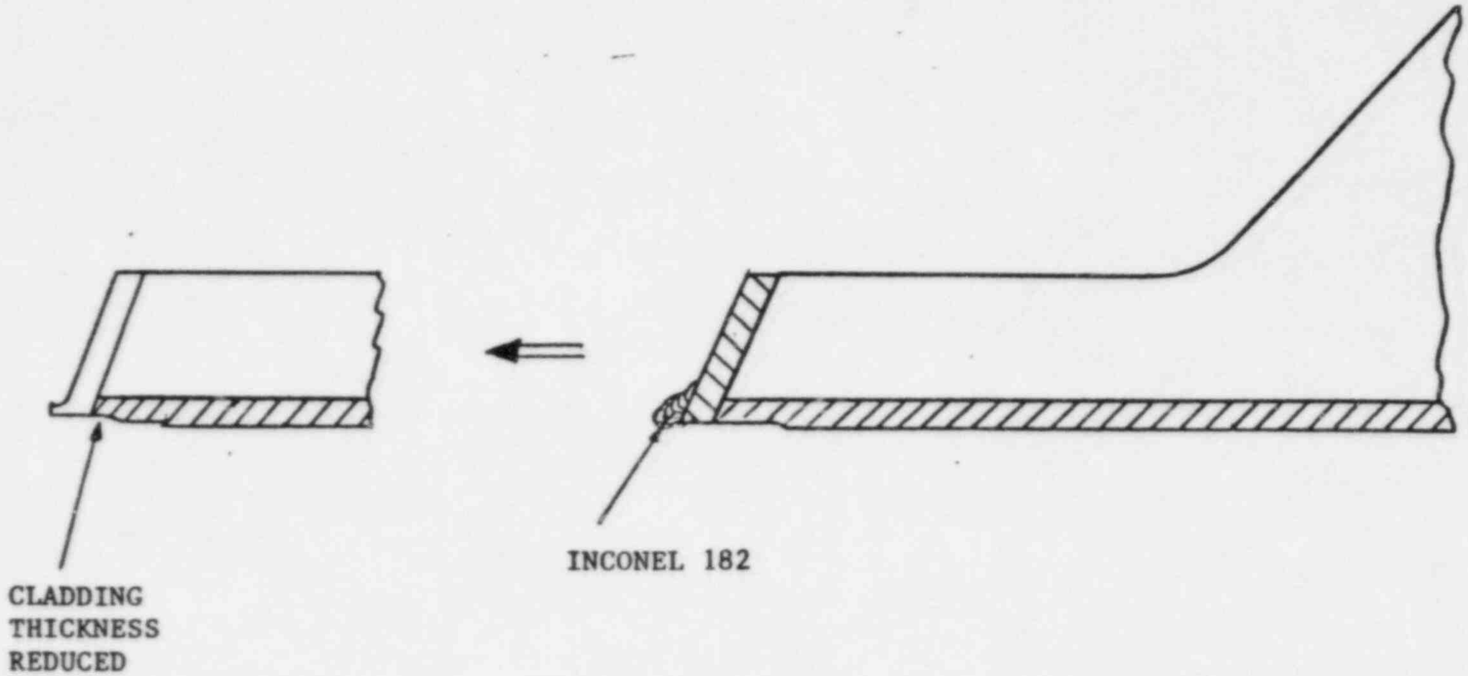
SHOP FABRICATION

- MACHINE SAFE END -



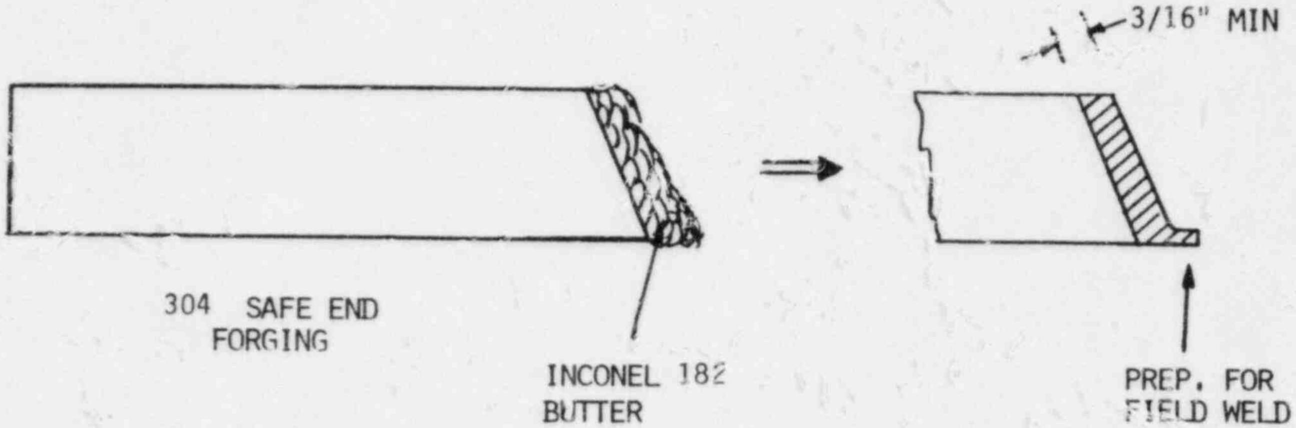
SHOP FABRICATION

- REMOVE 304 SAFE END ON I.D. -
- REWELD I.D. WITH INCONNEL 182



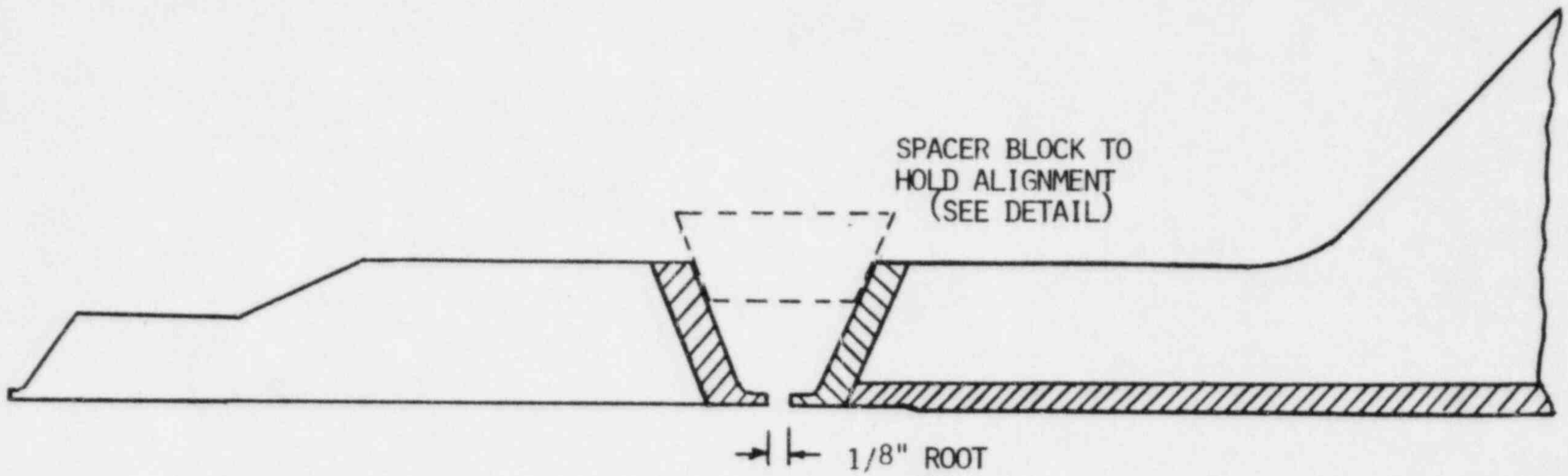
SHOP FABRICATION

- REMOVE SAFE END
- BUILDUP FOR "J" FIELD PREP.

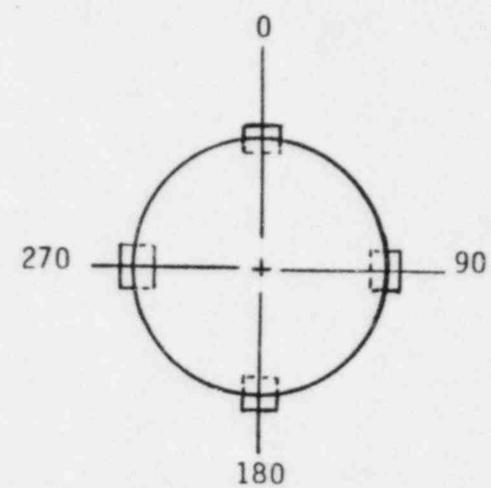


SHOP FABRICATION

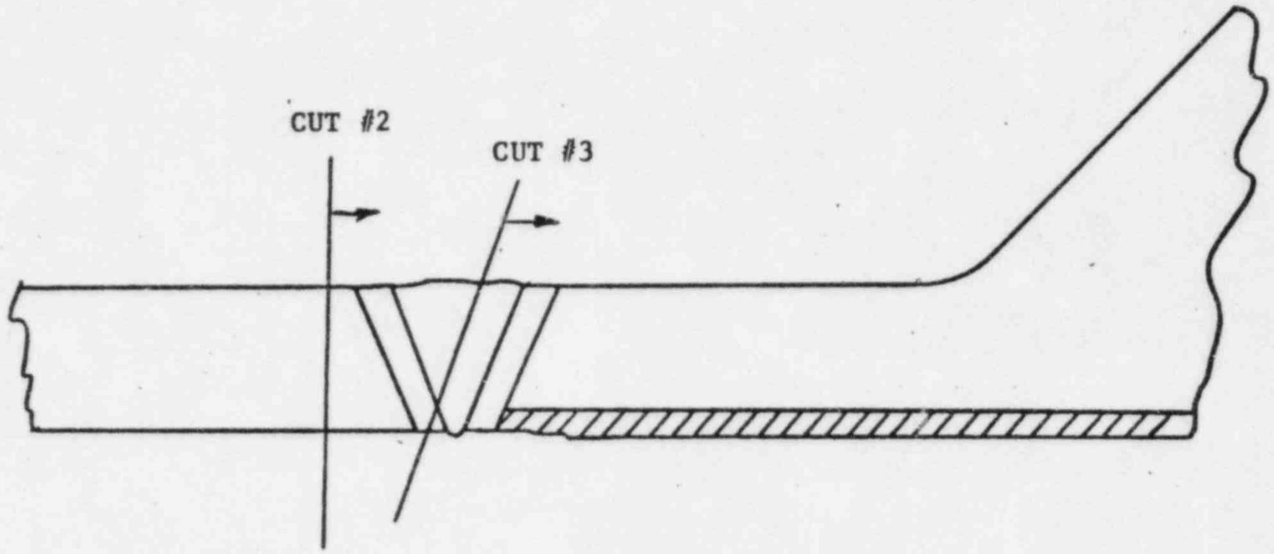
- BUTTER WITH INCONEL 182
- PREP. FOR FIELD WELD



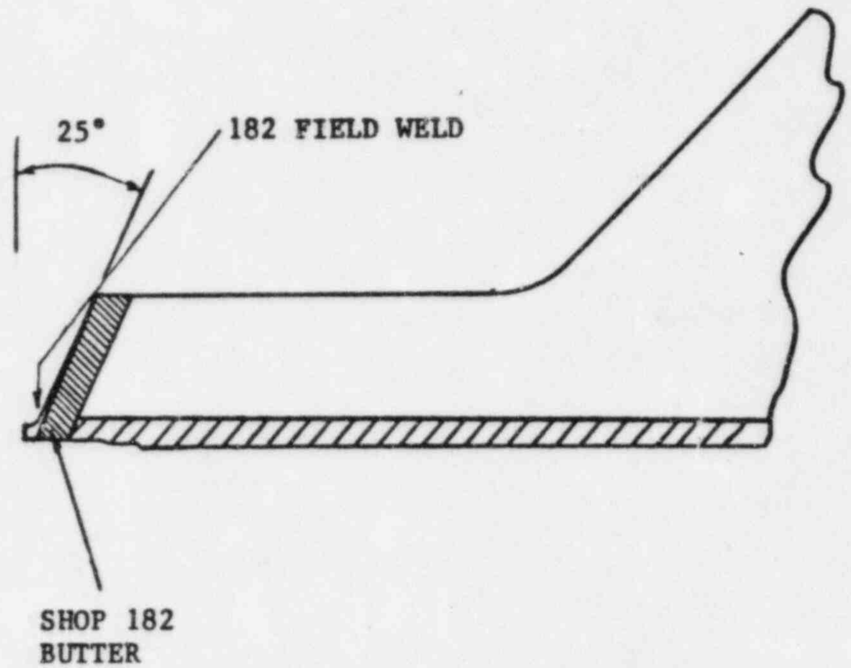
FIELD WELD



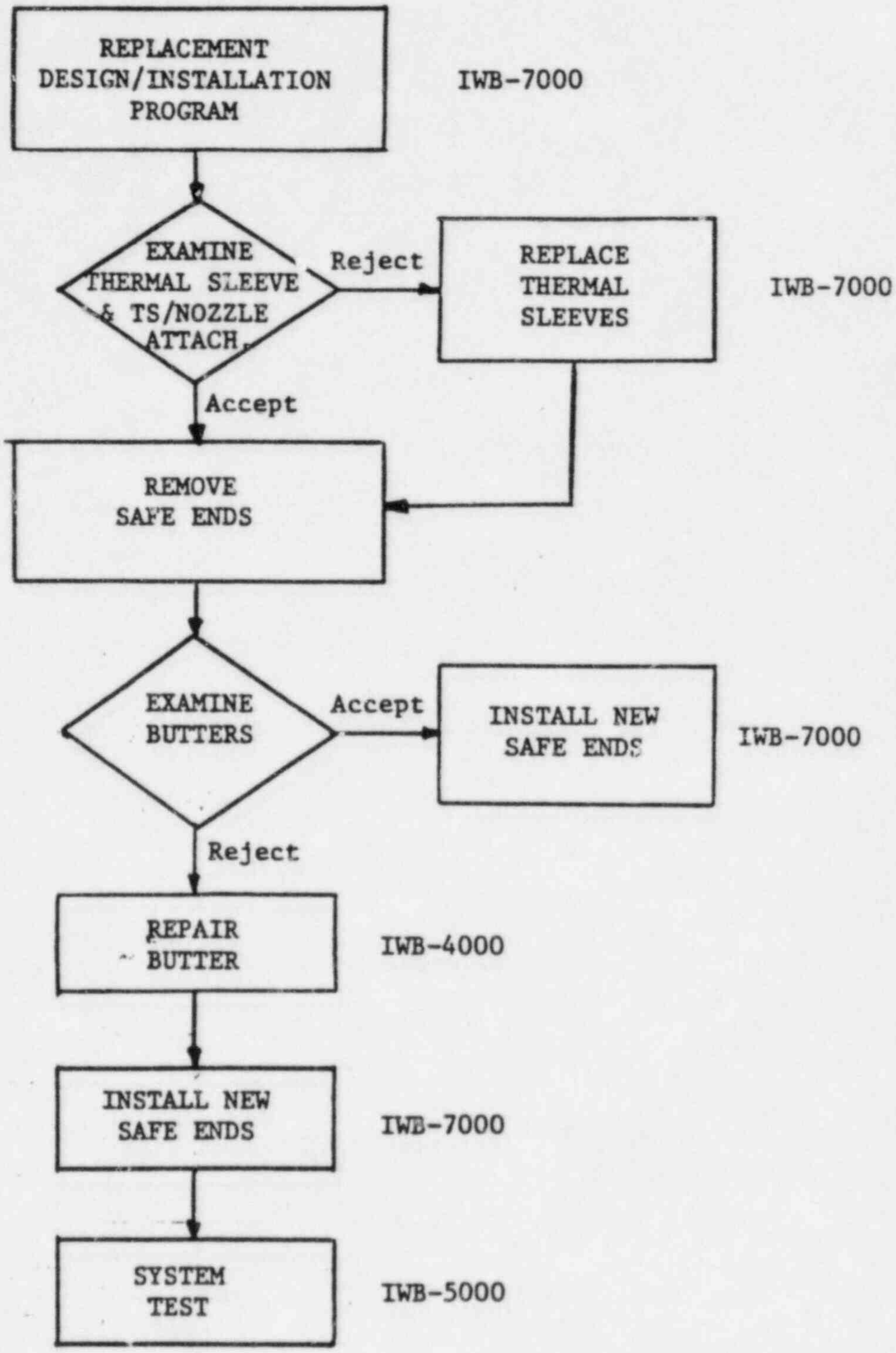
SPACER BLOCK
END VIEW



CURRENT FIELD REPLACEMENT



CURRENT FIELD REPLACEMENT


REPLACEMENT DESIGN/INSTALLATION PROGRAM
IWB-7000
EXAMINE THERMAL SLEEVE & TS/NOZZLE ATTACH.
Reject
REPLACE THERMAL SLEEVES
IWB-7000
Accept
REMOVE SAFE ENDS
EXAMINE BUTTERS
Accept
INSTALL NEW SAFE ENDS
IWB-7000
Reject
REPAIR BUTTER
IWB-4000
INSTALL NEW SAFE ENDS
IWB-7000
SYSTEM TEST
IWB-5000

PILGRIM RECIRC INLET

REPAIR OPTIONS

- o IF REMAINING BUTTER THICKNESS > 3/16"
  - REWELD WITH EXISTING PROCEDURE
- o IF REMAINING BUTTER THICKNESS < 3/16" ≥ 1/8"
  - REWELD WITH EXISTING PROCEDURE
  - NEED TO QUALIFY FOR 1/8" BUTTER
- o BUTTER THICKNESS < 1/8"
  - LOCAL POST WELD HEAT TREATMENT
  - HALF BEAD (TEMPER BEAD) REPAIR

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PILGRIM RECIRC INLET
LOCAL POST WELD HEAT TREATMENT

- o GE EXPERIENCED IN THIS TYPE OF REPAIR
  - NUCLENOR - 3 FEEDWATER NOZZLE/SAFE ENDS
  - NINE MILE POINT-1 - ISO-CONDENSER NOZZLE INCONEL BUTTER
- o APPLICATION AT PILGRIM
  - THERMAL SLEEVE WOULD NEED TO BE REMOVED
  - THERMAL STRESS ANALYSIS, HEAT TREATMENT AND WELDING PROCEDURE QUALIFICATIONS
  - NOZZLE MOCKUP FOR HEATING PROCESS DEVELOPMENT AND QUALIFICATION

HALF BEAD REPAIR

- o APPROVED ASME SECTION XI PROCESS
  - MANUAL STICK ELECTRODE (SMAW)
  - PREHEAT TO 300°F
  - POSTHEAT 450 - 550°F, 2 HOURS
  - 182 MATERIAL AS ORIGINAL

- o APPLICATION
  - LOCAL GRINDOUTS FOR BUTTER < 1/8"
  - FULL BUTTER REPAIR IF NECESSARY
  - LOCAL GRINDOUTS INTO LOW ALLOY STEEL

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NOZZLE REPAIR

APPROACH

- o MACHINE BACK TO REMOVE CRACKING/SLAG
    - UT INSPECTION
    - PT INSPECTION
    - ETCH AND UT VERIFY BUTTER THICKNESS
- o LOCALLY REMOVE INDICATIONS
    - CONTROLLED GRINDING
    - PROGRESSIVE PT
- o REPAIR AREAS AS REQUIRED

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STATUS OF NOZZLES

-INLETS-

NOZZLE	CRACKING	REMAINING PT INDICATIONS	HALF BEAD REPAIR
N2A	NO	0	NO
N2B	YES	0	YES
N2C	NO	3	NO
N2D	NO	5	NO
N2E	NO	7	NO
N2F	YES	15	YES
N2G	NO	0	NO
N2H	NO	0	READY FOR SE
N2J	YES	0	YES
N2K	NO	0	READY FOR SE

-OUTLETS-

N1A	NO	0	NO
N1B	YES	-SAFE END IN PLACE-	

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HALF BEAD REPAIR

- o APPLICATIONS TO DATE
  - ISOLATED USE FOR BWR CLADDING REPAIR
  - FEEDWATER NOZZLE REPLACEMENTS (PWR)
- o CURRENT TECHNICAL THRUSTS
  - "HALF BEAD" VS. TEMPERBEAD
  - RESIDUAL STRESSES
  - HAZ GRAIN REFINEMENT - CEGB WORK
  - HAZ HARDNESS
  - AUTOMATIC GTAW DEVELOPMENTS - EPRI/B&W

REPAIR TO CONSIDER LATEST TECHNOLOGY

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HALF BEAD REPAIR

- QUALIFICATION APPROACH -

o ASME CODE QUALIFICATION

- BEND AND TENSILE TESTS
- HAZ IMPACTS
- RESTRAINED TEST WELDS

o WELDING POSITION EFFECTS

- VERTICAL UP
- HORIZONTAL

o PROCESS VARIABLES

- WELDING PARAMETER CONTROL
- LAYER SEQUENCE/BEAD OVERLAP
- GRINDING/LAYER THICKNESS

o TEMPERING EFFECTIVENESS

- HAZ MICROHARNESS IMPROVEMENT
- MICROSTRUCTURAL EXAMINATIONS

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HALF BEAD REPAIR

- QUALIFICATION RESULTS -

- o SECTION XI REQUIREMENTS COMPLETED
  - SIDE BEND TESTS
  - TENSILE TESTS
  - ALL WELD METAL TENSILES
  - HAZ IMPACTS
- o HAZ HARDNESS EXAMINATIONS
  - APPROXIMATELY 50 PROFILES - 15-20 READINGS PER PROFILE
  - VERTICAL AND HORIZONTAL
  - EDGES, ROOT, SIDES, STARTS, STOPS, ETC.
  - 350 KNOOP AVERAGE ACHIEVED WITH TEMPERBEAD PROCESS VS. 450 KNOOP AVERAGE AS WELDED
- o HAZ MICROSTRUCTURE
  - FINE GRAIN
  - TEMPERED STRUCTURE

HALF BEAD REPAIR

- QUALIFICATION RESULTS -

(continued)

o RESIDUAL STRESS - EVALUATION RESULTS

- SIMILAR TO ANY OTHER REPAIR
- BUTT WELD STRESS PREDOMINATES

HALF BEAD REPAIR

- THERMAL ANALYSIS-

- o FINITE ELEMENT ELASTIC/PLASTIC
- o THERMAL ANALYSIS
  - VERIFY HALF BEAD THROUGH-WALL TEMPERATURE WITH THERMAL SLEEVE IN PLACE
  - DETERMINE NOZZLE HEATING REQUIREMENTS AND THERMAL GRADIENTS
- o STRESS ANALYSIS RESULTS - INLET AND OUTLET
  - NOZZLE AND BUTTER RESIDUAL STRESSES NEGLIGIBLE
  - CLADDING STRAIN AND RESIDUAL STRESS LOW AND WITHIN ACCEPTABLE LIMITS

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HALF BEAD REPAIR

- HEATING PROCESS -

- o CONTROLLED ELECTRICAL RESISTANCE
- o CONFIRM BY ANALYSIS
- o QUALIFY IN MOCKUP

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NOZZLE REPAIR

SUMMARY

- PLANNED REPAIR PROGRAM UNDERWAY INCLUDING:
  - FAILURE ANALYSIS
  - EXAMINATION TO DETECT CRACKING
  - REPAIR OF UNACCEPTABLE INDICATIONS
- SPECIAL REPAIR PROCEDURES QUALIFIED FOR DEEP GRINDOUTS OR THIN BUTTER
  - HALF BEAD REPAIR
  - LOCAL POSTWELD HEAT TREATMENT
- HYDROGEN WATER CHEMISTRY IMPLEMENTATION PLANNED AS FINAL MITIGATION

TECHNICALLY COMPLETE PLAN IN PLACE AND READY TO PROCEED

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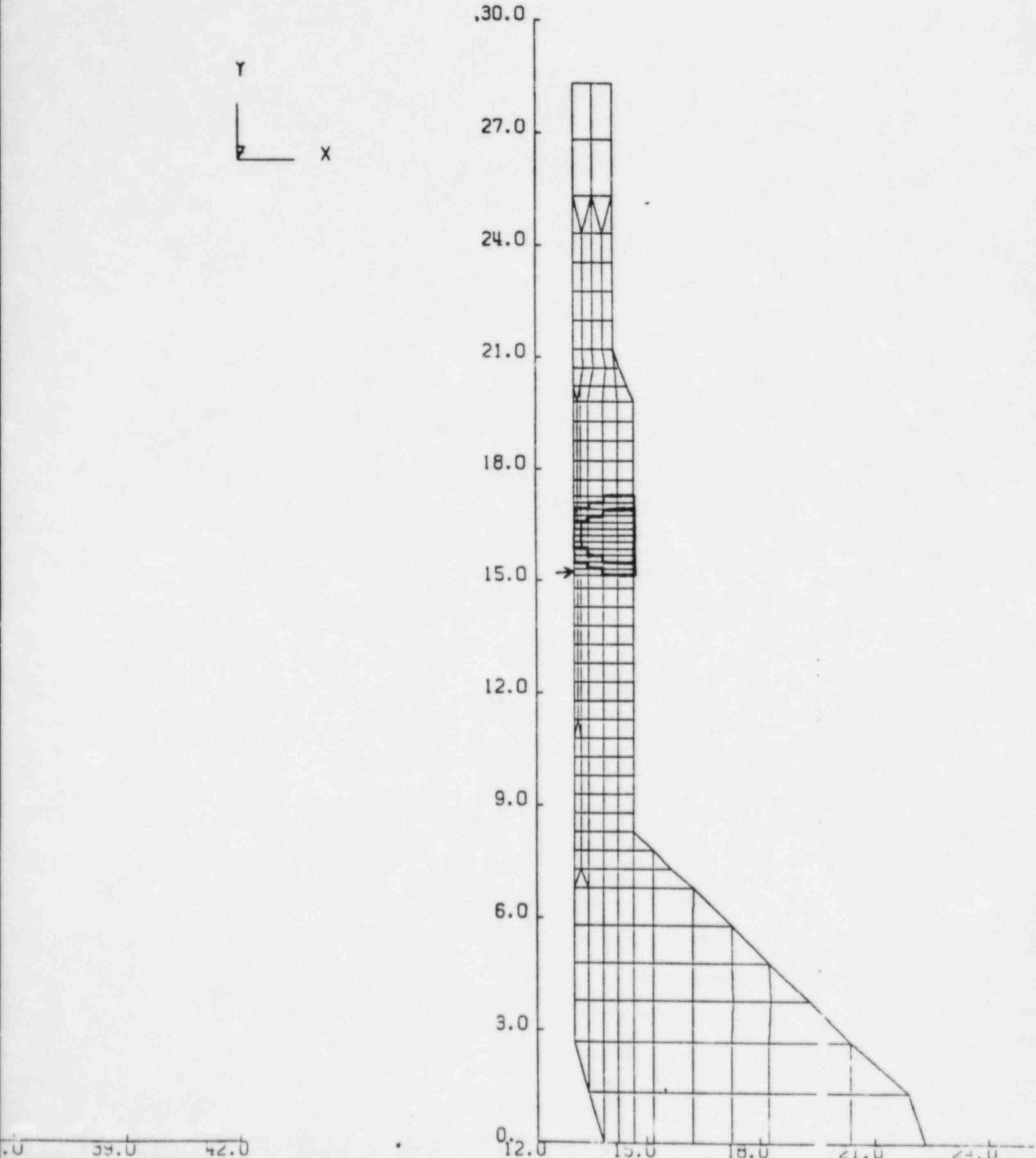
SERVICE PERFORMANCE

SERVICE PERFORMANCE

- RESIDUAL STRESS ANALYSIS
- EXPLANATION OF OBSERVED CRACKING
- EFFECT OF FINAL WELD ON STRESSES RESULTING FROM HALF BEAD WELD REPAIR
- STRUCTURAL MARGIN

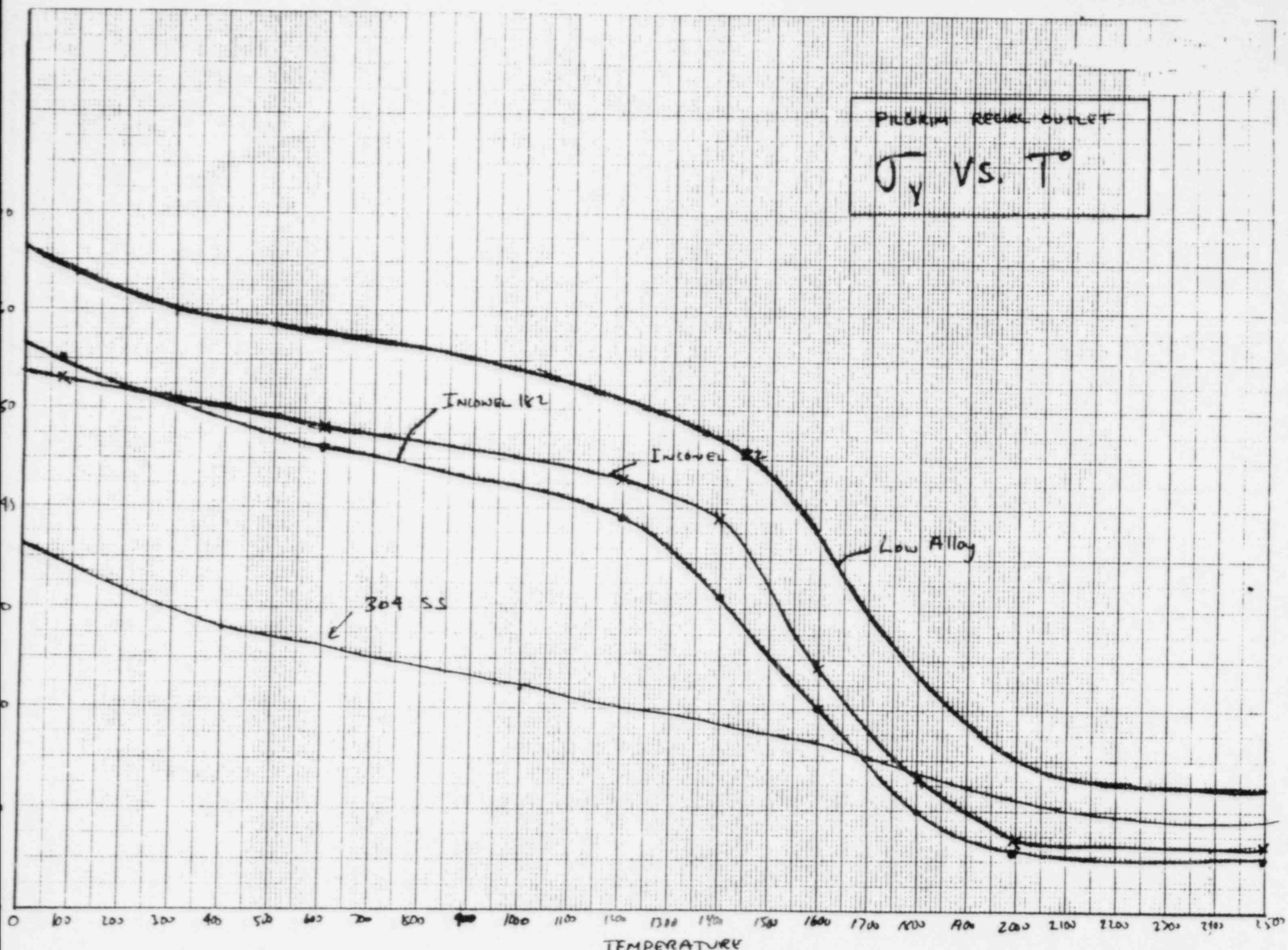
RESIDUAL STRESS ANALYSIS

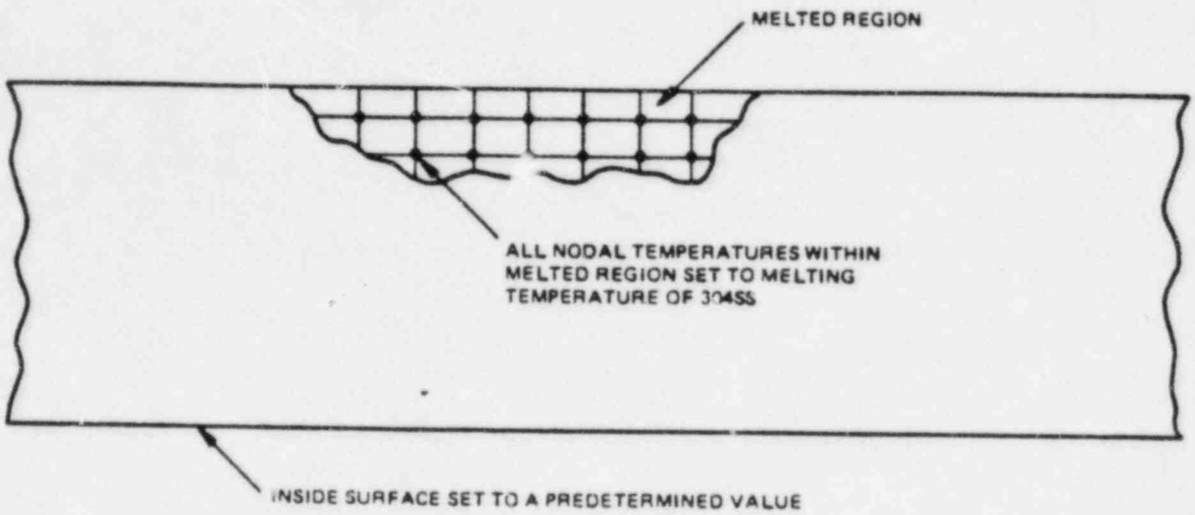
- ANALYSIS PERFORMED USING ANSYS WITH TYPICAL MATERIAL PROPERTIES
- TEMPERATURE DEPENDENT PROPERTIES USED
- BILINEAR KINEMATIC HARDENING VON MISES YIELD CRITERION
- WELD TEMPERATURE DISTRIBUTION BASED ON THE NUGGET AREA HEAT METHOD. SINGLE PASS WELD CONSIDERED.
- RESULTS SHOW HIGHER HOOP STRESS ALMOST UNIFORM THROUGH THE WALL THICKNESS

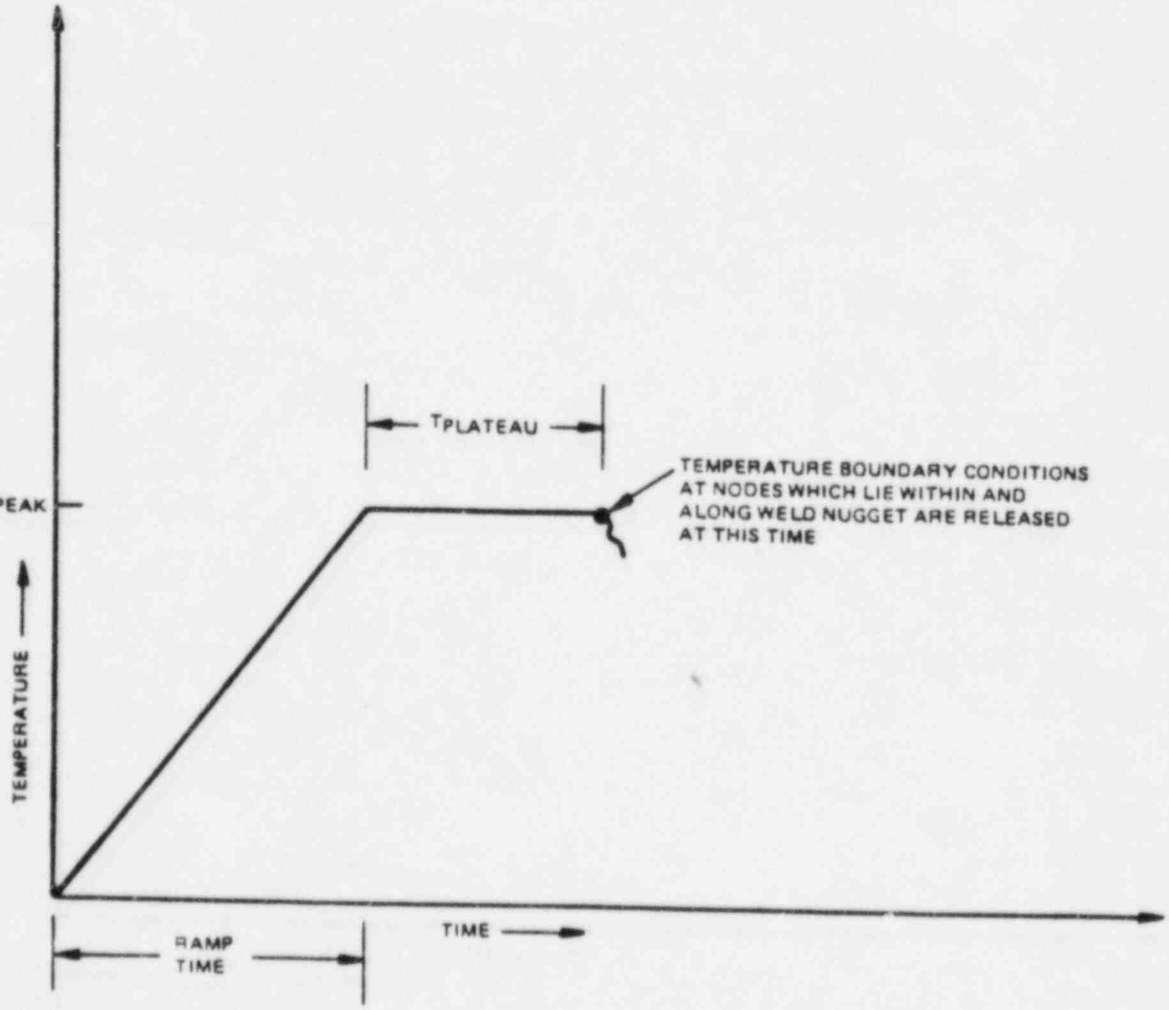


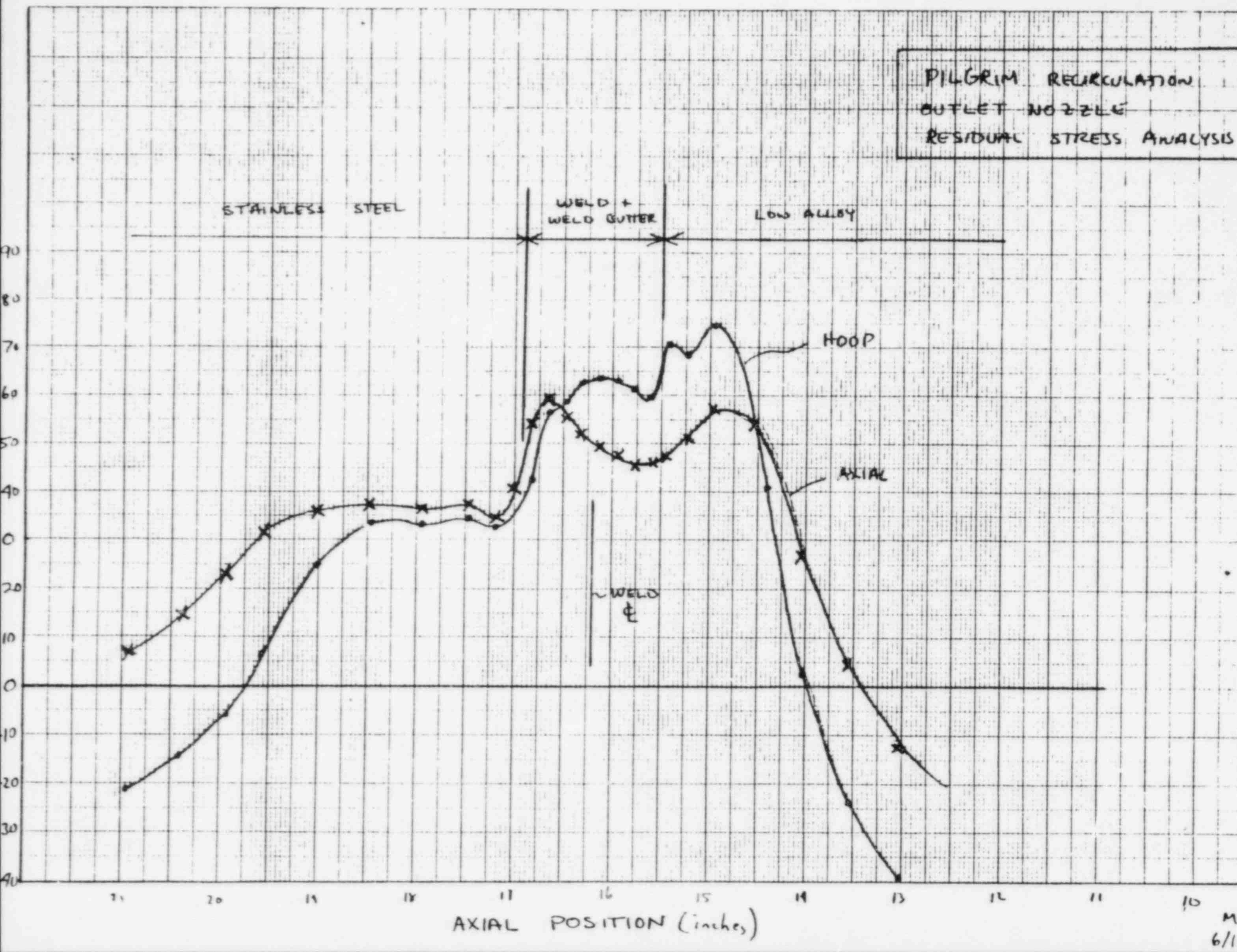
GEOMETRY ANSYS 2

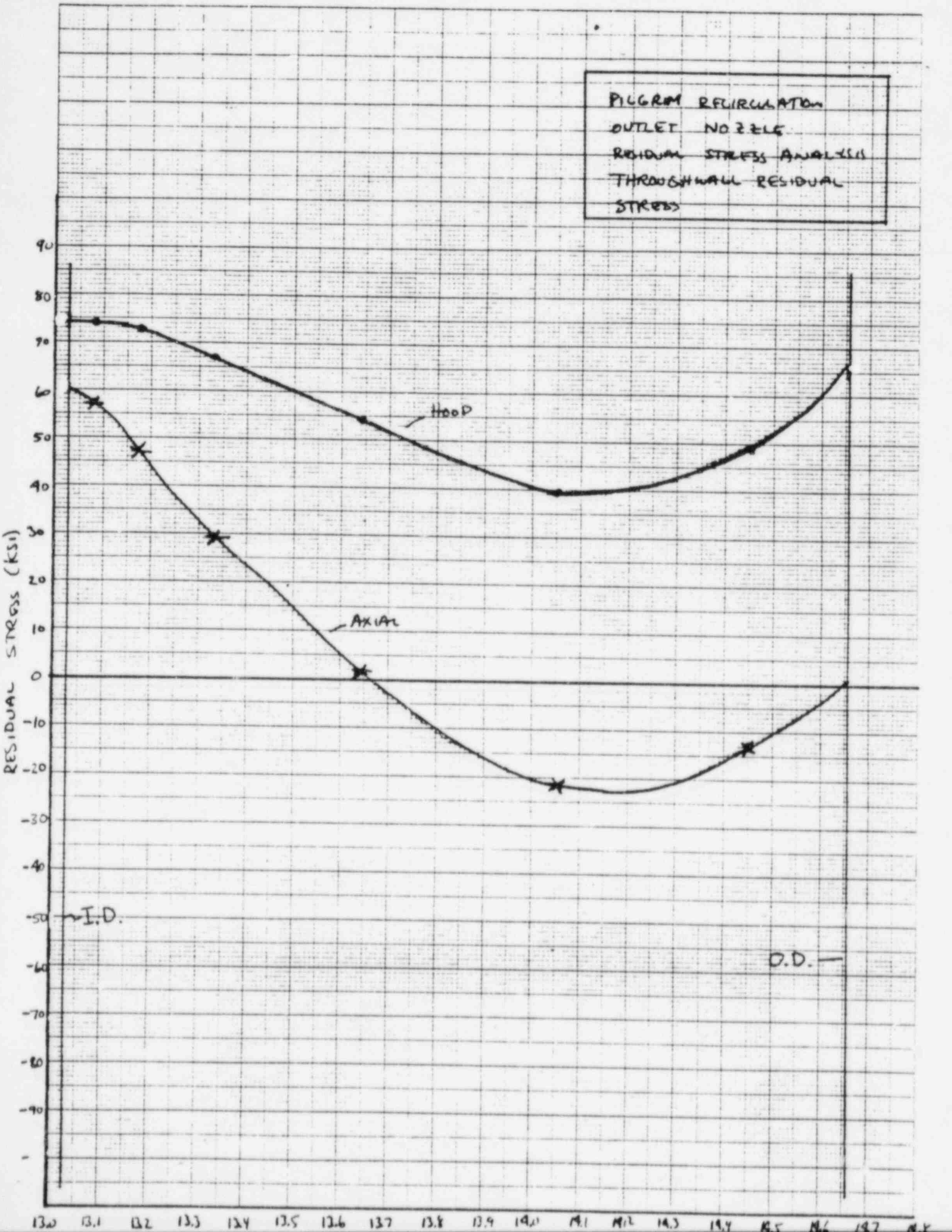
PILGRIM RECIRC OUTLET NOZZLE


PILGRIM RECIRC OUTLET
σ_Y VS. T°
Low Alloy
INCONEL 182
INCONEL 82
304 SS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
TEMPERATURE


MELTED REGION
ALL NODAL TEMPERATURES WITHIN MELTED REGION SET TO MELTING TEMPERATURE OF 304SS
INSIDE SURFACE SET TO A PREDETERMINED VALUE


TPLATEAU
TPEAK
TEMPERATURE BOUNDARY CONDITIONS AT NODES WHICH LIE WITHIN AND ALONG WELD NUGGET ARE RELEASED AT THIS TIME
TEMPERATURE
TIME
RAMP TIME


PILGRIM RECIRCULATION
OUTLET NOZZLE
RESIDUAL STRESS ANALYSIS
STAINLESS STEEL
WELD + WELD BUTTER
LOW ALLOY
HOOP
AXIAL
~WELD ℄
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
21
20
19
18
17
16
15
14
13
12
11
10
AXIAL POSITION (inches)
MLH
6/13/84

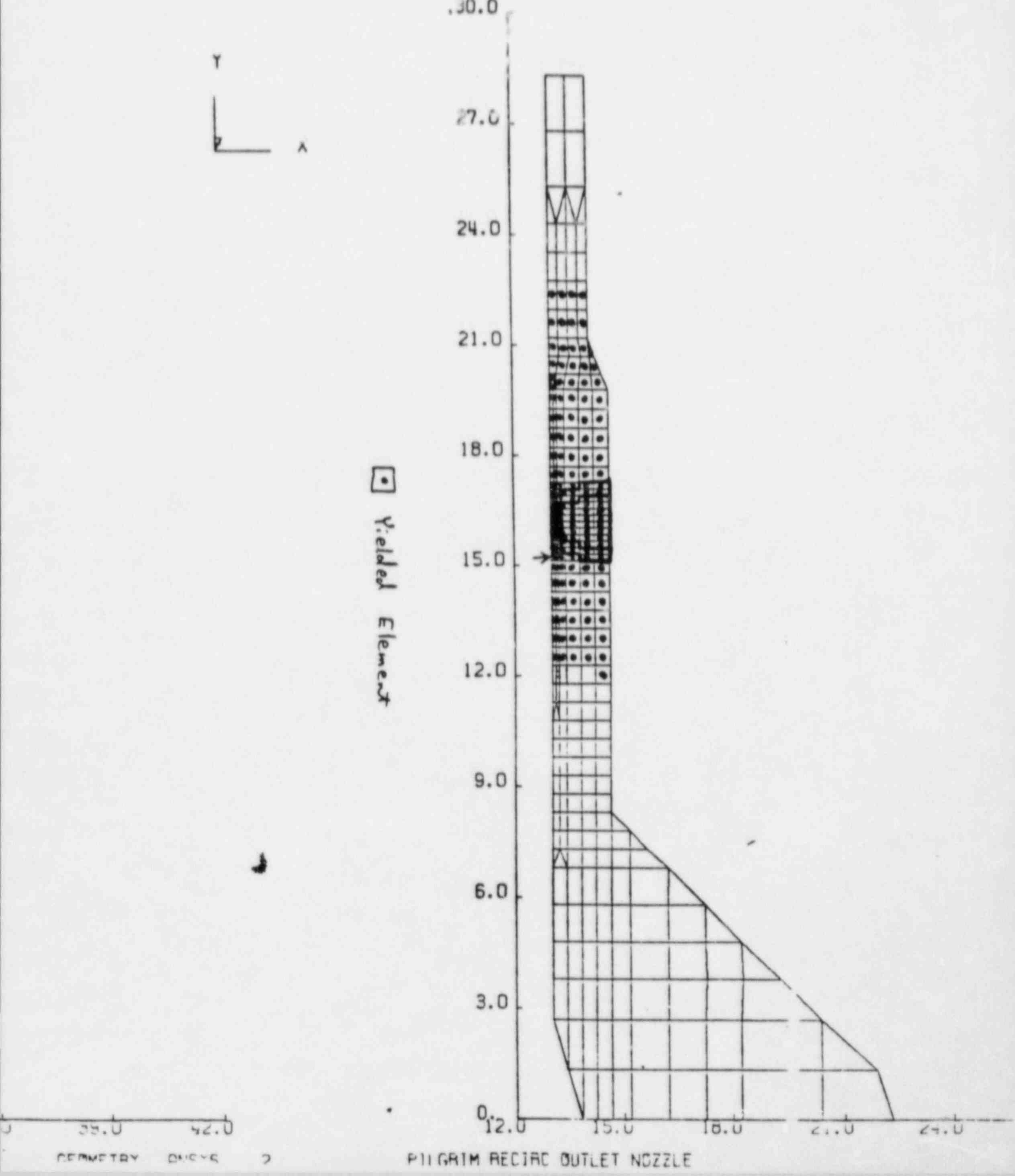

PILGRIM RECIRCULATION
OUTLET NOZZLE
RESIDUAL STRESS ANALYSIS
THROUGHWALL RESIDUAL
STRESS
HOOP
AXIAL
RESIDUAL STRESS (KSI)
I.D.
O.D.
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
13.0
13.1
13.2
13.3
13.4
13.5
13.6
13.7
13.8
13.9
14.0
14.1
14.2
14.3
14.4
14.5
14.6
14.7

EXPLANATION OF THE OBSERVED CRACKING

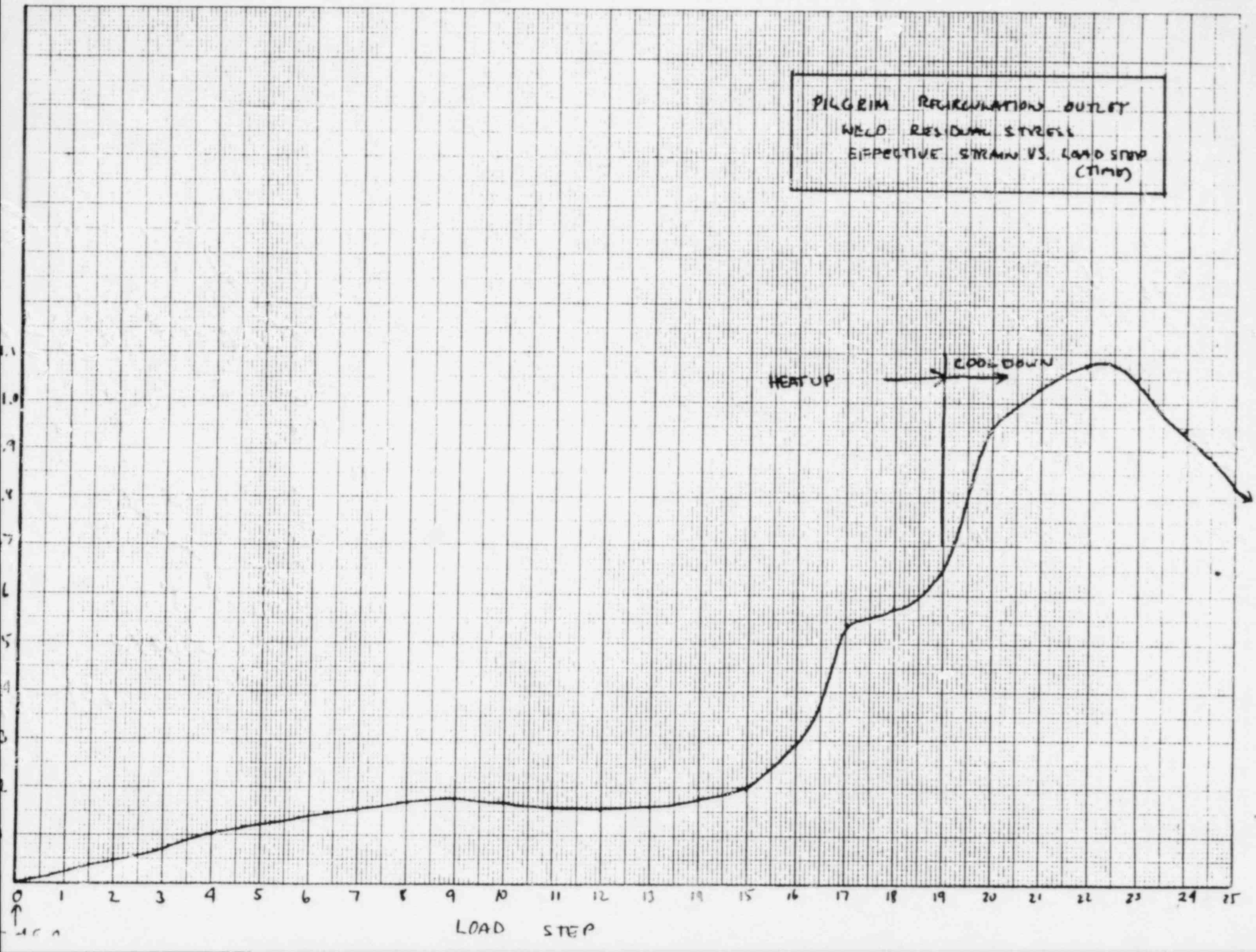
- PRIMARY HOOP STRESS DUE TO PRESSURE 10 KSI
- WELD RESIDUAL STRESS 50 - 70 KSI
- CIRCUMFERENTIAL STRESSES SUFFICIENT TO EXPLAIN THE OBSERVED CRACKING
- PREDOMINANT AXIAL CRACKING DUE TO HIGHER PRESSURE STRESS AND WELD RESIDUAL STRESS

EFFECT OF FINAL WELD ON STRESSES DUE TO HALF BEAD REPAIR

- FINAL WELD PRODUCES EXTENSIVE YIELDING IN THE WELD BUTTER AND THE SURROUNDING LOW ALLOY STEEL MATERIAL
- THE PLASTIC YIELDING IS SUFFICIENT TO OVERWHELM PREVIOUS RESIDUAL STRESSES
- STUDIES ON IHSI HAVE CONFIRMED THE ROLE OF PLASTICITY IN ELIMINATING PREVIOUS STRESS STATE
- FINAL STRESSES IN THE WELD AND SURROUNDING MATERIAL ARE ESSENTIALLY SAME AS DIFFERENT THAN THAT IN A WELD WITHOUT HALF BEAD REPAIR



30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.
12.0
15.0
18.0
21.0
24.0
42.0
Y
X
Yielded Element
GEOMETRY ANSYS 2
PILGRIM RECIRC OUTLET NOZZLE


PILGRIM RECIRCULATION OUTLET
WELD RESIDUAL STRESS
EFFECTIVE STRAIN VS. LOAD STEP
(TIME)
HEATUP
COOLDOWN
1.1
1.0
.9
.8
.7
.6
.5
.4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
LOAD STEP

STRUCTURAL MARGIN

- AXIAL CRACK SIZE INHERENTLY LIMITED BY THE WIDTH OF THE HAZ AROUND THE WELD

- THROUGH-WALL CRACK CAN BE TOLERATED

- CRITICAL CRACK SIZE CONSIDERING BRITTLE FRACTURE IN THE NOZZLE
  - 22 INCHES IN RECIRC INLET NOZZLE
  - 27 INCHES IN RECIRC OUTLET NOZZLE

- CRITICAL CRACK SIZE IN THE STAINLESS STEEL SAFE END
  - 25 INCHES IN RECIRC INLET NOZZLE
  - 39 INCHES IN RECIRC OUTLET NOZZLE

- AXIAL CRACKS DO NOT POSE SAFETY CONCERN

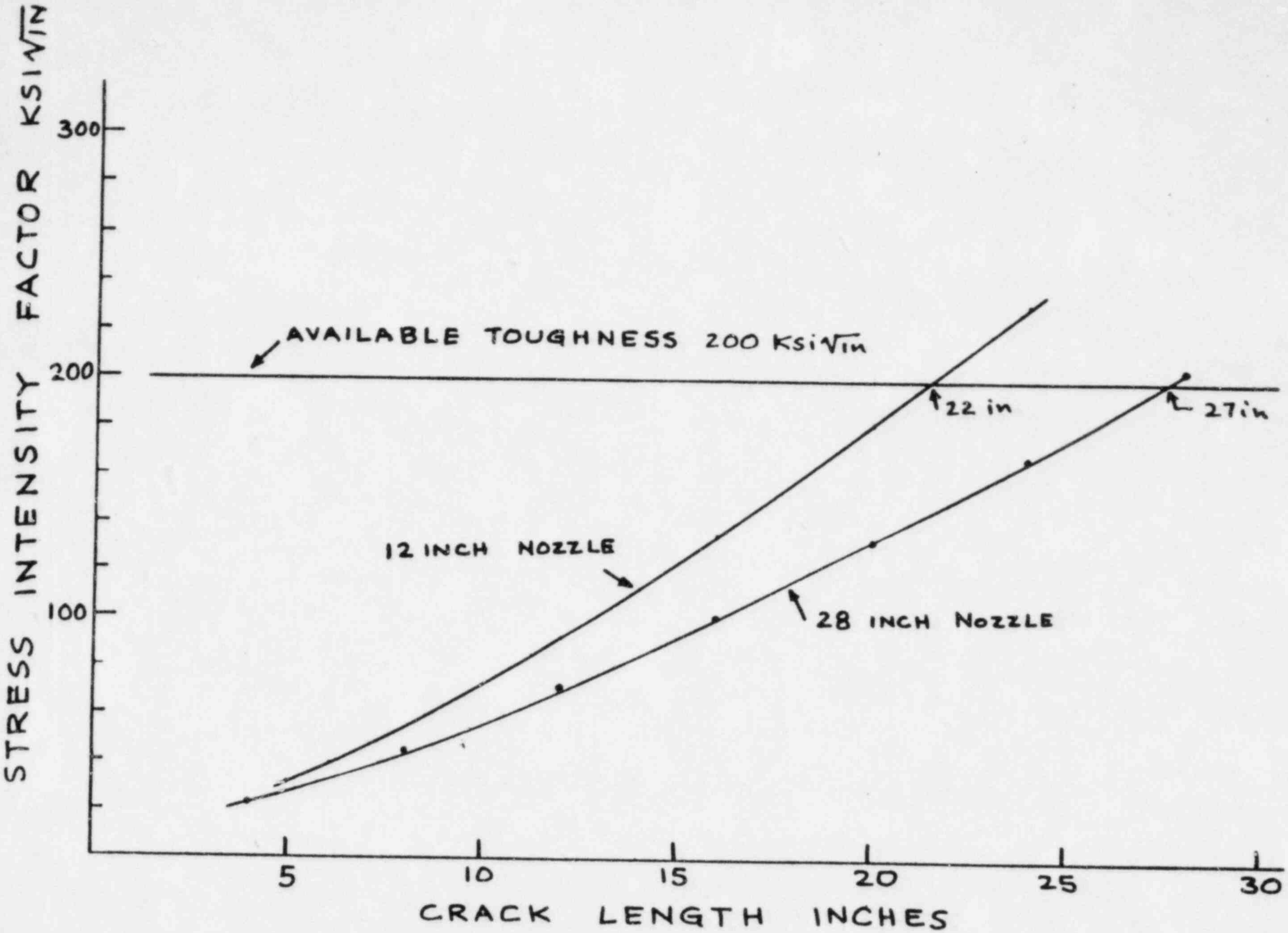


FIG 1 CRITICAL FLAW SIZE ASSUMING LEFM

SUMMARY

- 0 LAB DATA SHOWS
  - 182 MATERIAL SOMEWHAT LESS SUSCEPRIBLE THAN 304 SS
  - 82 MATERIAL (AND INCONEL 600) MUCH BETTER THAN 182
  - CRACK GROWTH IN 182 SIMILAR TO WELDED 304 SS - SLOW AND PREDICTABLE
- 0 BASED ON PT AND METALLOGRAPHY, CRACKING IN 182 BUTTERS IS AXIAL
- 0 FINITE ELEMENT ANALYSIS CONFIRMS AXIAL CRACKING IS EXPECTED MODE AND WILL REMAIN EXPECTED MODE FOLLOWING LOCAL WELD REPAIR
- 0 FROM A STRUCTURAL MARGIN STANDPOINT
  - SHORT AXIAL CRACKS NOT A CONCERN
- 0 LEAK-BEFORE-BREAK MARGINS REMAIN VALID
- 0 HWC OFFERS LONG TERM MITIGATION

METALLURGICAL CONSIDERATIONS

- O METALLOGRAPHY

- O REPAIR APPROACH

  - CLADDING
  - HYDROGEN WATER CHEMISTRY