TOLEDO EDISON

A Centerior Energy Company

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Docket Number 50-346

License Number NPF-3

Serial Number 1768

February 20, 1990

United States Nuclear Regulatory Commission
Document Control Desk
Washington, D. C. 20555

Subject: High Pressure Injection/Makeup Nozzle and Thermal Sleeve Program

Gentlemen:

The purpose of this letter is to document two recent meetings with the NRC Staff regarding the High Pressure Injection (HPI)/Makeup nozzle program at Davis-Besse Nuclear Power Station Unit 1 (DBNPS). A meeting to discuss the development of enhanced ultrasonic testing (UT) for the HPI/Makeup nozzle was held at the B&W Nuclear Service Company (B&W) offices in Lynchburg, VA on January 18, 1990. Another meeting relating to Toledo Edison's November 8, 1989 request (letter Serial Number 1726) for NRC approval of weld overlay, if repair of the HPI nozzle is necessary, was held on January 24, 1990 at the NRC offices in Rockville, MD. Enhanced UT of the HPI/Makeup nozzle during the sixth refueling outage (6RFO) is one of the followup activities resulting from discovery of the failed HPI/Makeup nozzle thermal sleeve during the fifth refueling outage (5RFO). Since 5RFO, a weld overlay design has been developed as a contingency should the enhanced UT disclose flaws necessitating repair of the nozzle.

The thermal sleeve, which had failed due to thermal fatigue, allowed makeup water to impinge on the mouth of the nozzle. Liquid dye penetrant (PT) inspection of the nozzle revealed indications in the cladding in the area where the thermal sleeve had failed. The manual UT examination performed at that time found no evidence of the flaws extending into the base metal. Conservative analysis indicated that significant flaw growth was not expected with an effective thermal sleeve in place. The failed thermal sleeve was replaced, minimum makeup flow was increased, and control over makeup flow was improved to reduce thermal cycling of the thermal sleeve. The NRC approved restart and operation for one cycle based on these actions and required Toledo Edison to identify followup actions for 6RFO. Toledo Edison's June 19, 1989 letter to the NRC (Serial Number 1664) identified planned actions for 6RFO.

The 6RFO actions include re-routing makeup flow to an alternate HPI nozzle, inspection of the thermal sleeve, and development of an enhanced UT technique to inspect the HPI/Makeup nozzle and the alternate nozzle. Although Toledo Edison does not expect these inspections to discover indications in the thermal sleeve or flaw growth in the nozzle, plans for thermal sleeve replacement and weld overlay repair of the nozzle have been developed as contingency measures.

On January 18, 1990, Toledo Edison and B&W representatives met with the NRC Staff at the B&W offices in Lynchburg, VA to review results of the development program for enhanced UT examination for the HPI/Makeup nozzles. This was a followup to an October 1989 meeting and the last planned for the enhanced UT development program. A copy of the meeting handout and list of attendees is attached (Attachment 1).

The background relating to failure of the thermal sleeve and discovery of PT indications in the nozzle was reviewed, and the intended use of UT data in nozzle structural evaluations to justify continued operation was explained. The development program and results were summarized and related to the intended use. It was shown that the system can reliably detect flaws penetrating into the base metal by more than 0.125 inch which is well below the depth where structural integrity of the nozzle would be compromised. It was also shown that flaws in most of the volume of the nozzle and adjacent reactor coolant piping can be adequately sized using time-based techniques. However, for a small zone inside the mouth of the nozzle, time-based sizing of axially-oriented flaws proved to be impractical and amplitude-based sizing was performed. Should flaws be detected in this zone, locally augmented sizing techniques will be employed. Mr. T. T. Taylor, of Battelle Pacific Northwest Laboratories (PNL), the NRC consultant, did not express any major concern with this approach.

During the course of the meeting, Mr. Taylor presented his evaluation of B&W's scanning results on test blocks previously supplied by PNL. The examination resulted in 100 percent detection of the flaws with no unflawed locations reported as containing flaws. Initially, it was thought that two flaws were reported in one of the blocks that PNL records indicated as having no flaws. Following the meeting, removal of the backing plate from the test block and close inspection revealed the presence of two notches in the locations reported by B&W. These notches had apparently been machined in the block and not recorded.

Based on the enhanced UT development program results, comments received at this meeting and in subsequent conversations with the NRC Staff, Toledo Edison concludes that the use of enhanced UT to assess the structural integrity of the HPI/Makeup nozzle is acceptable to the NRC. As requested by the Staff a report documenting the results of the enhanced UT development program is being prepared and will be submitted under separate cover.

On January 24, 1990, Toledo Edison and Structural Integrity Associates (SIA), Toledo Edison's consultant, met with the Staff at the NRC offices in Rockville, MD, to review Toledo Edison's November 8, 1989 request (Serial Number 1726) for NRC approval of weld overlay repair methodology for the HPI/Makeup nozzle. A list of attendees and copy of the meeting handout are attached (Attachment 2).

Toledo Edison had requested this meeting to resolve any Staff questions regarding the fracture mechanics analysis used to determine the allowable flaw size and the basis for the weld overlay design. Toledo Edison does not expect the enhanced UT to discover flaws in the HPI/Makeup nozzle necessitating a weld overlay repair. However, in the event that a repair is indicated, expeditious NRC approval for weld overlay will be required to prevent delay of the refueling outage schedule. A window of approximately eight weeks exists between completion of the UT and planned refilling of the reactor coolant system.

The weld overlay meeting opened with a brief overview of the history of the HPI/Makeup nozzle thermal sleeve issue and actions planned for 6RFO. The Staff members present indicated their belief that the driving force for the flaws in the cladding observed during 5RFO was thermal fatigue induced by the impingement of cold makeup water on the nozzle during the period of operation with the failed thermal sleeve. The Staff indicated that NRC approval for restart from 5RFO was based primarily on replacement of the failed thermal sleeve, thereby protecting the nozzle from the effects of impingement of cold makeup water. The Staff indicated their belief that, with an intact thermal sleeve, the primary mechanism for flaw growth is precluded and no significant flaw growth will occur.

SIA described the updated fracture mechanics analysis which is the basis for Toledo Edison's November 8, 1989 submittal (Serial Number 1726) and explained the reasons for the difference in conclusions from the earlier fracture mechanics analysis provided with Toledo Edison's September 15, 1988 submittal (Serial Number 1580). The earlier analysis was intentionally based on a conservative simplified model in order to support restart of the unit following discovery of the failed thermal sleeve during 5RFO. The model used at that time was a single edge flawed plate which assumed that the stresses were maintained uniform across the section at their inside surface value. Use of this model resulted in an ASME Section XI allowable flaw depth for brittle fracture prevention of 0.5 inch.

The updated analysis was performed using the **pc-Crack** code nozzle corner flaw model which is more representative of the actual configuration than the flat plate model used in the earlier analysis. With the updated analysis, the ASME Section XI allowable flaw depth for brittle fracture prevention is essentially through-wall indicating that brittle fracture is not a concern. This is

because the total applied stress intensity curve (pressure and thermal) for any flaw size up to through-wall, for the limiting HPI flow transient with an effective thermal sleeve, does not exceed the material fracture toughness with the applied ASME Code safety factor.

The **pc-Crack** nozzle corner flaw model results have been verified and found to be highly accurate with respect to experimental results of a study of pressure vessels containing nozzle corner flaws. A comparison of **pc-Crack** predictions for nozzle corner flaws with experimental results was presented. Two papers, "Fracture Mechanics Analysis of Japan Atomic Energy Research Institute (JAERI) Model Pressure Vessel Test," and "Fatigue Behavior of Nozzles of Light Water Reactor Pressure Vessel Model," which support this conclusion were provided to the Staff. Copies are attached (Attachments 3 and 4).

Based on the updated fracture mechanics analysis, Toledo Edison has concluded that brittle fracture is not a concern and the limiting flaw size is governed by ASME Section III structural reinforcement requirements. The Staff identified no specific technical concerns; however, they indicated that they would have to review the above referenced technical papers to assess the conservatism of Toledo Edison's conclusions.

The meeting proceeded to a discussion of the weld overlay repair development. Since brittle fracture is not a concern, the design approach is based on maintaining ASME Section III structural reinforcement requirements. The nozzle design was analyzed to determine the amount of existing excess reinforcement. Sufficient excess reinforcement exists to accommodate flaws up to 1.6 inches deep, beyond which additional reinforcement, i.e, weld overlay, would be required to maintain Section III margins.

The weld overlay process using automatic gas tungsten arc welding (GTAW) was developed for this application by Welding Services Incorporated. The mockups and tooling to demonstrate the capability under field constraints, weld procedure development, procedure qualification, pre- and post-weld heat treatment requirements, and post-weld non-destructive examination plans were discussed. Additionally, a study of the potential for flaw growth during application of the weld overlay was presented which concluded that there would be negligible flaw growth during welding. Staff attention focused primarily on the control of heat input during welding, the potential for flaw growth and the model for heat transfer used in the study. The Staff suggested that requirements on controls of heat input similar to those in the pending Code Case for tempered bead weld overlay be implemented. Additionally, the Staff indicated that the flaw growth study would have to be reviewed before a weld overlay repair could be approved.

In summary, NRC approval of a weld overlay repair would not be forthcoming prior to the availability of the HPI/Makeup nozzle enhanced UT results. The Staff indicated that they share Toledo Edison's belief that, with an intact thermal sleeve, no significant flaws will be identified unless they were pre-existing and were not detected during 5RFO, or an undefined failure mechanism is involved. If a large flaw is discovered, the most significant problem may be explanation of its existence and justification of the adequacy of corrective actions. Toledo Edison indicated that the inspection plan included repeating the 5RFO manual UT prior to the enhanced UT.

Toledo Edison believes that there are no significant technical issues prohibiting the use of weld overlay in this specific application, should repair of the nozzle be necessary. Having considered a range of alternatives, it is Toledo Edison's judgment that weld overlay reinforcement is the most appropriate and prudent contingency plan.

Toledo Edison appreciated the opportunity to discuss its plans with the NRC Staff. Should you have any questions concerning this matter, please call Mr. R. W. Schrauder, Manager - Nuclear Licensing, at (419) 249-2366.

Very truly yours,

PWS/ssg

cc: P. M. Byron, DB-1 NRC Senior Resident Inspector
A. B. Davis, Regional Administrator, NRC Region III
T. V. Wambach, DB-1 NRC Senior Project Manager

Docket Number 50-34
License Number NPF-
Serial Number 1768
Attachment 1

SECOND NRC REVIEW MEETING

ENHANCED ULTRASONIC EXAMINATION FOR HPI/MAKEUP NOZZLE

DAVIS BESSE NUCLEAR POWER STATION, UNIT 1

LYNCHBURG, VIRGINIA

JANUARY 18, 1990

TOLEDO EDISON COMPANY

B&W NUCLEAR SERVICE COMPANY

EPRI NDE CENTER

PURPOSE OF MEETING

TO UPDATE NRC ON PROGRAM AND PLANS IN PREPARATION FOR 6TH REFUELING OUTAGE SCHEDULED FOR FEBRUARY, 1990

TO ENSURE NRC UNDERSTANDING ON THE SPECIFIC APPLICATION OF DEVELOPED ENHANCED ULTRASONIC EXAMINATION TECHNIQUES

AGENDA

INTRODUCTION

PROGRAM SUMMARY

MOCKUP SCANNING DEMONSTRATION

DISCUSSION

CONCLUSION

HPI/MAKEUP NOZZLE - A1
THERMAL SLEEVE FRAGMENTS FOUND

JULY 2, 1988

TWO PIECES FROM END FOUND BELOW REACTOR CORE

FAILURE ATTRIBUTED TO THERMAL FATIGUE

FAILURE EXPOSES END OF NOZZLE TO COLD MAKEUP WATER

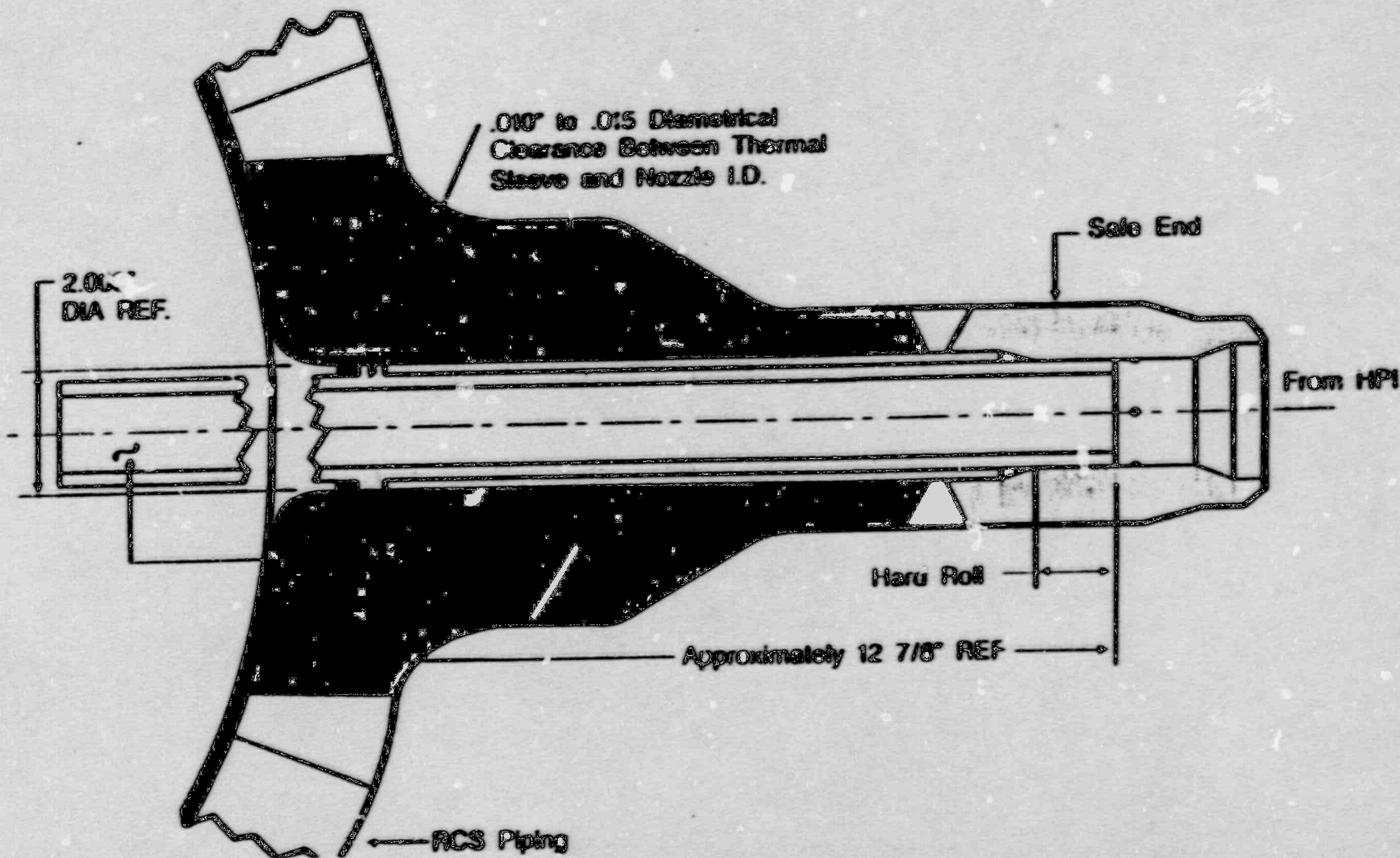
PT INDICATIONS SEEN IN NOZZLE IN AREA EXPOSED

INDICATIONS ATTRIBUTED TO THERMAL FATIGUE

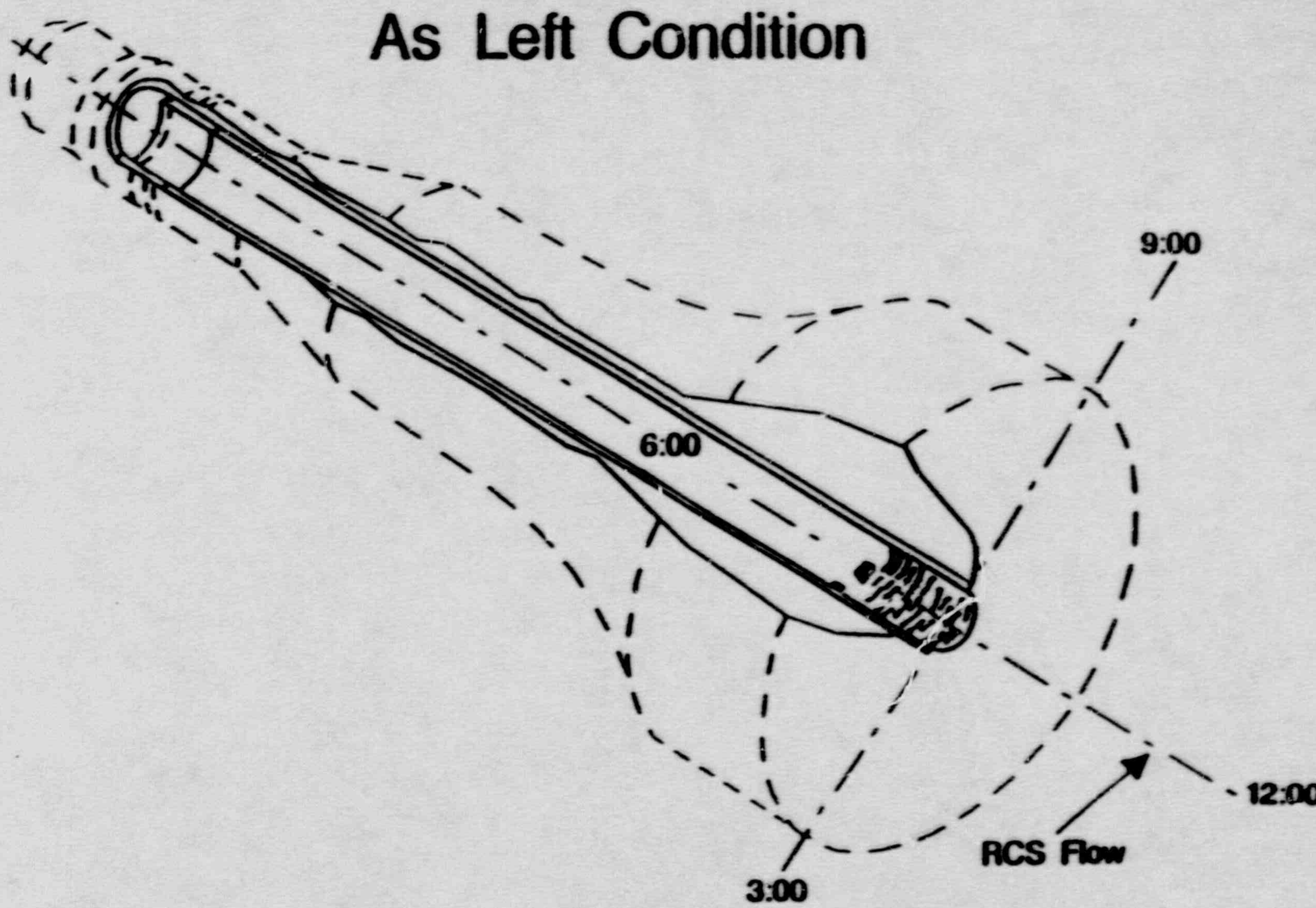
ANAYSIS INDICATES CRACK ARREST WITHIN CLAD LAYER

UT FINDS NO EVIDENCE OF FLAWS

Makeup/HPI Nozzle Original Thermal Sleeve Design



HPI Nozzle A1
As Left Condition



NRC APPROVED RETURN TO POWER BASED UPON SUBMITTAL

SERIAL NUMBER 1580, SEPTEMBER 14, 1988

COMPLETED COMMITMENTS

- o INCREASED MINIMUM BYPASS MAKEUP FLOW
- o IMPROVED CONTROL OVER MAKEUP FLOW
- o REPLACEMENT OF THERMAL SLEEVE WITH NEW DESIGN
- o UPDATE NRC ON:
  - PROGRESS OF FURTHER EVALUATIONS
  - ACTIONS TO BE TAKEN IN 6TH REFUELING OUTAGE

REMAINING COMMITMENT

"...TOLEDO EDISON PLANS TO OPERATE UNTIL THE NEXT REFUELING OUTAGE AT WHICH TIME THE HPI NOZZLE WILL BE RE-EXAMINED, RE-EVALUATED, AND REPAIRED AS REQUIRED."

RECENT SUBMITTAL TO NRC EXPLAINS TOLEDO EDISON PLANS

SERIAL NUMBER 1664, JUNE 19, 1989

- RE-ROUTE THE MAKEUP FLOW PATH TO HPI NOZZLE, A2

- FIBER-OPTIC EXAMINATION OF HPI/MOCKUP THERMAL SLEEVE

- ENHANCED UT OF THE HPI/MAKEUP NOZZLE (A1) FROM THE OUTSIDE

- ENHANCED UT OF ALTERNATE NOZZLE (A2) TO PROVIDE BASELINE INFORMATION

OUTAGE PLANS
6TH REFUELING OUTAGE

- PLANT OFF LINE - JANUARY 31, 1990

- NOMINAL OUTAGE DURATION - FOUR MONTHS

- NOZZLE AND THERMAL SLEEVE EXAMINATIONS TO BEGIN AS SOON AS CONTAINMENT ACCESS IS POSSIBLE - END OF 1ST WEEK IN FEBRUARY

- OUTAGE DURATION IS DEPENDENT ON ALL HPI NOZZLE AND THERMAL SLEEVE INSPECTIONS AND RELATED REMEDIAL ACTIONS BEING COMPLETED BY APRIL 12, 1990

PROGRAM OBJECTIVES

- o DEVELOP UT TECHNIQUES TO MONITOR AREAS AFFECTED BY THE FAILED THERMAL SLEEVE
  - GEOMETRY
  - ENHANCED DETECTION USING AUTOMATED SCANNING
- o DEMONSTRATE THE TECHNIQUES ON A NOZZLE/RC PIPE MOCKUP
- o DOCUMENT RESULTS OF DEVELOPMENT
  - DEMONSTRATE FLAW CHARACTERIZATION
  - SUITABLE AS INPUT TO FRACTURE MECHANICS ANALYSIS

ENHANCED ULTRASONIC EXAMINATION

DEVELOPMENT OBJECTIVES

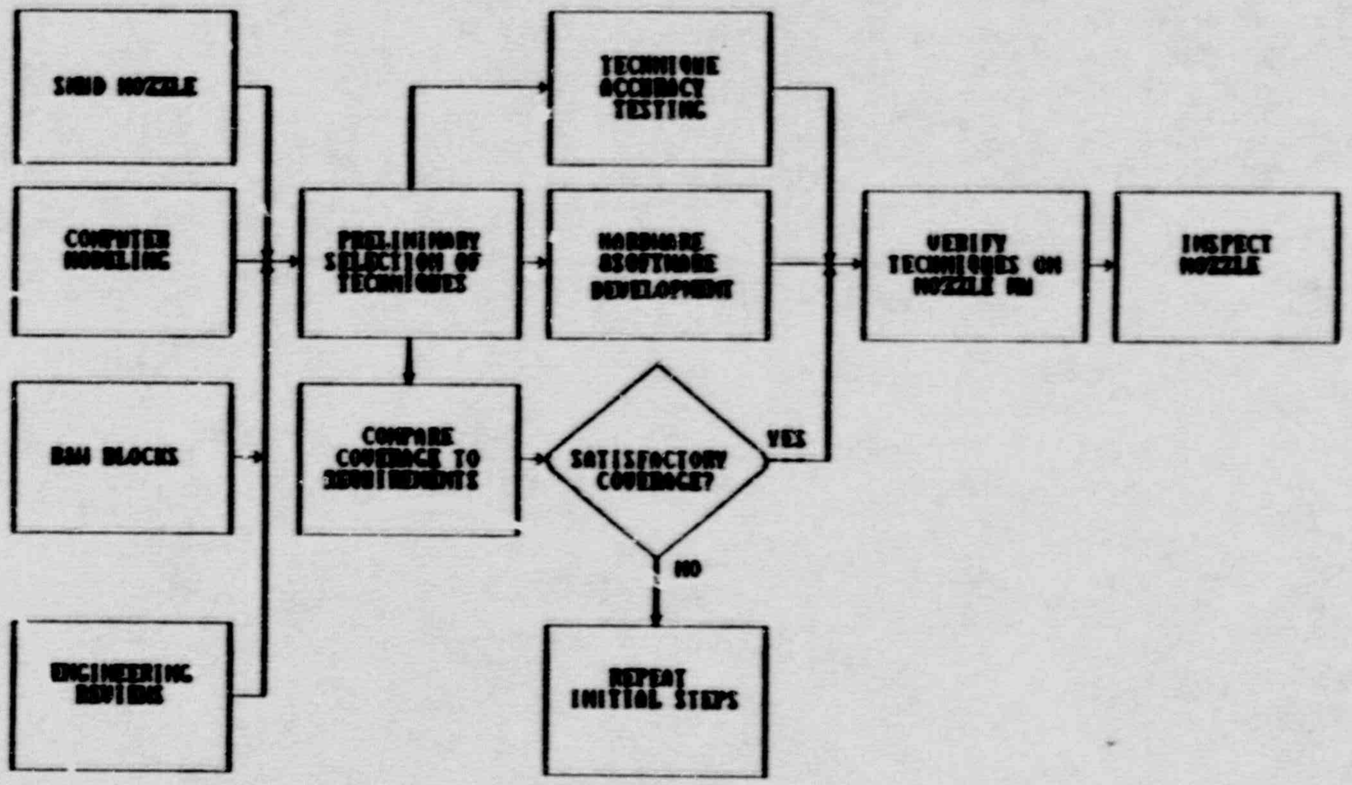
REQUIRED FOR SUBSEQUENT FLAW EVALUATION :

- o ABILITY TO DETECT AND LOCATE THERMAL FATIGUE FLAWS PENETRATING .125" OR MORE INTO THE BASE METAL WITHIN THE ZONE OF CONCERN
- o SIZING RESOLUTION ADEQUATE TO SHOW ANY FLAW GROWTH REMAINS WITHIN NOZZLE STRUCTURAL LIMITS
- o ABILITY TO DETERMINE CLADDING THICKNESS
- o AUTOMATED SCANNING TO ENSURE REPEATABLE RESULTS
- o ENHANCED FLAW DISPLAY "ACCUSONEX" TO PROVIDE CONSISTENT AND REPEATABLE RESULTS, MINIMIZING ERRORS OF INTERPRETATION

DESIRED BUT NOT MANDATORY :

- o ABILITY TO DETECT FLAWS WITHIN THE CLADDING

DEVELOPMENT PROGRAM FLOW

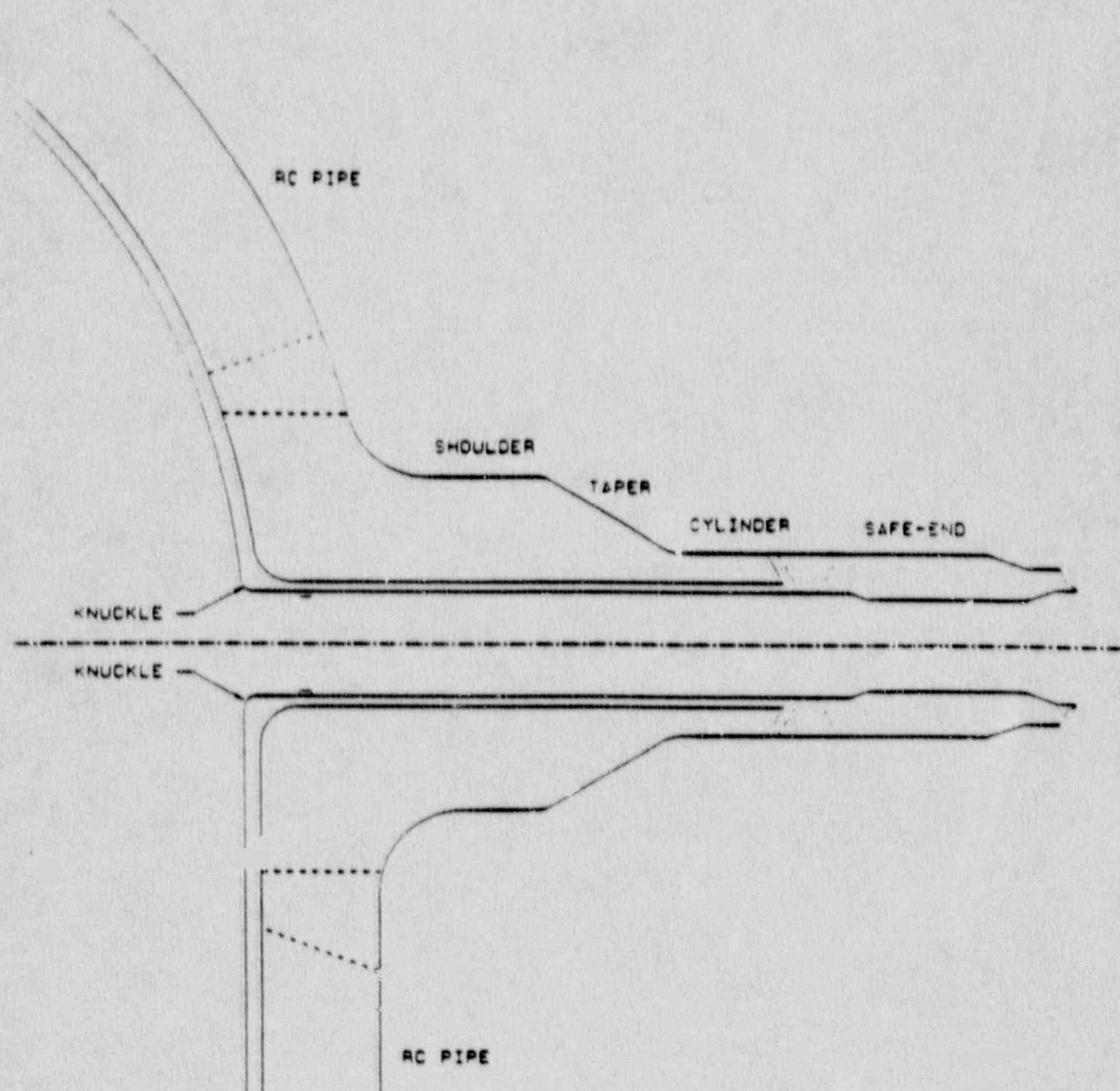


ELEMENTS OF PROGRAM

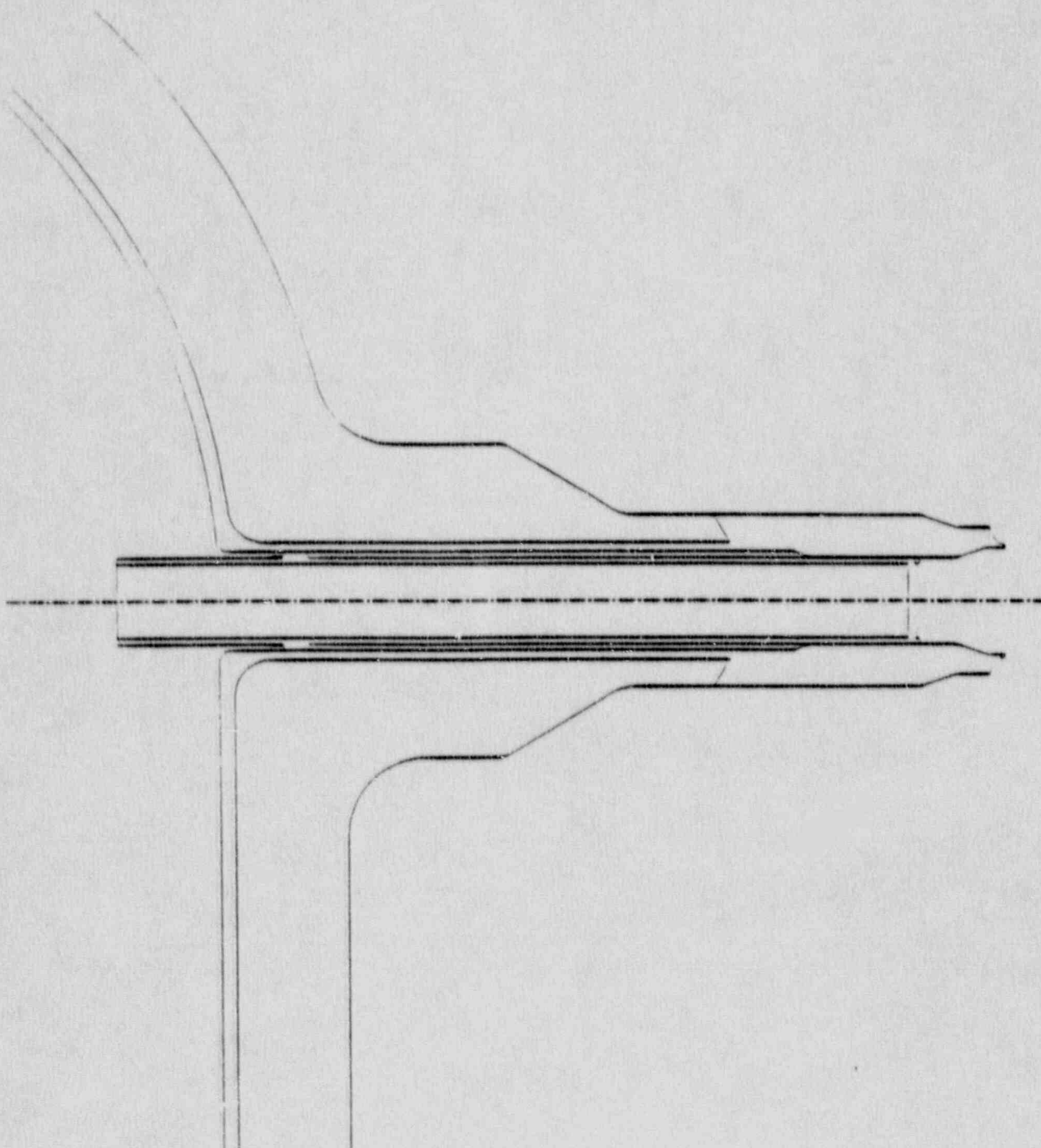
- o FABRICATE NOZZLE/RC PIPE MOCKUP WITH FLAWS
- o DETERMINE VOLUME TO BE SCANNED, DEVELOP SCAN PLAN
- o FABRICATE ACCESS MOCKUP, SELECT ROBOTIC SCANNERS, DEMONSTRATE ACCESSIBILITY
- o UTILIZE 3D CAD LAYOUT AND EPRI RAYTRACE PROGRAM TO PREDICT SCAN COVERAGE
- o DEVELOP UT TECHNIQUES SPECIFIC TO THIS APPLICATION
- o INCORPORATE ACCUSONEX DATA ACQUISITION AND ANALYSIS SYSTEM
- o STATISTICAL RESULTS OF BLIND TESTS TO DEMONSTRATE TECHNIQUES

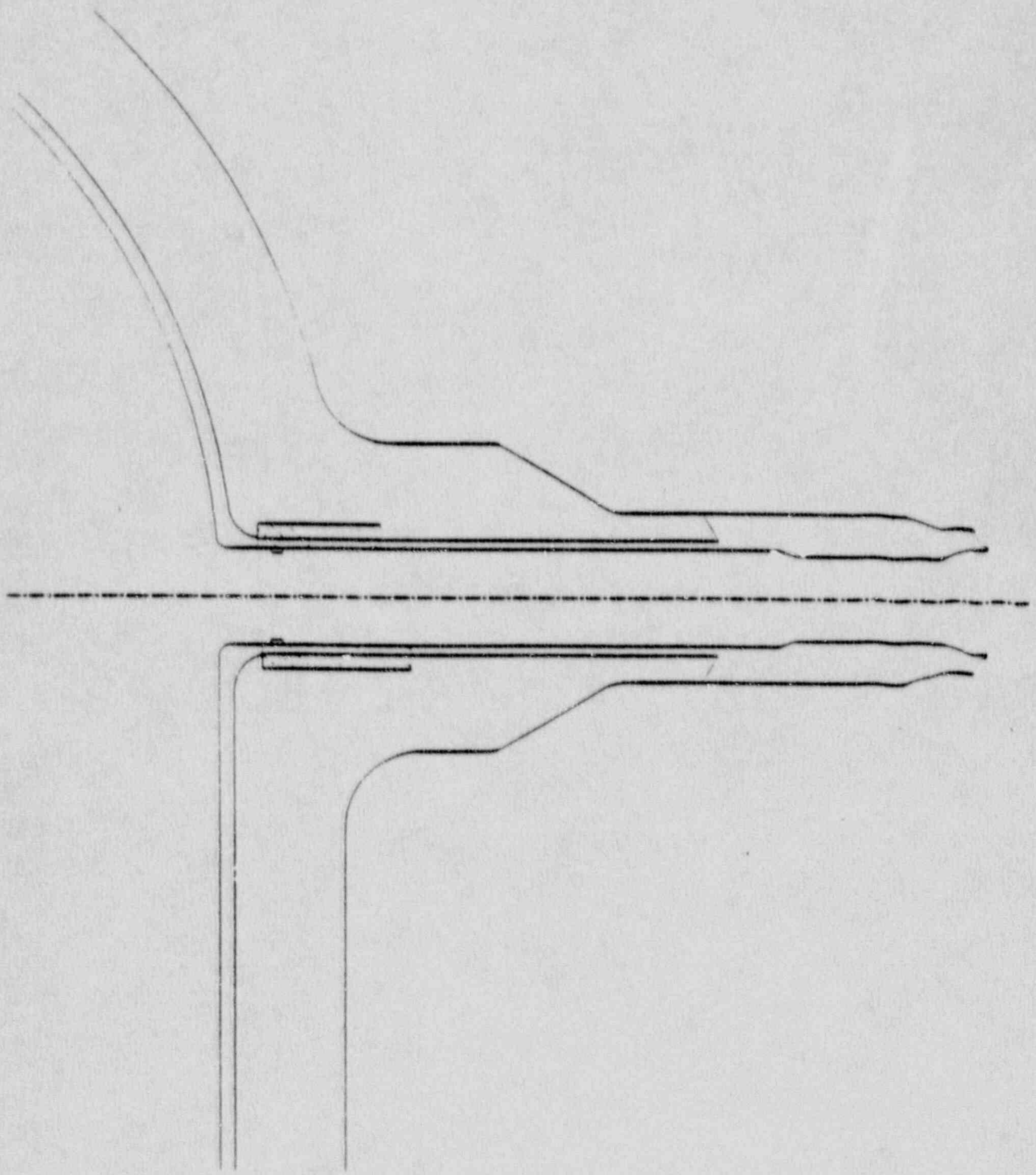
PROGRAM RESULTS

- o Inspection volume
- o Scan plan
- o Test results

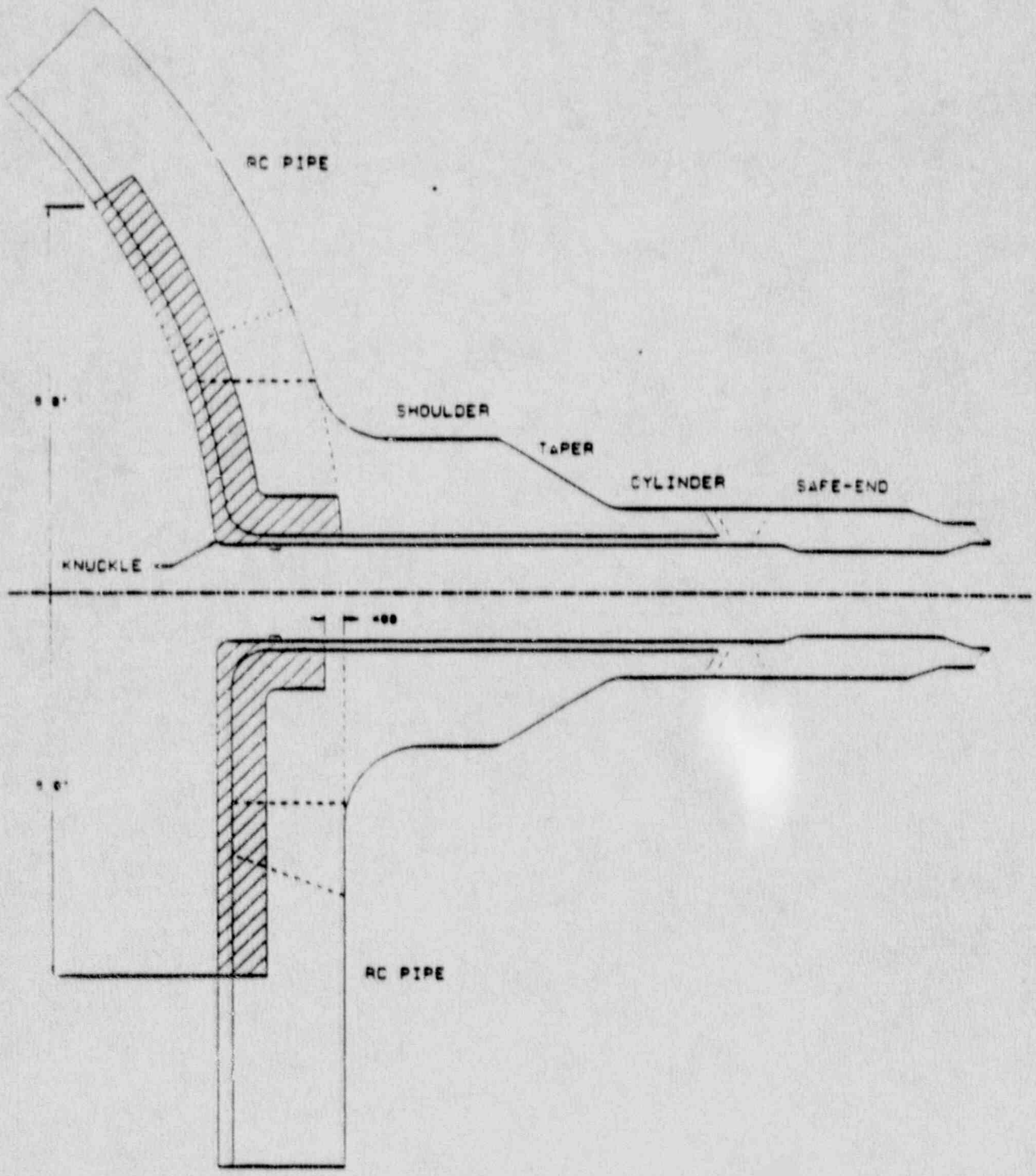


RC PIPE
SHOULDER
TAPER
CYLINDER
SAFE-END
KNUCKLE
KNUCKLE
RC PIPE





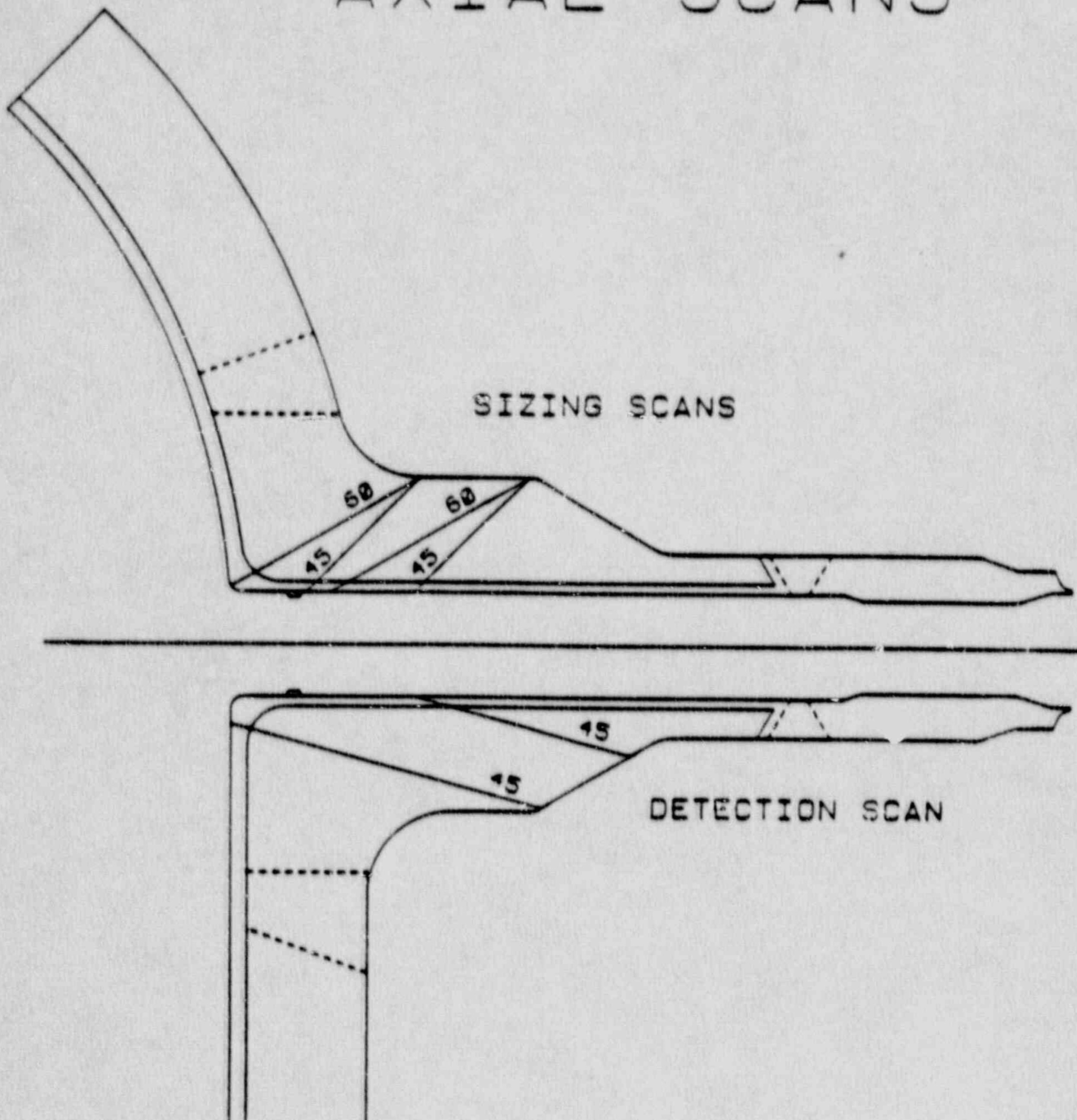
HPI NOZZLE EXAMINATION REGION



TEST RESULTS

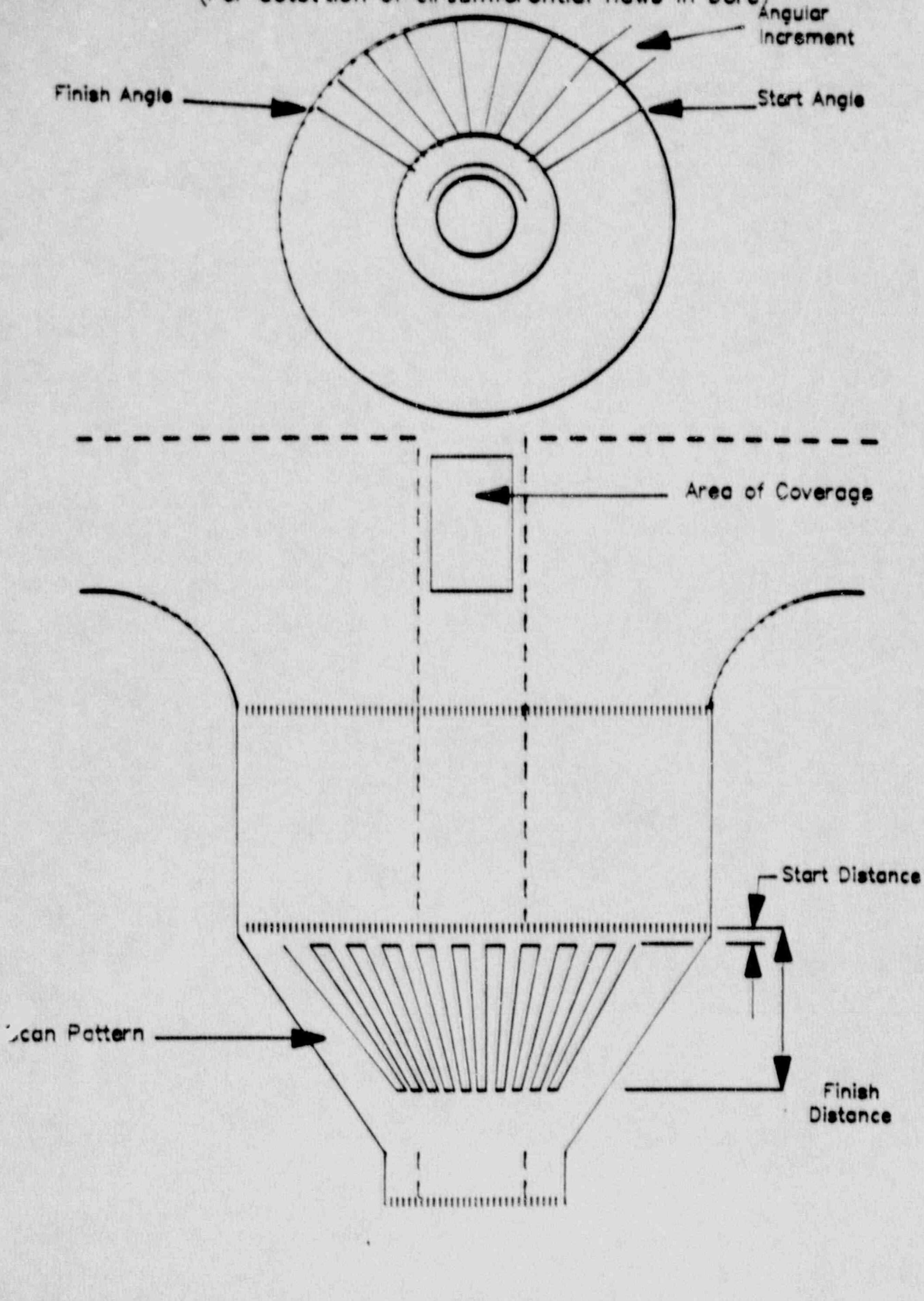
- o EPRI BLOCKS
  - \- 100% DETECTION
- o BATTELLE BLOCKS
  - \- 100% DETECTION
- o HPI NOZZLE
  - \- 100% DETECTION > 0.125 INCH

AXIAL SCANS

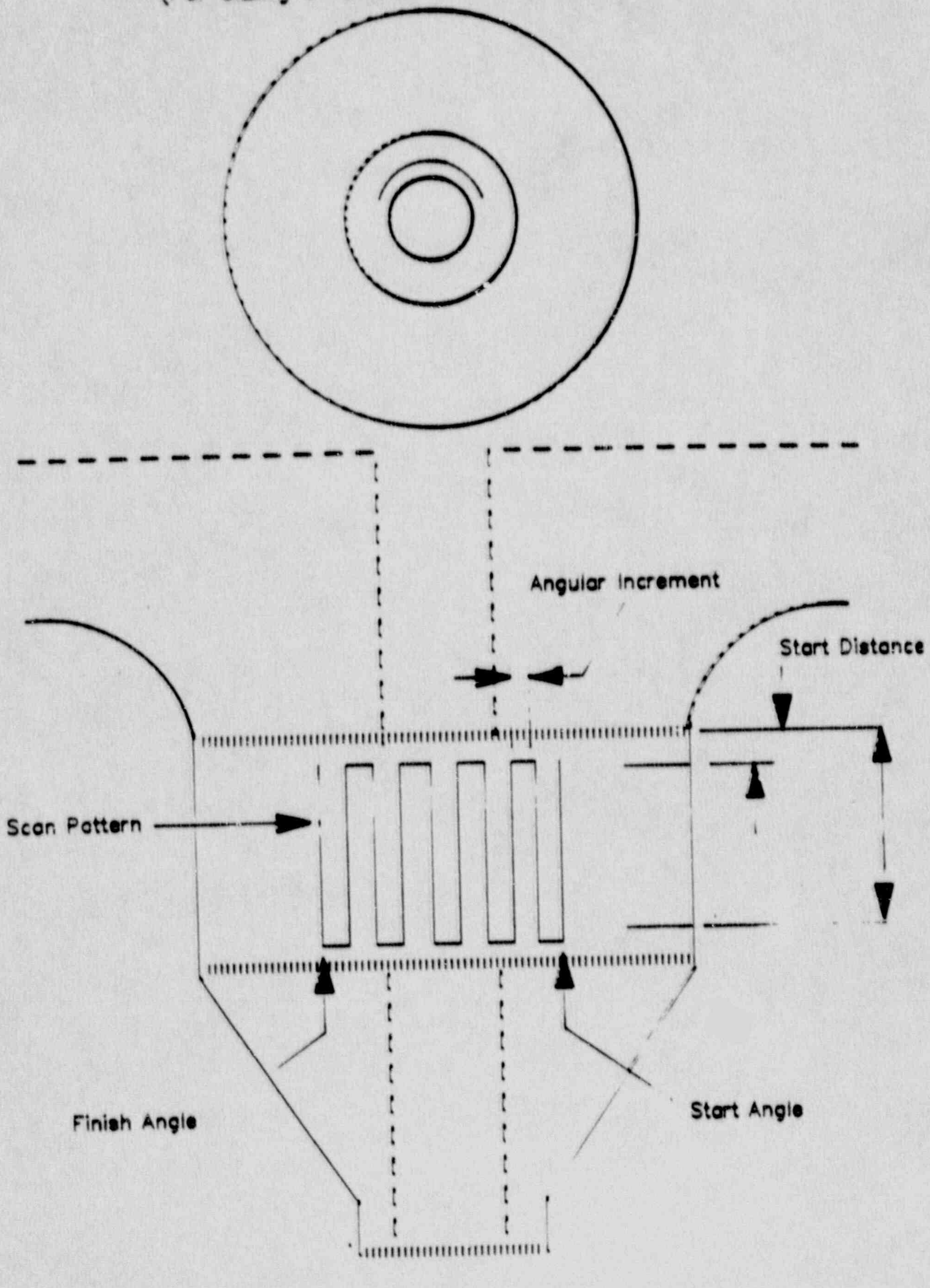


AXIAL TAPER SCAN

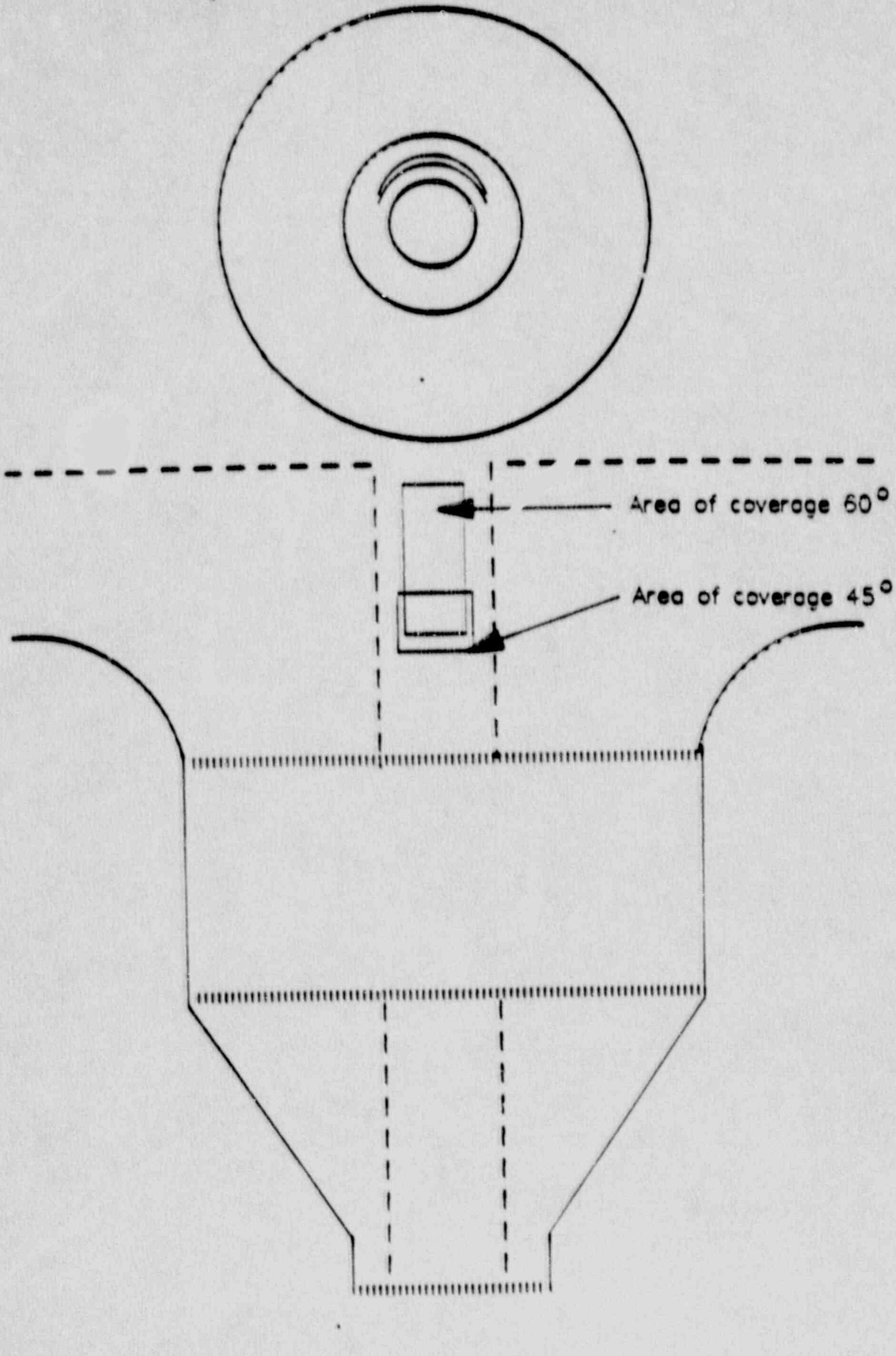
(For detection of circumferential flaws in bore)



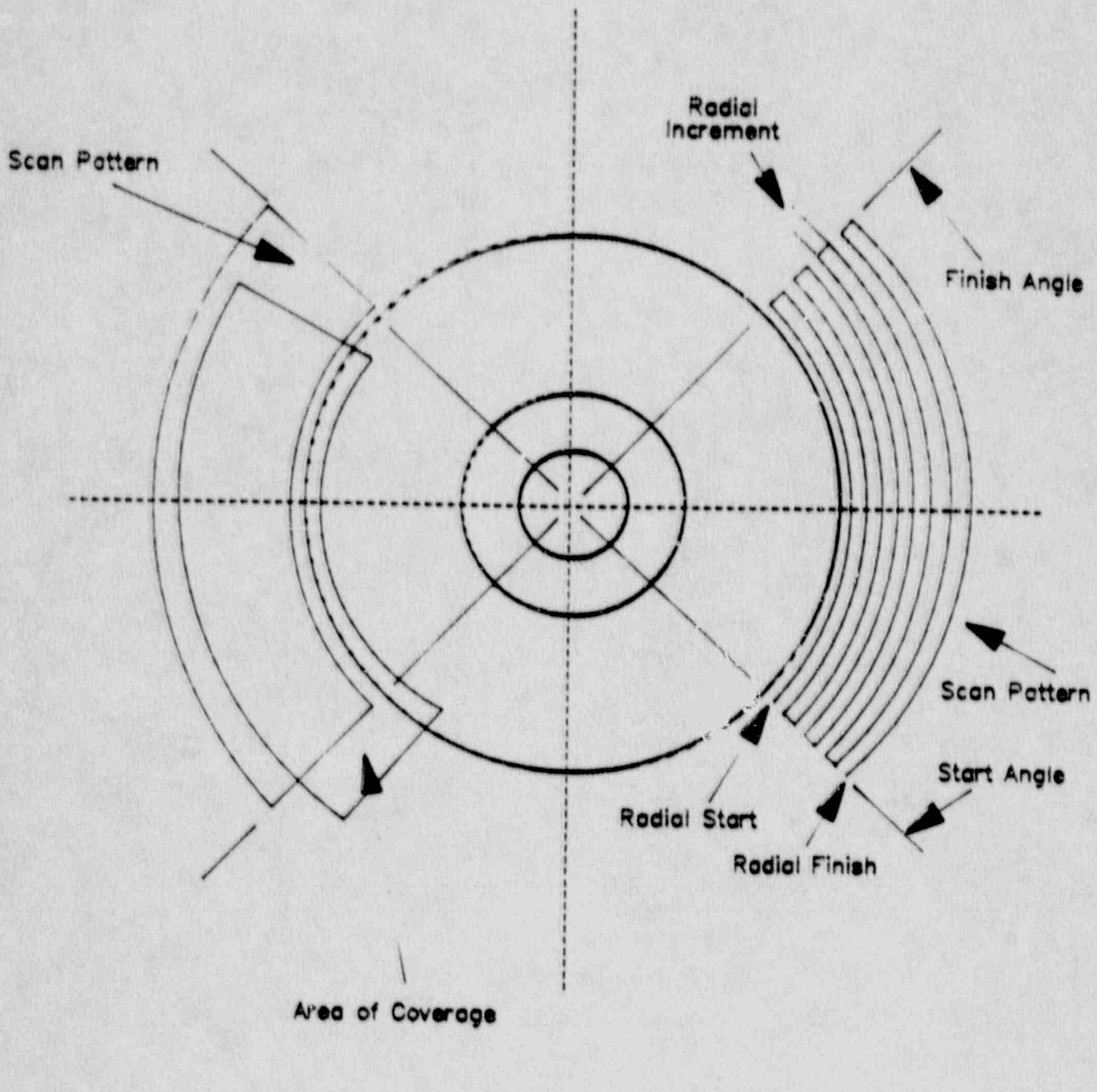
AXIAL SHOULDER SCAN
(For sizing of circumferential flaws in bore)



AXIAL SHOULDER SCAN
(For circumferential flaws in bore)

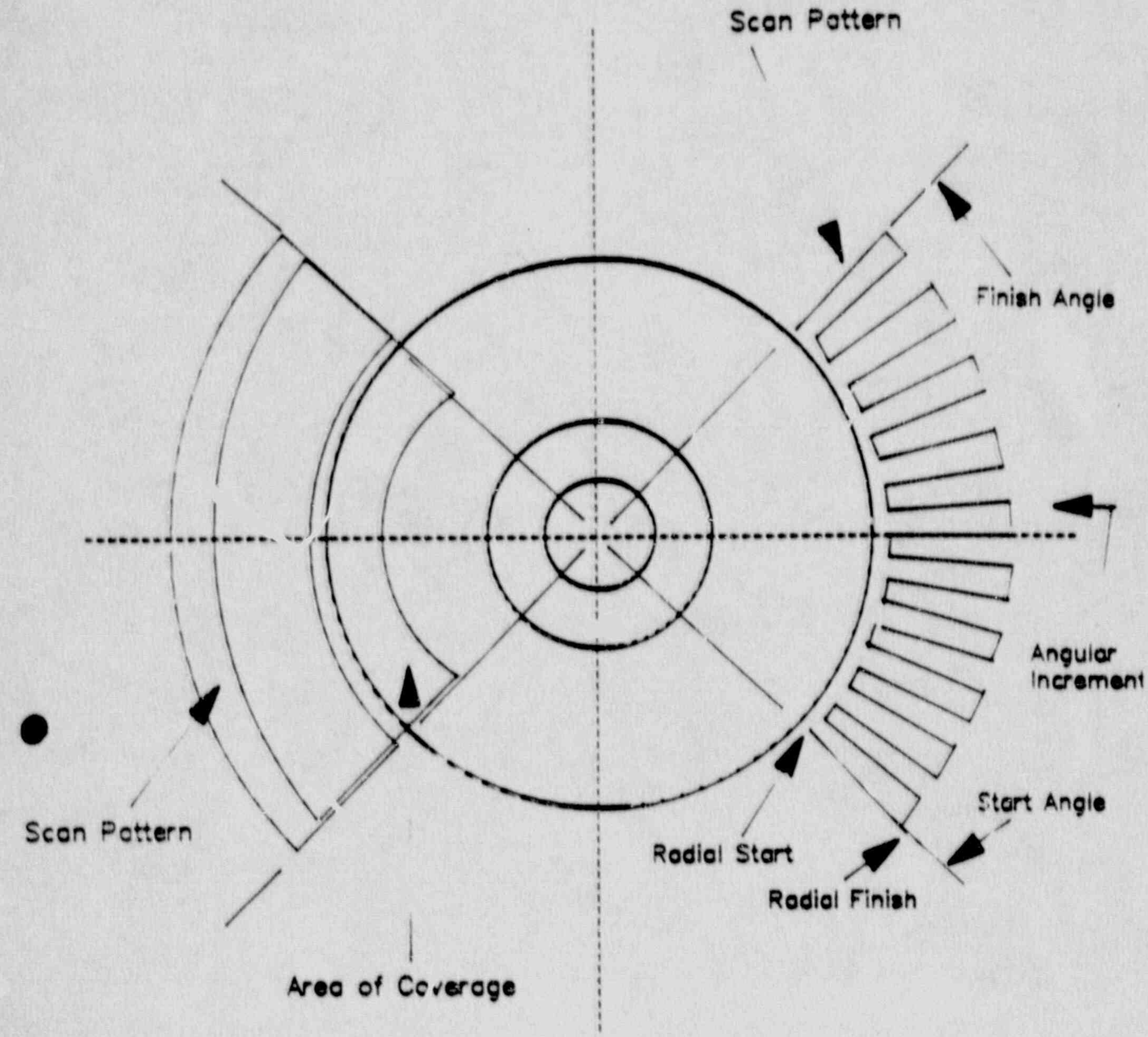


CIRCULAR SCAN
(For pipe side radial flaws)



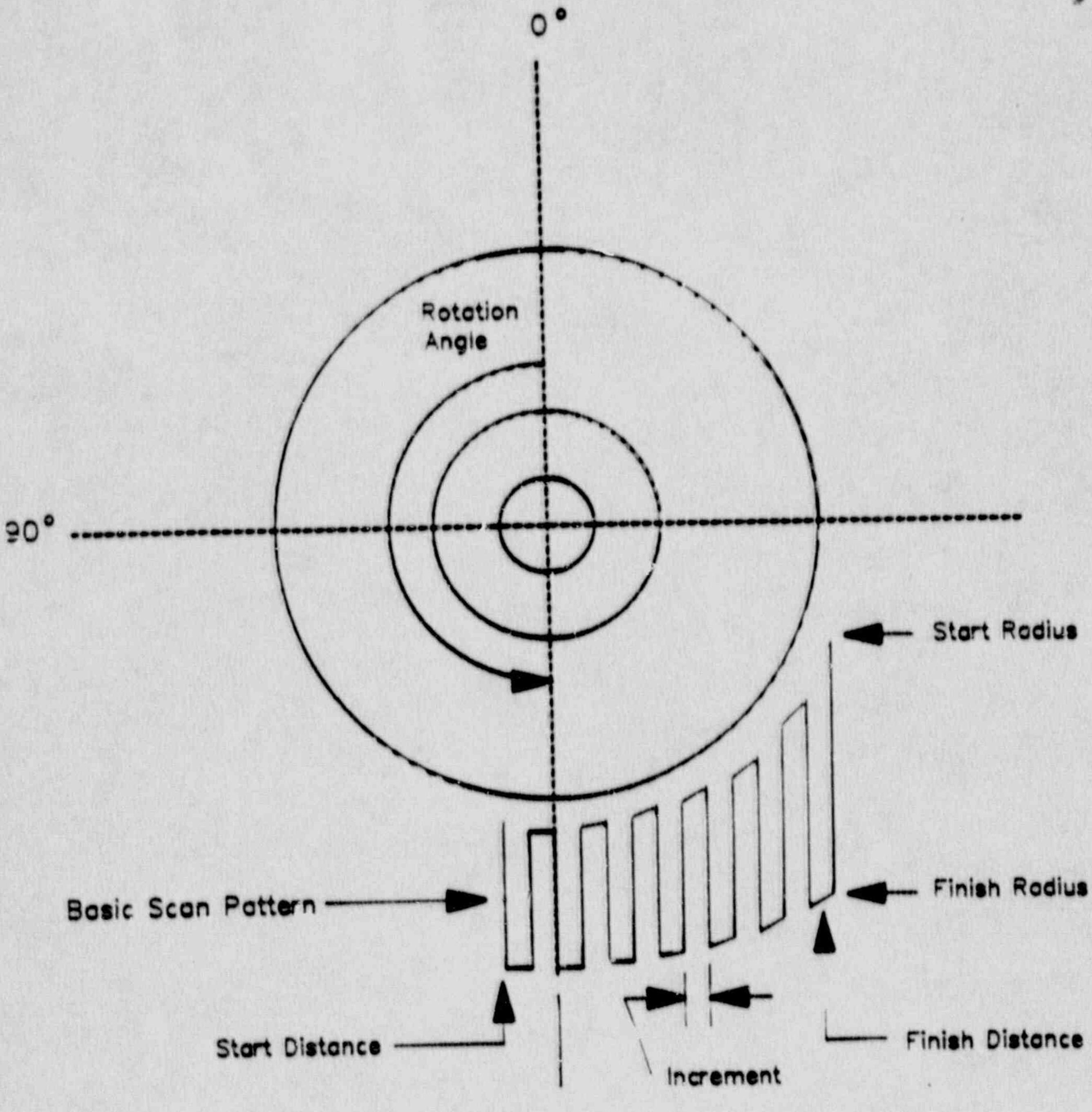
RADIAL SCAN

(For pipe side circumferential flaws)



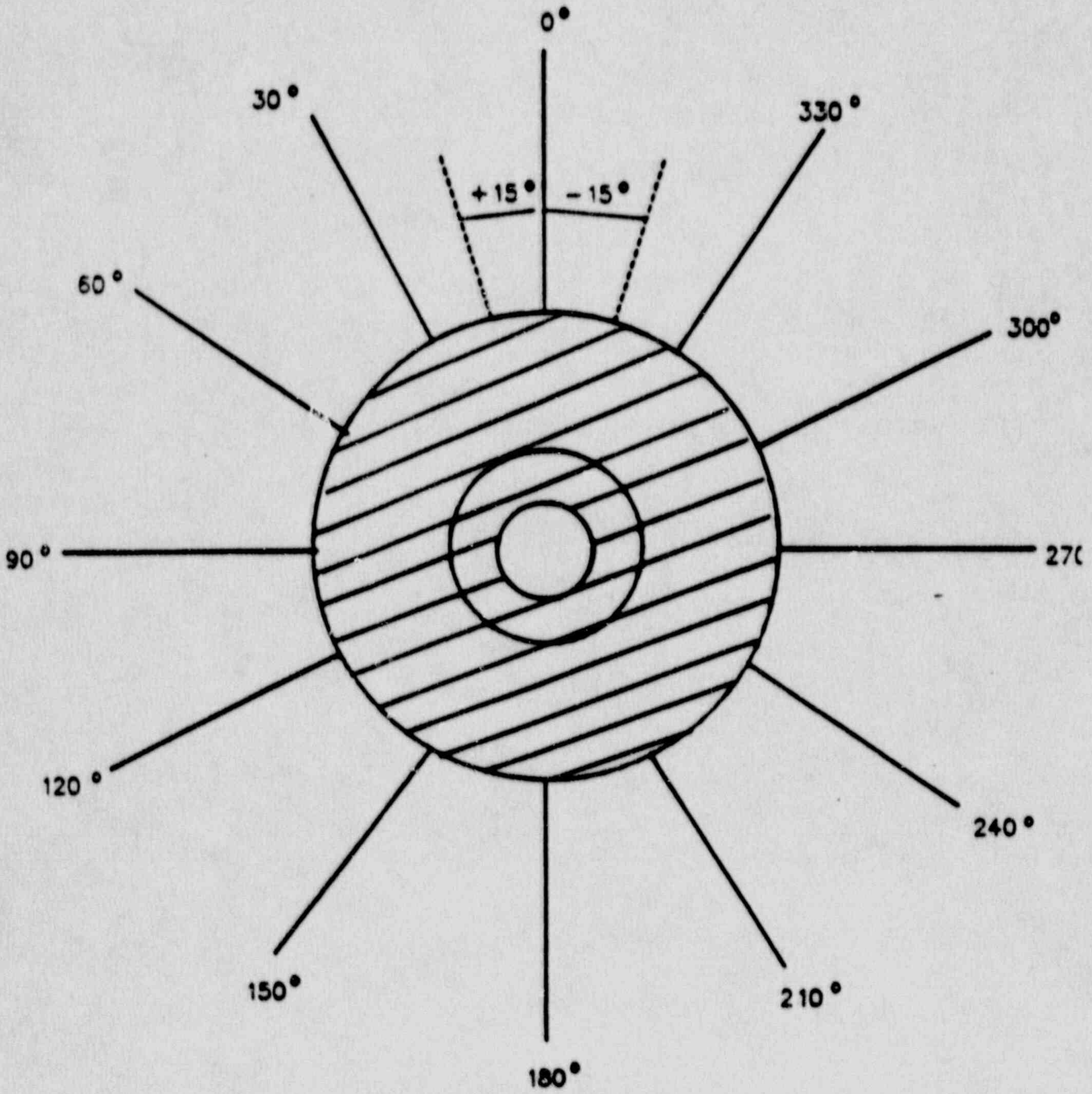
TANGENT SCAN

(For axial flaws in the bore and radial and circumferential flaws in the knuckle)



TANGENT SCAN

(For axial flows in the bore and radial and circumferential flows in the knuckle)



Rotation Angles

SEARCH UNIT AND TRANSDUCER SELECTION

Nominal Beam Angle (Degrees)	Detection Diameter/Frequency (Inch)	Detection Diameter/Frequency (MHz)	Sizing Diameter/Frequency (Inch)	Sizing Diameter/Frequency (MHz)	Element	Application
45 S	3/8	1.5			Single-Flat	Axial Scan on Taper
45 S & L 60 S & L			3/8 3/8	5.0 5.0	Single-Flat Single-Flat	Axial Scan on Shoulder of Nozzle
45 S	1/2	2.25	1/2	5.0	Single-Flat	Radial Scan on Main Pipe
45 S	1/2	2.25	1/2	5.0	Single-Flat	Circular Scan on Main Pipe
57 S & L 66 S & L 75 S & L	1/2 1/2 1/2	2.25 2.25 2.25	1/2 1/2 1/2	5.0 5.0 5.0	Single-Flat Single-Flat Single-Flat	Tangential Scan on Main Pipe

HPI PROGRAM TEST RESULTS

<u>EPRI TEST BLOCKS</u>

* BLIND SAMPLES
* EDM NOTCHES AND THERMAL FATIGUE CRACKS

FLAW POPULATION: 34

8 CRACKS
26 NOTCHES

DETECTION RATE: 100%

SIZING RESULTS:

OVERALL PERFORMANCE
RMS ERROR: 0.064"
STD. DEV.: 0.062"

CRACKS
RMS ERROR: 0.062"
STD. DEV.: 0.029"

NOTCHES
RMS ERROR: 0.060"
STD. DEV.: 0.042"

HPI PROGRAM TEST RESULTS

BATTELLE BLOCKS

* BLIND SAMPLES
* THERMAL FATIGUE CRACKS

FLAW POPULATION: 9

SIZING RESULTS:

TO BE SUPPLIED LATER BY BATTELLE

HPI PROGRAM TEST RESULTS

HPI NOZZLE MOCKUP

* EDM NOTCHES
* CLAD CRACKS

FLAW POPULATION: 17

5 CLAD CRACKS
12 NOTCHES
(8 NOTCHES => 0.125" PENETRATION INTO BASE METAL)

DETECTION RATE:

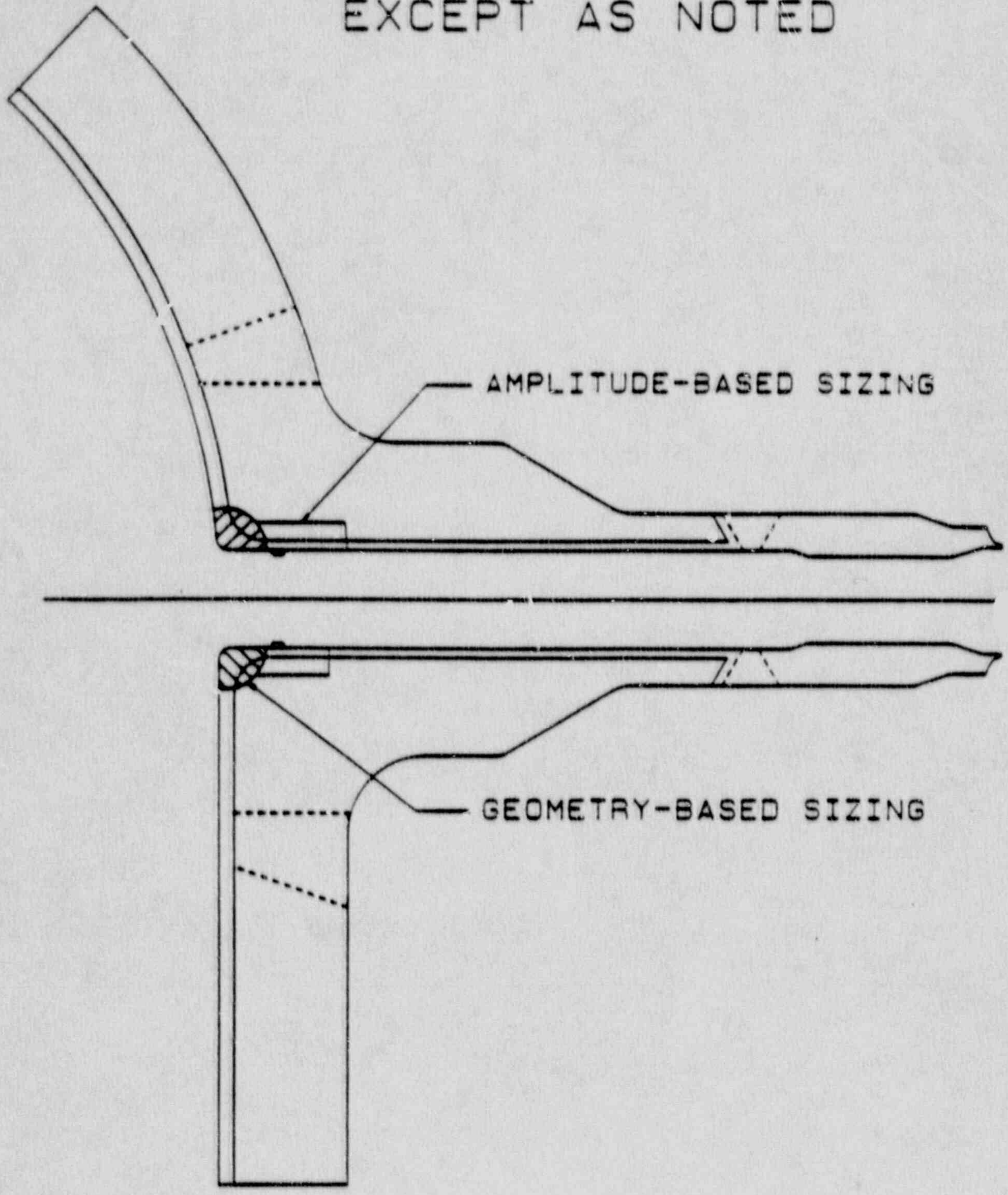
100 % OF ALL FLAWS => 0.125" PENETRATION INTO BASE METAL

SIZING RESULTS:

TIME-OF-FLIGHT SIZING

RMS ERROR: 0.081
STD. DEV.: 0.035

TIME-OF-FLIGHT SIZING THROUGHOUT EXCEPT AS NOTED



SUPPLEMENTAL SIZING TECHNIQUES WILL BE APPLIED ON A CASE BY CASE BASIS FOR ANY DETECTED FLAWS

ENHANCED UT DEVELOPMENT

CONCLUSIONS

- SCANNING ZONE ENCOMPASSES AREA OF OBSERVED SURFACE INDICATIONS AND PREVIOUS EXPOSURE TO COLD MAKEUP WATER WITH A MARGIN

- FLAWS PENETRATING INTO BASE METAL CAN BE RELIABLY DETECTED IN SIZES WELL BELOW DEPTH REQUIRING ADDITIONAL REINFORCEMENT

- FLAWS WITHIN REGIONS FOR TIME-BASED SIZING CAN BE RELIABLY SIZED

- SIZING OF FLAWS DETECTED IN OTHER REGIONS WILL BE SUPPLEMENTED BY LOCALIZED TECHNIQUES

- LONGITUDINAL WAVE SCAN WILL BE USED TO OBSERVE FLAWS IN CLADDING IN THE ZONE OF CONCERN

ENHANCED UT MEETING

January 18, 1990

Lynchburg Va

John ?. Concklin	BWNS	804 385 0335
MICHAEL D. SHEPHERD	TED	419/249-2440
Stan Walker	EPRI NDE Center	704/547-6031
Tom Taylor	PNL	509/375-2858
Mike Brophy	BWNS	(804) 847-3765
Frank Litton	NRC	
MIKE HACKER	BWNS	804-847-3788
John Shepard	BWNS	804-385-2754
H. J. CORDLE	TOLEDO EDISON	419-321-7712

Docket Number 50-346
License Number NPF-3
Serial Number 1768
Attachment 2

DAVIS-BESSE NUCLEAR POWER STATION
HPI/MAKEUP NOZZLE PROGRAM

PRESENTED TO:

NUCLEAR REGULATORY COMMISSION

BY:

TOLEDO EDISON

AND

STRUCTURAL INTEGRITY ASSOCIATES

JANUARY 24, 1990

DAVIS-BESSE NUCLEAR POWER STATION
HPI/MAKEUP NOZZLE PROGRAM

AGENDA

I. Brief Review of Overall Program

II. Fracture Mechanics Analysis Update

- Finite Element Analysis
- Allowable Crack Size
- Experimental Verification of pc-CRACK Model

III. Weld Overlay Repair Development

- Design Approach
- Welding Development
- Post Repair NDE
- Study of Potential for Crack Growth During Welding

IV. Discussion

89-001PR

HPI/MAKEUP NOZZLE - A1
THERMAL SLEEVE FRAGMENTS FOUND
July 2, 1988

TWO PIECES FROM END FOUND BELOW REACTOR CORE

FAILURE ATTRIBUTED TO THERMAL FATIGUE

FAILURE EXPOSES END OF NOZZLE TO COLD MAKEUP WATER

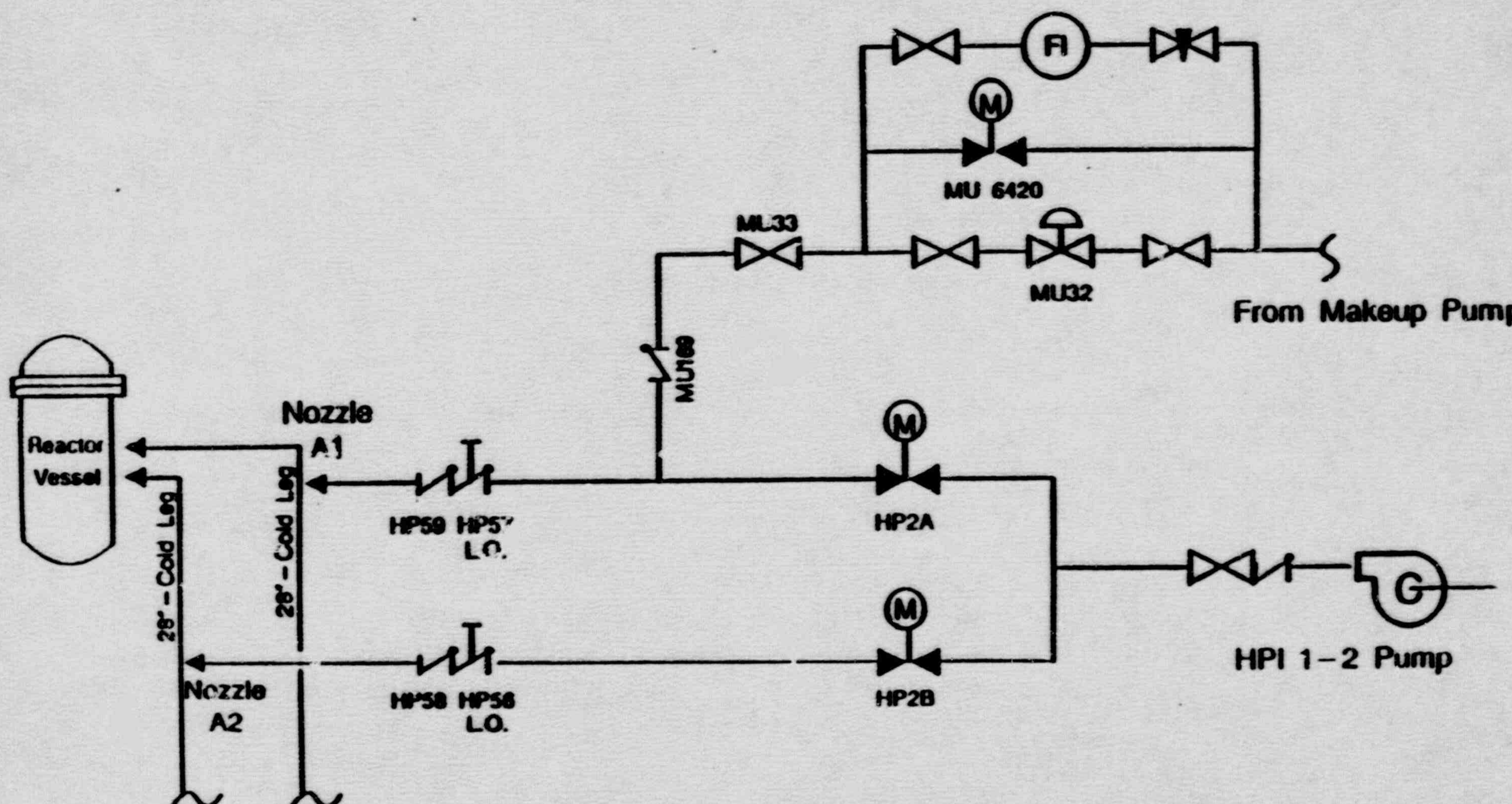
PT INDICATIONS SEEN IN NOZZLE IN AREA EXPOSED

INDICATIONS ATTRIBUT[illegible]O THERMAL FATIGUE

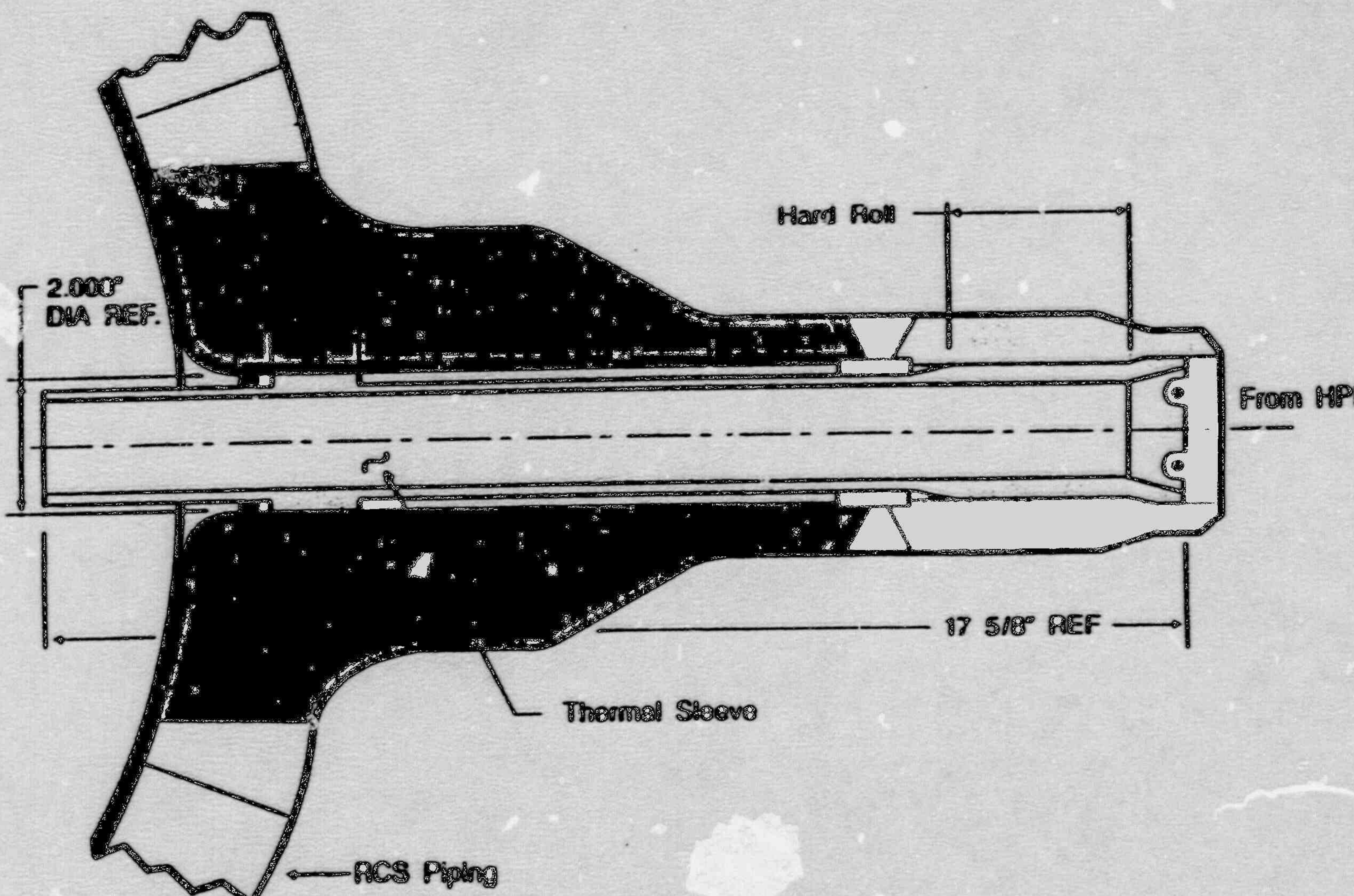
ANALYSIS INDICATES CRACK GROWTH NOT EXPECTED WITH EFFECTIVE THERMAL SLEEVE IN PLACE

UT UTILIZED AT THE TIME FOUND NO EVIDENCE OF FLAWS IN BASE METAL

MU/HPI Flow Configuration



Makeup/HPI Nozzle Replacement
Thermal Sleeve Design



NRC APPROVED RETURN TO POWER
BASED UPON SUBMITTAL

SERIAL NUMBER 1580, SEPTEMBER 14, 1988

COMPLETED COMMITMENTS

- INCREASED MINIMUM BYPASS MAKEUP FLOW
- IMPROVED CONTROL OVER MAKEUP FLOW
- REPLACEMENT OF THERMAL SLEEVE

RECENT SUBMITTAL TO NRC
EXPLAINS TOLEDO EDISON PLANS

SERIAL NUMBER 1664, JUNE 19, 1989

- RE-ROUTE THE MAKEUP FLOW PATH TO HPI NOZZLE, A2
- FIBER-OPTIC EXAMINATION OF HPI/MAKEUP THERMAL SLEEVE
- ENHANCED UT OF THE HPI/MAKEUP NOZZLE (A1) FROM THE OUTSIDE
- ENHANCED UT OF ALTERNATE NOZZLE (A2) TO PROVIDE BASELINE INFORMATION

OUTAGE PLANS
6TH REFUELING OUTAGE

- PLANT OFF LINE - JANUARY 31, 1990

- NOMINAL OUTAGE DURATION - FOUR MONTHS

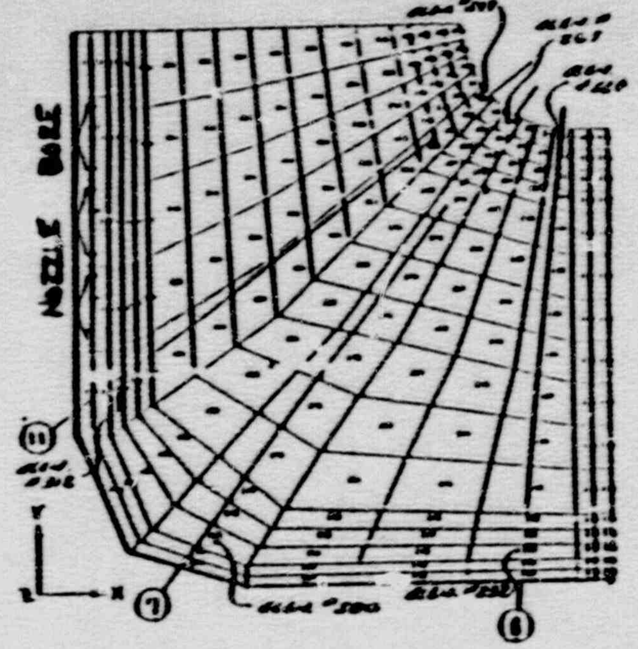
- NOZZLE AND THERMAL SLEEVE EXAMINATIONS TO BEGIN AS SOON AS CONTAINMENT ACCESS IS POSSIBLE - END OF 1ST WEEK IN FEBRUARY

- OUTAGE DURATION IS DEPENDENT ON ALL HPI NOZZLE AND THERMAL SLEEVE INSPECTIONS AND RELATED REMEDIAL ACTIONS BEING COMPLETED BY APRIL 12, 1990

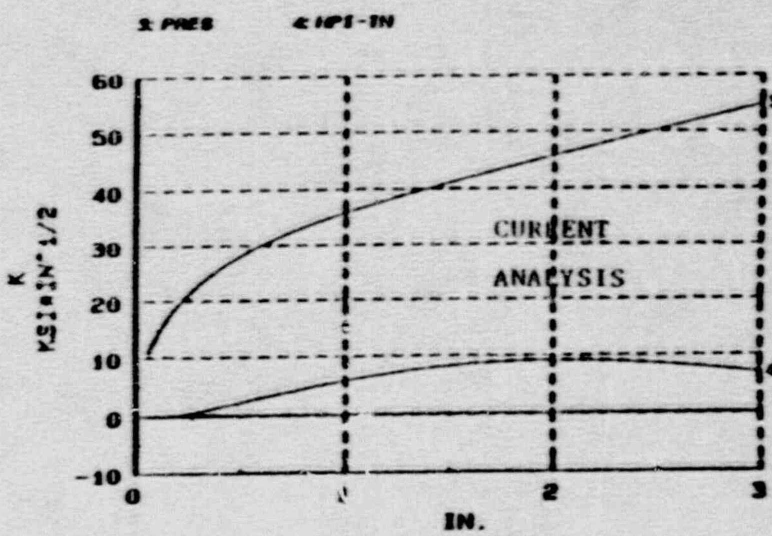
II. FRACTURE MECHANICS ANALYSIS UPDATE

- Original F.M. Analysis by B&W Performed to Address Cladding Only Cracking Observed During 05R
  - Section XI Allowable Flaw Size = 0.5"
  - Clad Depth Cracking (0.2") Not Predicted to Grow to This Depth in 40 Years
- F.M. Analysis Updated as Basis for Weld Overlay Design
  - Section XI Allowable Flaw Size Essentially Through-Wall (Leak-Before-Break)
  - Flaw Size Above Which Weld Overlay Required = 1.6" Based on Nozzle Reinforcement Requirements
  - In Summary - No Brittle Fracture Concern
    - Overlay Design Based on Ductile Limit Load Considerations as in Stainless Steel Pipe

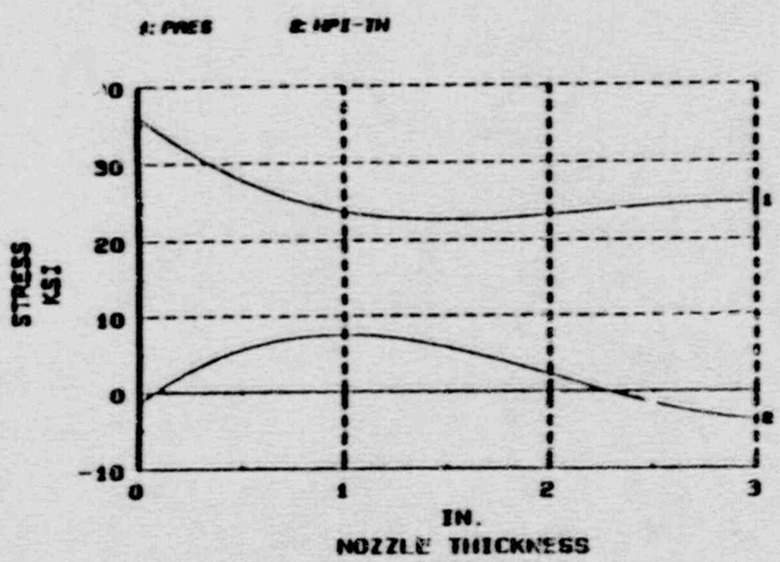
90-002PR



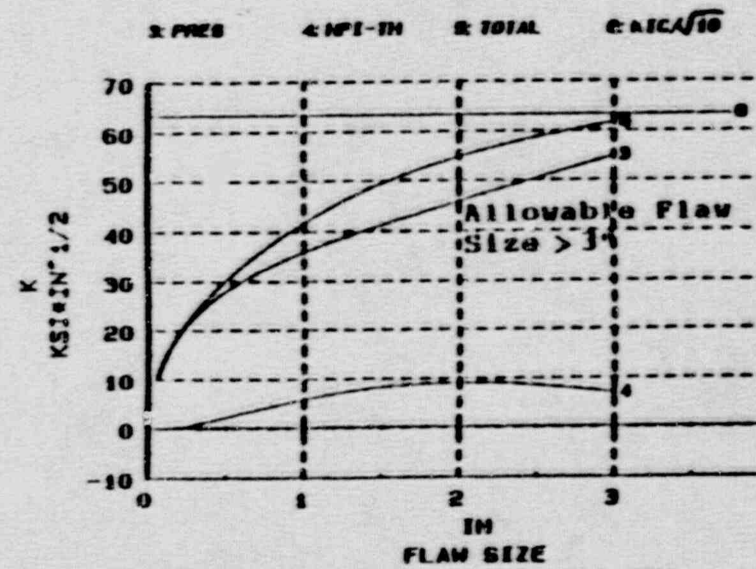
2-1A - Finite Element Model



2-1C - STRESS INTENSITIES



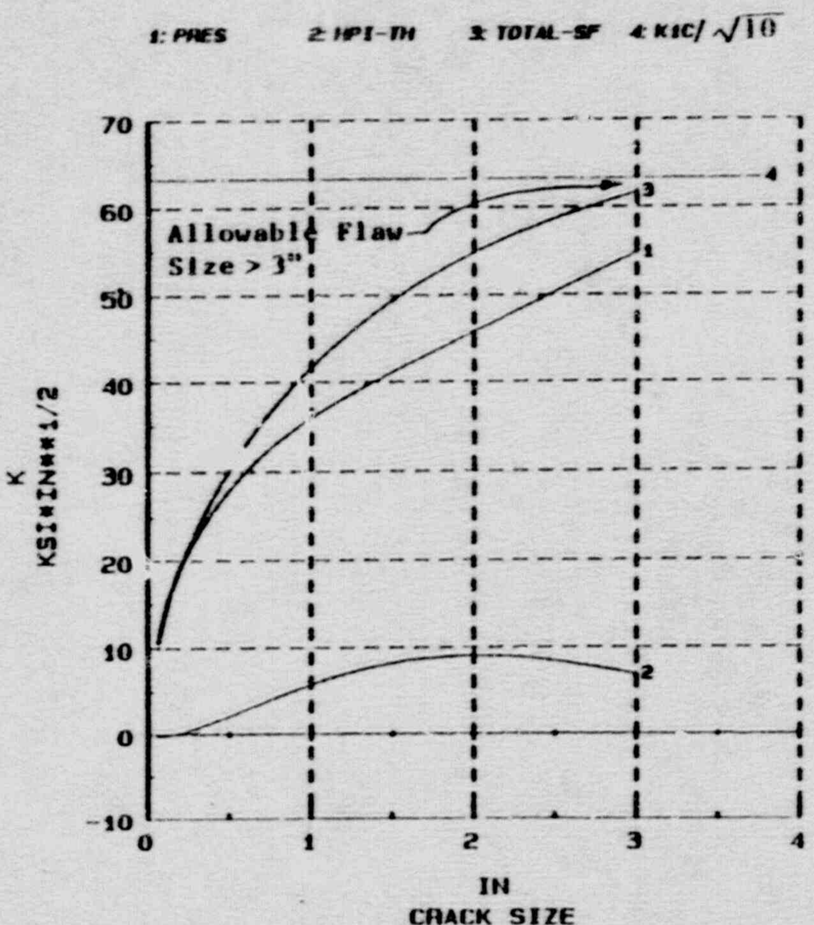
2-1B - STRESS DATA



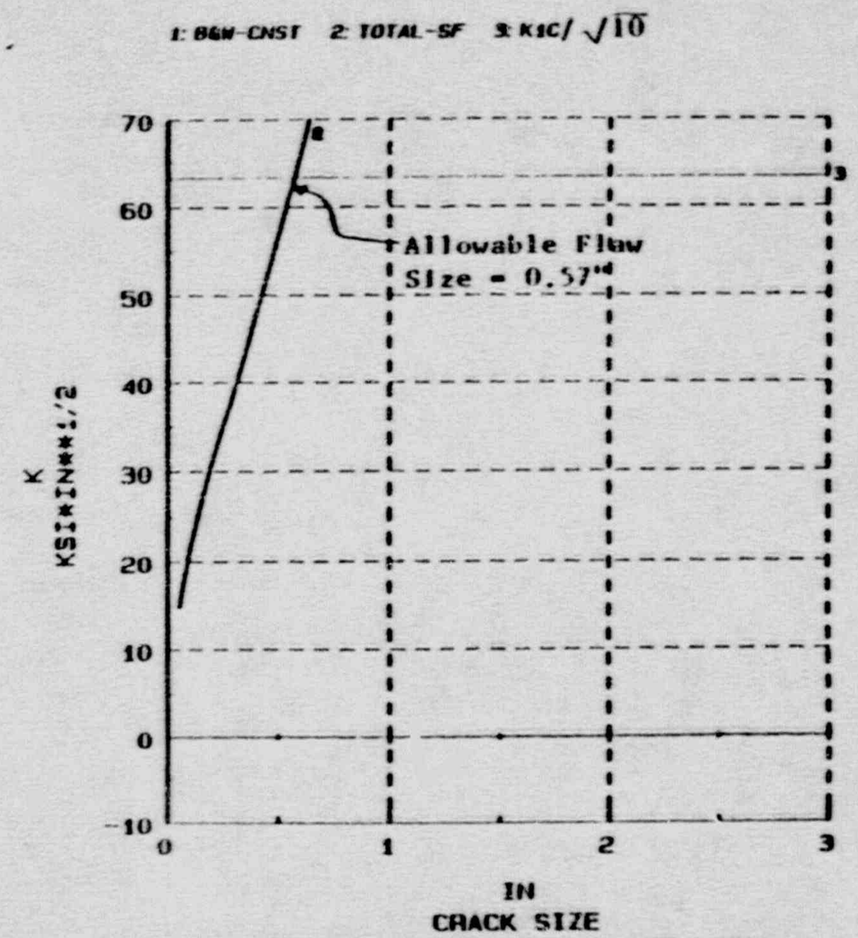
2-1D - ALLOWABLE FLAW DEPTH

ASME Section XI Allowable Flaw Depth Determination

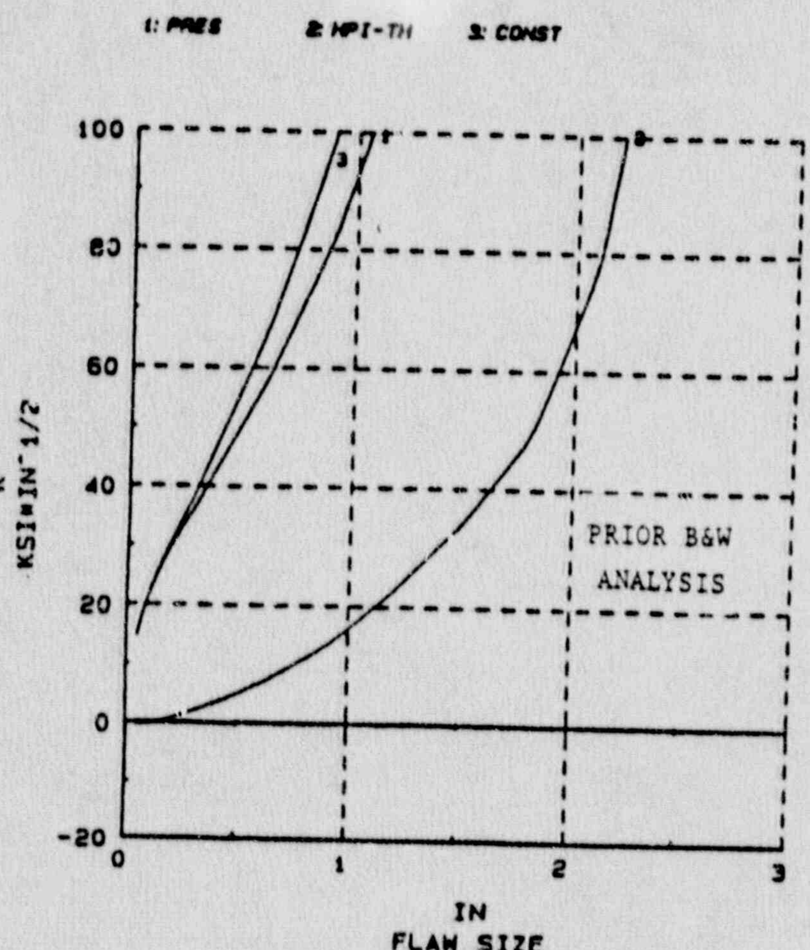
Allowable Flaw Size Evaluation



NOZZLE CORNER CRACK MODEL



SINGLE-EDGE CRACKED PLATE MODEL



2-2A - STRES^ INTENSITIES

VERIFICATION OF pc-CRACK NOZZLE CORNER CRACK MODEL

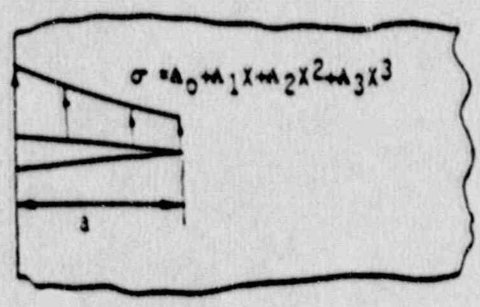
(WITH RESPECT TO JAERI EXPERIMENT)

- Nozzle Corner Crack Modeled Using Standard pc-CRACK Technology

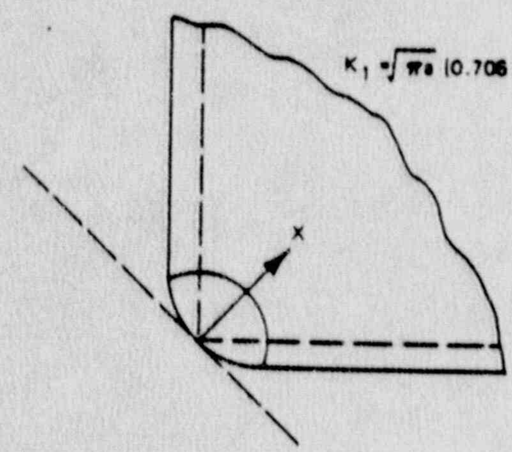
- Fatigue Crack Growth Simulated Using Air Crack Growth Law

- Results Agreed Well With Experimental Crack Growth Predictions

90-004PR



$$K_1 = \sqrt{\pi a}\,\left(0.706\,A_0 + 0.537\left(\frac{2a}{\pi}\right)A_1 + 0.448\left(\frac{a^2}{2}\right)A_2 + 0.393\left(\frac{4a^3}{3\pi}\right)A_2\right)$$



pc-CRACK Nozzle Corner Crack Model

EXPERIMENTAL VERIFICATION OF PC-CRACK MODEL

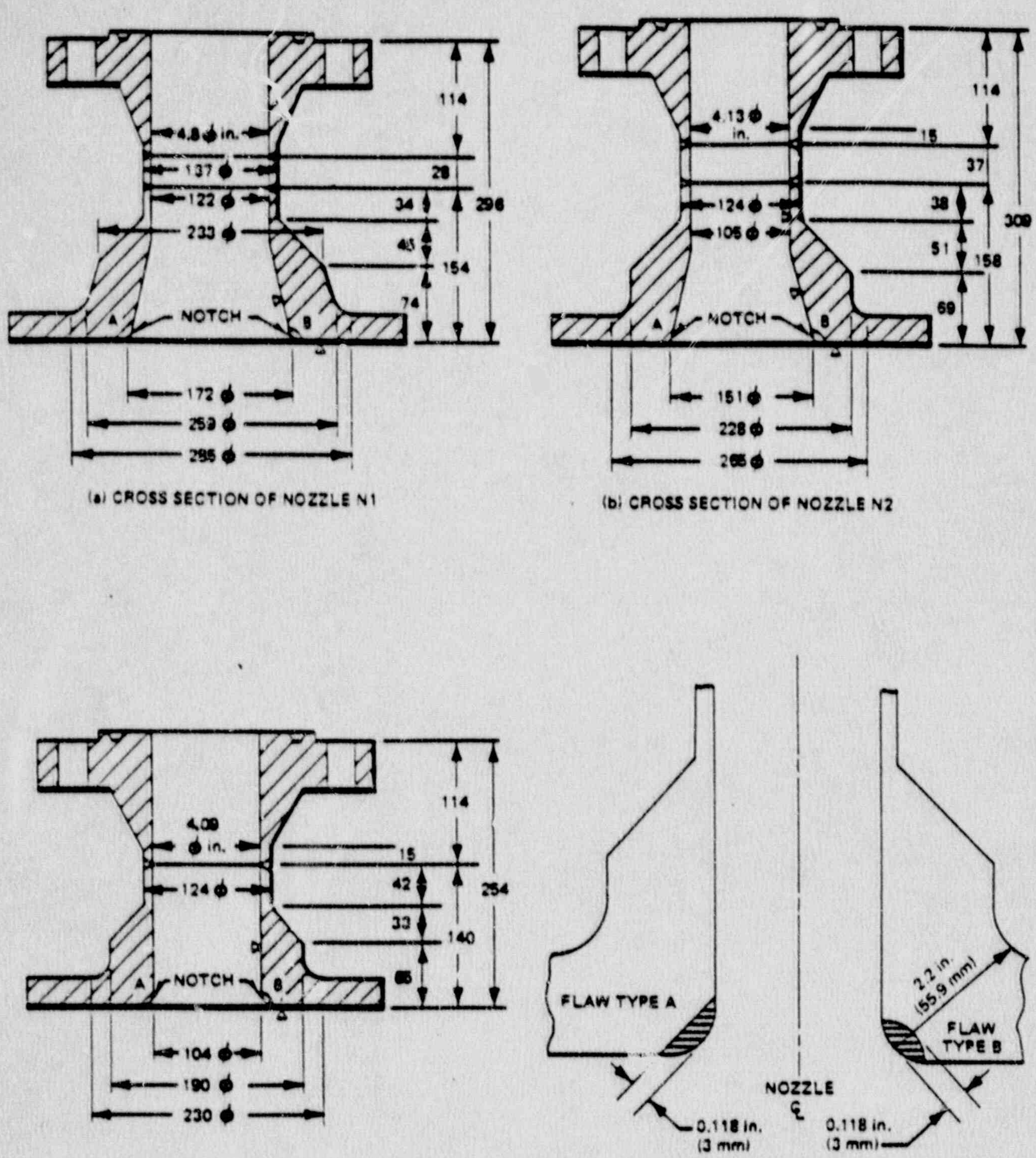
JAERI CRACK GROWTH EXPERIMENT

- Scale Model Pressure Vessel
  - Low Alloy Steel
  - Diameter = 40 in.
  - Wall Thickness = 0.6 in.

- Several Nozzles w/Simulated Corner Flaws
  - Nozzle Thickness 2.2 in.
  - Initial Flaw Depth = 0.12 in.

- Cyclically Pressurized to Failure
  - 0 - 1566 psi - 0
  - 30,000 Cycles

- Failure Defined as Leakage from Nozzle
  i.e., Leak-Before Break



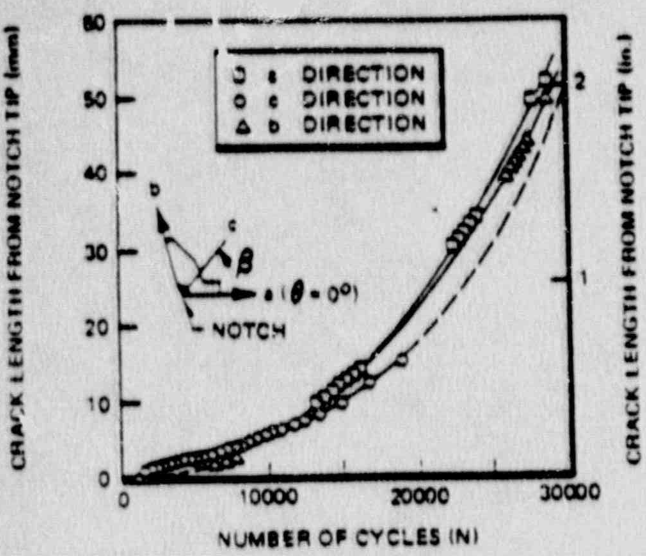
(a) CROSS SECTION OF NOZZLE N1

(b) CROSS SECTION OF NOZZLE N2

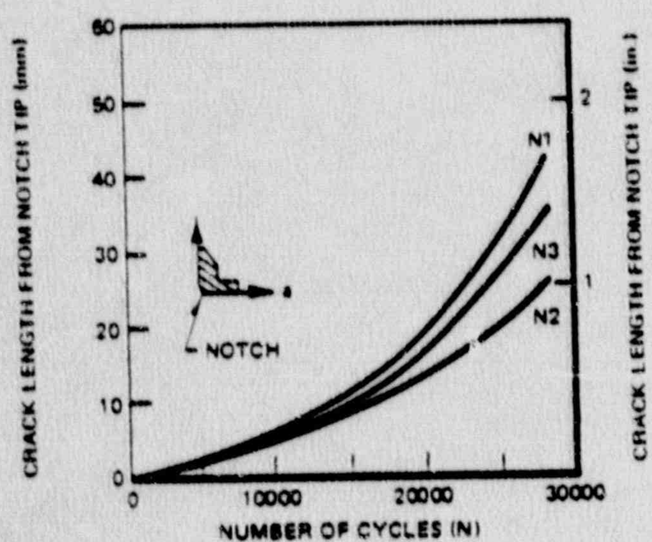
(c) CROSS SECTION OF NOZZLE N3

(d) MACHINED FLAW TYPE ILLUSTRATED

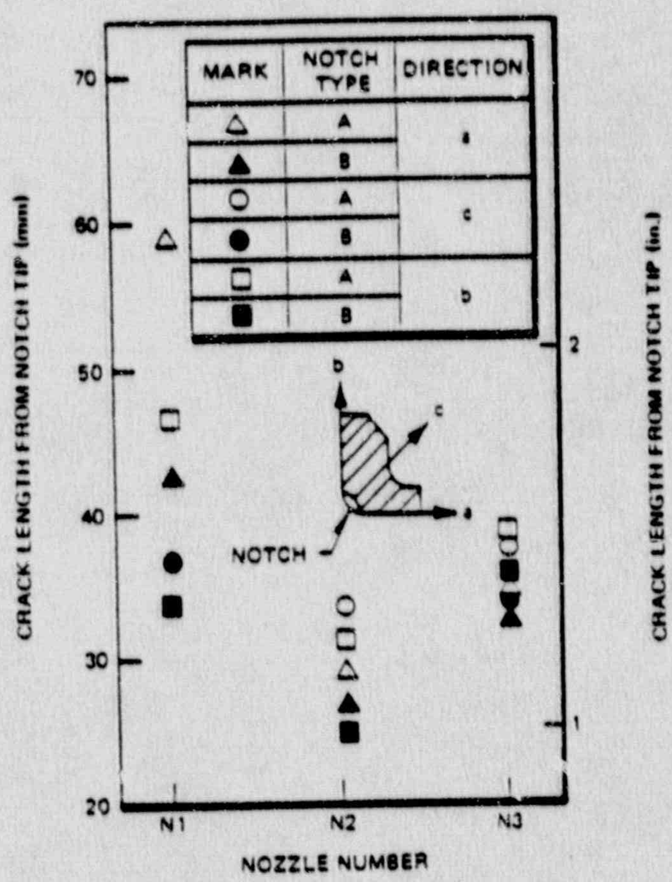
Flawed Nozzles Used in JAERI Crack Growth Experiment



(a) CRACK LENGTH FROM NOTCH TIP OF FLAW TYPE A FOR NOZZLE N1

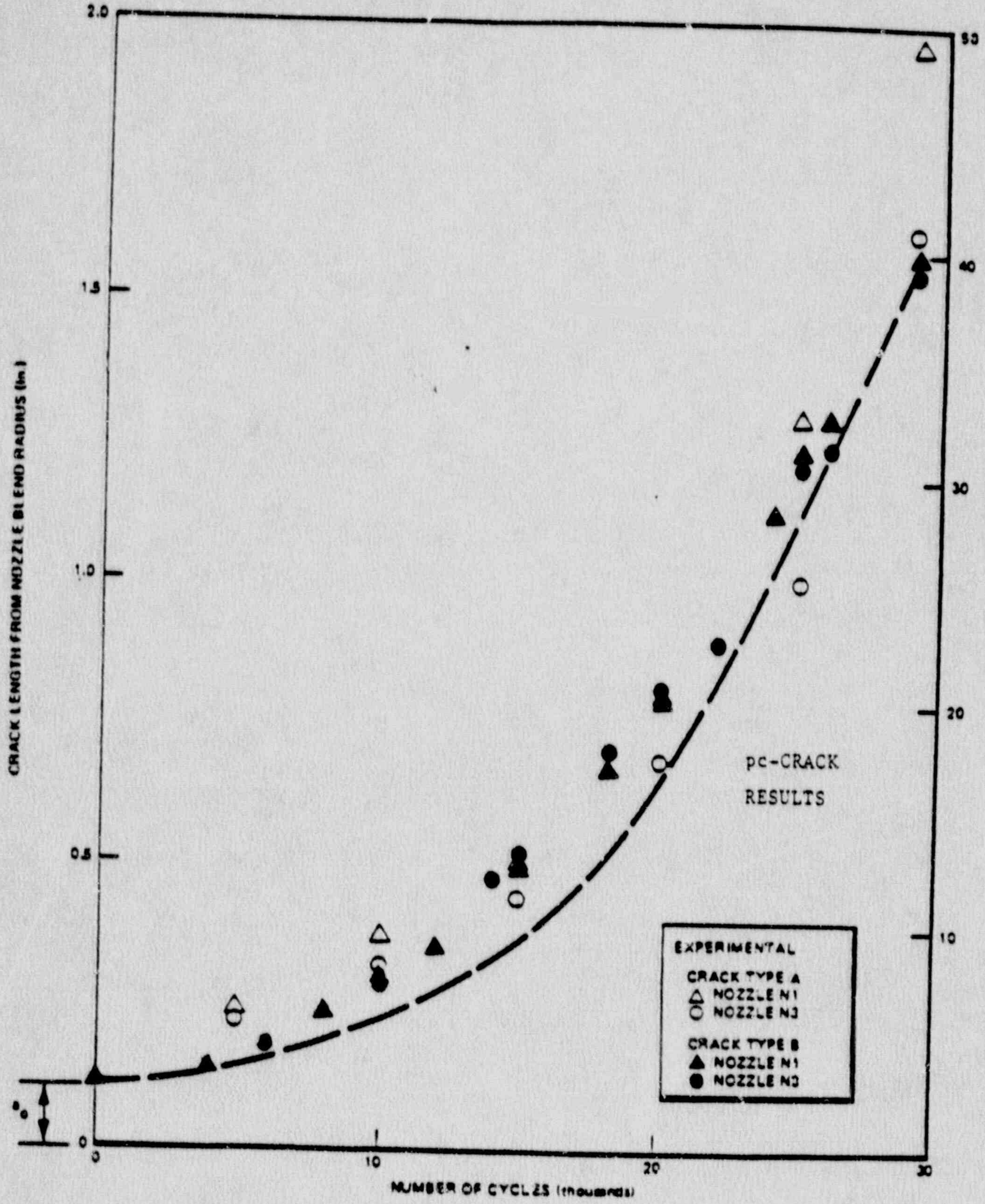


(b) CRACK LENGTH FROM NOTCH TIP FOR FLAW TYPE B IN a–DIRECTION (SHELL SIDE) FOR N1, N2 AND N3 NOZZLES



(c) CRACK LENGTH FROM NOTCH TIP FOR a–, b–, AND c–DIRECTION OF N1, N2 AND N3 NOZZLES

JAERI Experimental Crack Growth Results



Verification of pc-CRACK Nozzle Corner Crack Model
With Respect to JAERI Crack Growth Experiments

III. WELD OVERLAY REPAIR DEVELOPMENT

- Design Approach
  - Nozzle Reinforcement Requirements
  - Reinforcement as a Basis for Weld Overlay Design
- Welding Procedure Development
  - Mockup/Procedure Development
  - Procedure Qualification
- Post-Repair NDE
- Study of Potential for Crack Growth During Welding

90-0C6PR

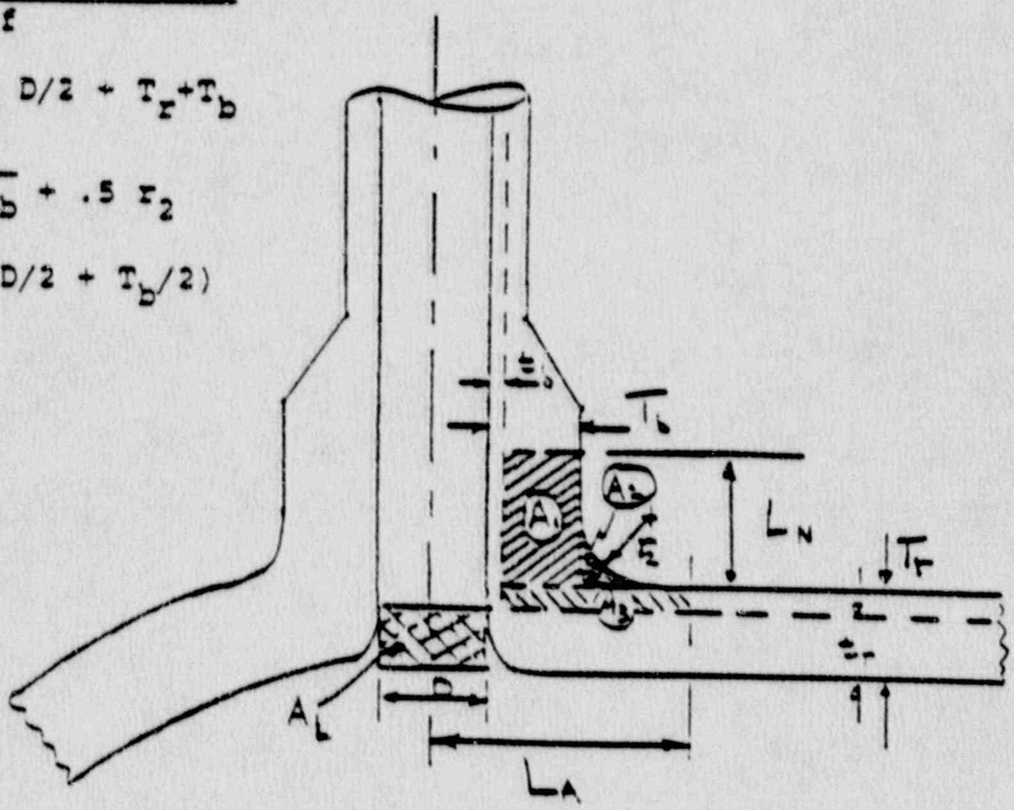
DAVIS-BESSE HPI NOZZLE REINFORCEMENT REQUIREMENTS

LIMITS OF REINFORCEMENT
Greater of

$L_A = D$ (or) $D/2 + T_r + T_b$

$L_N = .5\sqrt{r_m T_b} + .5\ r_2$

$(r_m = D/2 + T_b/2)$



AREA REQUIRED TO BE REPLACED:

$A_L = Dt_r$

AREA AVAILABLE FOR REINFORCEMENT:

$$[A_1 + A_2 + A_3] \times \frac{S_m \text{ Nozz.}}{S_m \text{ Run}}$$

where: $A_1 = 2\ L_N\ (T_b - t_b)$

$A_2 = 2(r_2^{\ 2} - \frac{\pi}{4} r_2^{\ 2}) = .43\ r_2^{\ 2}$

$A_3 = 2(L_A - D/2 - t_b)(T_r - t_r)$

REINFORCEMENT REQUIREMENTS AS A BASIS FOR WELD OVERLAY DESIGN

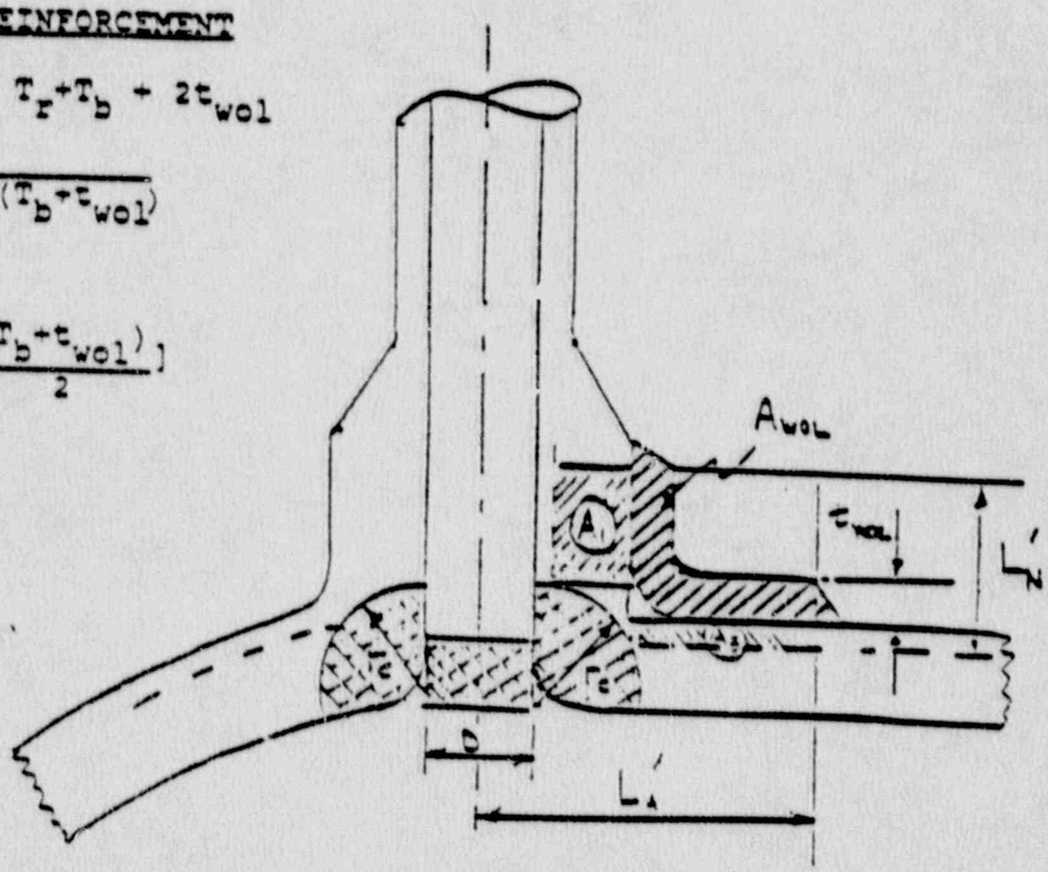
LIMITS OF REINFORCEMENT

$L'_A = D/2 + T_r + T_b + 2t_{wol}$

$L'_N = .5\sqrt{r_m(T_b + t_{wol})}$

$+ .5r_2$

$[r_m = D/2 + \frac{(T_b + t_{wol})}{2}]$



AREA REQUIRED TO BE REPLACED:

$A = Dt_r + \pi r_c^2/2$

AREA AVAILABLE FOR REINFORCEMENT:

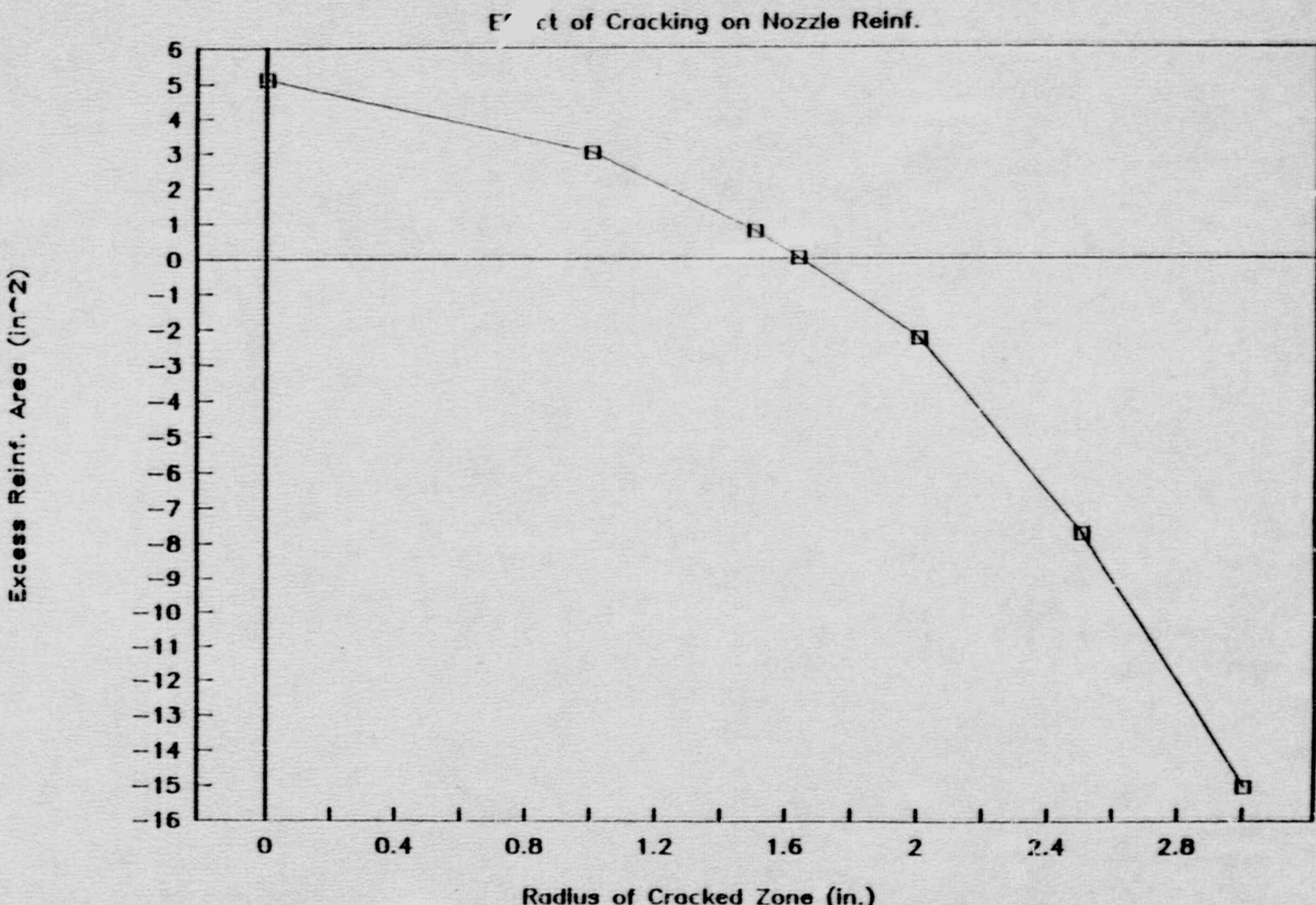
$A_1 = 2\ (L'_N - X)\ (T_b - t_b)$ $\qquad X = (r_c - t_r)$ if>0

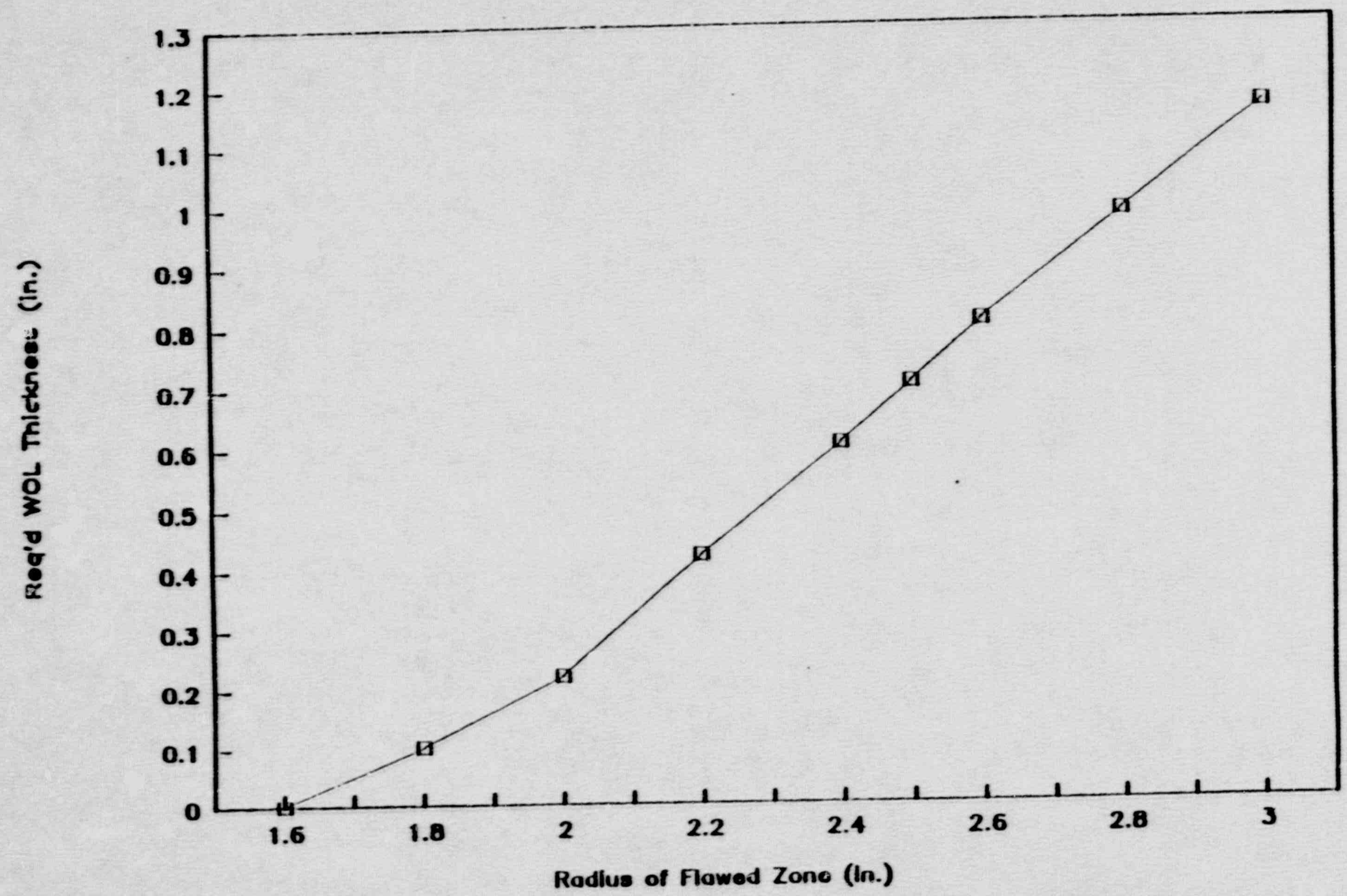
= 0 otherwise

$A_3 = 2(L'_A - D/2 - r_c)\ (T_r - t_r)$

$A_{wol} = [t_{wol} \times (L'_N - (T_r - t_r)) + t_{wol}(L'_A - D/2 - T_b - t_{wol})] \times 2$

DAVIS-BESSE HPI NOZZLE



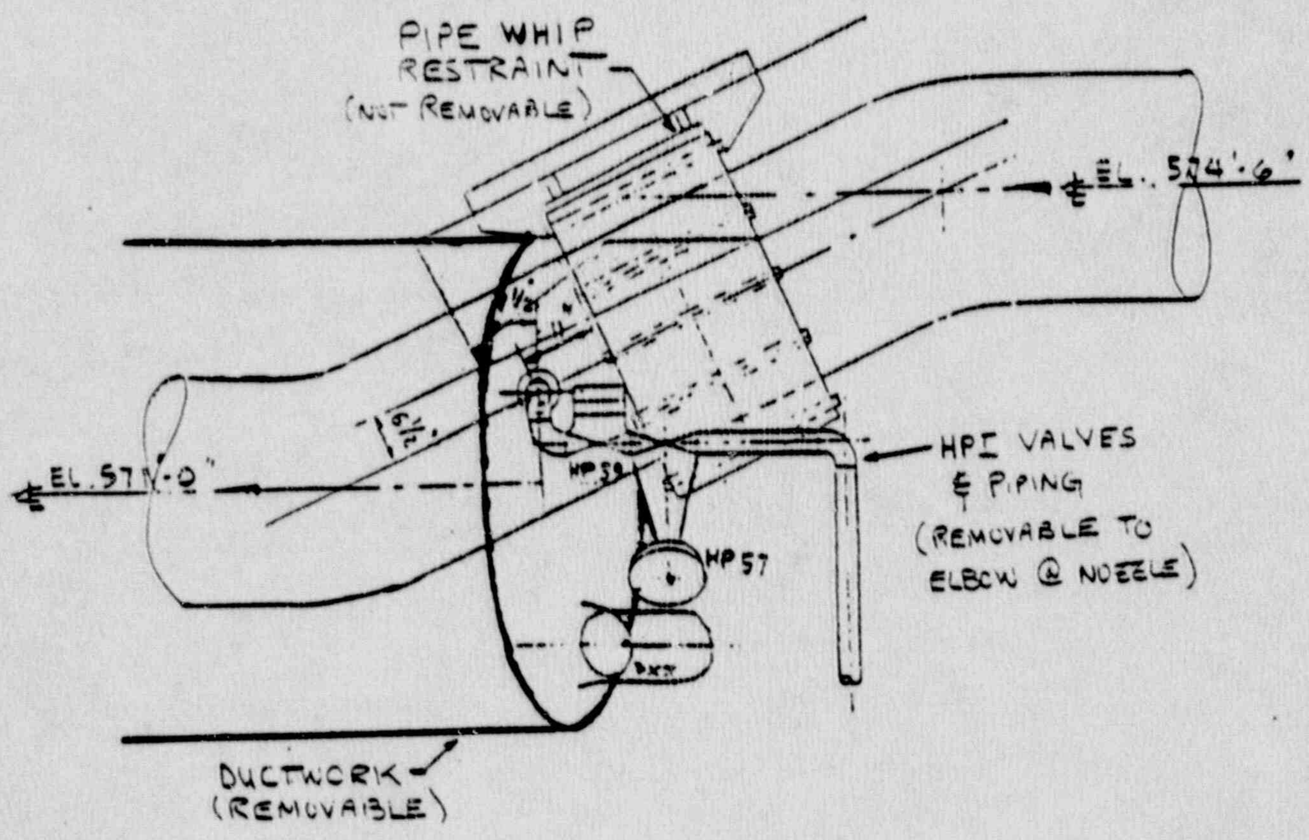


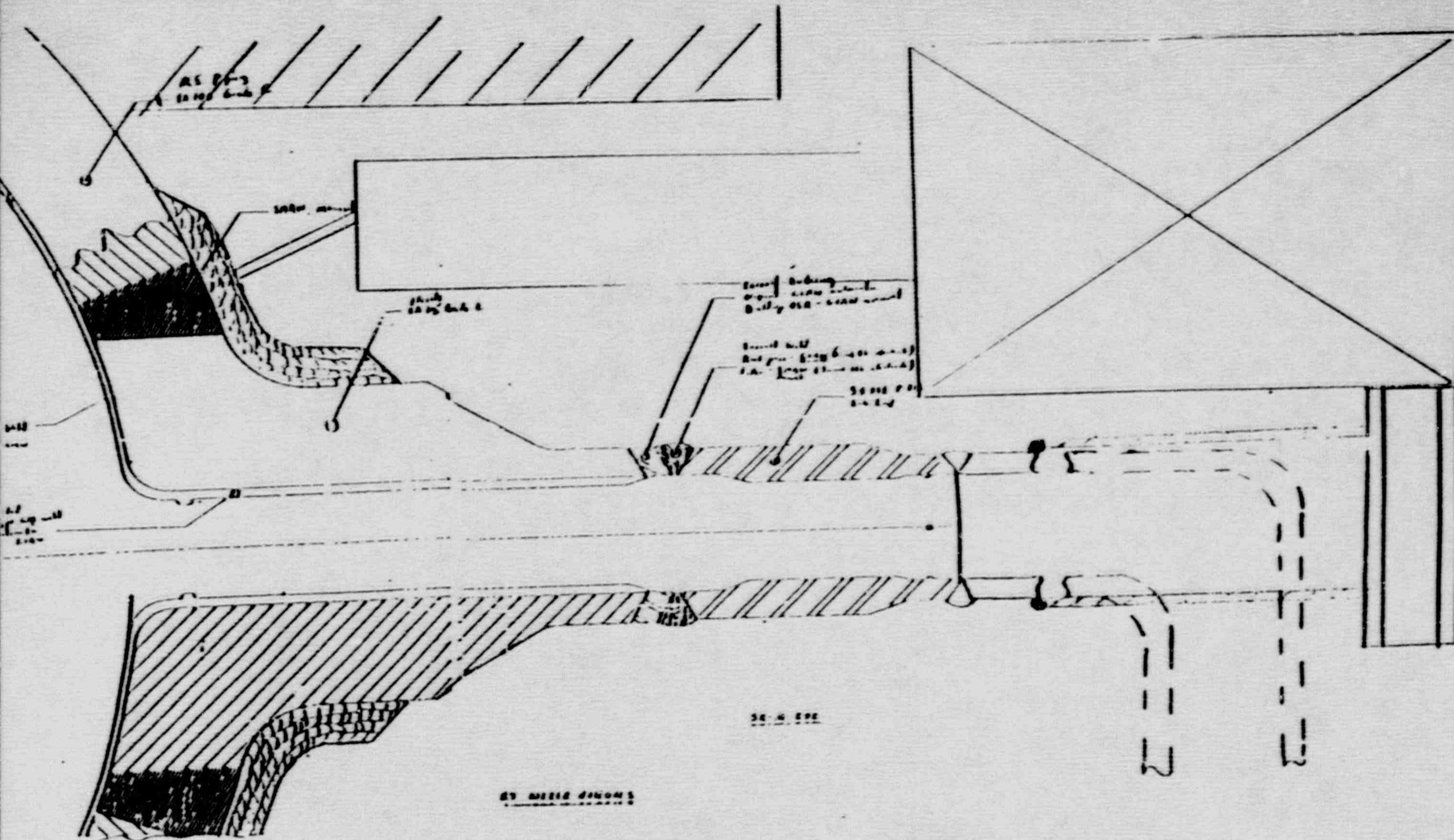
Davis-Besse HPI Nozzle - Required WOL Thickness for Nozzle Reinf.

WELDING PROCEDURE DEVELOPMENT FOR HPI/MAKEUP NOZZLE WELD OVERLAY REPAIR

- Development of Welding Technique for Overlay Application
  - Automatic GTAW
  - Repair Using Carbon Steel Weld Metal
  - Preheat and PWHT Per Sections III, IX and XI of Code
  - Mockup and Tooling By Welding Services, Inc. to Demonstrate Capability (Including Field Constraints)
  - Weld Procedure Specification and Procedure Qualification

SCHEMATIC OF HPI NOZZLE SHOWING INTERFERENCES AND CONSTRAINTS





Schematic of Weld Overlay Repair Plan

WELD PROCEDURE SPECIFICATION AND PROCEDURE QUALIFICATION FOR AUTOMATIC GTAW PROCESS

- Develop For P-1 Group 2 Materials (Thickness > 1.5")

- Heat Treat Qualification Plate to Simulate Current PWHT Condition at Davis-Besse

- Perform Procedure Qualification Per Sections III and IX of Code
  - Tensile Tests
  - Bend Tests
  - Toughness Tests

- Produce Qualified Procedure for Overlay Application

90-008PR

DAVIS-BESSE HPI NOZZLE WELD OVERLAY POST-REPAIR NDE PLANS

- Inspection for Soundness of Weld Overlay Deposit (Qualifies Repair for Single Fuel Cycle)
  - Straight Beam UT
  - Shear Wave UT
  - Section V Calibration Blocks

STUDY OF POTENTIAL FOR CRACK GROWTH DURING OVERLAY WELDING

- Elastic-Plastic Weld 3 Finite Element Analysis
- Stress Intensity Based Upon pc-CRACK Corner Crack Model
- ASME Section XI Fatigue Crack Growth Law
- Two Crack Depths Modeled
    - 1.6 inches
    - 2.5 inches

90-010PR

RESULTS OF CRACK GROWTH DURING OVERLAY WELDING STUDY

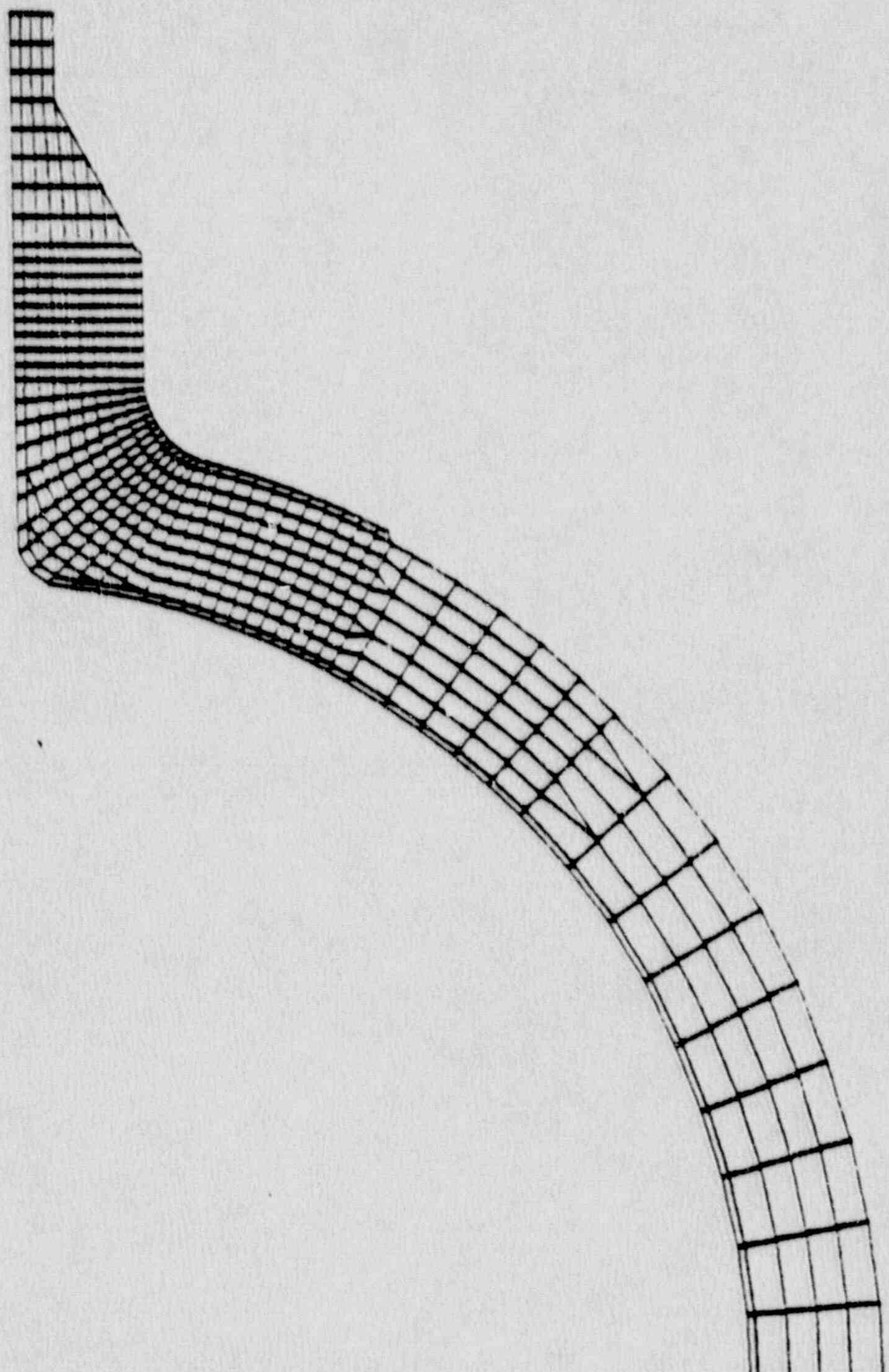
- Analysis Shows $K_I < K_{IC}$ For Both Crack Depths

- No Crack Growth Due to Crack Instability is Predicted

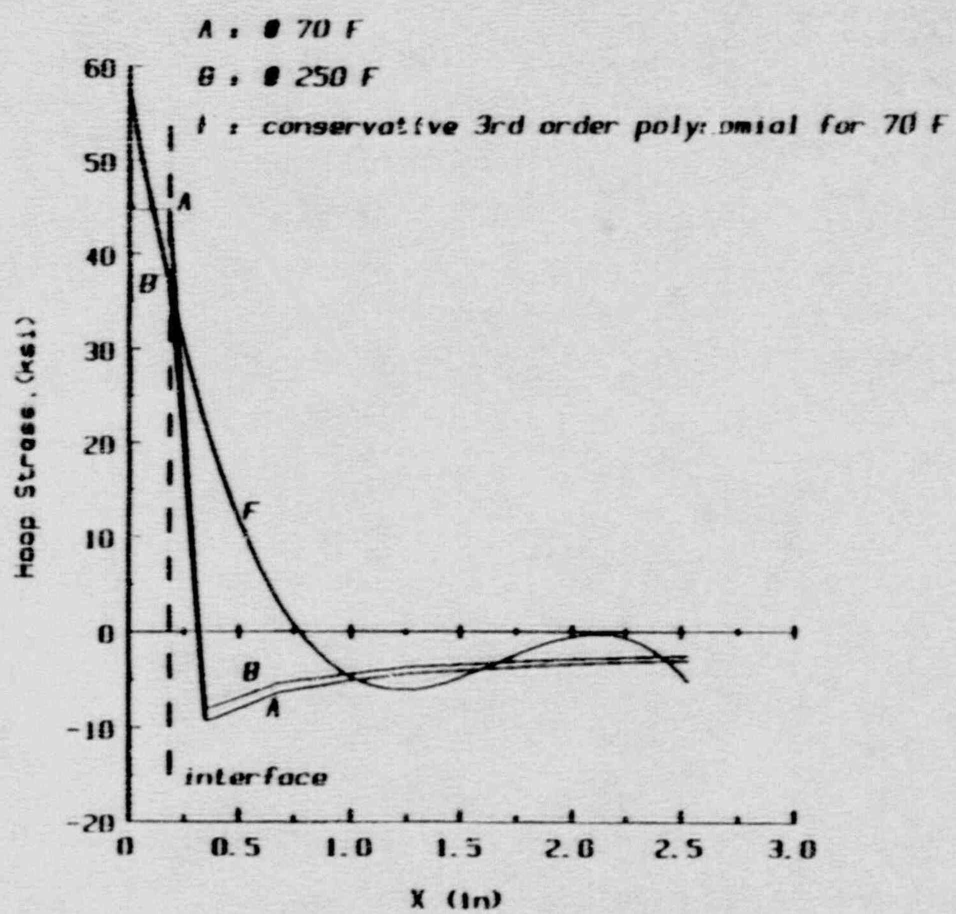
- 250 Fatigue Cycles Modeled To Simulate Weld Passes

- Negligible (17 Mils) Crack Growth Due To Fatigue Is Predicted

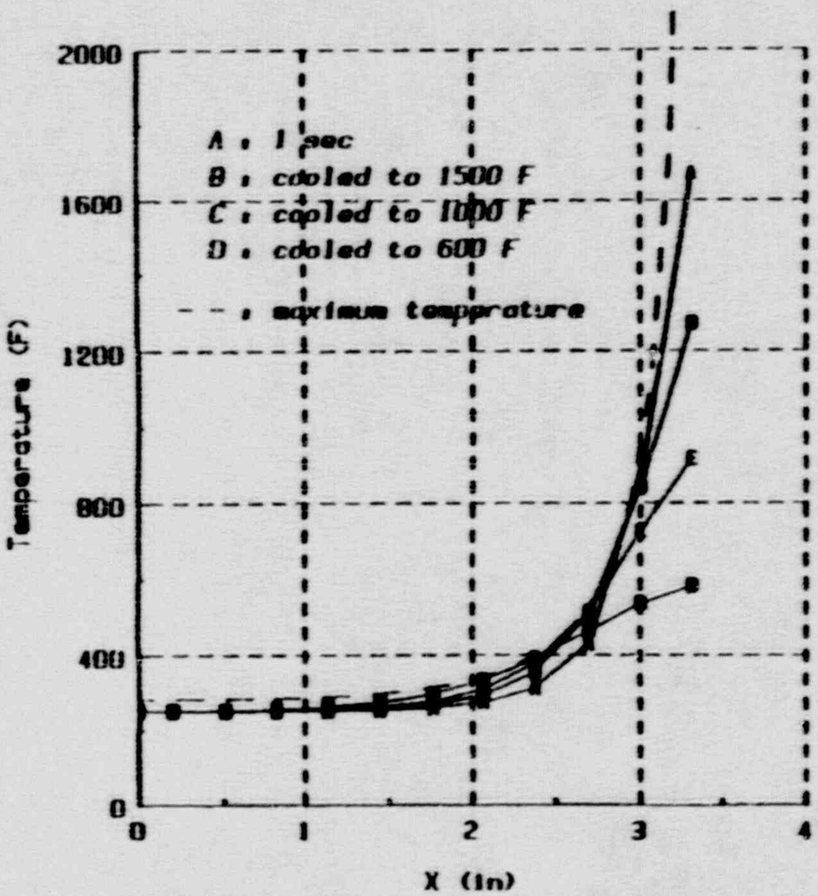
90-011PR



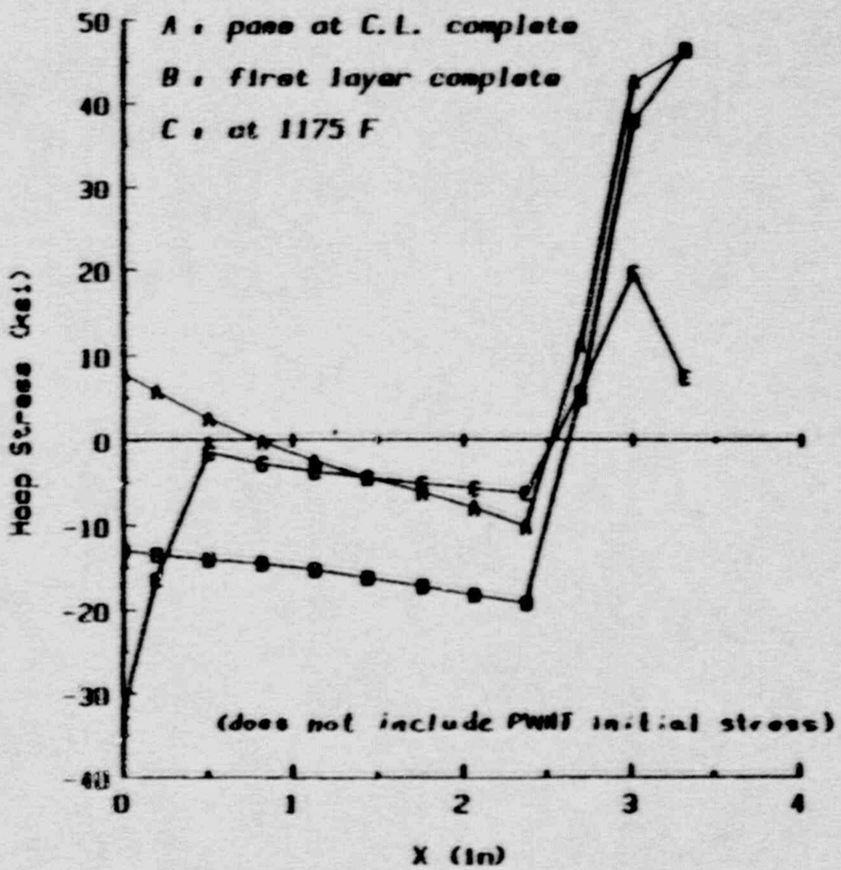
Finite Element Model Used For Crack Growth Analysis



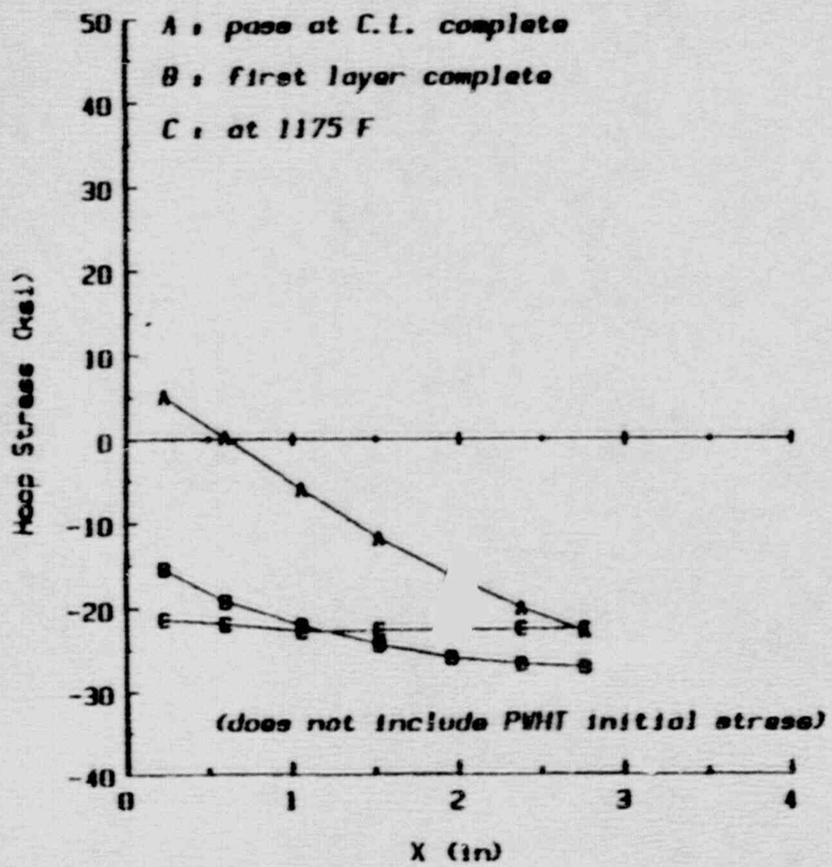
Initial Stress from PWHT



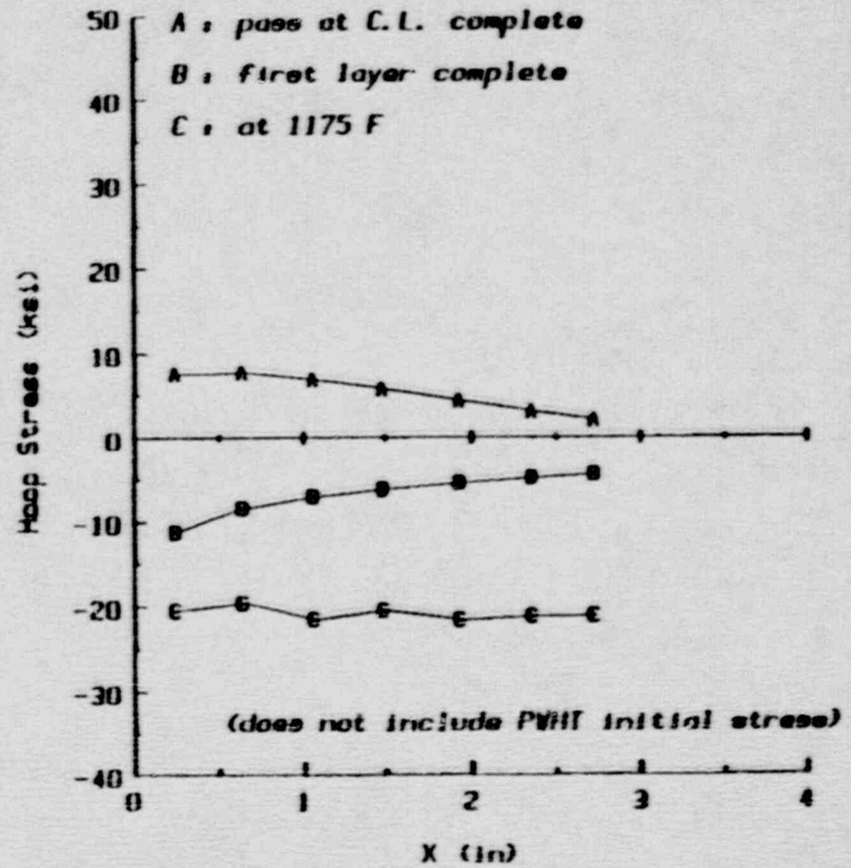
Temperature Due to Welding at Crack C.L.



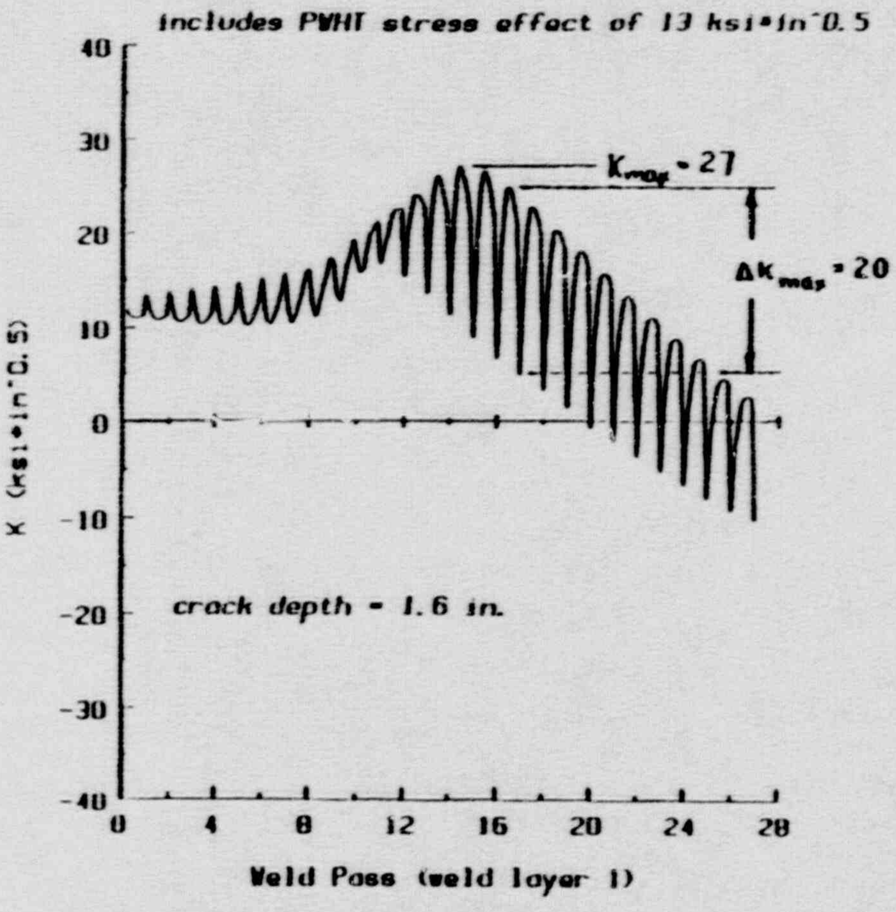
Crack C.L. Hoop Stress Behavior



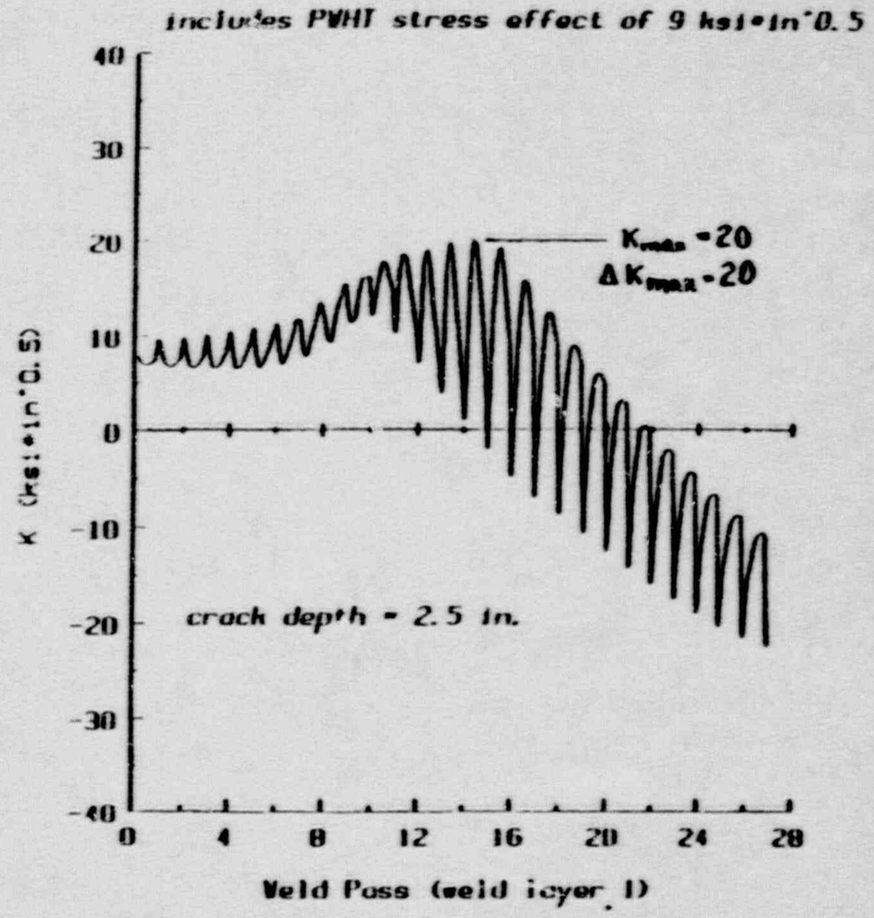
Nozzle Surface Hoop Stress Behavior



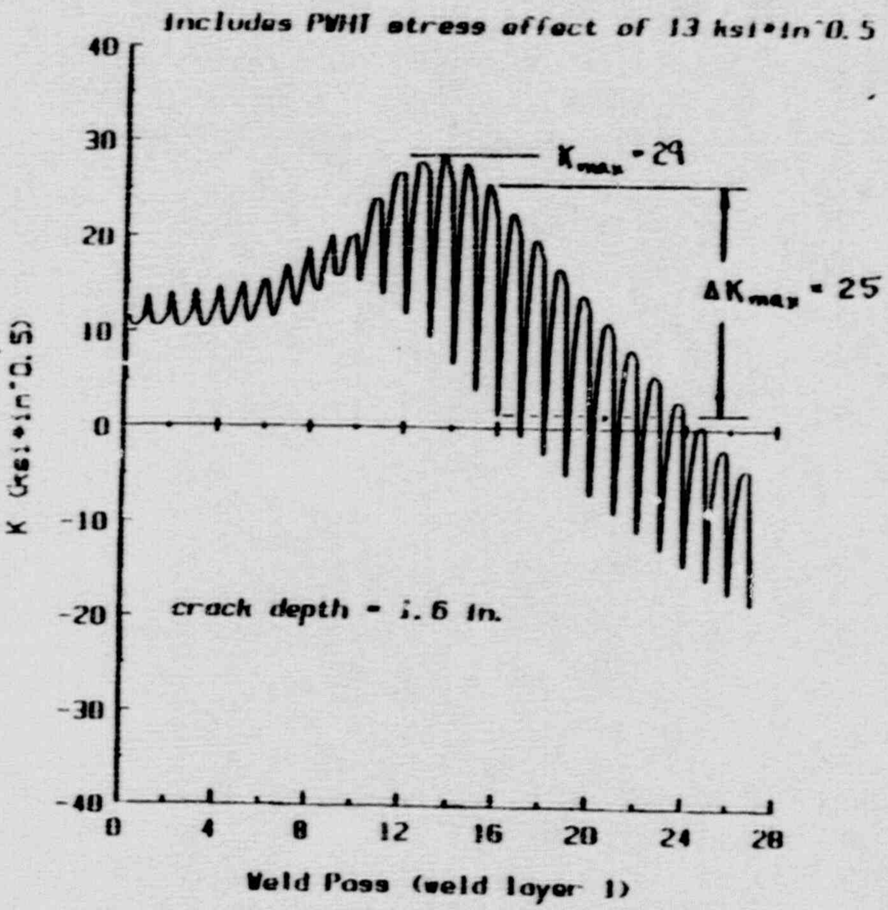
Pipe Surface Hoop Stress Behavior



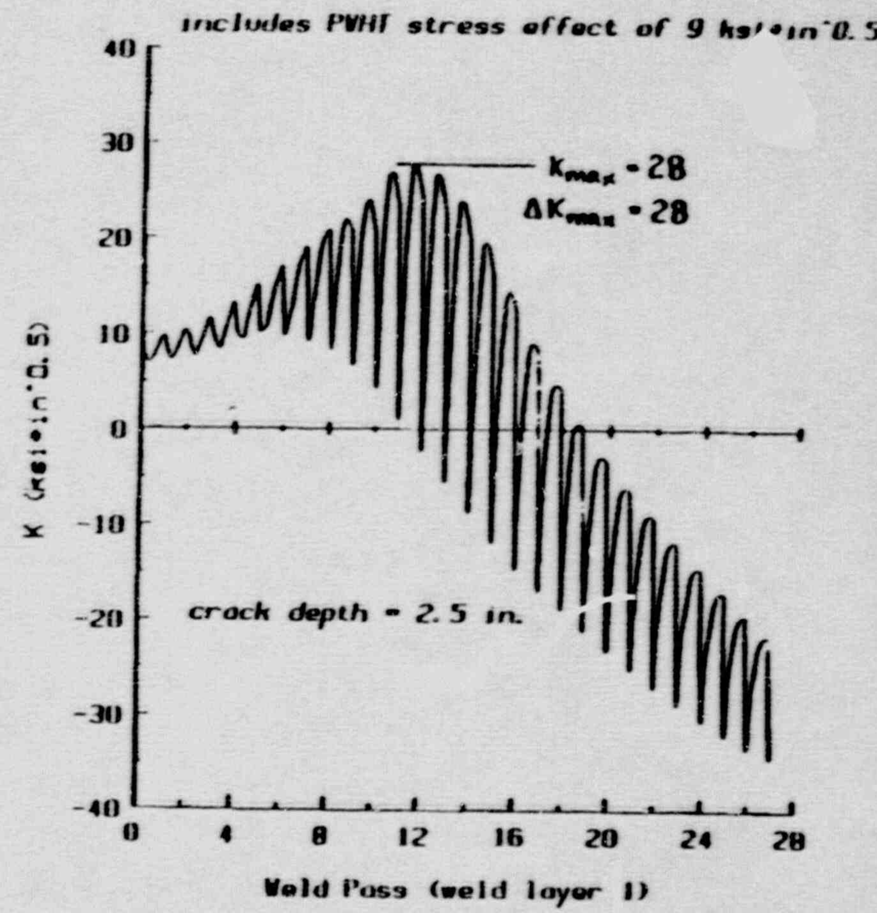
K History at the crack C.L.



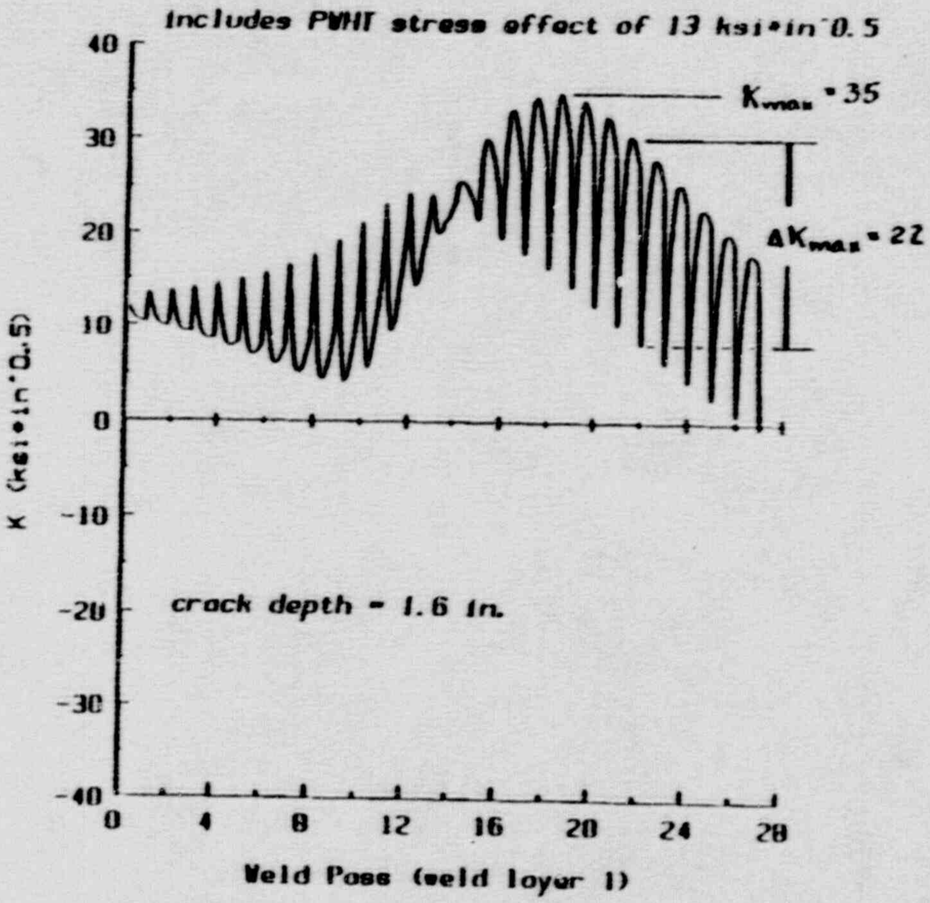
K History at the crack center line



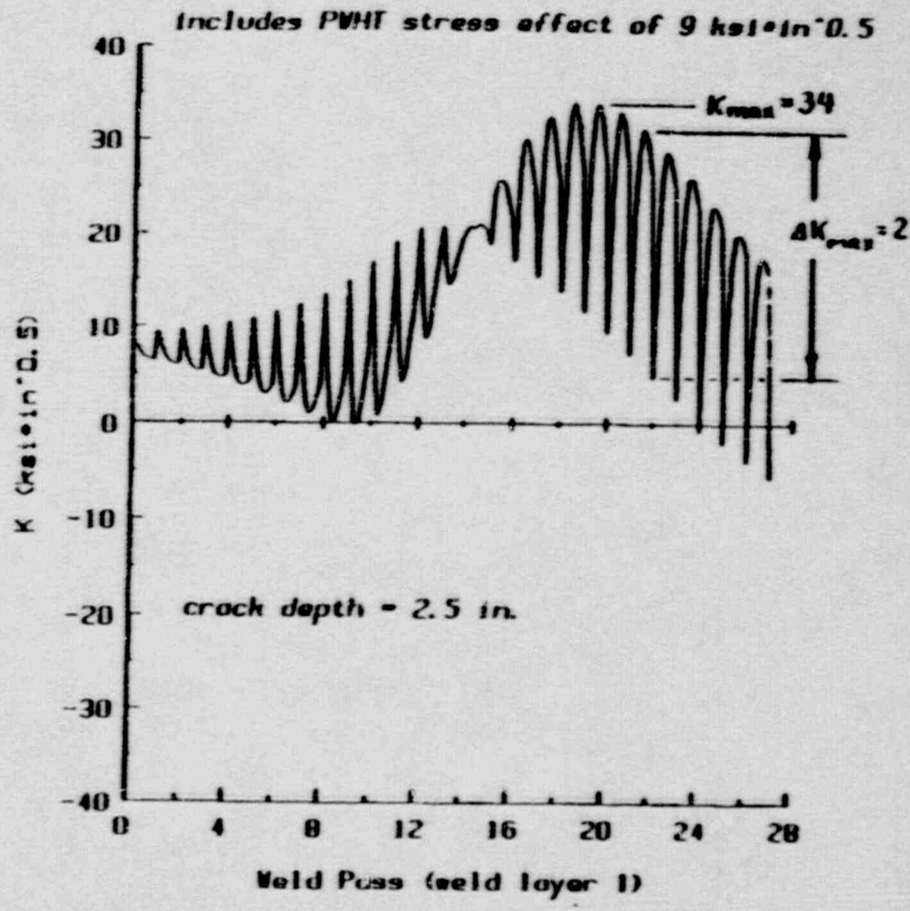
K History based on nozzle surface stresses



K History based on nozzle surface stresses



K History based on pipe surface stresses



K History based on pipe surface stresses

ATTENDANCE LIST 1/24/90

DAVIS BESSE

TEMPORARY REPAIR CONTINGENCY PLANS

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