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

FEB 08 1988

Docket Nos. 50-348
and 50-364

LICENSEE: Alabama Power Company (APCo)

FACILITY: Joseph M. Farley Nuclear Plant, Units 1 and 2

SUBJECT: SUMMARY OF MEETING HELD ON JANUARY 15, 1988, BETWEEN NRC AND APCo REPRESENTATIVES TO DISCUSS GENERIC IMPLICATIONS OF A CRACKED 6-INCH SAFETY INJECTION PIPE AT FARLEY UNIT 2 (TAC 66773)

Introduction

The NRC Project Manager (E. Reeves) reviewed the purpose of the meeting as noticed. The meeting was requested by NRC to have APCo discuss the event, the actions taken following the event, the results of the metallurgical examinations, the causal factors (thermal fatigue), the actions taken to preclude further problems, and a review of the small break loss of coolant accident reanalysis. The list of attendees and a meeting agenda are enclosed. Enclosure pages 1-98 are the handouts used during the meeting.

Discussion

APCo (R. P. McDonald, Senior Vice President Nuclear) provided the opening remarks and noted that J. Garlington of APCo would coordinate the presentations which included Westinghouse representatives (G. Rao, D. Rourty and R. Magee) and APCo (R. Fucich and S. Burns). The handouts were used extensively during the discussions of each specific area identified in the enclosed agenda. A brief synopsis is given in these minutes.

The event occurred at Unit 2 on December 8, 1987, as described in Licensee Event Report No. 87-010 dated January 6, 1988. A coolant pressure boundary leakage of slightly less then 1.0 gpm was discovered in a section of safety injection (SI) piping on the reactor coolant system loop B cold leg. The unit was operating at 33 percent power prior to shutdown on December 9. The refueling outage for Cycle 6 operation had been completed on December 2, 1987.

APCo (R. Fucich) presented a discussion, II. Overview (enclosure pages 1-7), including the crack summary, event chronology, testing methodology and instrumentation installed on loop B and C SI line sections. He stated that the interim engineering evaluation attributes the crack to thermal fatigue and supports continued operation of both units while the evaluation is being finalized.

APCo (S. Burns) presented a discussion, III. Inspections (enclosure pages 8-16), including test personnel, procedures, and non-destructive examination (NDE) techniques. The results using enhanced ultrasonic techniques confirmed the presence of cracks on both sides of weld #16 with approximately 6-inches of combined length. The through-wall crack was about one inch in length at the 6 o'clock position (bottom of a horizontal line). Table 1 on enclosure page 16 shows the NDE test results of the 6-inch loop B SI line welds including weld #16 which cracked.

Westinghouse (G. RAO) presented a discussion, IV.1 Metallurgical Evaluations (enclosure pages 17-47), with the objective of establishing the mechanism and causes of the cracking. A summary of the results of surface examination confirmed the presence of circumferential cracks, one on each side of the weld, approximately three inches long which then ran into the weld metal near the 6 o'clock location (refer to pages 22 and 23 of enclosure). Fractographic examination results suggest that cracking was initiated on the ID surface and progressed radially outward to the OD. The conclusion is that the cracking occurred by a high cycle fatigue mechanism. No abnormalities were reported in the mechanical or chemical properties of the pipe or the weld.

Westinghouse (D. Rourty) presented a discussion, IV.2 Evaluations of Unit 2 Loop Experience (enclosure pages 48-53), describing the operational test program installed on loop B and on loop C as a control location. Both thermal measuring instruments and vibration instruments were utilized in the analysis. The thermal measurements revealed that large temperature stratifications (exceeding 200°F) and temperature fluctuations existed from the top to the bottom of the SI pipe in the bottom of the pipe where the failures (cracks) occurred. The evaluation shows that cooler water in small quantities (less than 1 gpm estimated) was flowing through the upstream checkvalve in the B loop SI piping. The colder water came from a leaking bypass valve around the boron injection tank. When the flow was diverted to reduce the pressure upstream of the check valve, the temperature cycling and stratification ceased.

Westinghouse (D. Rourty) continued with a discussion, IV.3 Analytical Evaluations and IV.4 Conclusions (enclosure pages 54-58), which concluded that the pipe cracked by fatigue due to thermal loads resulting from thermal cycling combined with temperature stratification.

The discussion continued with agenda item V, Forward Looking Evaluations and Actions, with the participation of Westinghouse and APCo representatives. This included discussions of fluid systems, impact of in-leakage on the nozzle thermal sleeve, and other lines subject to similar experiences. Other lines were the auxiliary spray line, normal charging and alternate charging lines, and both the cold leg and hot leg SI lines. Westinghouse (R. Magee and D. Rourty) gave these discussions. The conclusion was that a potential mechanism exists on the hot leg SI line as well as the cold leg SI line, but the probability is minimized given a secure pressure boundary from cooler water in-leakage as occurred in the B loop cold leg SI line where the crack was found. The auxilary spray line and the normal and alternate changing lines would not be of significant concern according to the evaluation presented (enclosure pages 59-71).

Thermal sleeves located inside the SI lines at the entry to the reactor coolant loop were considered in the evaluation. Farley Unit 1 and 2 B loop cold leg SI line thermal sleeves were previously dislodged and recovered in the reactor vessels (Unit 1 during the 1983 refueling outage and Unit 2 during the recent outage). Westinghouse has recommended elimination of thermal sleeves from such plant designs later then the Farley time frame. Previous Westinghouse studies have concluded that the thermal sleeve failures resulted from flow induced vibration. The discussion, V.2 Thermal Sleeve Considerations (enclosure pages 72 and 73), concludes that the thermal sleeve integrity and nozzle integrity would not be affected by the thermal mechanism which caused the pipe cracks.

Westinghouse (D. Rourty) concluded the discussion with agenda item V.3, Continued Acceptability of Units 1 and 2 (enclosure pages 74-93). The review was very comprehensive including the list of items shown on page 74 of the enclosure. The thermal cycling mechanism which resulted in the crack projection was clearly shown by use of temperature profiles versus time plotting. A conclusion was drawn that the preliminary leak-before-break evaluations indicate that no double ended break would occur prior to leak detection.

Summary

The licensee (R. McDonald) summarized future actions being considered at this time as follows:

(1) Additional monitoring review
(2) Completion of the final Westinghouse analyses
(3) Contact with Owner's Group in active lead role
(4) A revised entry to the INPO Notepad to supplement their earlier one
(5) Westinghouse considering letter to customers

APCo (J. Garlington) presented agenda item VI, A Small Break Loss of Coolant Accident (SBLOCA) Evaluation (enclosure pages 94-98). He noted that a letter dated January 14, 1988, has been sent to NRC with the detailed description per 10 CFR 50.46, Appendix K. Evaluation results (see page 97 of enclosure) show a +46°F spillage correction and a + 9°F reporting correction. Thus, Units 1 and 2 proposed fuel peak clad temperatures are 1875°F and 1758° F, respectively. Considerable margin exists to the 10 CFR 50.46 limit of 2200°F.

In closing, APCo (R. McDonald) expressed appreciation for the opportunity to review the current status of the actions taken since the event occurred. NRC (G.Lainas) expressed the staff's appreciation to APCo for a very complete and detailed licensee presentation. At this point the meeting adjourned.

/S/

Edward A. Reeves, Senior Project Manager
Project Directorate II-1
Division of Reactor Projects - I/II

Enclosures:
As Stated

cc w/Enclosure:
See next page

PM:PDII-1	D:PDII-1
EReeves	EAdensam
2/5/88	2/8/88

MEETING SUMMARY DISTRIBUTION

Docket No. 50-~~400~~ 348, 364
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Enclosure

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Gutti Rao, Westinghouse
Clem Eicheldinger, Westinghouse
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MEETING AGENDA

JANUARY 15, 1988

Farley Nuclear Plant Unit 2 Cold Leg
Safety Injection Line Crack

9:00 a.m.	I.	Preface - Opening Remarks	R. P. McDonald
9:10 a.m.	II.	Overview	R. S. Fucich
9:35 a.m.	III.	Inspections - Nondestructive examinations at FNP	S. T. Burns
	IV.	Evaluations With Respect to Unit 2 B Loop Experience	Westinghouse
9:45 a.m.		1. Metallurgical evaluations -- GUTTI RAO - W	
10:30 a.m.		2. Test instrumentation -- DAVID ROURTY - W	
10:45 a.m.		3. Analytical evaluations -- DAVID ROURTY - W	
11:20 a.m.		4. Conclusion	
	V.	Forward Looking Evaluations and Actions (Units 1 & 2)	
11:30 a.m.		1. Discussion of other locations in Units 1 and 2 subject to same concern	Westinghouse ROBERT MAGEE
11:40 a.m.		2. Thermal sleeve evaluations	Westinghouse D. ROURTY
11:50 a.m.		3. Continued acceptability of Unit 2 B loop CL SI line and components	Westinghouse D. ROURTY
12:00 p.m.		4. Summary of future actions	R. P. McDonald
12:10 p.m.	VI.	Small Break LOCA Analysis	J. E. Garlington
12:20 p.m.	VII.	Questions and Answers	All
	VIII.	Conclusion	R. P. McDonald

II. OVERVIEW - R. FUCICH

CRACK SUMMARY

EVALUATIONS AND TESTING CONDUCTED TO DATE INDICATE THAT THE CRACKING RESULTED FROM FATIGUE CAUSED BY THERMAL CYCLING

OVERVIEW PURPOSE

TO QUICKLY REVIEW THE EVENT AND ACTIONS TAKEN TO DETERMINE ITS CAUSE

TO SET THE STAGE FOR OTHER PRESENTATIONS WHICH WILL PROVIDE DETAILS OF INSPECTIONS AND EVALUATIONS WHICH HAVE BEEN PERFORMED TO DATE

CRACK EVENT CHRONOLOGY

12/08/87 (2255) UNIT 2 AT 33% POWER RETURNING FROM REFUELING OUTAGE

- CONTAINMENT COOLER DRAIN POT LEVELS NOTED AS ABNORMALLY HIGH

- A CONTAINMENT ENTRY WAS MADE WHICH IDENTIFIED A LEAK IN THE VICINITY OF THE B LOOP RESISTANCE TEMPERATURE DETECTOR (RTD) MANIFOLD

A UNIT SHUTDOWN WAS MADE TO REPAIR THE LEAK

CLOSE EXAMINATION AFTER SHUTDOWN REVEALED PRESSURE BOUNDARY LEAKAGE IN A WELDED JOINT (WELD 16) ON THE B LOOP COLD LEG SI/RHR SIX INCH LINE BETWEEN A CHECK VALVE AND THE RCS LOOP

WHILE IN HOT STANDBY LEAKAGE WAS SLIGHTLY LESS THAN ONE GALLON PER MINUTE

12/09/87 (1916) UNIT 2 ENTERED COLD SHUTDOWN

CONVENTIONAL ULTRASONIC EXAMINATION (UT) LOCATED THE CRACK BUT DID NOT INDICATE A REPORTABLE INDICATION

ENHANCED UT WAS USED TO LOCATE AND VERIFY THE EXTENT OF THE CRACK; X-RAY (RT) CONFIRMED CRACK

AS UNIT 1 WAS IN A SHUTDOWN (EQ MODIFICATIONS), THE FOLLOWING INVESTIGATIONS WERE CARRIED OUT ON BOTH FNP UNITS TO DETERMINE THE EXTENT OF THE PROBLEM AND POSSIBLE CAUSES:

- WELDS ON EACH SIX INCH COLD LEG SI/RHR LINES WERE INSPECTED USING ENHANCED UT
- FABRICATION AND CONSTRUCTION X-RAYS FOR THESE WELDS WERE REVIEWED FOR ANY POSSIBLE MISSED INDICATIONS
- ALL SIX LINES WERE WALKED DOWN FOR EVIDENCE OF VIBRATION OR BINDING AND GENERAL PIPING GEOMETRY
- THE FATIGUE ANALYSES WERE REVIEWED
  - NO OTHER CRACKS WERE FOUND NOR WERE ANY CONDITIONS FOUND WHICH COULD EXPLAIN THE CRACK

THE FOLLOWING ADDITIONAL ITEMS WERE REVIEWED FOR THE UNIT 2 B LINE:

- STRESS REPORT
- HOT FUNCTIONAL TEST DATA
- OPERATION HISTORY (SAFETY INJECTIONS, CHEMISTRY EXCURSIONS, WATER HAMMER, ETC.)
  - NO EVIDENCE WAS FOUND TO EXPLAIN THE CRACKED JOINT

THE PIPE SECTION WAS REMOVED AND SENT TO WESTINGHOUSE FOR EXAMINATION

- PRELIMINARY RESULTS INDICATED A FATIGUE MECHANISM
- NO SIGNIFICANT MOVEMENT WAS NOTED WHEN THE PIPE WAS CUT

WHILE THE PIPE SECTION WAS REMOVED, A VISUAL EXAMINATION WAS CONDUCTED ON THE NOZZLE INSIDE DIAMETER FOR DEGRADATION CAUSED BY THE LOSS OF THE THERMAL SLEEVE

REPLACEMENT PIPING WAS WELDED IN PLACE, EXAMINED AND TESTED AS REQUIRED BY THE ASME CODE

RESISTANCE TEMPERATURE DETECTORS AND ACCELEROMETERS WERE ATTACHED TO THE REPAIRED LOOP B PIPING AND TO LOOP C AS A CONTROL

THE REPAIRED LINE WAS MONITORED DURING ITS HEATUP TO VERIFY THERMAL MOVEMENT WAS AS PREDICTED AND THAT IT WAS NOT BINDING

TEMPERATURE DATA REVEALED A THERMAL CYCLE OCCURRING IN THE B LOOP, DOWNSTREAM OF V051B

FLOW FROM THE BORON INJECTION TANK BYPASS LINE WAS DIVERTED TO THE BORON INJECTION SURGE TANK

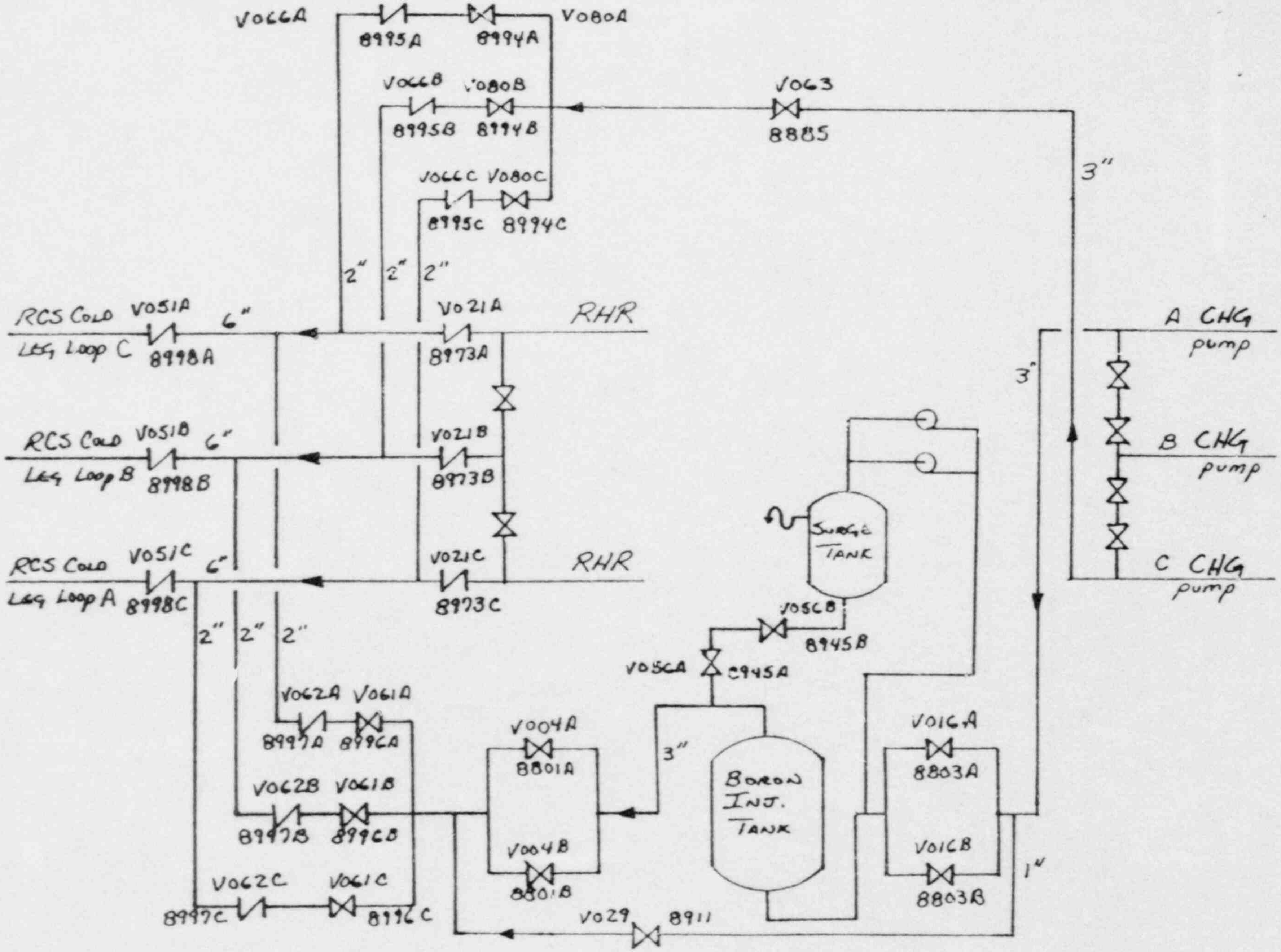
THERMAL CYCLING ON THE B LOOP, DOWNSTREAM OF V051B, STOPPED; HOWEVER, A THERMAL CYCLE APPEARED UPSTREAM

VIBRATION DATA COLLECTION WAS TERMINATED WHEN VIBRATION WAS ELIMINATED AS A POTENTIAL CAUSE

THE UPSTREAM THERMAL CYCLING STOPPED IN THE EARLY MORNING HOURS OF 01/08/88 BEFORE A CAUSE COULD BE DETERMINED

AN INTERIM ENGINEERING EVALUATION WAS OBTAINED WHICH ATTRIBUTES THE CRACK TO THERMAL FATIGUE AND WHICH SUPPORTS CONTINUED OPERATION OF BOTH UNITS WHILE THE EVALUATION IS BEING FINALIZED

TEMPERATURE MONITORING IS CONTINUING



VO66A
8995A
8994A
VO80A
VO66B
VO80B
8995B
8994B
VO63
8885
3"
VO66C
VO80C
8995C
8994C
2"
2"
2"
RCS COLD
LEG LOOP C
VO51A
8998A
6"
VO21A
8973A
RHR
A CHG
pump
3"
RCS COLD
LEG LOOP B
VO51B
8998B
6"
VO21B
8973B
B CHG
pump
SURGE
TANK
RCS COLD
LEG LOOP A
VO51C
8998C
6"
VO21C
8973C
RHR
C CHG
pump
2"
2"
2"
VO5CB
8945B
VO5CA
8945A
VO62A
VO61A
8997A
8996A
VO04A
8801A
3"
BORON
INJ.
TANK
VO16A
8803A
VO62B
VO61B
8997B
8996B
VO04B
8801B
VO16B
8803B
1"
VO62C
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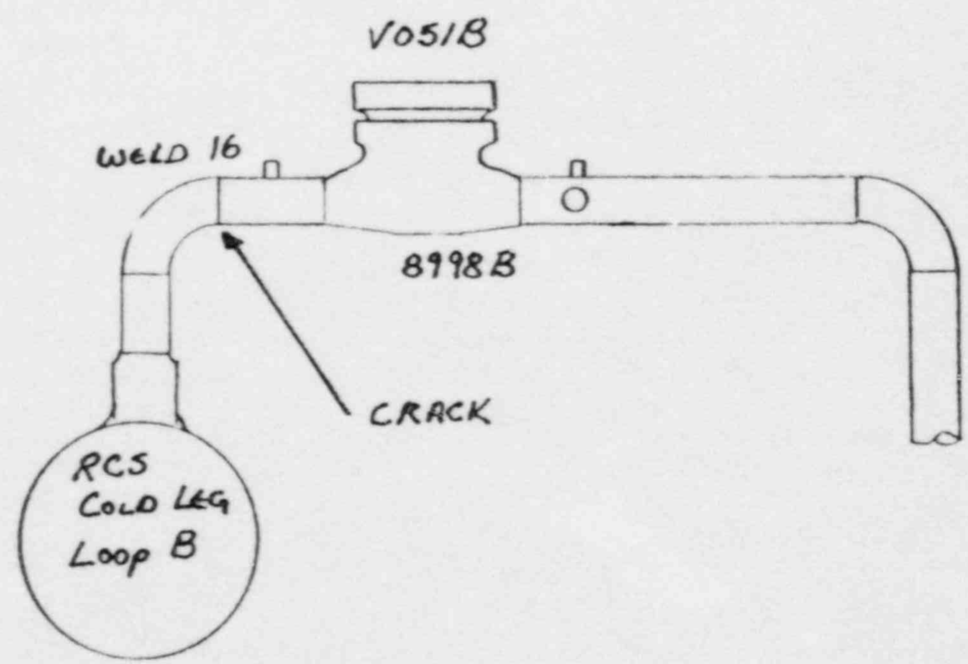
8997C
8996C
VO29
8911



NOT TO SCALE

(7)

III. INSPECTIONS — S. BURNS

1. Personnel and Procedures

   ° Personnel Certifications

   ° Procedures

2. NDE Methods, Techniques and Results

   ° Liquid Penetrant Examination

   ° Ultrasonic Examination

     - Preservice and Inservice History

     - Conventional Technique

     - Enhanced Technique

     - Summary of Results

   ° Radiographic Examination

   ° Visual Examination

   ° Construction Radiograph Review

1. PERSONNEL AND PROCEDURES

- Personnel certified to Level II or III for major NDE methods in accordance with Section XI and ASNT-TC-1A (1980)

- UT personnel certified to EPRI Program for IGSCC detection, sizing and overlay inspection in BWR plants

- UT procedures used:

  - Most conservative application of Section XI, Appendix III (S83) requirements

  - Replicated conventional procedures utilized for ISI to Section XI and Section V (S75)

- Other procedures used:

  - Standard practice per Section V and XI requirements

2. NDE METHODS, TECHNIQUES AND RESULTS

° Liquid Penetrant Examination

- Attempted for information purposes only
- Solvent based technique inappropriate for this application
- No meaningful results obtained

° Ultrasonic Examination

- Preservice and Inservice Inspection history of cracked weld
  - ° Preservice Inspection (8-20-79)
    - 0° and 45° shear wave examinations
    - visual examination
    - no indications recorded
  - ° Inservice Inspection (4-17-86)
    - 45° shear wave examination
    - no indications recorded
- Conventional ultrasonic examination
  - ° 45° shear wave transducer - 3/8", 2.25 MHz
  - ° upstream, downstream and two directional circumferential scans
  - ° no recordable indications in excess of reference levels
  - ° scanning factors (Figure 1)
    - pipe configuration limits elbow side exam due to intrados
    - weld crown configuration
    - signal masking due to counter bore and root geometries
    - beam redirection decreases angle below ideal 45°

- Enchanced ultrasonic examination
  - ° 45° shear wave transducer - 3/8", 2.25 MHz
  - ° same scanning directions
  - ° 60° shear wave transducer - 3/8", 1.5 MHz
  - ° upstream and downstream scans
  - ° circumferential scan at higher angles will not permit examination of ID region
  - ° detected crack-like indications (Figure 2)
  - ° enhancements:
    - beam redirection effects on 60° shear wave improve their detection ability as true angle approaches 45°
    - additional 8 db gain improves scanning sensitivity of 45° transducer
    - recording level at 50% DAC of ~~scanning~~ REFERENCE sensitivity
- Summary of results
  - ° Unit 2 (Table 1 and Figure 3)
    - one recordable indication on Loop B, weld No. 16
    - no other recordable indications on Loops A or C
  - ° Unit 1
    - Loops A, B and C had no recordable indications except for 3 welds which exhibited OD geometry (verified by signal dampening)

° Radiographic Examination

- Ir 192 source at 54 curies
- Double loaded cassettes using Type M film or equivalent
- Confirmed presence of crack with line filled
  - ° crack located on elbow side
  - ° approximately 2 1/2" long

- Confirmed presence of cracks with line empty
  - ° cracks located on both sides of weld
  - ° approximately 6" long (total combined length)

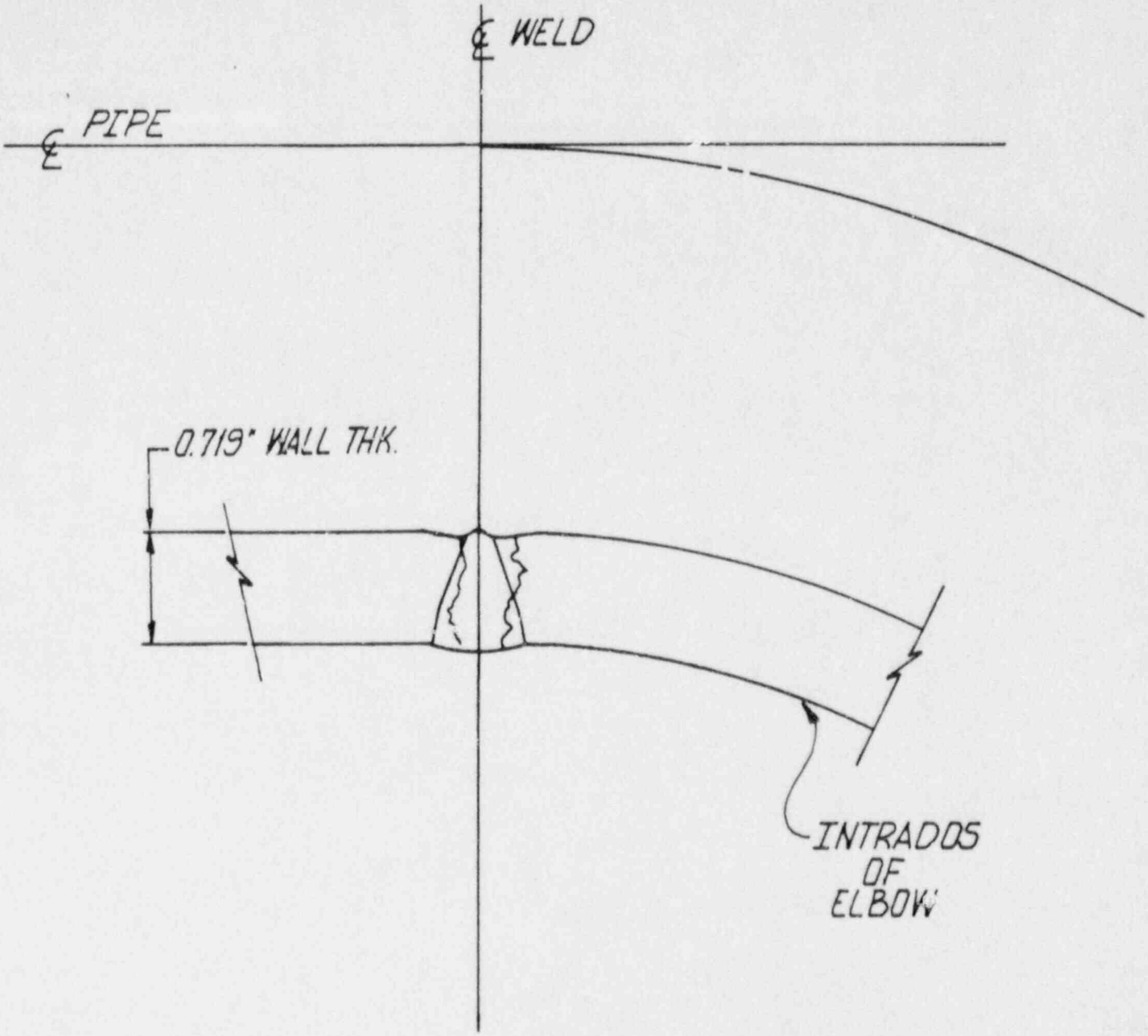
° Visual Examination (Information Only)

- Utilized high resolution video camera
- VT-1 visual examination
- Confirmed satisfactory condition of thermal sleeve nozzle ID, especially areas where the sleeve was tack welded to the nozzle

° Construction Radiograph Review

- Purpose: To evaluate construction film and disposition of indications as shown on original reader sheets against the Section III Code requirements
- In most cases, reader sheet accurately reflected film interpretation
- There was insufficient information to fully disposition 5 indications (4 on Unit 2 and 1 on Unit 1) found in the review
- Corrective actions:
  - ° Unit 2, Loop B - None required as both welds were removed as a part of the repair (Table 1 and Figure 3)
  - ° Unit 2, Loop A - Both welds were radiographed and results were satisfactory
  - ° Unit 1, Loop C - One weld will be radiographed at the next refueling outage

(2)



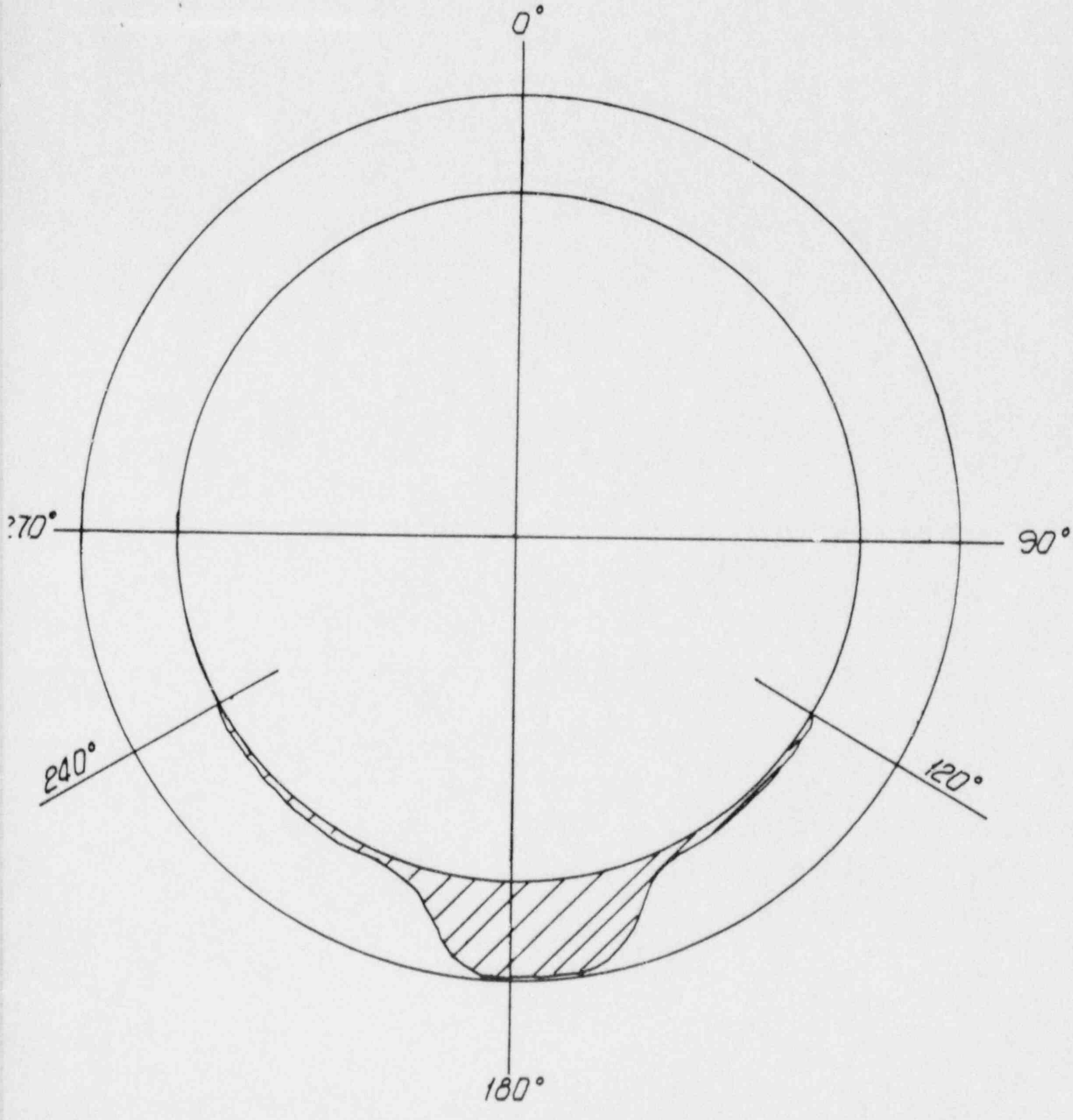
FARLEY NUCLEAR PLANT
UNIT 2
APR-1 4210 WELD NO. 16

6" ELBOW
SCH. 160

(13)

(1)

6" ELBOW
SCH. 160
WALL THK. 0.719"



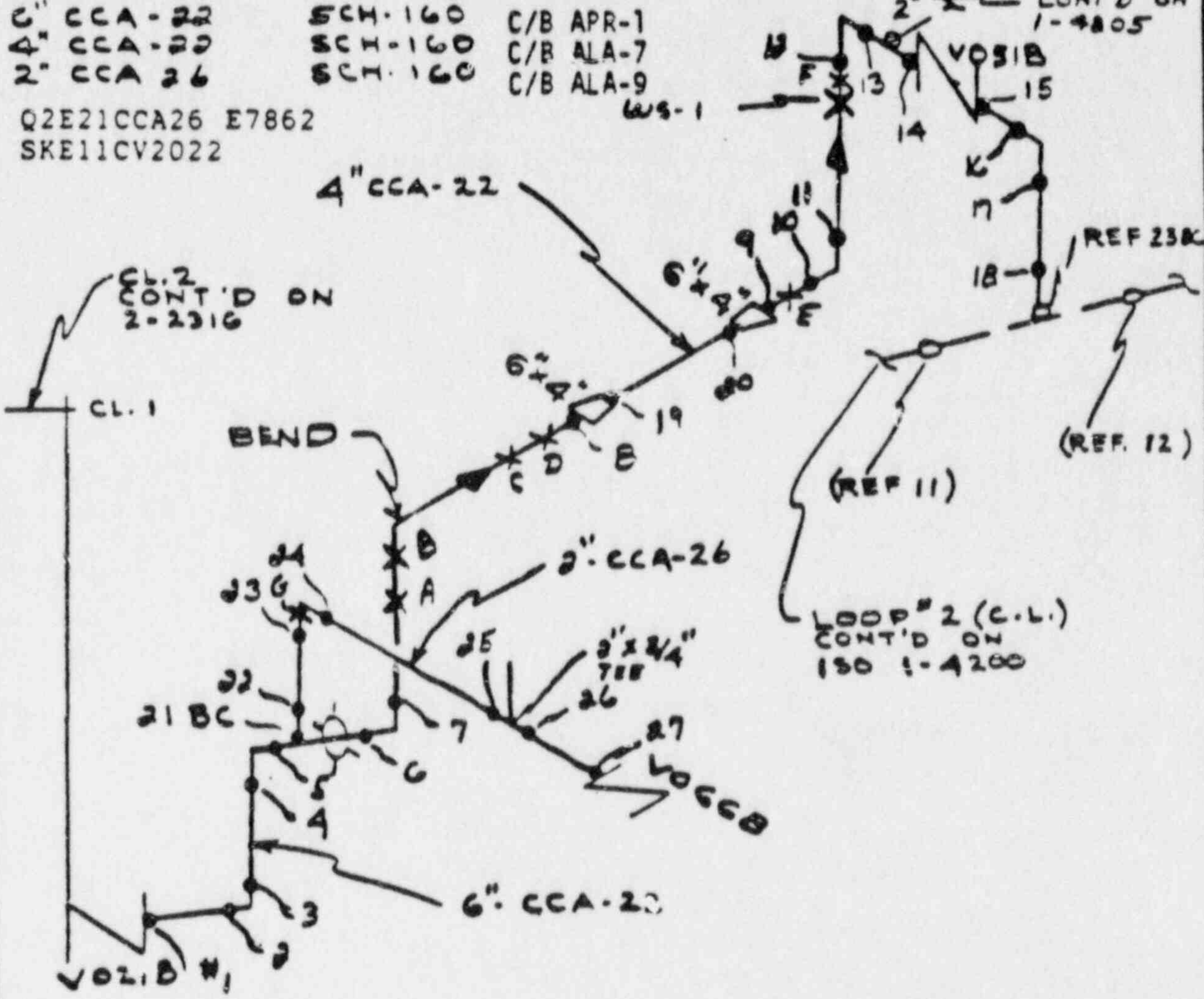
FARLEY NUCLEAR PLANT-UNIT 2
APR-1 4210
WELD NO: 16

APR 1-4210

LOOP #2 6"-4"+2" SIS (C.L.)

6" CCA-22 SCH-160 C/B APR-1
4" CCA-22 SCH-160 C/B ALA-7
2" CCA 26 SCH-160 C/B ALA-9

Q2E21CCA26 E7862
SKE11CV2022



A	2SI-R145
B	2SI-R148
C	2SI-R146
D	2SI-R147
E	2SI-R149
WS-1	2SI-R150
F	2SI-R151
G	2SI-BR9

16-BW 6"
2-BW 4"
6-SW 2"
1-BC 2"
1-WS
7-SC

D35

GEN. REV. 3

TABLE 1

FARLEY NUCLEAR PLANT - UNIT 2
NDE RESULTS FROM INSPECTION
OF 6" LOOP B SI LINE & RECORDS REVIEW

SKETCH NO.	WELD NO.	UT RESULTS	RT REVIEW	RT RESULTS
APR 1-[illegible]210	18	NRI	RI (3)	- (5)
	17	NRI	NC	NRI (6)
	16	RI (1)	RI (4)	RI (5) (7)
	15	NRI	NC	-
	14	NRI	-	-
	13	NRI	-	-
	12	NRI (2)	-	-

KEY:

NRI = NO RECORDABLE INDICATIONS
RI = RECORDABLE INDICATIONS
NC = NO CHANGE FROM DISPOSITION ON ORIGINAL RT READER SHEET

NOTES:

1. Crack-like indications determined to be approximately 6" long and 100% through-wall for a distance of 1" and centered at the 6 o'clock position.

2. Partial examination due to support clamp.

3. Slag indication 3/16" long evaluated to be acceptable.

4. Porosity with linear indications located outside the area of interest.

5. These welds were removed and replaced as a part of the repair.

6. Weld No. 17 was radiographed to confirm the absence of defects as a result of a non-recordable indication found by UT.

7. Informational radiographs verified the presence of cracks on both sides of the weld.

IV. 1. METALLURGICAL EVALUATIONS - G. RAO

OBJECTIVES:

- O ESTABLISH THE MECHANISM AND CAUSE(S) OF THE OCCURRENCE OF CRACKING
- O DEVELOP INFORMATION THAT WOULD BE HELPFUL IN TAKING CORRECTIVE ACTIONS

METALLURGICAL EVALUATIONS

MAJOR TASKS:

- O SURFACE EXAMINATIONS
- O NDE EXAMINATIONS
- O METALLOGRAPHIC EXAMINATIONS
- O FRACTOGRAPHIC EXAMINATIONS
- O CHEMISTRY EVALUATIONS
- O MICROHARDNESS MEASUREMENTS

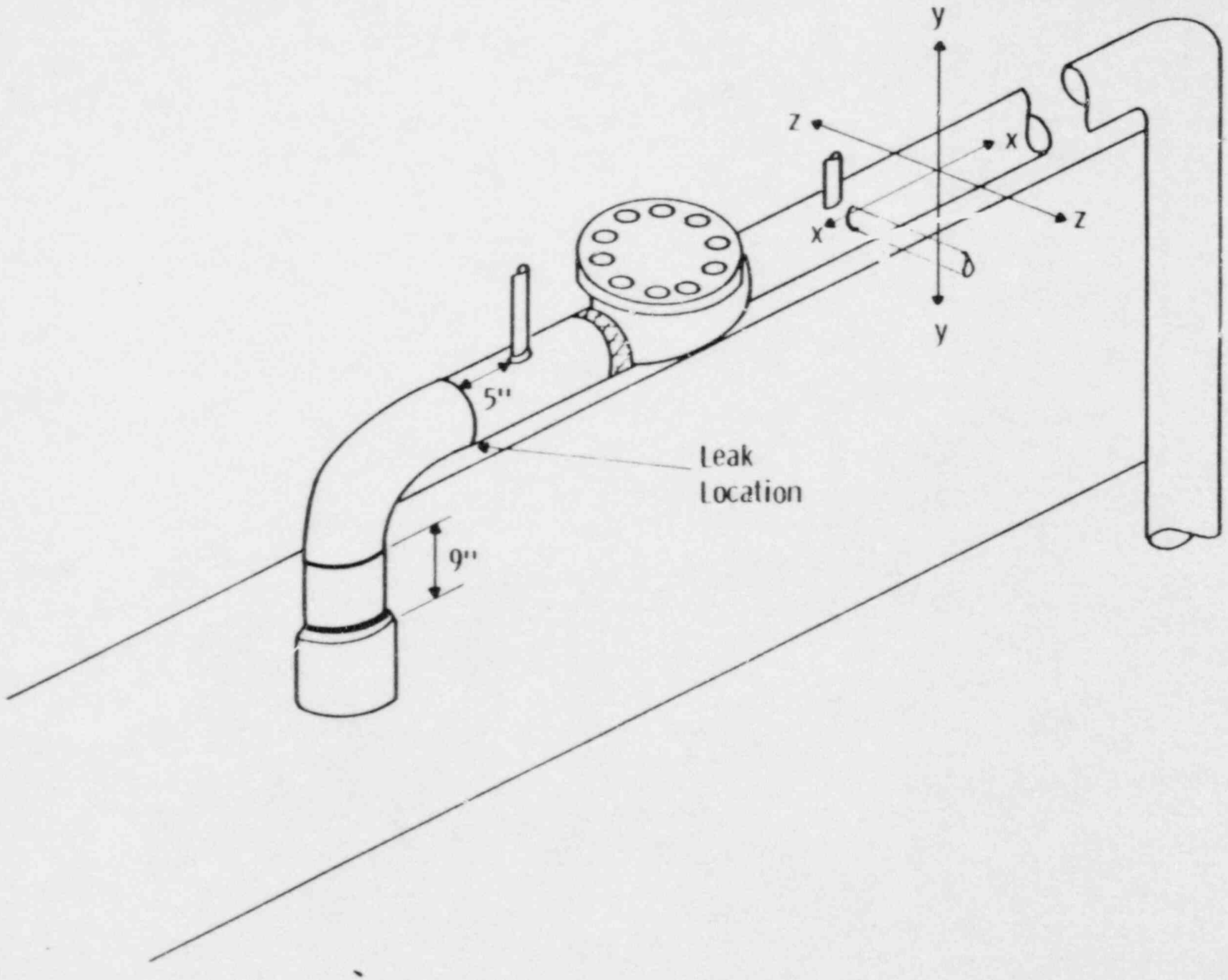
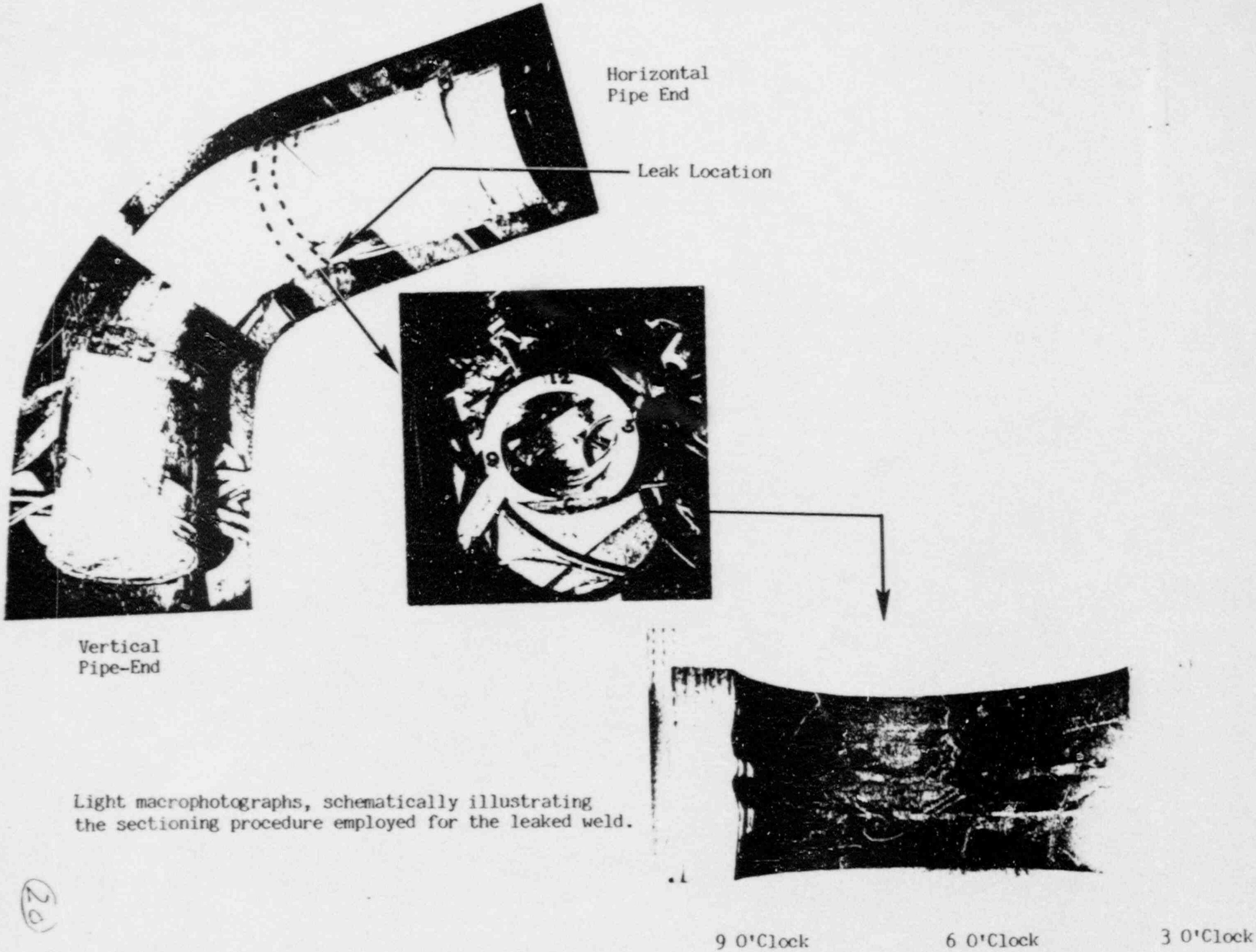


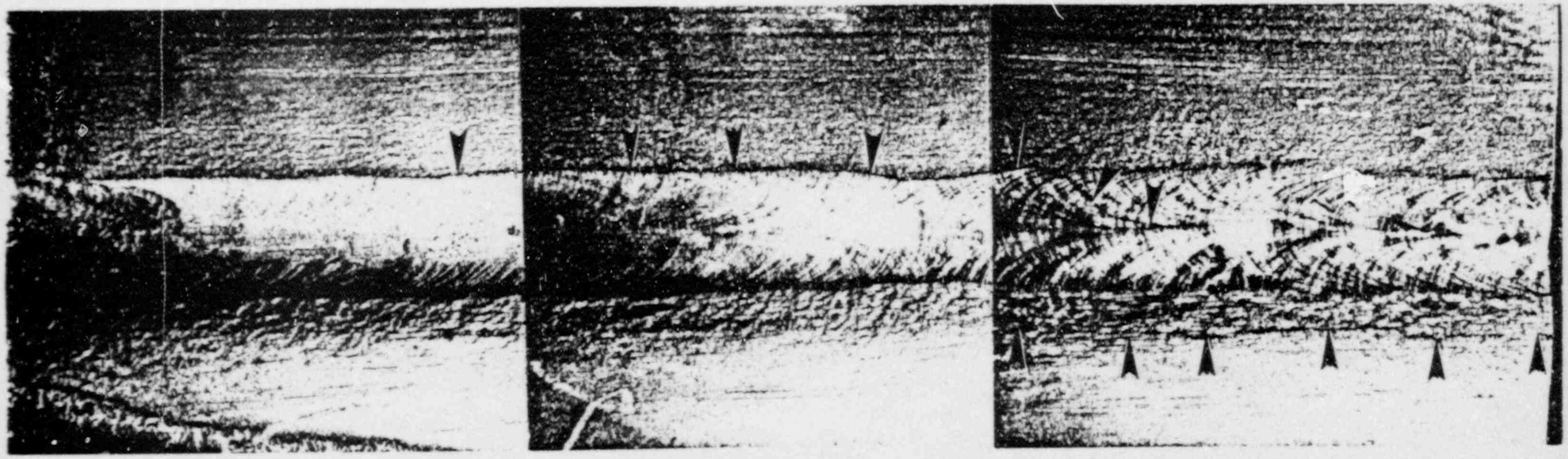
Fig. — Schematic illustration of the SI line configuration showing the location of leakage.

(19)



Light macrophotographs, schematically illustrating the sectioning procedure employed for the leaked weld.

2a



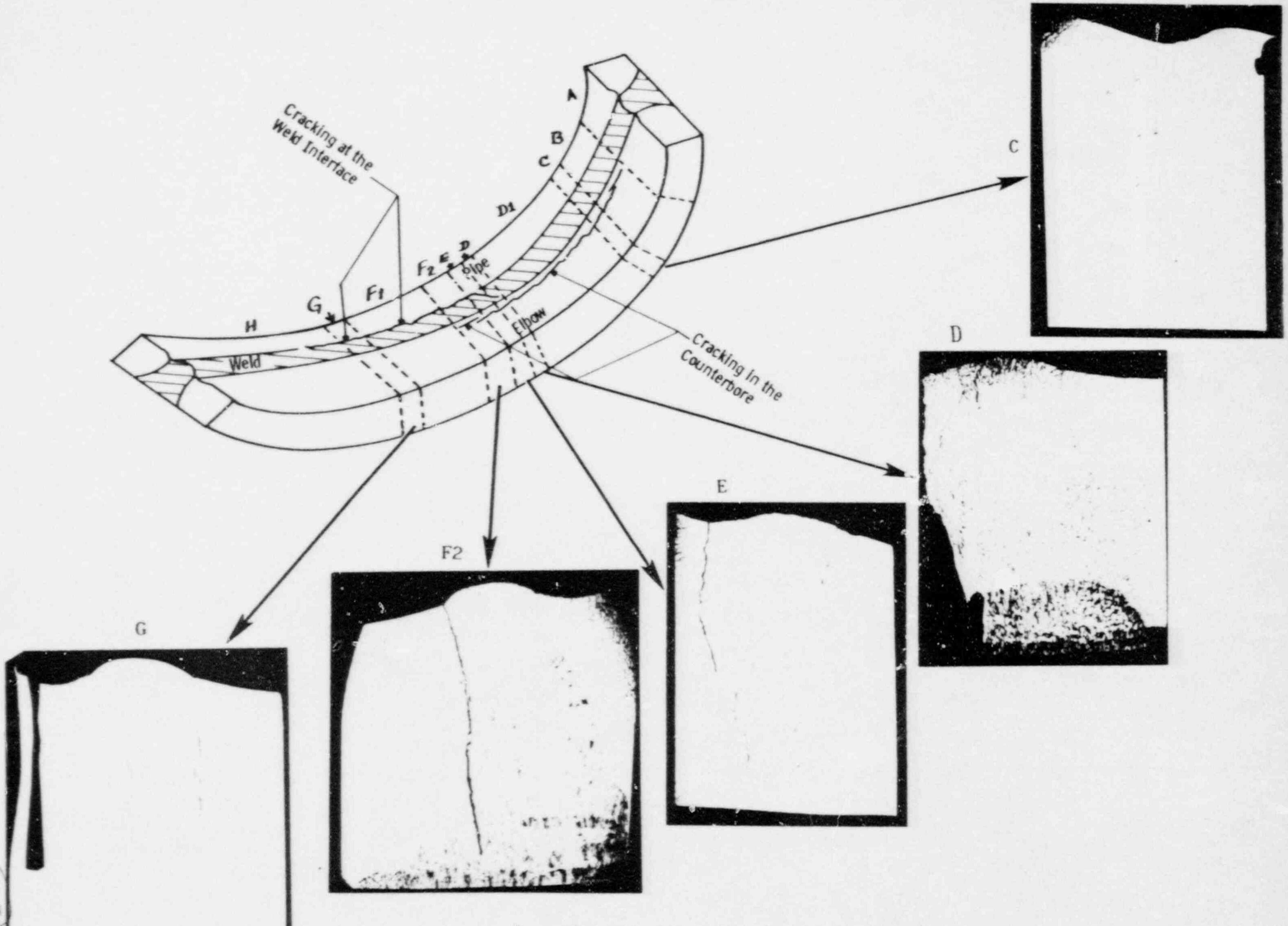
6 O'Clock

(21)

ID surface examination results of the elbow-to-horizontal pipe weld joint showing the location of cracks seen on the elbow side and the pipe side. (3.25x)

SUMMARY OF SURFACE EXAMINATION RESULTS

O SURFACE EXAMINATION RESULTS OF THE ID SURFACE OF THE WELD JOINT AT THE LEAK LOCATION CONFIRMED THE PRESENCE OF CIRCUMFERENTIAL CRACKS ONE ON EACH SIDE OF THE WELD. THE CRACK ON THE PIPE SIDE WAS LOCATED AT THE WELD INTERFACE, MEASURED APPROXIMATELY THREE INCHES LONG, AND RAN INTO THE WELD METAL NEAR THE SIX O'CLOCK LOCATION OF THE PIPE. THE CRACK ON THE ELBOW SIDE WAS LOCATED IN THE COUNTERBORE REGION OF THE BASE METAL, RAN ALONG THE SURFACE MACHINING GROOVES, AND MEASURED APPROXIMATELY THREE INCHES IN LENGTH.



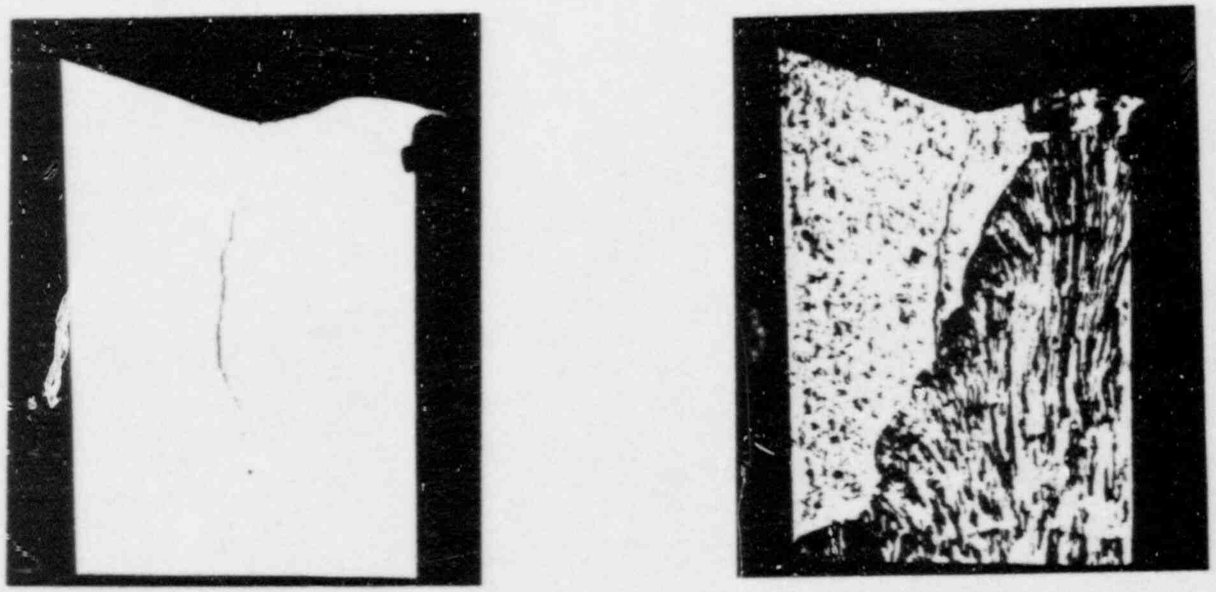
General morphology of cracks seen on transverse sections taken at various locations along the weld.

(Light Etch)

(Macro-Etch)

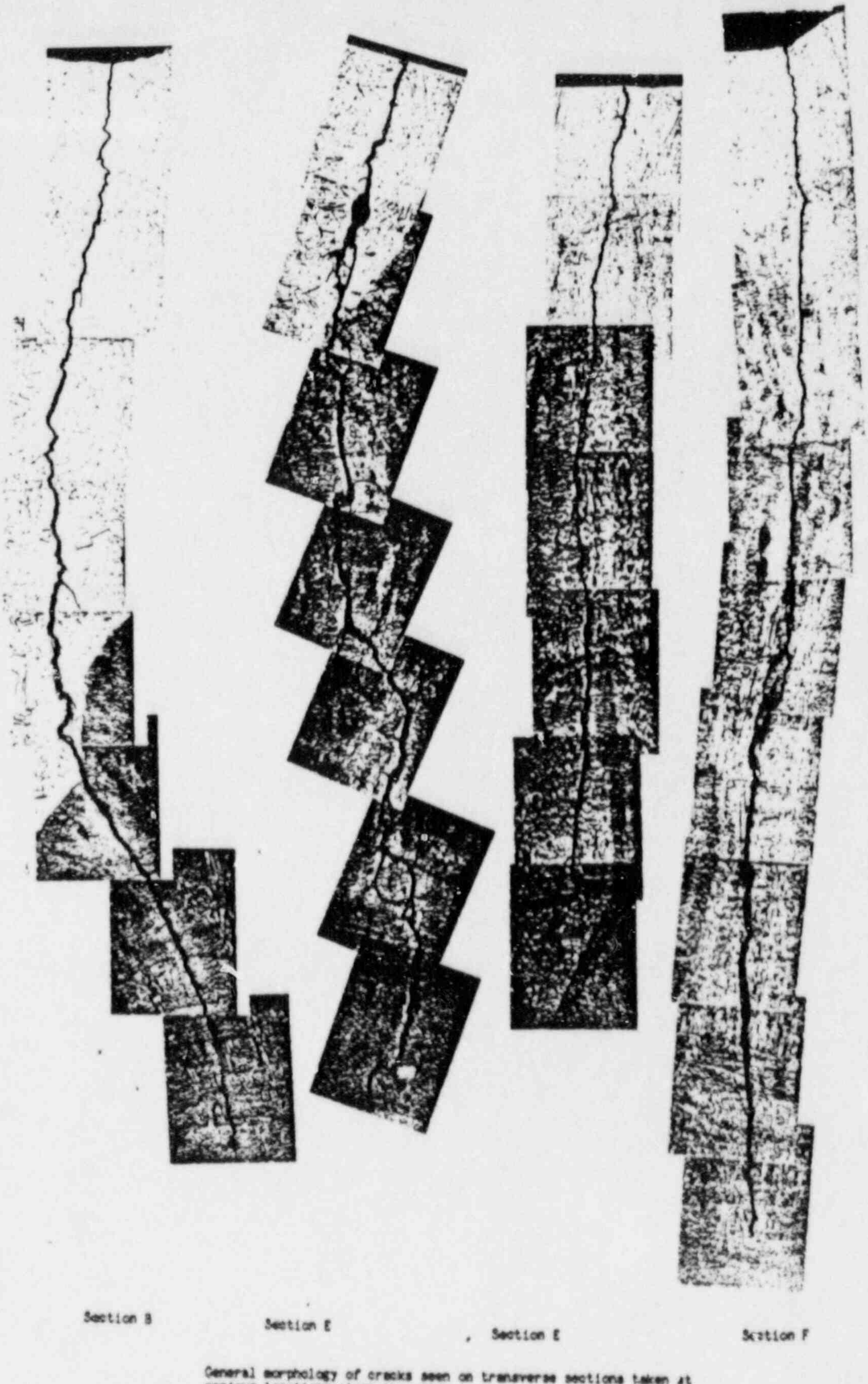
(Darkfield)

Light optical micrographs shown in different lighting conditions, illustrating the location and morphology of crack at the weld-to-pipe interface(F-2 3.25X)



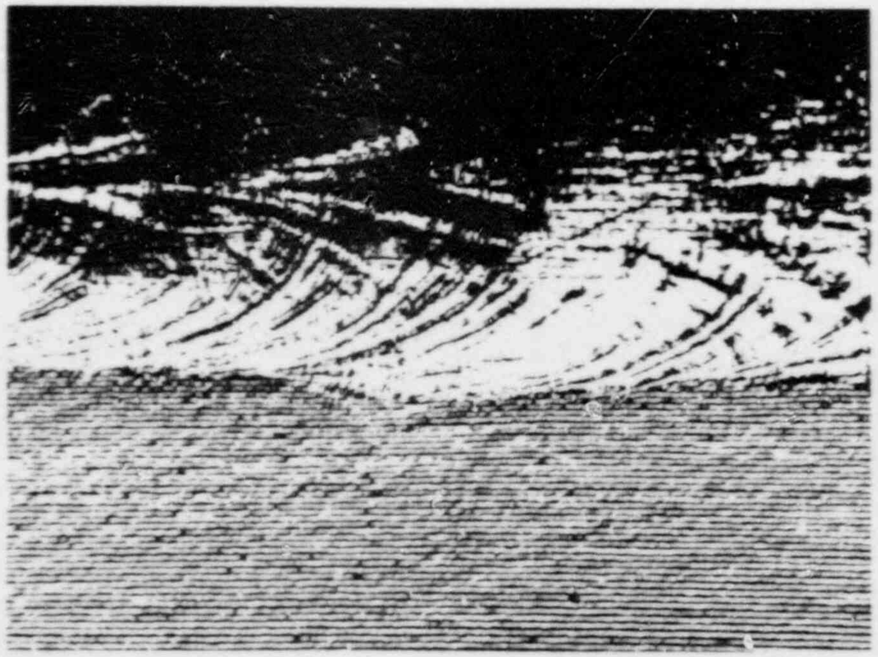
Light optical metallography results of the Section "C" illustrating the HAZ microstructures.

25



Section B   Section E   Section E   Section F

General morphology of cracks seen on transverse sections taken at various locations along the weld.



(8x)

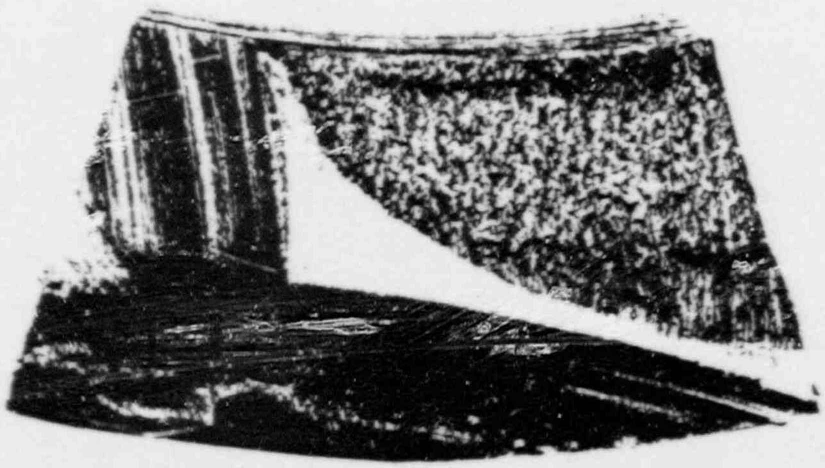
(100x)

Illustration of the initiation of cracks at the ID surface machining groves in the counterbore region of the elbow.

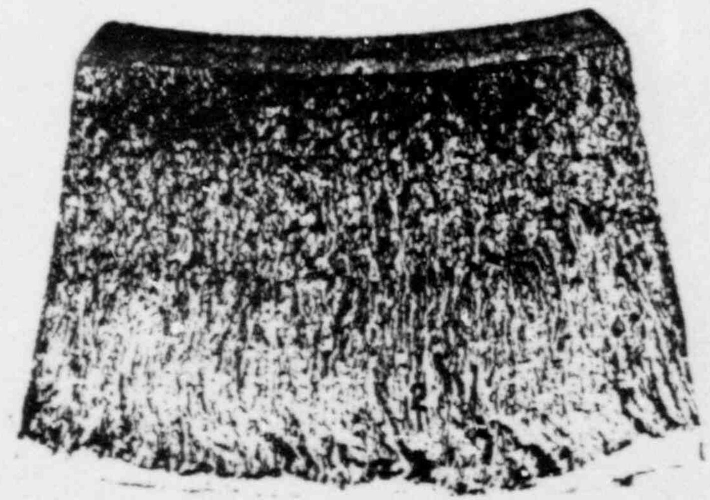
SUMMARY OF METALLOGRAPHIC EXAMINATION RESULTS

O METALLOGRAPHIC EXAMINATIONS CONDUCTED ON TRANSVERSE SECTIONS TAKEN AT SEVERAL CIRCUMFERENTIAL LOCATIONS IN THE REGION OF CRACKING, CONFIRMED THAT THE ID SURFACE CRACKING WAS EXTENDED DEEP INTO THE PIPE THICKNESS ALL THE WAY UP TO THE OD SURFACE OF THE PIPE. THE RESULTS SHOWED THAT THE MAJOR CRACK IN THE ELBOW SIDE INITIATED AT THE KNEE OF THE COUNTERBORE REGION, PROGRESSED THROUGH THE BASE METAL AND TERMINATED IN THE WELD METAL. THE CRACK ON THE PIPE SIDE WAS INITIATED AT THE WELD METAL TO BASE METAL INTERFACE AND PROGRESSED THROUGH THE WELD METAL TOWARDS THE OUTSIDE DIAMETER SURFACE. THE CRACKING WAS PRIMARILY STRAIGHT AND TRANSGRANULAR IN CHARACTER. NO APPRECIABLE BRANCHING OR CRACK DEPOSITS WERE OBSERVED. METALLOGRAPHIC EXAMINATIONS CONDUCTED ON SEVERAL SECTIONS THROUGH THE MAJOR CRACKS FAILED TO CONFIRM THE PRESENCE OF ANY MAJOR DEFECTS IN THE WELD METAL. THE METALLOGRAPHIC EXAMINATIONS ALSO CONFIRMED THE PRESENCE OF SEVERAL FINE CRACKS INITIATED FROM THE MACHINED GROOVES OF THE COUNTERBORE REGION OF THE ELBOW.

THE OVERALL RESULTS OF THE METALLOGRAPHIC EXAMINATIONS CONFIRMED THAT THE WELD CRACKING WAS INITIATED ON THE ID SURFACE AND PROGRESSED RADIALLY OUTWARDS TOWARD THE OD SURFACE. THE CRACKING WAS DEEPEST (THROUGHWALL) NEAR 6 O'CLOCK LOCATION OF THE PIPE. THE CRACKING WAS PRIMARILY CONTROLLED BY TENSILE LOADS AXIAL TO THE PIPE WITH NO APPRECIABLE CONTRIBUTION FROM ENVIRONMENTAL FACTORS.

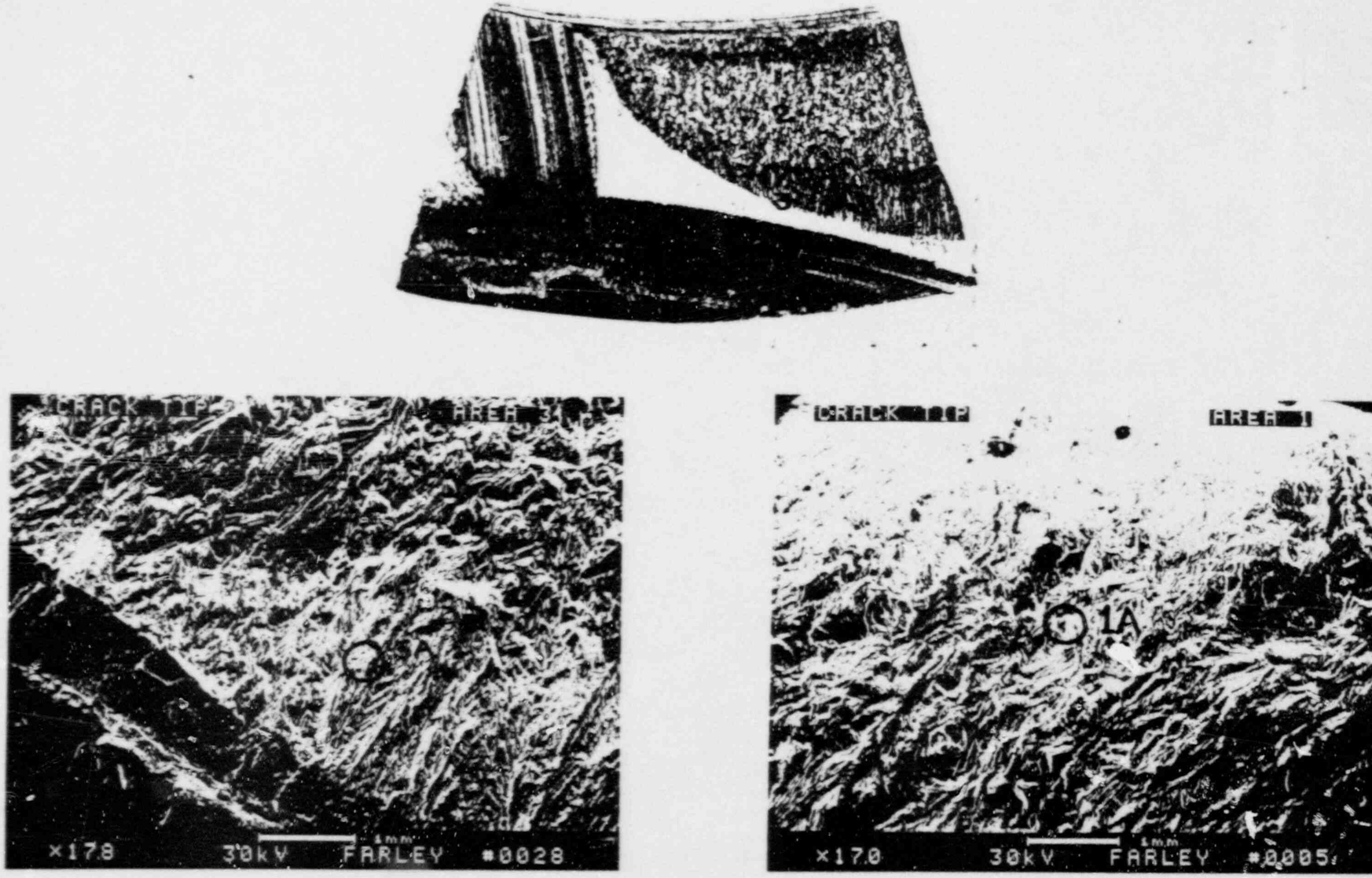


Sample B



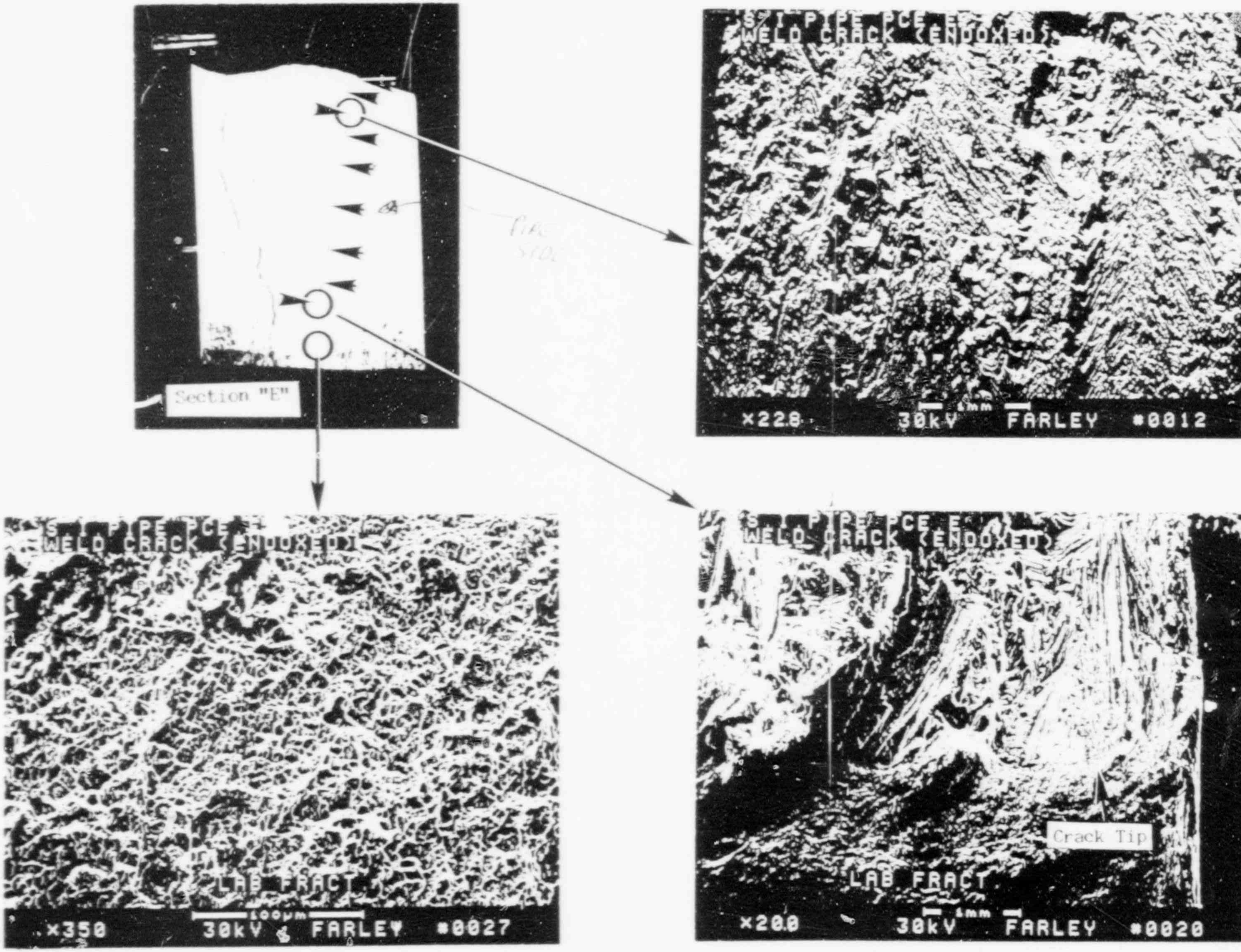
Sample D

Light optical fractographs illustrating the fracture morphology of the cracks seen in pieces B and D. (3.25x)

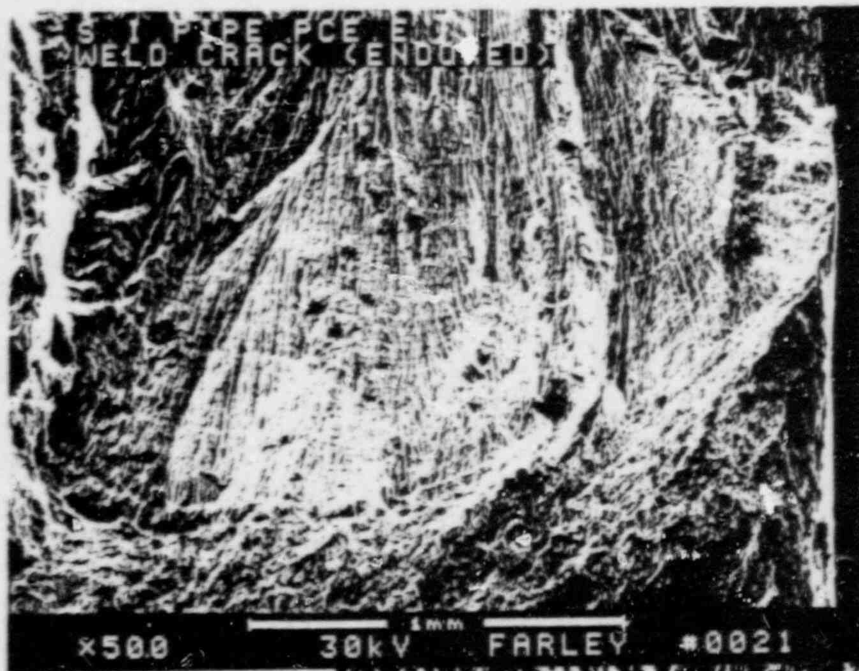


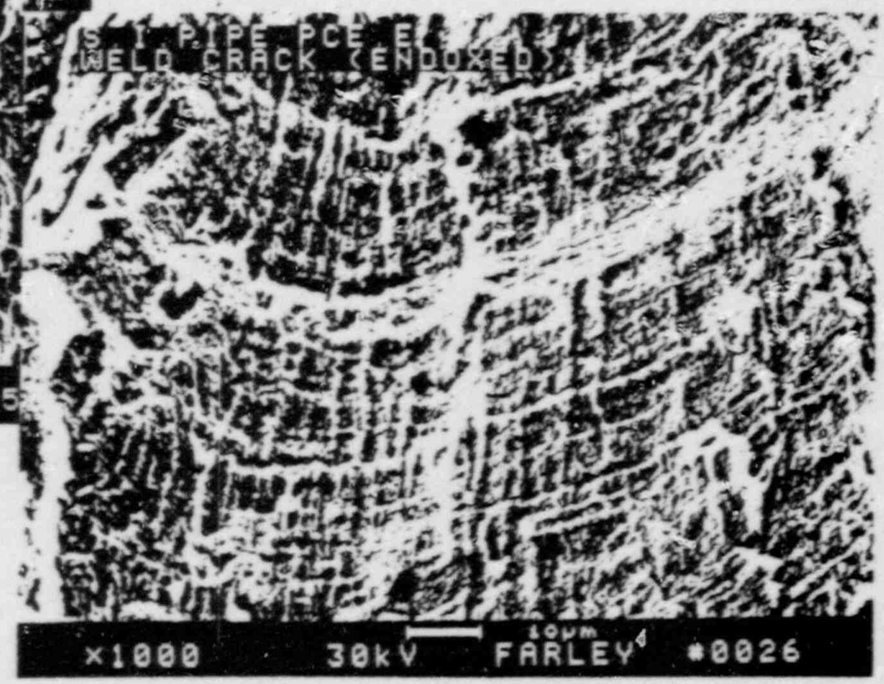
(30)

Scanning electron fractographs illustrating the fracture morphology of crack in piece "B"

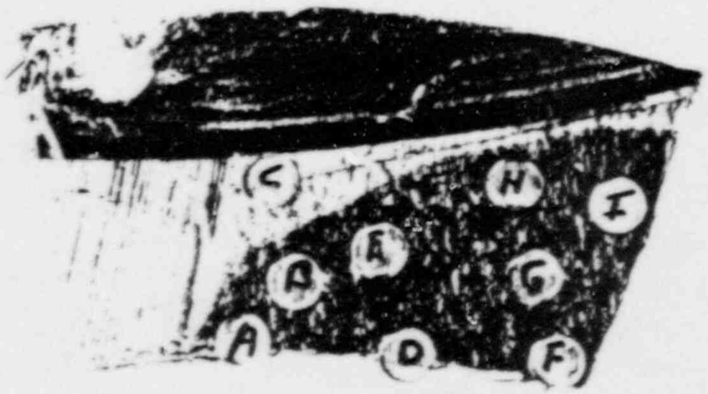


Scanning electron fractographs of the endoxed weld crack on the pipe side illustrating the morphology of the field fractured and laboratory fractured regions.

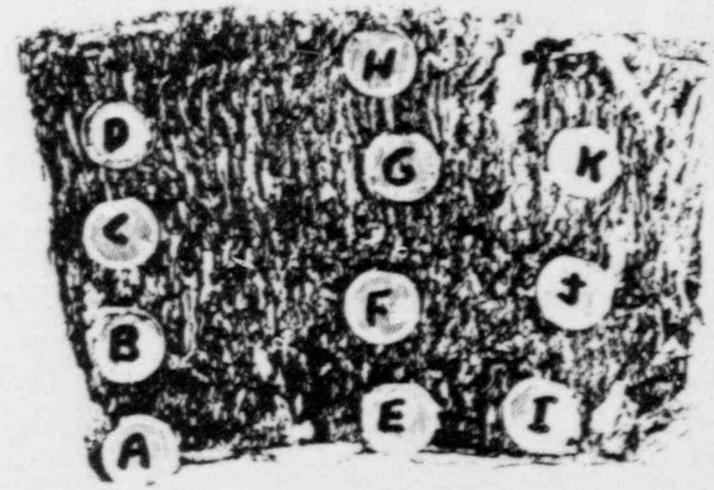




Scanning electron fractographs of the endoxed weld crack on the pipe side illustrating the evidence of fatigue striations.

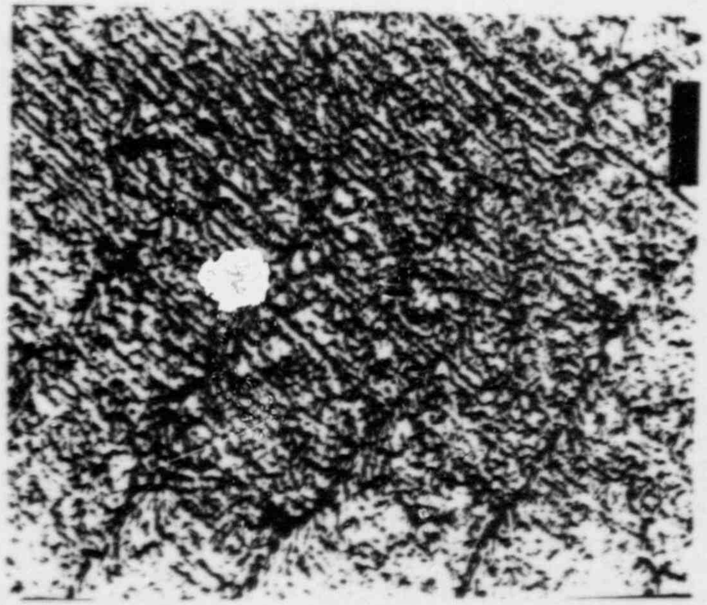


Sample B



Sample D

Light optical fractographs illustrating the positioning of various replica grids employed for the examination of the evidence for fatigue striations in Samples B and D. (3.25x)

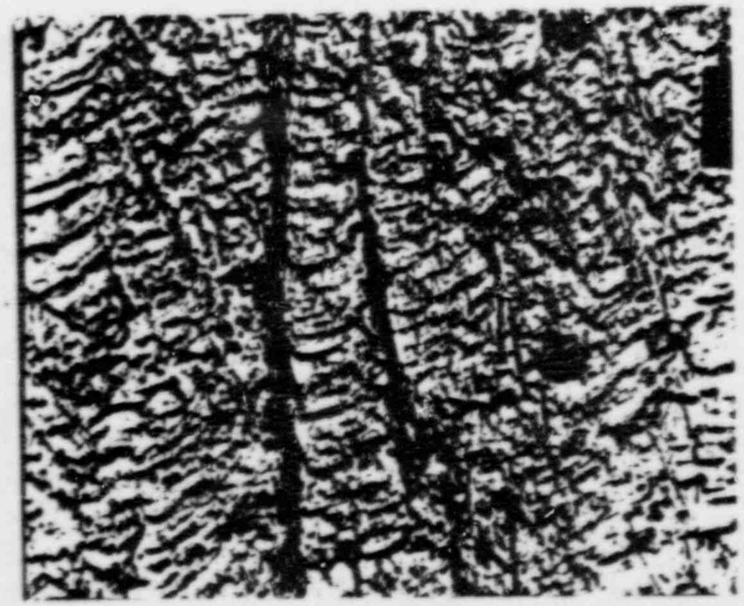


(13,000X)

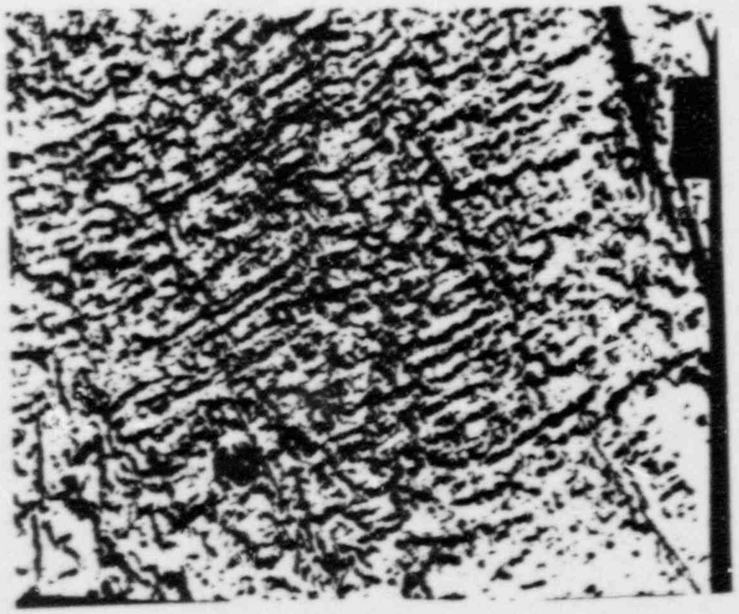
(22,000X)

Replica transmission electron micrographs illustrating the typical appearence of the fatigue striations seen at grid location G in sample B.

34



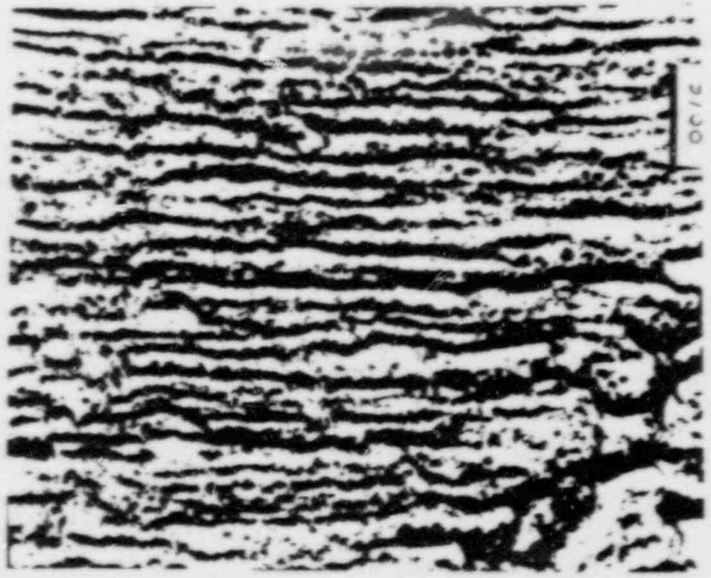
(6000X)



(10,000X)

Replica transmission electron micrographs illustrating the typical appearence of the fatigue striations seen at grid location I in sample D.

(3600X)



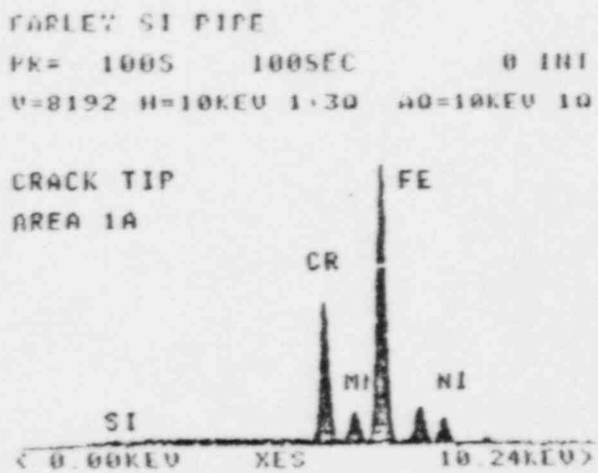
(17,000X)

Replica transmission electron micrographs illustrating the typical appearence of the fatigue striations seen at grid location F in sample B.

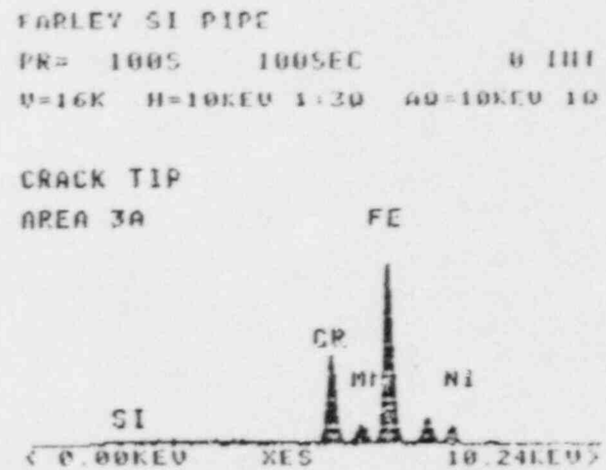
SUMMARY OF FRACTOGRAPHIC EXAMINATION RESULTS

O FRACTOGRAPHIC EXAMINATION OF THE FRESHLY OPENED CRACKS BOTH IN THE BASE METAL AND WELD METAL REGIONS SHOWED THAT THE CRACKING WAS INITIATED ON THE INSIDE DIAMETER SURFACE AND PROGRESSED RADIALLY OUTWARDS TO THE OUTSIDE DIAMETER SURFACE. CRACKING APPEARS TO HAVE BEEN INITIATED AT SEVERAL LOCATIONS OVER A BROADER REGION OF THE ID SURFACE RATHER THAN FROM A SINGLE ISOLATED INITIATION SITE. THE FRACTURE MORPHOLOGY FOLLOWED TRANSGRANULAR FACETS. HIGHER MAGNIFICATION SCANNING ELECTRON FRACTOGRAPHY CONFIRMED THE PRESENCE OF FATIGUE STRIATIONS PROGRESSING FROM THE INSIDE DIAMETER SURFACE TO ALL THE WAY TO THE CRACK TIP NEAR OUTSIDE DIAMETER SURFACE. THE EVIDENCE OF FATIGUE STRIATIONS WAS ALSO CONFIRMED IN THE FRESHLY OPENED CRACK IN THE WELD METAL. HIGH RESOLUTION TRANSMISSION ELECTRON MICROSCOPY CONDUCTED ON REPLICAS TAKEN FROM VARIOUS LOCATION THE ENDOXED FRACTURE FACES CONFIRMED THAT THE FATIGUE STRIATION SPACING RANGED FROM APPROXIMATELY 4×10^{-6} TO 8×10^{-6} INCHES.

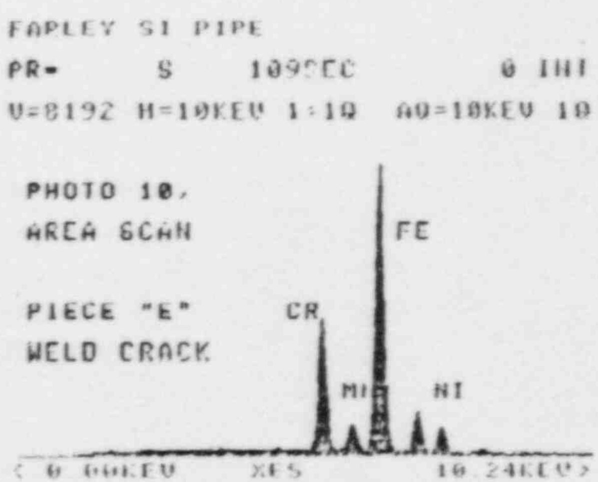
THE OVERALL RESULTS SUGGEST THAT CRACKING WAS INITIATED ON THE ID SURFACE AND PROGRESSED RADIALLY OUTWARD TO THE OD. CRACKING OCCURRED BY HIGH CYCLE FATIGUE MECHANISM.



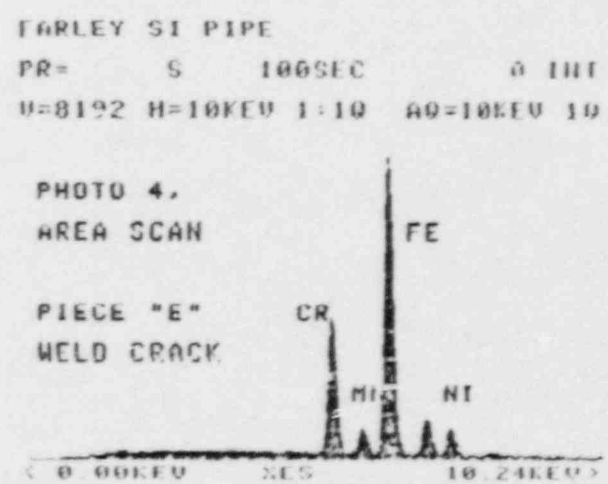
(a)



(a)



(b)



(b)

Typical energy dispersive X-ray analysis results obtained from the crack deposits seen on the a) elbow and b) pipe cracks, in the "as opened" conditions.

CHEMISTRY ANALYSIS RESULTS OF THE ID SURFACE DEPOSITS

(ELEMENT/COMPOUND GMS/AREA SWABBED)	F	CL	PO_4	NO_3	SO_4
CLEAN AREA	0.32	21.3	1.02	9.6	19.4
ID SURFACE	0.37	21.0	1.02	9.3	16.1

NO EVIDENCE OF ANY CORROSIVE ELEMENTS WAS SEEN ON THE ID SURFACE

SUMMARY OF CHEMISTRY ANALYSIS RESULTS

ELEMENT (WT O/O)	CR	MN	CU	CO	NI	MO	P	S	SI	C	FE
ELBOW MATERIAL	19.30	1.74	0.109	0.081	10.58	0.143	0.021	0.021	0.429	0.046	BAL
HORIZ. PIPE	18.48	1.72	0.121	0.056	10.68	0.155	0.018	0.014	0.474	0.068	BAL
WELD METAL	19.86	1.33	0.158	0.10	10.10	0.154	0.016	0.013	0.376	0.022	BAL
TYPE 304 S. STEEL REQUIREMENTS	18-20	2.0 MX	--	--	8 - 10.5	--	0.045	0.03	1.0 MX	0.08 MX	BAL
TYPE 308 S. STEEL STICK ELECTRODE REQUIREMENTS	19.5-22 19.21	1.0-2.5	0.75 MX	--	9-11 10-12	0.75 MX	0.03 MX	0.03 MX	0.3-0.65	0.08 MX	BAL

THE CHEMISTRY OF THE ELBOW AND PIPE MATERIALS MET THE TYPE 304 STAINLESS STEEL REQUIREMENTS.
THE CHEMISTRY OF THE WELD METAL MET THE TYPE 308 STAINLESS STEEL STICK ELECTRODE REQUIREMENTS.

(40)

SUMMARY OF CHEMISTRY EVALUATION RESULTS

O CHEMISTRY EVALUATION OF CRACK DEPOSITS BY ENERGY DISPERSIVE X-RAY ANALYSIS FAILED TO CONFIRM EVIDENCE OF ANY AGGRESSIVE ELEMENTS CONTRIBUTING TO THE CRACKING PROCESS. WET CHEMISTRY ANALYSIS RESULTS OF THE PIPE, ELBOW AND WELD MATERIALS SHOWED THAT THE ELBOW AND PIPE MATERIALS MEET THE TYPE 304 STAINLESS STEEL REQUIREMENTS WHILE THE WELD METAL MEETS THE TYPE 308 STAINLESS STEEL REQUIREMENTS.

THE OVERALL RESULTS OF THE CHEMISTRY EVALUATIONS SHOWED THAT NO CORROSIVE ELEMENTS CONTRIBUTED TO THE CRACKING PROCESS AND THAT THE ELBOW, PIPE AND WELD MATERIALS MEET THE SPECIFICATION REQUIREMENTS.

SUMMARY OF MICROHARDNESS MEASUREMENT RESULTS

	AVERAGE KNOOP HARDNESS	APPROX. TENSILE STRENGTH (KSI)
ELBOW MATERIAL	160	70
PIPE MATERIAL	158	70
WELD METAL	207	91

NO ABNORMALITIES IN THE STRENGTH LEVELS OF THE ELBOW, PIPE AND WELD MATERIALS

HAZ MICROHARDNESS MEASUREMENT RESULTS

SERIAL NUMBER	DISTANCE FROM CRACK	KHN 500 GMS	APPROX. TENSILE STRENGTH
1	.005	238.2	107
2	.010	230.8	102
3	.015	210.7	92
4	.020	210.7	92
5	.025	211.7	93
6	.035	222.7	100
7	.055	236.9	107
8	.075	199.6	88
9	.095	192.1	85
10	.115	196.8	87
11	.135	172.8	77
12	.155	203.5	90

EBLOW HAZ HAS A SLIGHTLY HIGHER HARDENER COMPARED TO THE UNAFFECTED BASE METAL

SUMMARY OF MICROHARDNESS MEASUREMENT RESULTS

O MICROHARDNESS MEASUREMENTS MADE ON THE POLISHED SECTION OF THE WELD JOINT SHOWED THAT THE MICROSTRUCTURES OF THE ELBOW, WELD AND PIPE MATERIALS, RESPECTIVELY CORRESPONDED TO KNOOP HARDNESS LEVELS OF 160, 207 AND 158. THESE HARDNESS VALUES CORRESPONDED TO AN APPROXIMATE TENSILE STRENGTH LEVELS OF 90 KSI IN THE WELD METAL AND 70 KSI IN THE PIPE AND ELBOW MATERIALS.

NO ABNORMALITIES IN MECHANICAL PROPERTIES WERE SEEN.

OTHER MECHANISMS

- O NO EVIDENCE OF BRANCHING, CRACK DEPOSITS OR CONTAMINANTS. STRESS CORROSION IS NOT A MECHANISM.

- O NO EVIDENCE OF OVERLOAD DIMPLES. OVERLOAD IS NOT A MECHANISM.

- O NO WELD DEFECTS. HOT CRACKING OR OTHER WELD DEFECTS ARE NOT CONTRIBUTING FACTORS.

CONCLUSIONS

- THE OBSERVED CRACKING IN THE FARLEY 2 SI LINE WELD WAS INITIATED AT THE ID SURFACE AND PROGRESSED RADIALLY OUTWARD TOWARDS THE OD SURFACE OF THE PIPE.

- THE CRACKING OCCURRED BY HIGH CYCLE FATIGUE MECHANISM.

- MACHINING MARKS IN THE COUNTER BORE REGION (IN THE ELBOW) AND THE WELD INTERFACE (IN THE PIPE) SERVED AS PREFERRED SITES FOR CRACK INITIATION.

- THE FATIGUE STRIATION SPACINGS ON THE FRACTURE FACE VARIED APPROXIMATELY BETWEEN 2×10^{-6} IN. TO 8×10^{-6} IN.

NONDESTRUCTIVE EXAMINATION RESULTS

- O FLUORESCENT DIE PENETRANT TEST RESULTS OF THE ID SURFACE OF THE ELBOW TO VERTICAL PIPE WELD JOINT DID NOT REVEAL EVIDENCE OF ANY ID INITIATED CRACKING.

- O RT EXAMINATIONS RESULTS OF THIS WELD JOINT SHOWED PRESENCE OF ACCEPTABLE LEVEL OF INCLUSION SITES IN THE WELD.

- O PT EXAMINATION RESULTS OF THE ID SURFACE OF THE ELBOW, BOTH ON THE INTRADOS AND EXTRADOS REGIONS DID NOT SHOW EVIDENCE OF ANY ID INITIATED CRACKING.

CONCLUSION: THE ELBOW AND THE WELD JOINT #17 MAY NOT BE SEEING THE LOADING CONDITIONS SEEN BY WELD #16

IV.2 EVALUATIONS OF UNIT 2 B LOOP EXPERIENCE - D. ROURTY

2. OPERATIONAL TEST PROGRAM

A. SELECTION OF INSTRUMENTATION

- o ASSUMED CRACK RESULTED FROM FATIGUE

  MECHANICAL - VIBRATION

  THERMAL - STRATIFICATION & CYCLING

- o VIBRATION MEASUREMENTS: ACCELEROMETERS

  TYPE: PIEZOELECTRIC, ENDEVCO 7701-100

  RANGE: 1 - 5000 HZ, 0 - 1000 g

- o THERMAL MEASUREMENTS RTD'S

  TYPE: PLATINUM SURFACE RTD; HY-CAL: RTS-63

  RANGE: - 100^{o} TO 900^{o}F

- o STRAIN GAUGES NOT USED DUE TO INHERENT DIFFICULTIES WITH CYCLIC THERMAL LOADINGS

B. SELECTION OF TEST LOCATIONS

- VIBRATION

  LOOP B - CRACK LOCATION

  LOOP C - CONTROL

  MAXIMUM ANTICIPATED VIBRATION

- THERMAL

  LOOP B - CRACK LOCATION

  LOOP C - CONTROL

  OUTSIDE WALL TEMPERATURE

- LOOP C AS CONTROL

  LOOP A HAD ADDITIONAL RIGID RESTRAINT NEAR VALVE V051

  LOOP C HAS LONGER HORIZONTAL RUN AND COULD EXHIBIT MORE EFFECTS OF STRATIFICATION

  LOOP A OR LOOP C ACCEPTABLE AS CONTROL, FINAL CHOICE BASED ON CONTAINMENT ACCESS CONSIDERATIONS

C. SUMMARY OF TEST RESULTS

1. VIBRATION

FFT ANALYSIS TO OBTAIN PEAK SPECTRUM

REVIEWED FREQ. RANGE 4-100 HZ

MAXIMUM G LEVELS APPROX: .1

MAXIMUM DISPLACEMENT LEVELS: .00077 INCHES

2. THERMAL RESULTS PRIOR TO BIT FLOW DIVERSION

LOOP B: LARGE STRATIFICATION
215^{O}F DOWNSTREAM
128^{O}F UPSTREAM

LOOP B: TEMPERATURES FLUCTUATE SIGNIFICANTLY, PARTICULARLY AT BOTTOM OF PIPE, PERIOD OF CYCLING BETWEEN 2 AND 20 MINUTES

LOOP C: VERY LITTLE STRATIFICATION OR FLUCTUATIONS

CONCLUSIONS

LOOP C CONFIGURATION AS EXPECTED

LOOP B PROBABLY HAD SMALL FLOW OF COOLER WATER FLOWING INTO DOWNSTREAM PIPING

D. EVALUATION OF CAUSE OF DOWNSTREAM THERMAL CYCLING

- o COOLER WATER IN SMALL QUANTITIES FLOWED INTO RCS PIPING AT VARIOUS RATES
- o FLOW REQUIRED A WATER SOURCE WITH GREATER THAN RCS PRESSURE (CHARGING SYSTEM)
- o TWO POSSIBLE CAUSES IDENTIFIED:
  - o VALVE 8885 LEAKAGE - 3" GATE
  - o VALVE 8911 LEAKAGE - 1" GLOBE - BYPASS LINE

IV.2

E. BIT FLOW DIVERSION

- o LEAKAGE FLOW DIVERTED TO BIT SURGE TANK
- o RTD READINGS INDICATE DOWNSTREAM STRATIFICATION AND CYCLING STOPPED
- o NO CHANGE IN LOOP C READINGS
- o TEMPORARY THERMAL CYCLING OBSERVED UPSTREAM ON LOOP B
- o CURRENTLY STEADY-STATE RESPONSE ON ALL READINGS, POSSIBLY FLOW IN LOOP B UPSTREAM
- o CONCLUSION:

  FLOW DIVERSION HAS STOPPED COLD WATER FLOW TO RCS

  MOST LIKELY CAUSE OF LEAKAGE WAS VALVE 8911

IV.2

F. THERMAL - AFTER B. I. FLOW DIVERSION - CURRENT STATUS

- o LOOP B DOWNSTREAM STRATIFICATION AND TEMPERATURE FLUCTUATION
- o LOOP C - NO EFFECT
- o INITIALLY OBSERVED LOW FREQUENCY THERMAL OSCILLATIONS, UPSTREAM LOOP B
- o CURRENTLY LOOP B AND C STEADY STATE

IV.3 ANALYTICAL EVALUATIONS - D. ROURTY

A. VIBRATION

- o CORRELATED SPECTRAL CURVES TO MODAL ANALYSIS
- o MAXIMUM STRESS ABOUT 500 PSI AT WELD
- o CONCLUSION: VIBRATION HAD NEGLIGIBLE EFFECT ON OBSERVED PIPE CRACK

B. COLD SPRING

- o SMALL AMOUNT OF COLD SPRING (ABOUT .6 INCH) EVALUATED
- o LESS THAN 500 PSI AT WELD
- o CONCLUSION: NOT RELATED TO PIPE CRACK

C. VALVE EFFECTS

- o VALVE LEAKAGE THROUGH SMALL GLOBE VALVE PRIMARY CAUSE OF CYCLING
- o THE EXPECTED OPENING AND CLOSING OF THE CHECK VALVE (V051B) WITH A SMALL ΔP PROBABLY CAUSED THE FLUCTUATION IN THE THERMAL LOAD
- o BACK LEAKAGE AT CHECK VALVE CAN CAUSE STRATIFICATION BUT NOT THERMAL CYCLING
- o NO KNOWN RELATIONSHIP BETWEEN CHECK VALVE PERFORMANCE AND MECHANISM OBSERVED

IV.3.D THERMAL CYCLING EVALUATIONS

1. THERMAL STRESS ANALYSIS

   a) DEVELOPMENT OF THERMAL LOADING

      - FINITE ELEMENT CORRELATION OF OUTSIDE WALL TEMPERATURE AND INSIDE TEMPERATURE INDICATES FULL TEMPERATURE CYCLING AND THREE MINUTE PERIOD REASONABLE ASSUMPTION

      - CONCLUSION:
        - REASONABLE TO ASSUME 550° TO 100° CYCLING
        - REASONABLE TO ASSUME 3 MINUTE PERIOD

   b) THERMAL CYCLING STRESSES

      - UNIFORM TEMPERATURE CYCLES APPLIED TO 2-D AXISYMMETRIC FINITE ELEMENT MODEL

      - MAXIMUM 550° TO 100° STEP CHANGES, 3 MINUTE PERIOD

      - MAXIMUM MINIMUM STRESS PROFILE DETERMINED

D. THERMAL CYCLING EVALUATION

2. FRACTURE MECHANICS/FATIGUE CRACK GROWTH

a) ANALYSIS BASED ON METALOGRAPHY

- o STRIATION SPACING USED TO ESTIMATE DA/DN VS T
- o DA/DN = CRACK GROWTH PER CYCLE
  T = WALL THICKNESS
- o USE DA VS T CURVE TO ESTIMATE ΔK
  ΔK = RANGE OF STRESS INTENSITY
- o USE K TO DETERMINE ΔS
  ΔS = RANGE OF APPLIED STRESS
- o OBTAIN CYCLES TO LEAKAGE

b) ANALYSIS BASED ON THERMAL STRESS ANALYSIS

- o THERMAL STRESS USED IN FATIGUE CRACK GROWTH CALCULATION
- o DA/DN FOR AUSTENITIC STAINLESS STEEL
  $DA/DN = (2.42 \times 10^{-20})(E)(\Delta K)^{3.3}$
  E = ENVIRONMENTAL FACTOR (2.0)
- o OBTAIN CYCLES TO LEAKAGE

CONCLUSION: STRESS PROFILE CALCULATED FROM STRIATION SPACING IS CHARACTERISTIC OF THERMAL LOADINGS

IV.3.

3. ASME FATIGUE EVALUATION

- o PURPOSE: CALCULATE USAGE FACTORS PER ASME CODE SECTION III, FOR SIS COLD LEG PIPING

- o EVALUATION INCLUDED ALL CLASS 1 PIPING COMPONENTS ON 6" SIS COLD LEG LINES PLUS RCL NOZZLE

- o LOADINGS INCLUDED:
  - -- DESIGN TRANSIENTS (SI, RHR, OBE, ETC.)
  - -- THERMAL CYCLING (BEFORE AND AFTER B.I. FLOW DIVERSION)

- o CONCLUSION:
  ALL COMPONENTS SATISFY ASME REQUIREMENTS FOR PLANT LIFE

IV.4 CONCLUSION

- PIPE CRACK WAS NOT CAUSED BY POOR FABRICATION/INSTALLATION/ MATERIALS
- PIPE CRACK WAS NOT CAUSED BY ENVIRONMENTAL CONSIDERATIONS
- PIPE CRACK WAS NOT CAUSED BY DESIGN LOADINGS
- PIPE CRACK WAS NOT CAUSED BY VIBRATION
- PIPE CRACK WAS NOT RELATED TO CHECK VALVE MAINTENANCE HISTORY
- CRACKING CAUSED BY FATIGUE DUE TO THERMAL LOADS
- THERMAL LOADS RESULTED FROM THERMAL CYCLING COMBINED WITH STRATIFICATION
- THERMAL CYCLING AND STRATIFICATION CAUSED BY COOLER WATER FLOW FROM HIGH PRESSURE UPSTREAM SOURCE TO RCS
- COOLER WATER FLOW PROBABLY RESULTED FROM LEAKAGE THROUGH 1" BIT BYPASS VALVE
- SIS COLD LEG PIPING SATISFIES ASME REQUIREMENTS

V. FLUID SYSTEMS EVALUATION OF A AND C COLD LEG INJECTION LINES

- NDE PROVIDED NO EVIDENCE OF THERMAL CYCLING ON A AND C LOOPS
- GIVEN THE AMOUNT OF IN-LEAKAGE, THE EVALUATION OF THE LOOP B TEMPERATURE TRACES CONCLUDES THAT THE A AND C LOOPS WERE NOT EFFECTED
- INSTRUMENTATION ON C LOOP DETECTED NO THERMAL CYCLING

CONCLUSION:

LOOP B PROVIDED A PREFERRED LEAK PATH AND WAS THEREFORE THE ONLY EFFECTED LINE.

05023.RDM

FLUID SYSTEMS EVALUATION OF IMPACT OF IN-LEAKAGE ON THERMAL SLEEVE

- IN-LEAKAGE WAS RELATIVELY SMALL, AND UNABLE TO SWEEP THE ENTIRE CROSS SECTION OF THE 6" HORIZONTAL SI LINE

- RELATIVELY COLD FLUID WOULD HAVE TO TRAVEL 22" ALONG THE HORIZONTAL SECTION AND 17" ALONG THE VERTICAL SECTION BEFORE REACHING THE THERMAL SLEEVE

- THE VERTICAL SECTION IS CHARACTERIZED BY SIGNIFICANT MIXING OF FLUID GIVEN:

  - CIRCULATION DUE TO NATURAL CONVECTION

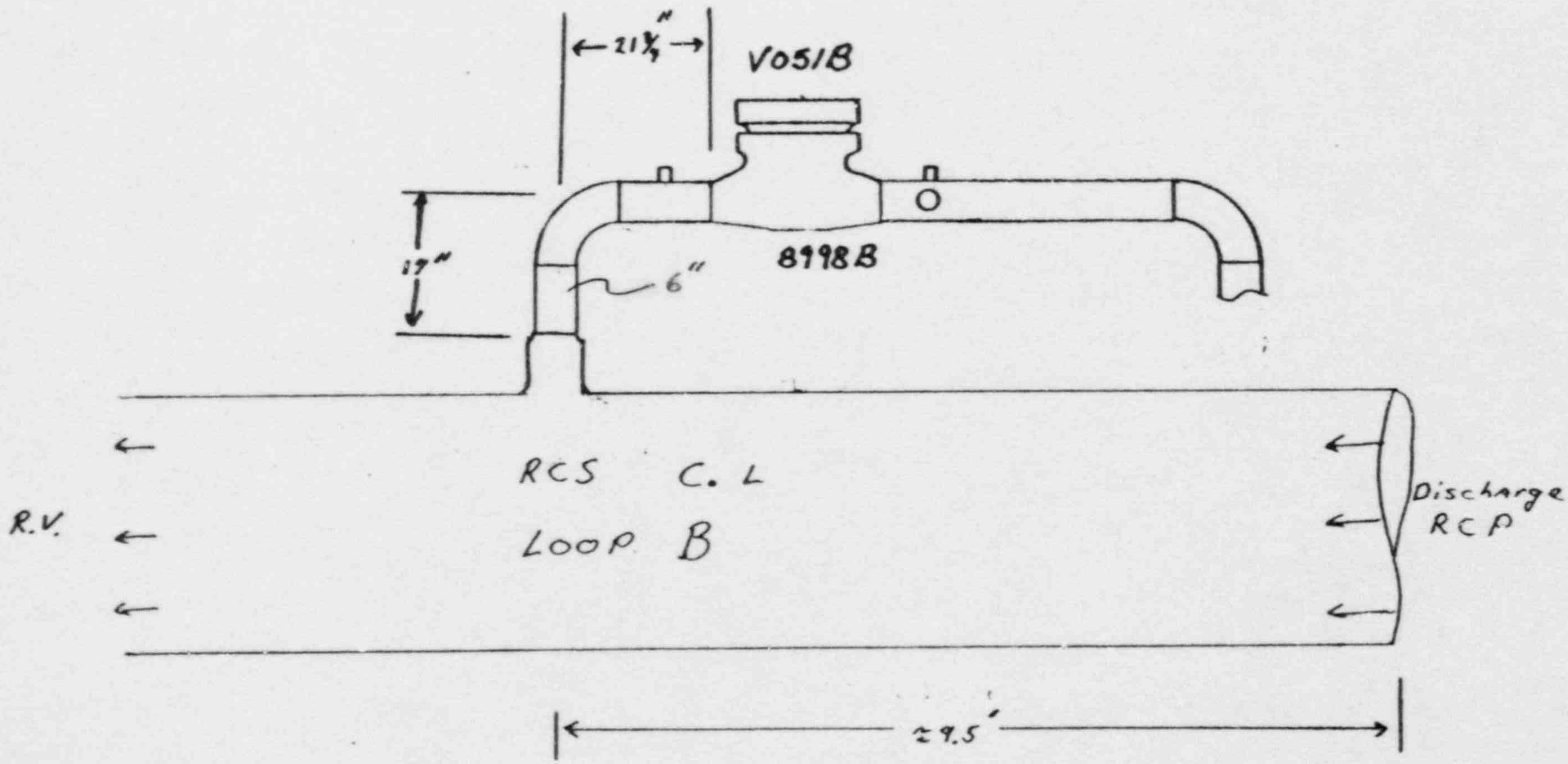
  - PROXIMITY TO THE DISCHARGE OF THE RCP

CONCLUSION:

GIVEN THE AMOUNT OF IN-LEAKAGE, DISPERSION EFFECTS IN THE HORIZONTAL AND VERTICAL PIPE SECTIONS PRECLUDES THE THERMAL SLEEVE FROM EXPERIENCING THE THERMAL TRANSIENT

05023.RDM

Loop B C. L. Injection Line



OTHER LINES SUBJECT
TO
SIMILAR EXPERIENCES

CRITERIA:

ANY ISOLATED LINE WHERE RELATIVELY COLD FLUID COULD BE INJECTED INTO THE RCS DUE TO AN IN-LEAKAGE FROM A HIGH PRESSURE SOURCE.

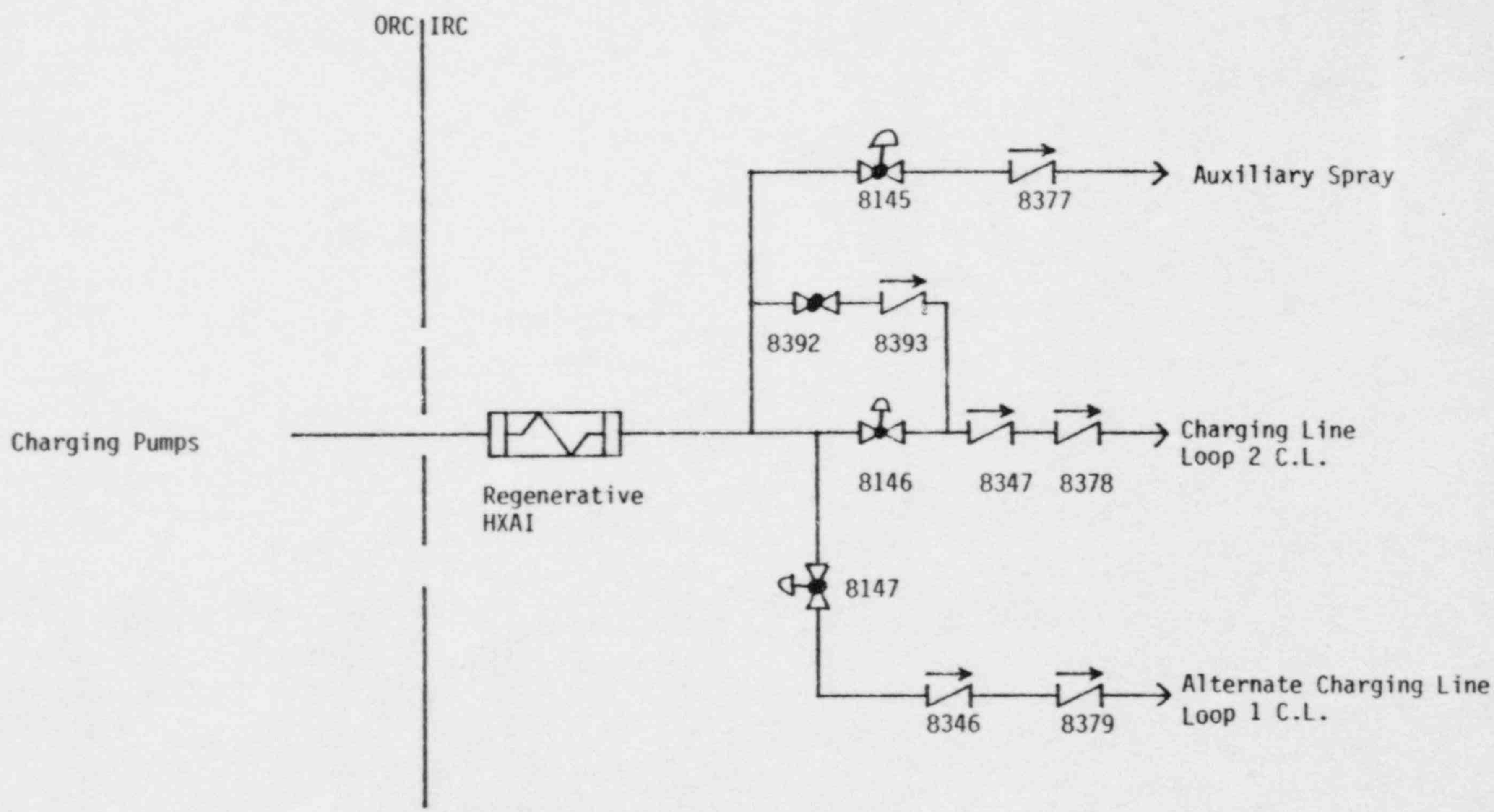
HIGH PRESSURE SOURCE:

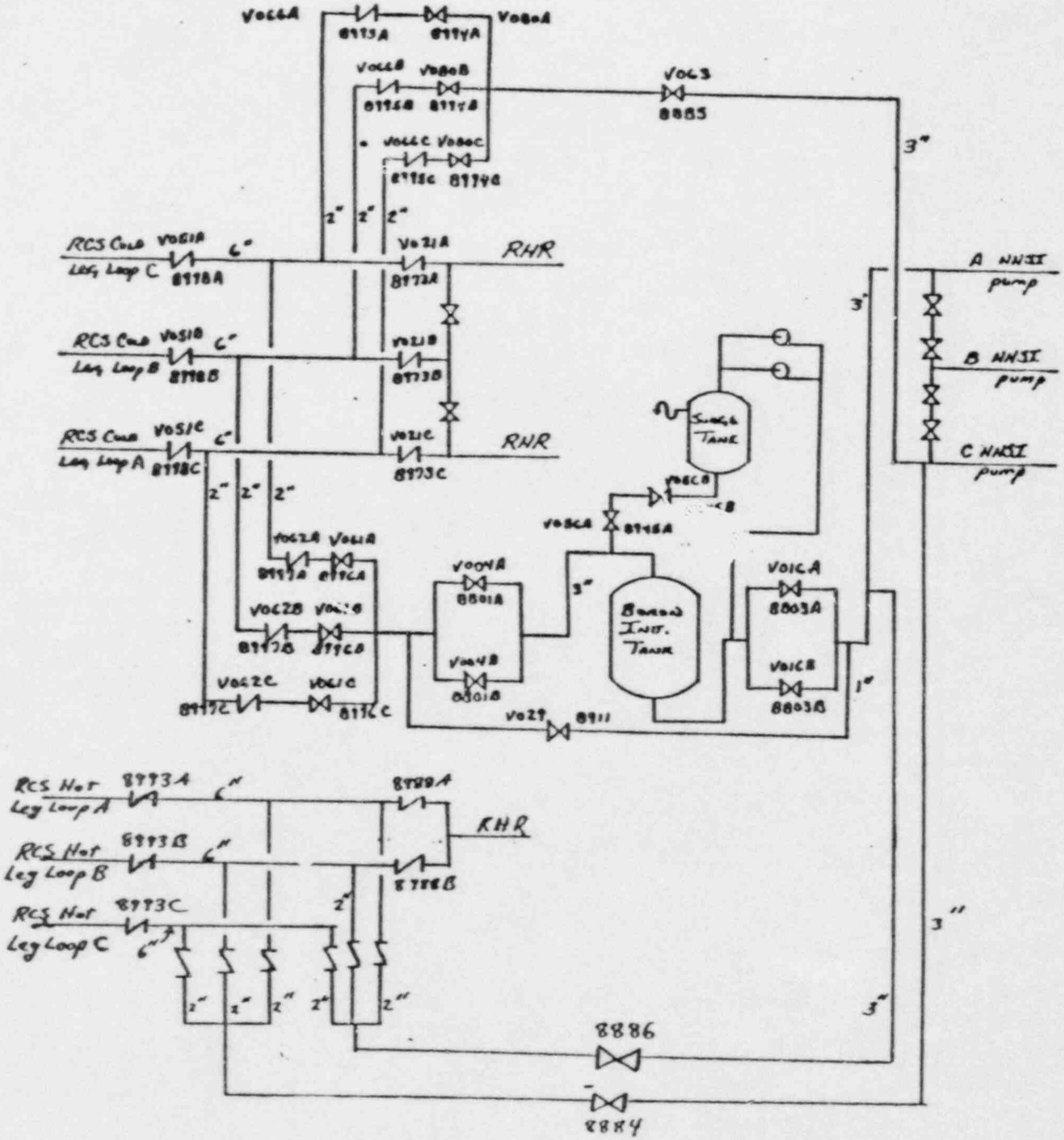
THE CHARGING/SI SYSTEM IS THE ONLY ON LINE HIGH PRESSURE SOURCE CAPABLE OF INJECTING FLOW INTO THE RCS DURING NORMAL OPERATING PRESSURES.

OTHER LINES WHERE POTENTIAL MECHANISM EXISTS

- AUXILIARY SPRAY LINE
- CHARGING OR ALTERNATE CHARGING LINES
- HHSI C. L. INJECTION LINES
- HHSI H. L. INJECTION LINES

Charging, Alternate Charging and Auxiliary Spray Lines





RCS Cold Leg Loop C
RCS Cold Leg Loop B
RCS Cold Leg Loop A
RHR
RHR
Surge Tank
Boron Inj. Tank
A NHSI pump
B NHSI pump
C NHSI pump
RCS Hot Leg Loop A
RCS Hot Leg Loop B
RCS Hot Leg Loop C
RHR
8885
8801A
8801B
8803A
8803B
8911
8886
8884
3"
6"
2"
1"

AUXILIARY SPRAY LINE:

- LEAKAGE WOULD HAVE TO OCCUR ACROSS 8145
- DELTA P ACROSS VALVE IS LOW (APPROXIMATELY 7 PSID)
- IN-LEAKAGE TEMPERATURE IS APPROXIMATELY 500°F

CHARGING AND/OR ALTERNATE CHARGING LINES:

- LEAKAGE WOULD HAVE TO OCCUR ACROSS 8147, 8146, OR 8392
- DELTA P ACROSS VALVES IS (APPROXIMATELY 7 PSID)
- IN-LEAKAGE TEMPERATURE IS APPROXIMATELY 500°F

HHSI C. L. AND H. L. INJECTION LINES:

- LEAKAGE WOULD HAVE TO OCCUR ACROSS VALVES 8885, 8886, 8884 OR 8911
- DELTA P ACROSS VALVES IS APPROXIMATELY 320 PSID
- IN-LEAKAGE TEMPERATURE IS APPROXIMATELY 100°F

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QUALITATIVE EVALUATION OF VALVE LEAKAGE

THREE PRIMARY FACTORS EFFECTING PROBABILITY OF VALVE TO MAINTAIN A SECURE PRESSURE BOUNDARY

- VALVE TYPE
- VALVE OPERATOR
- DELTA P

VALVE TYPE

- GATE VALVE IS HIGHLY RELIABLE
- GLOBE VALVE IS SLIGHTLY LESS RELIABLE THAN GATE

VALVE OPERATOR

- MOV PROVIDES THE TIGHTEST AND MOST REPEATABLE SEAT
- AIR OPERATOR IS SLIGHTLY LESS EFFECTIVE
- MANUAL VALVES ARE LEAST LIKELY TO MAINTAIN A SECURE PRESSURE BOUNDARY

DELTA P

- LOWER DELTA P REDUCES LIKELIHOOD OF VALVE LEAKAGE

VALVE CHARACTERISTICS

VALVE	SIZE	TYPE	OPERATOR	MAX ΔP	RELATIVE PROBABILITY OF LEAKAGE
8145	2"	GLOBE	AIR	7 PSID	LOW
8147 8146	3"	GLOBE	AIR	7 PSID	LOW
8392	3/4"	GLOBE	MANUAL	7 PSID	LOW–MED
8885 8884 8886	3"	GATE	MOV	320 PSID	LOW
8911	1"	GLOBE	MANUAL	320 PSID	MED

EVALUATION OF INDIVIDUAL LINES

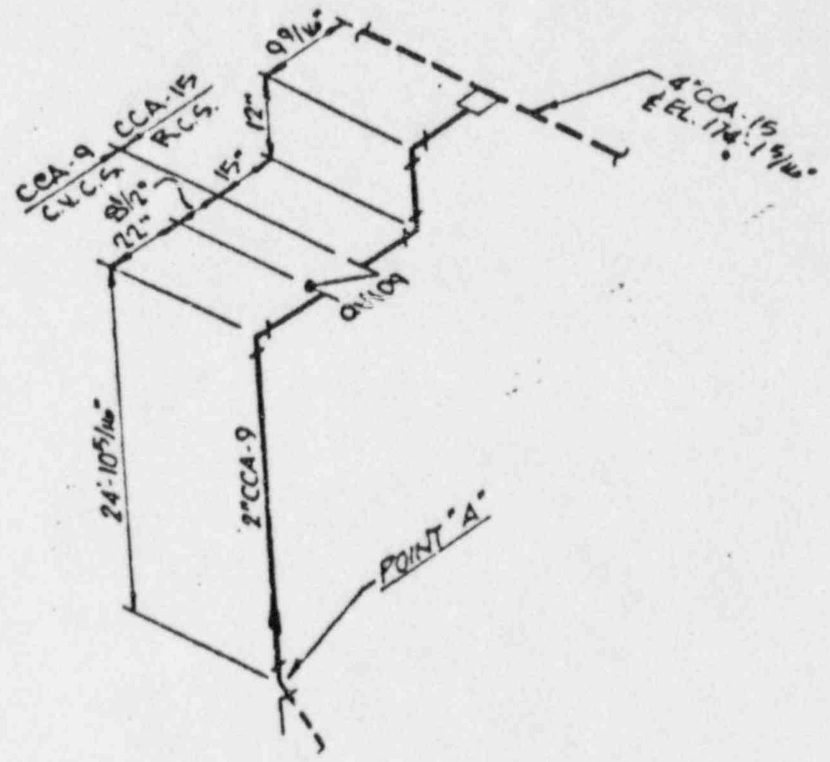
AUXILIARY SPRAY LINE

- LOW PROBABILITY OF IN-LEAKAGE
  - LOW DELTA P
  - RELIABLE PRESSURE BOUNDARY
- IN-LEAKAGE INITIATES AT A RELATIVELY HIGH TEMPERATURE
- PRESENCE OF COLD TRAP DOWNSTREAM OF LAST CHECK VALVE REDUCES TEMPERATURE GRADIENT ACROSS THE VALVE

CONCLUSION:

THE AUXILIARY SPRAY LINE DOWNSTREAM OF LAST C.V IS NOT SUBJECT TO THERMAL CYCLING

Auxiliary Spray Injection
Line to Normal Spray Line



CHARGING LINES (NORMAL AND AUXILIARY)

- LOW PROBABILITY OF IN-LEAKAGE
  - LOW DELTA P
  - RELIABLE PRESSURE BOUNDARY
- IN LEAKAGE INITIATES AT A RELATIVELY HIGH TEMPERATURE
- CHARGING LINES ARE INSULATED, THEREFORE COOLDOWN OF IN-LEAKAGE PRIOR TO INJECTION INTO RCS IS MINIMIZED

CONCLUSION:

EVALUATION SUGGESTS THAT THERMAL CYCLING IS HIGHLY UNLIKELY

. HHSI H. L. AND C. L. INJECTION LINES

- LOW PROBABILITY OF IN-LEAKAGE

  - H. L. INJECTION LINE PRESSURE BOUNDARY IS PROVIDED BY MOV GATE VALVES

  - WITH 8801A/B OPEN, THE C. L. INJECTION LINE PRESSURE BOUNDARY IS PROVIDED BY MOV GATE VALVE

CONCLUSION:

ALTHOUGH THE POTENTIAL MECHANISM EXISTS ON THE H. L. INJECTION LINES THE PROBABILITY OF THERMAL CYCLING IS MINIMIZED GIVEN A SECURE PRESSURE BOUNDARY.

WITH LEAKAGE THROUGH THE BIT BYPASS LINE DIVERTED, THE C. L. INJECTION LINE HAS AN EQUALLY SECURE PRESSURE BOUNDARY. PROBABILITY OF THERMAL CYCLING IS MINIMIZED.

V.2 THERMAL SLEEVE CONSIDERATIONS

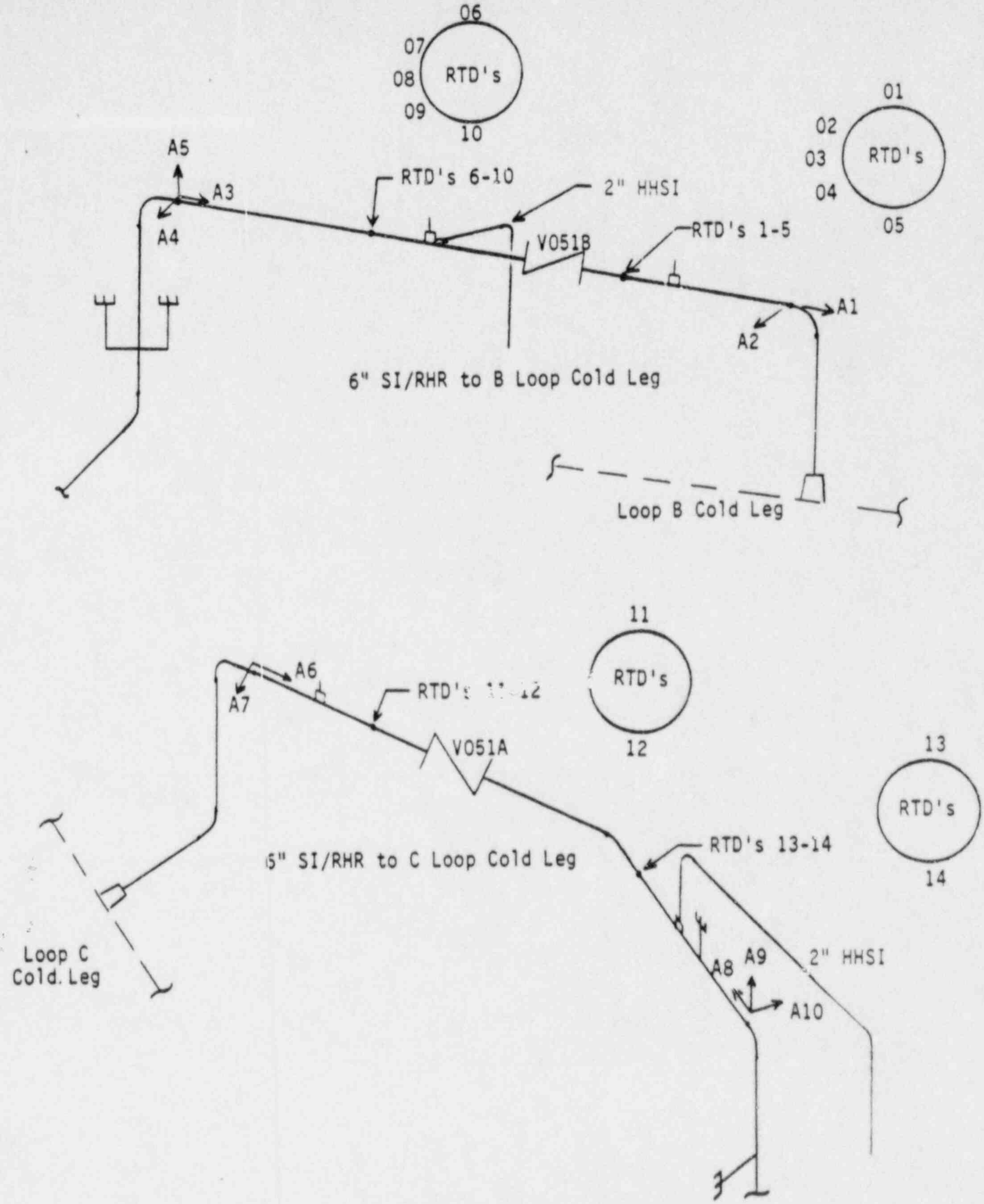
- o SUMMARY OF CURRENT PLANT STATUS
- o THERMAL SLEEVES INCORPORATED IN ORIGINAL DESIGN TO PROTECT PRESSURE BOUNDARY FROM THERMAL SHOCK
- o ANALYTICAL METHODS AVAILABLE AT TIME OF ORIGINAL DESIGNS NOT ABLE TO EVALUATE STRUCTURAL INTEGRITY OF COMPONENT
- o FINITE ELEMENT TECHNIQUES AND IMPROVEMENTS IN ASME CODE ANALYSIS PERMITTED QUALIFICATION OF NOZZLE WITH AND WITHOUT SLEEVE
- o FARLEY SIS NOZZLES QUALIFIED WITH AND WITHOUT SLEEVES
- o RECOMMENDATION MADE TO ELIMINATE SLEEVE FROM DESIGN
- o ANALYSIS OF RECORD CONSIDERED DESIGN TRANSIENTS
- o THERMAL MIXING CONSIDERED BUT INSUFFICIENT ΔT IN NOZZLE REGION TO CAUSE FATIGUE
- o SIS LOOP B THERMAL CYCLING DID NOT HAVE IMPACT ON NOZZLE INTEGRITY
- o PRELIMINARY THERMAL HYDRAULIC EVALUATION DEMONSTRATE FLOW MIXING IN VERTICAL RISER BEFORE NOZZLE REGION
- o THIS IS SUPPORTED BY LACK OF INDICATION IN DOWNSTREAM WELDS

V .2

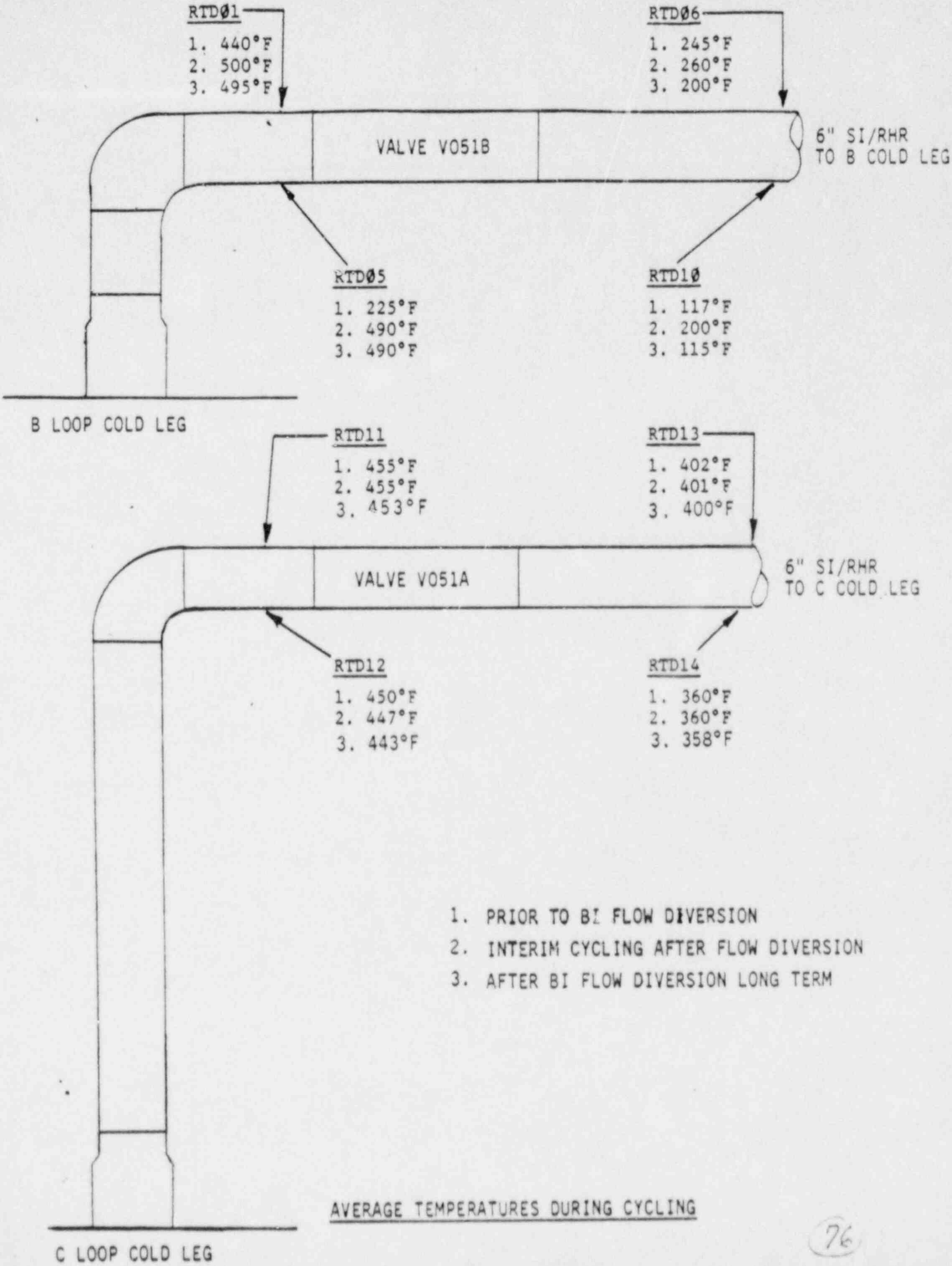
- o UT ON NOZZLE SAFE-END WELD FOUND NO RECORDABLE INDICATIONS
- o UT/RT/AND PT ON DOWNSTREAM (INSIDE AND OUTSIDE SURFACES) ELBOW WELD FOUND NO INDICATION OF CRACK
- o PREVIOUS STUDY'S CONCLUDED THERMAL SLEEVE FAILURE RESULTED FROM FLOW INDUCED VIBRATION
- o VIBRATION LOADS ON CRACKED WELD RESULTING FROM THE SLEEVE PROTRUDING INTO THE RCS FLOW HAVE BEEN EVALUATED AND ARE NOT CONSIDERED PROBABLE SOURCES OF FATIGUE
- o CONCLUSIONS
    - o NOZZLE INTEGRITY NOT AFFECTED BY SIS LOOP B THERMAL MECHANISM, WITH OR WITHOUT SLEEVES
    - o THERMAL SLEEVE INTEGRITY PROBABLY NOT RELATED TO SIS LOOP B THERMAL MECHANISM

V .3 CONTINUED ACCEPTABILITY OF UNITS 1 AND 2

- o SYSTEMS DESIGN EVALUATION INDICATES SIS COLD LEG MOST LIKELY CANDIDATE
- o NDE ON PIPING COVERED ALL MOST SUSCEPTIBLE REGIONS WITH NO RECORDABLE INDICATIONS
- o UNIT 2 CYCLING MECHANISM ELIMINATED
- o UNIT 1 SCHEDULED FOR OUTAGE IN MARCH:
  NDE FOUND NO RECORDABLE INDICATIONS
  INSUFFICIENT TIME FOR THERMAL CYCLING TO PROPAGATE CRACK THROUGH-WALL
- o PRELIMINARY LEAK-BEFORE-BREAK EVALUATIONS INDICATE NO DOUBLE END BREAK PRIOR TO LEAK DETECTION



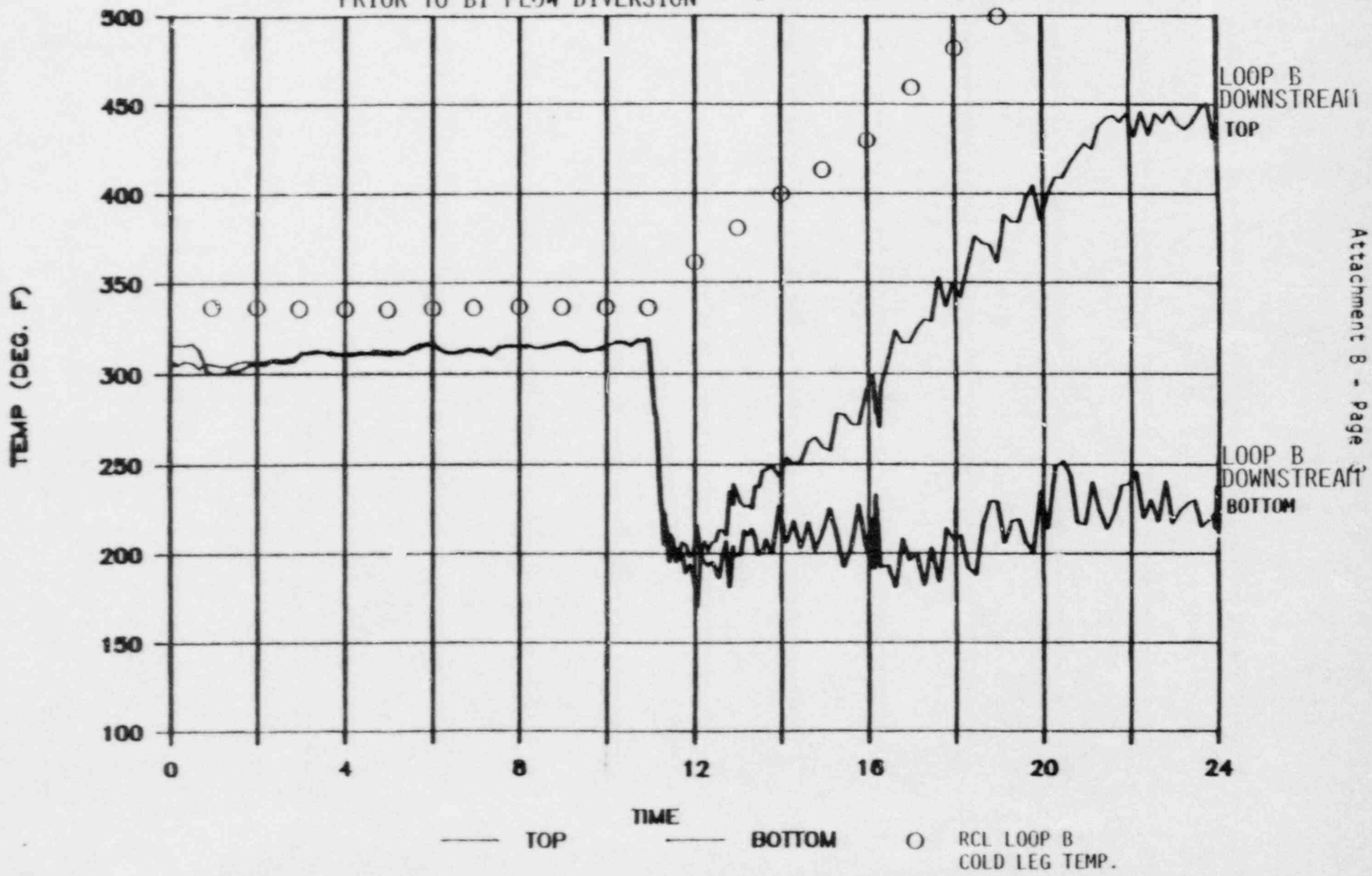
IDENTIFICATION OF INSTRUMENTATION



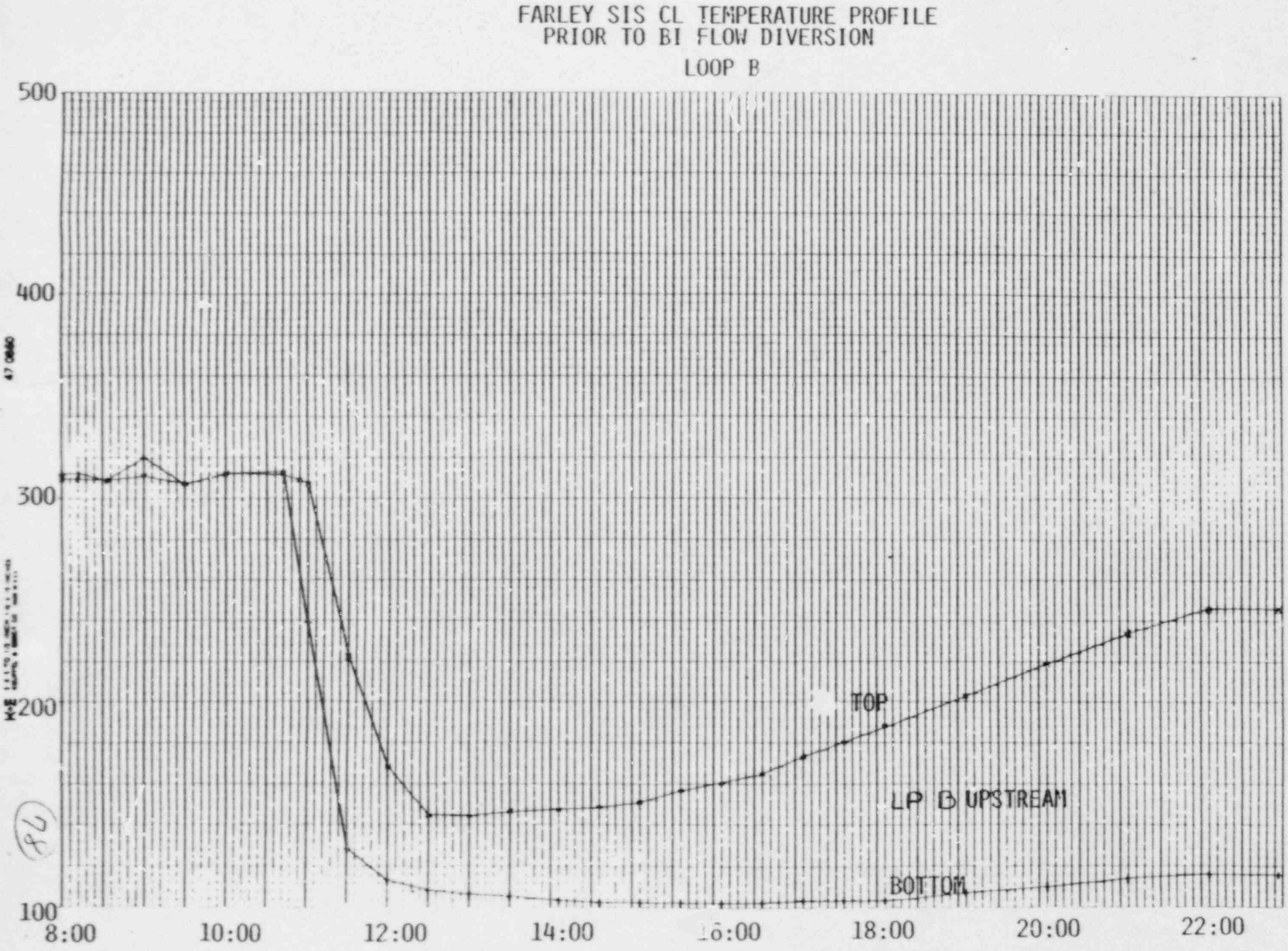
AVERAGE TEMPERATURES DURING CYCLING

FARLEY SIS CL TEMPERATURE PROFILE

PRIOR TO BI FLOW DIVERSION - B LOOP DOWNSTREAM



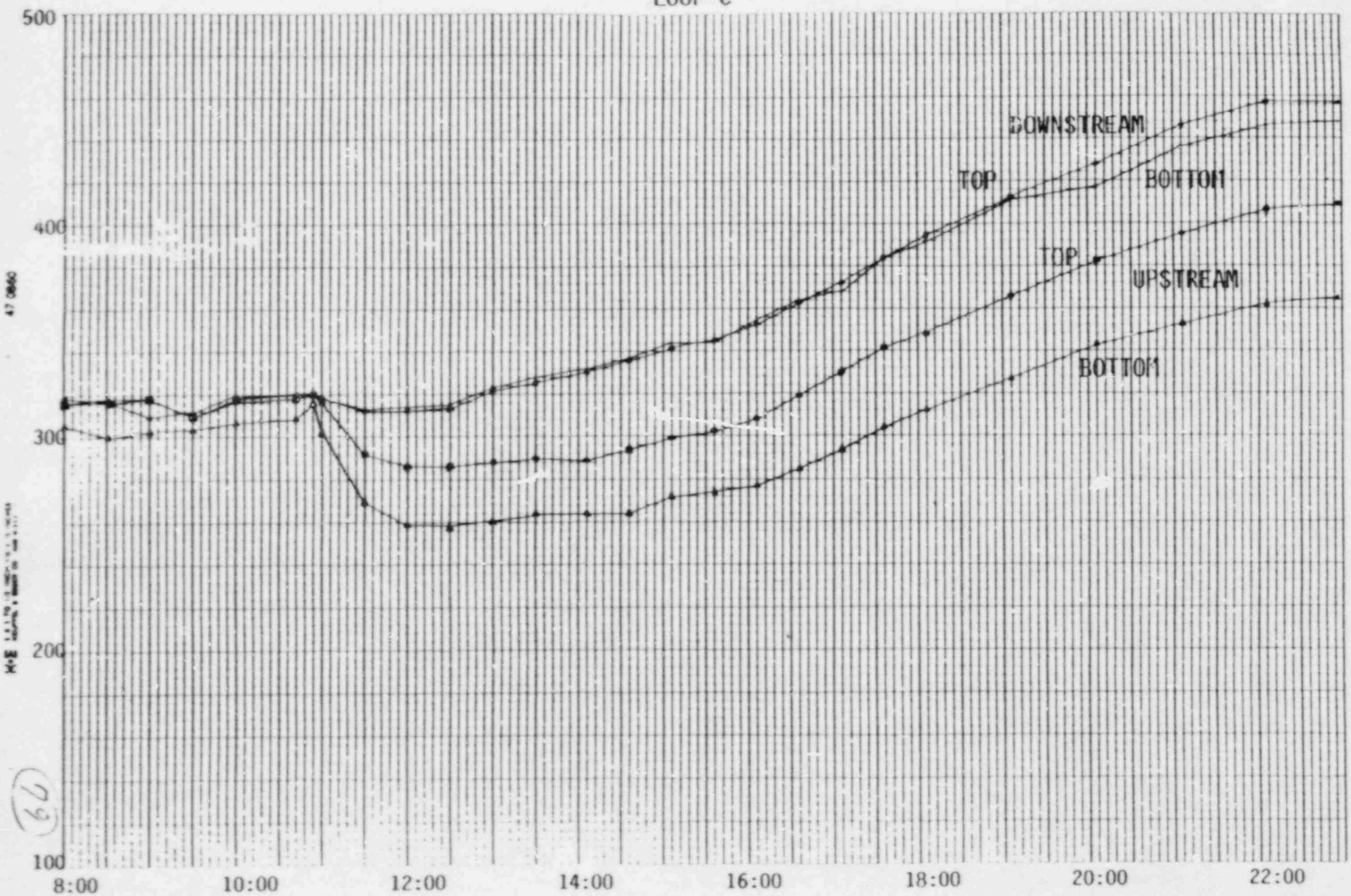
Attachment B - Page


FARLEY SIS CL TEMPERATURE PROFILE
PRIOR TO BI FLOW DIVERSION
LOOP B
500
400
300
200
100
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
TOP
LP B UPSTREAM
BOTTOM

(86)

FARLEY SIS CL TEMPERATURE PROFILE
PRIOR TO BI FLOW DIVERSION

LOOP C



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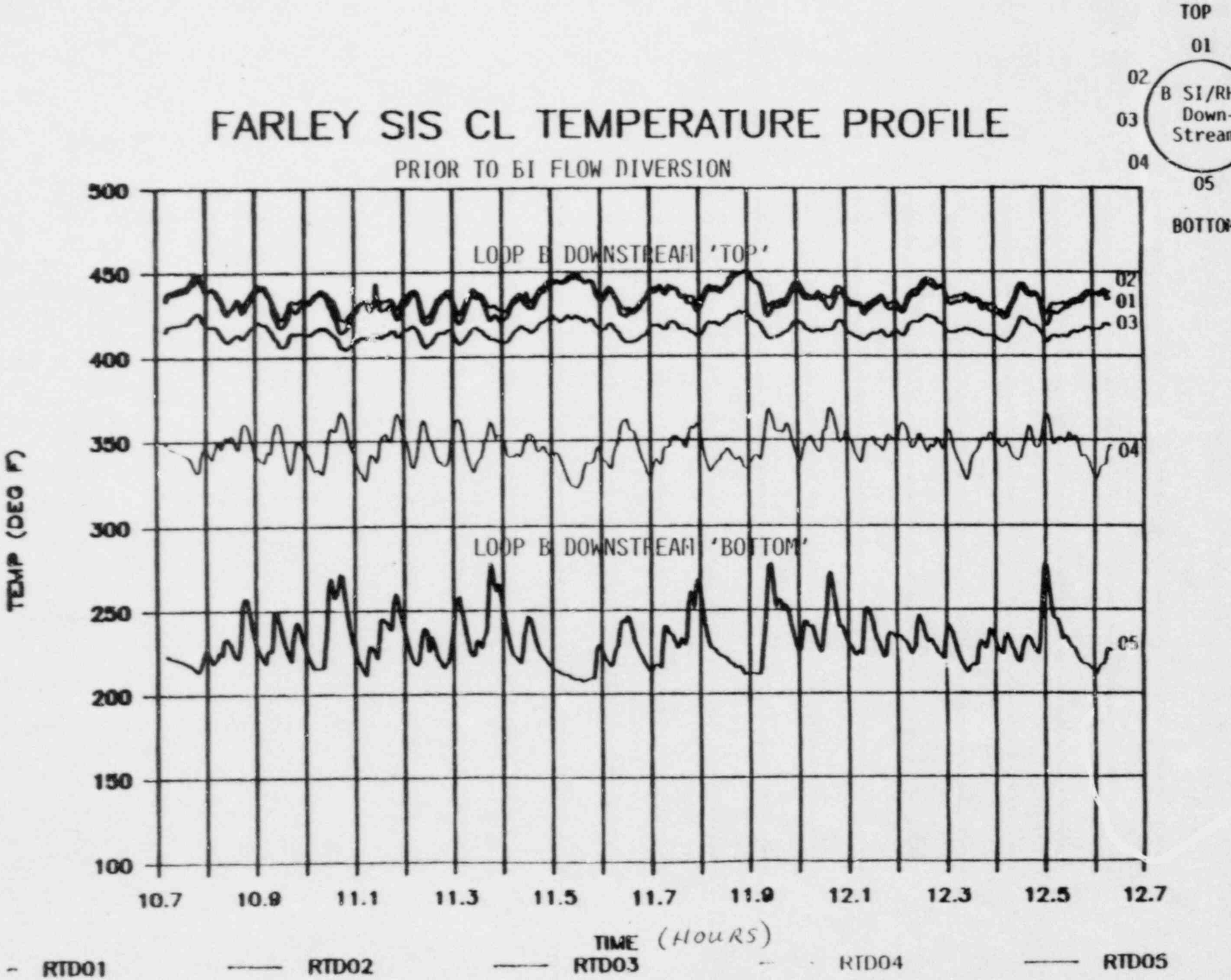
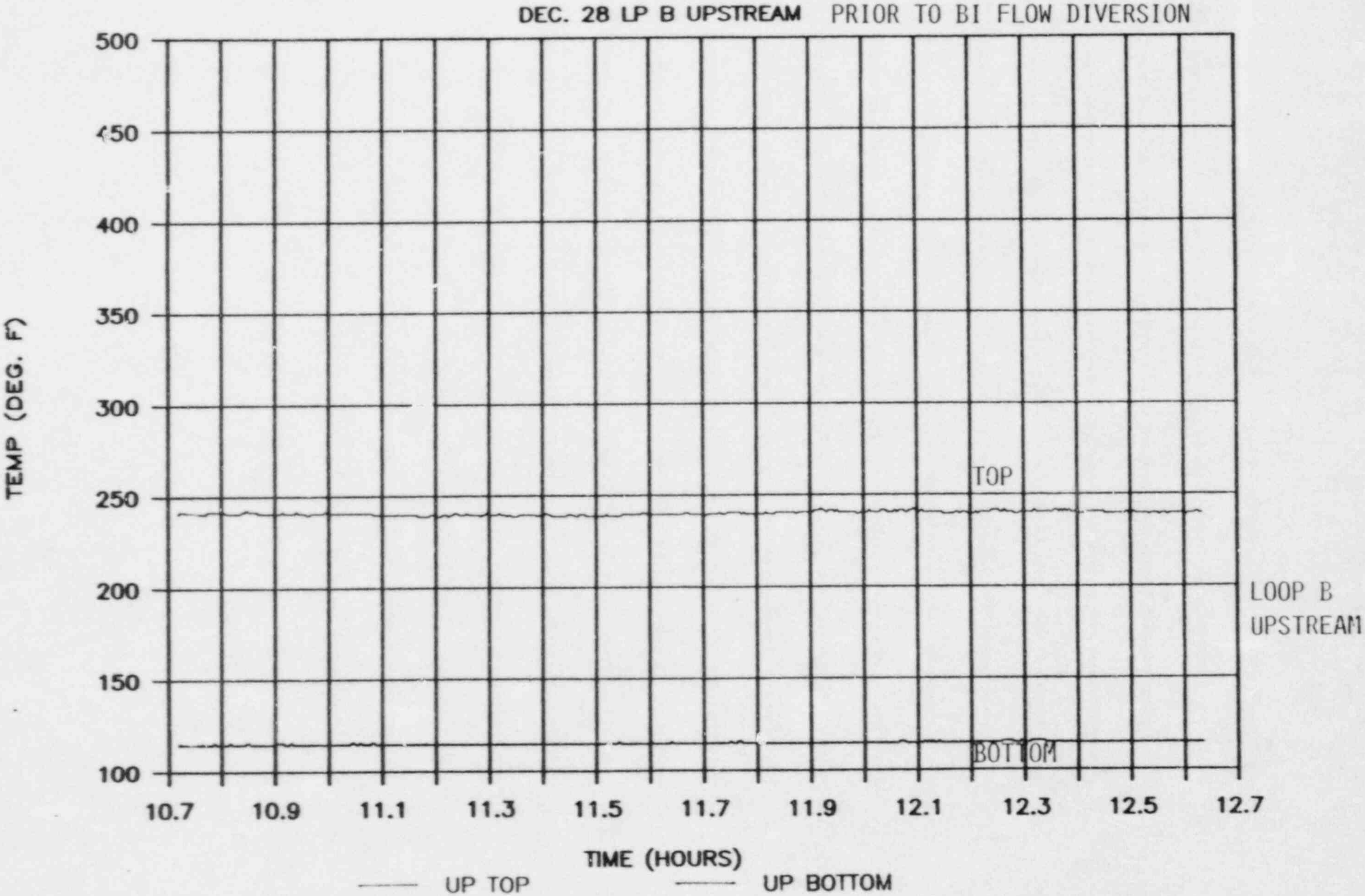


FARLEY SIS CL TEMPERATURE PROFILE
PRIOR TO BI FLOW DIVERSION
TOP
01
02
03
04
05
B SI/RHR Down-Stream
BOTTOM
LOOP B DOWNSTREAM 'TOP'
LOOP B DOWNSTREAM 'BOTTOM'
TEMP (DEG F)
500
450
400
350
300
250
200
150
100
10.7
10.9
11.1
11.3
11.5
11.7
11.9
12.1
12.3
12.5
12.7
TIME (HOURS)
RTD01
RTD02
RTD03
RTD04
RTD05

(80)

FARLEY SIS CL TEMPERATURE PROFILE



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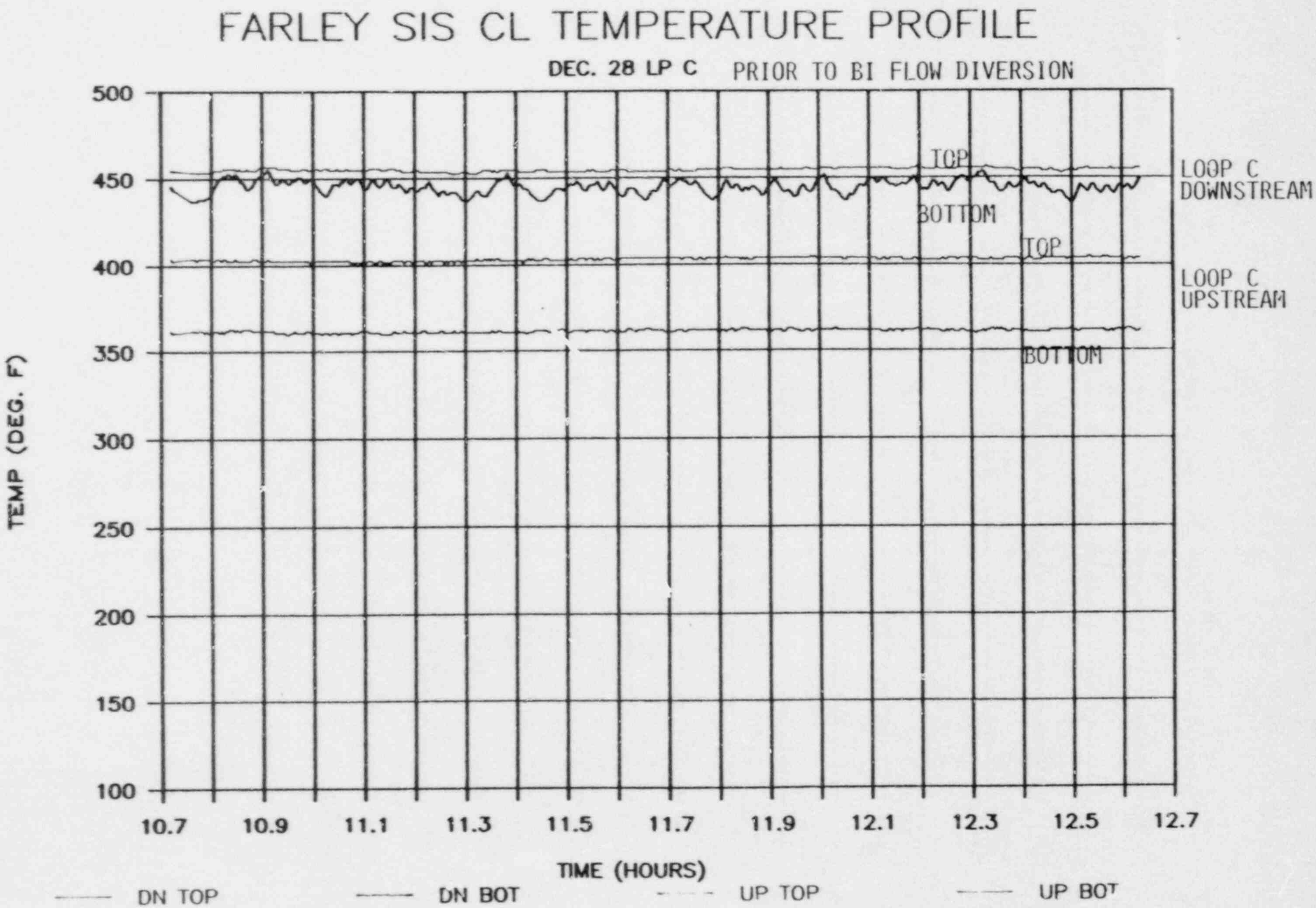
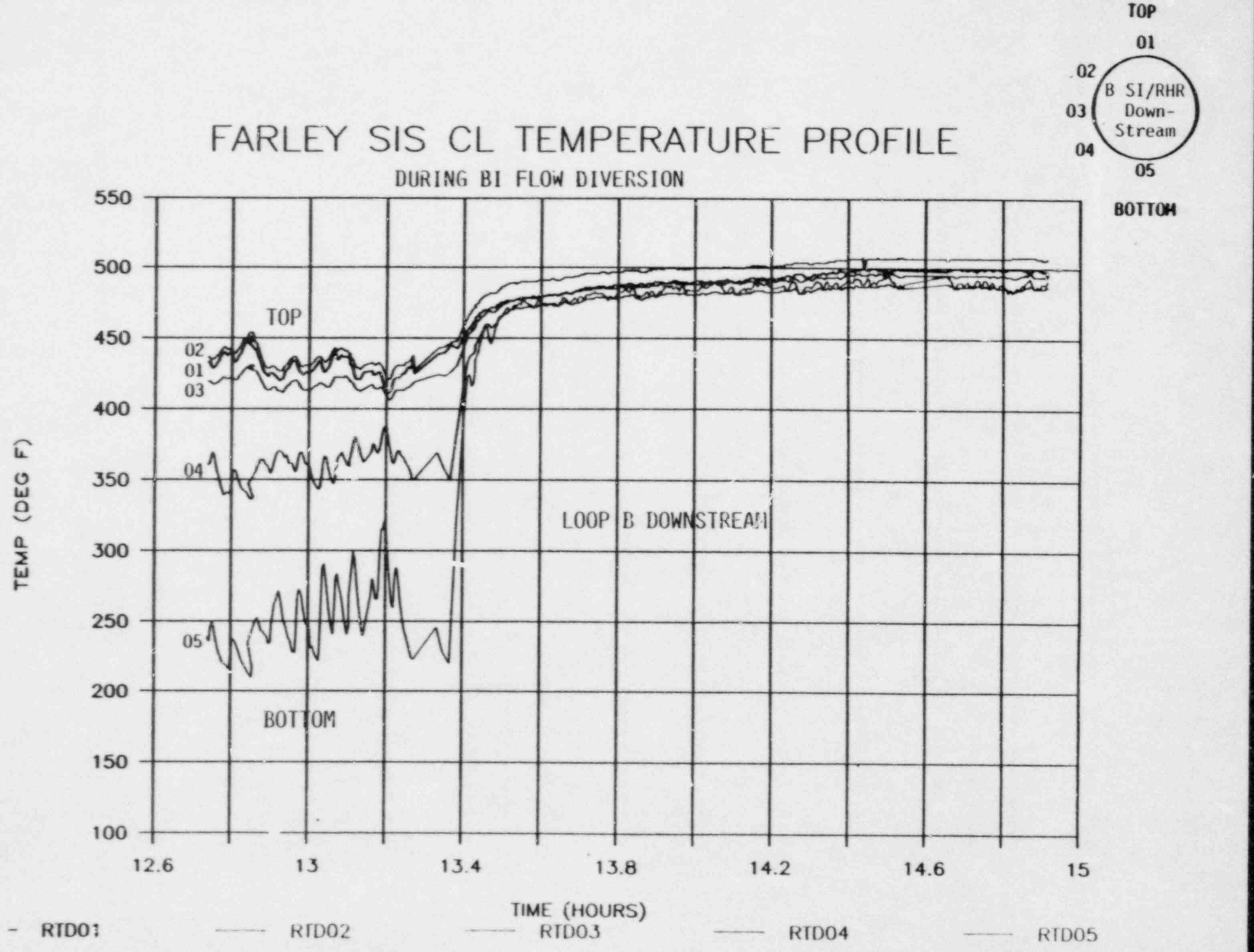
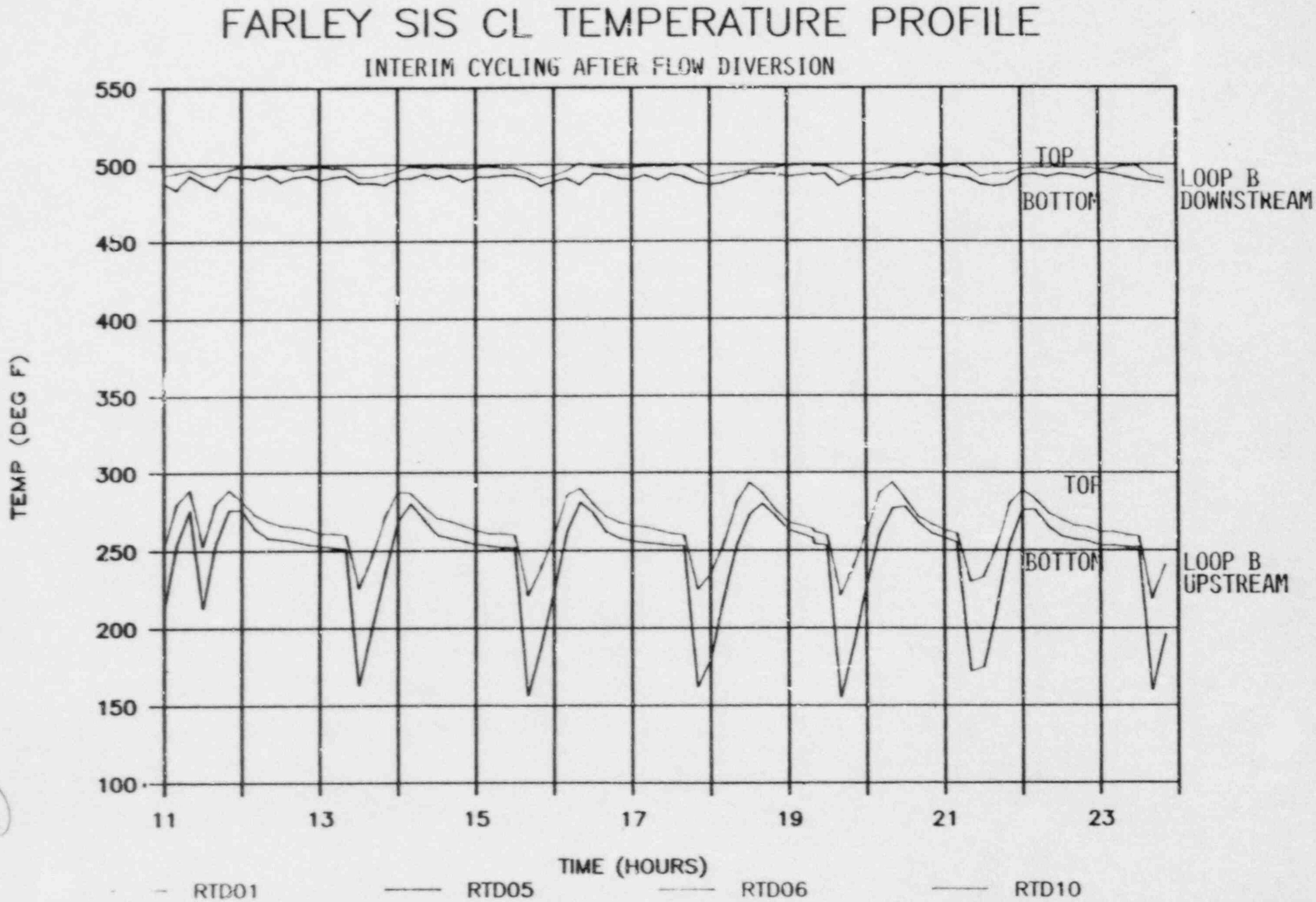

FARLEY SIS CL TEMPERATURE PROFILE
DEC. 28 LP C PRIOR TO BI FLOW DIVERSION
TEMP (DEG. F)
500
450
400
350
300
250
200
150
100
10.7
10.9
11.1
11.3
11.5
11.7
11.9
12.1
12.3
12.5
12.7
TIME (HOURS)
TOP
BOTTOM
LOOP C DOWNSTREAM
TOP
BOTTOM
LOOP C UPSTREAM
DN TOP
DN BOT
UP TOP
UP BOT

(82)

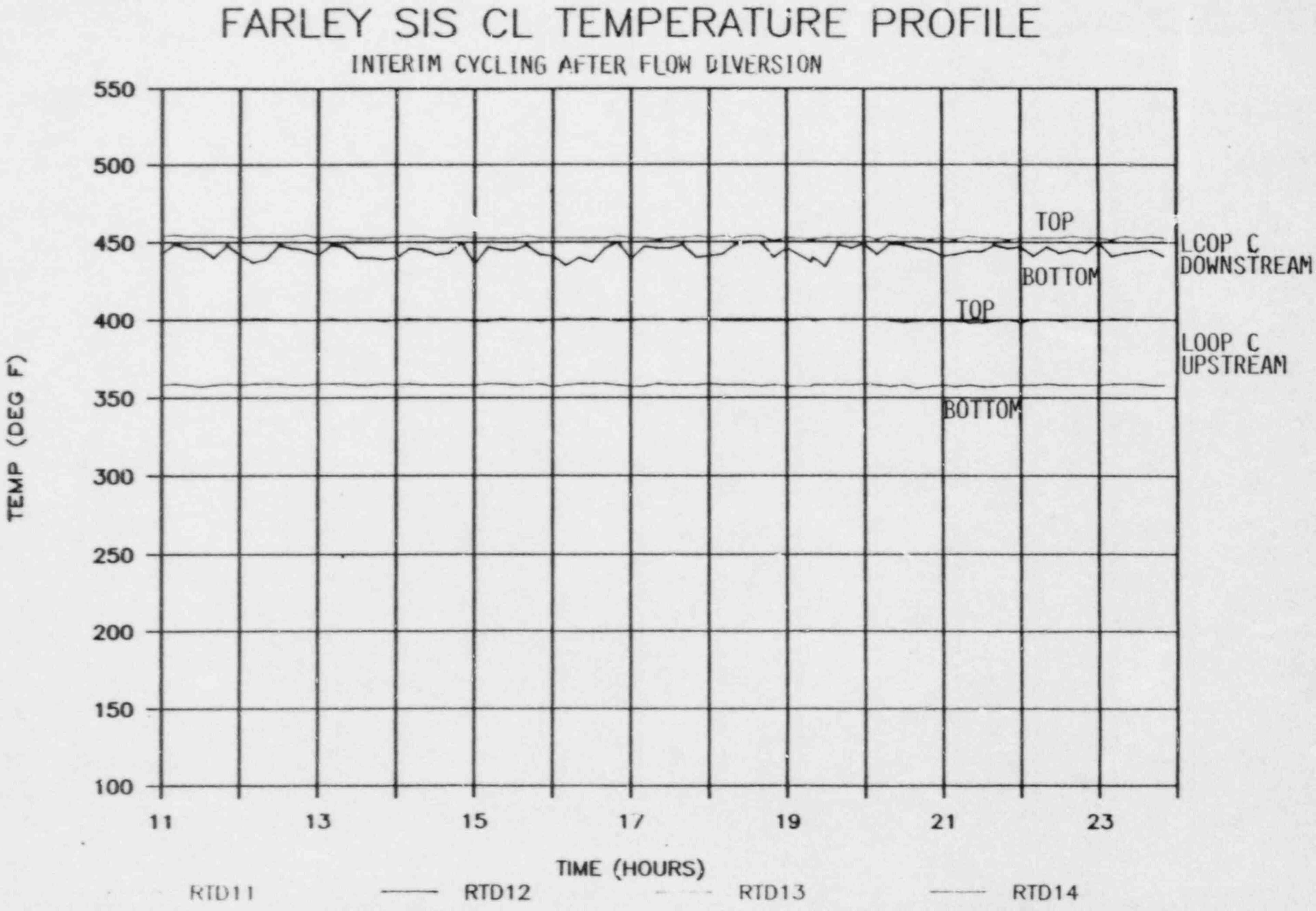


FARLEY SIS CL TEMPERATURE PROFILE
DURING BI FLOW DIVERSION
TOP
01
02
B SI/RHR Down-Stream
03
04
05
BOTTOM
TEMP (DEG F)
550
500
450
400
350
300
250
200
150
100
TOP
02
01
03
04
05
LOOP B DOWNSTREAM
BOTTOM
12.6
13
13.4
13.8
14.2
14.6
15
TIME (HOURS)
RTD01
RTD02
RTD03
RTD04
RTD05

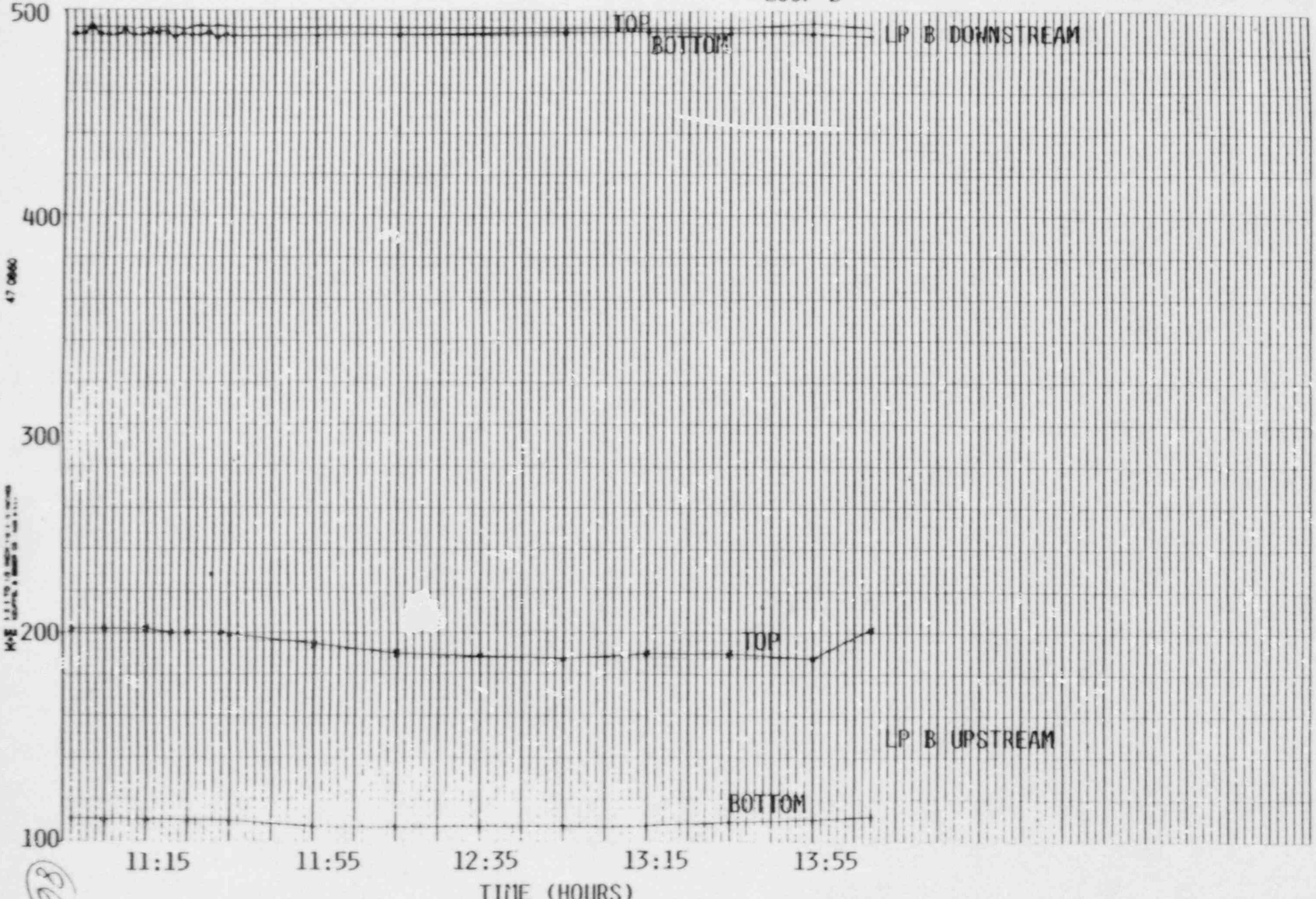
83



FARLEY SIS CL TEMPERATURE PROFILE
INTERIM CYCLING AFTER FLOW DIVERSION
550
500
450
400
350
300
250
200
150
100
TEMP (DEG F)
11
13
15
17
19
21
23
TIME (HOURS)
TOP
BOTTOM
LOOP B
DOWNSTREAM
TOP
BOTTOM
LOOP B
UPSTREAM
RTD01
RTD05
RTD06
RTD10


FARLEY SIS CL TEMPERATURE PROFILE
INTERIM CYCLING AFTER FLOW DIVERSION
TEMP (DEG F)
550
500
450
400
350
300
250
200
150
100
TOP
LCOP C
DOWNSTREAM
BOTTOM
TOP
LOOP C
UPSTREAM
BOTTOM
11
13
15
17
19
21
23
TIME (HOURS)
RTD11
RTD12
RTD13
RTD14

FARLEY SIS CL TEMPERATURE PROFILE
AFTER BI FLOW DIVERSION LONG TERM
LOOP B



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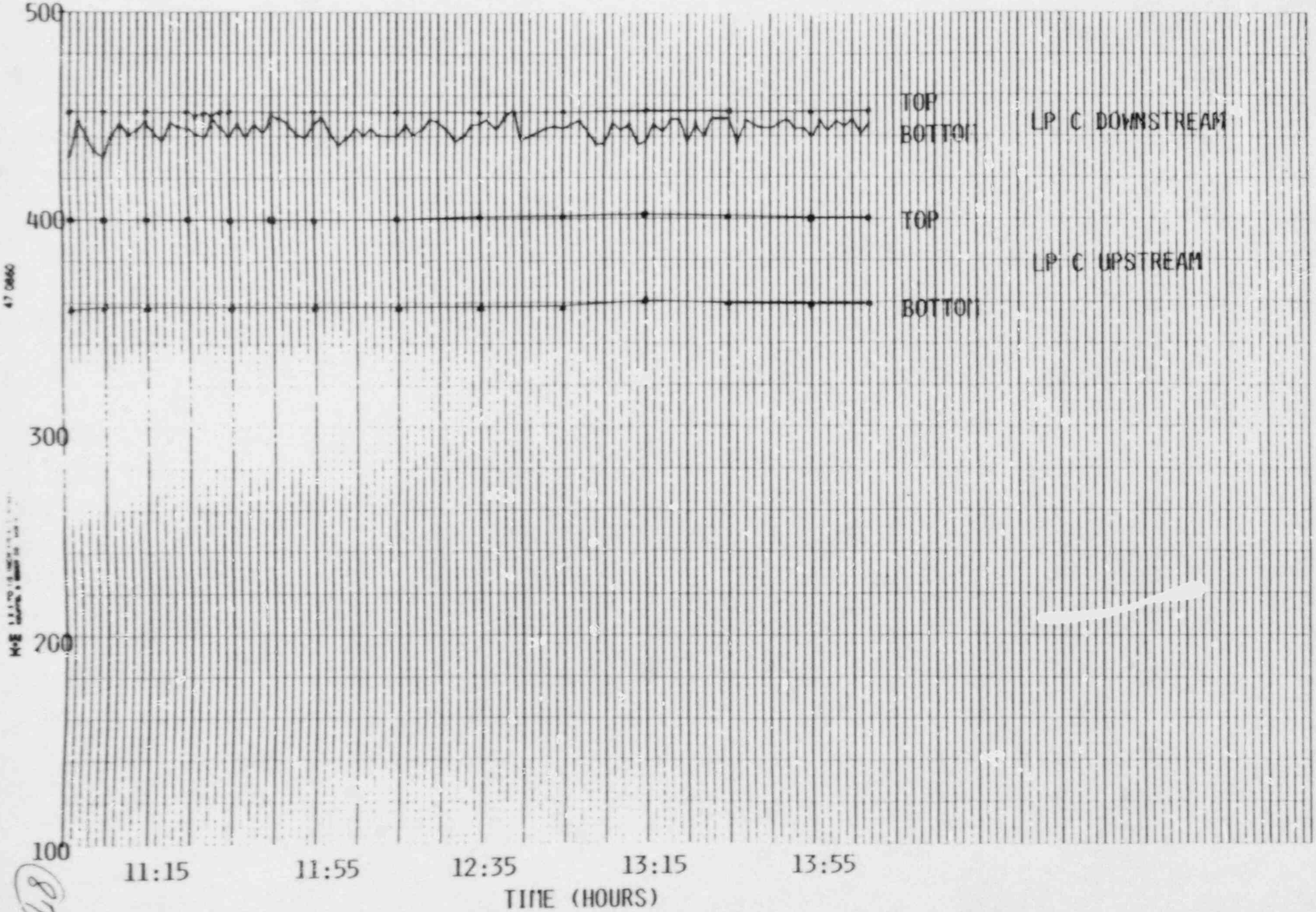
FARLEY SIS CL TEMPERATURE PROFILE
AFTER BI FLOW DIVERSION LONG TERM
LOOP C



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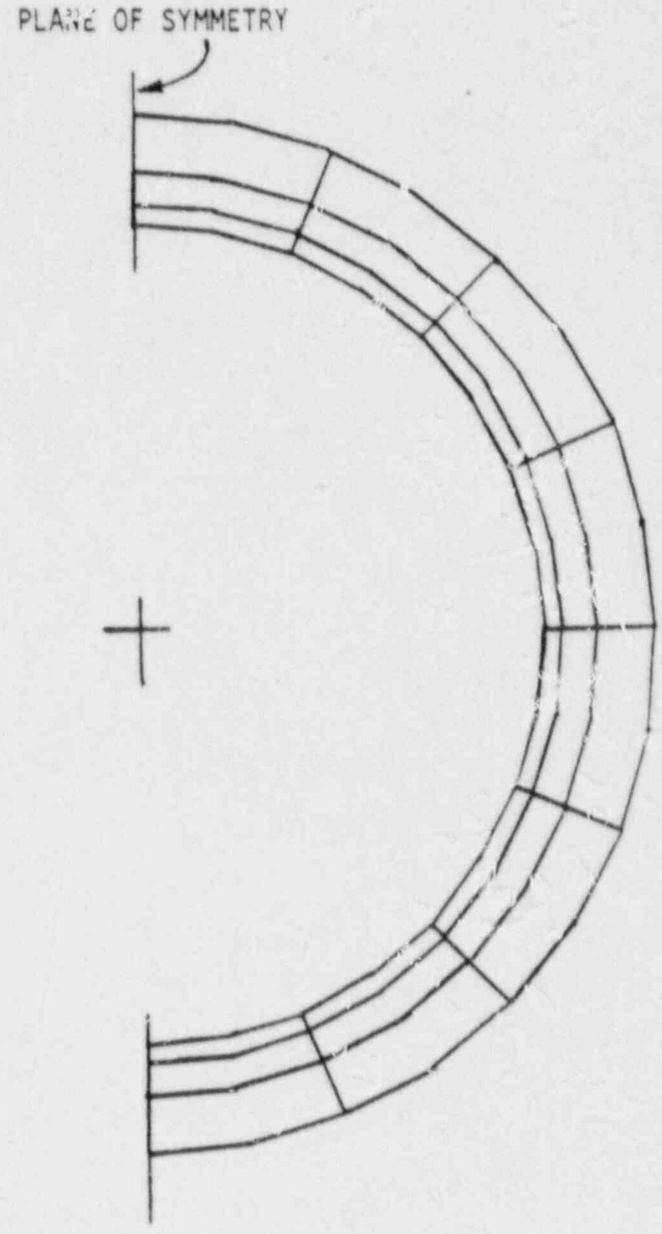
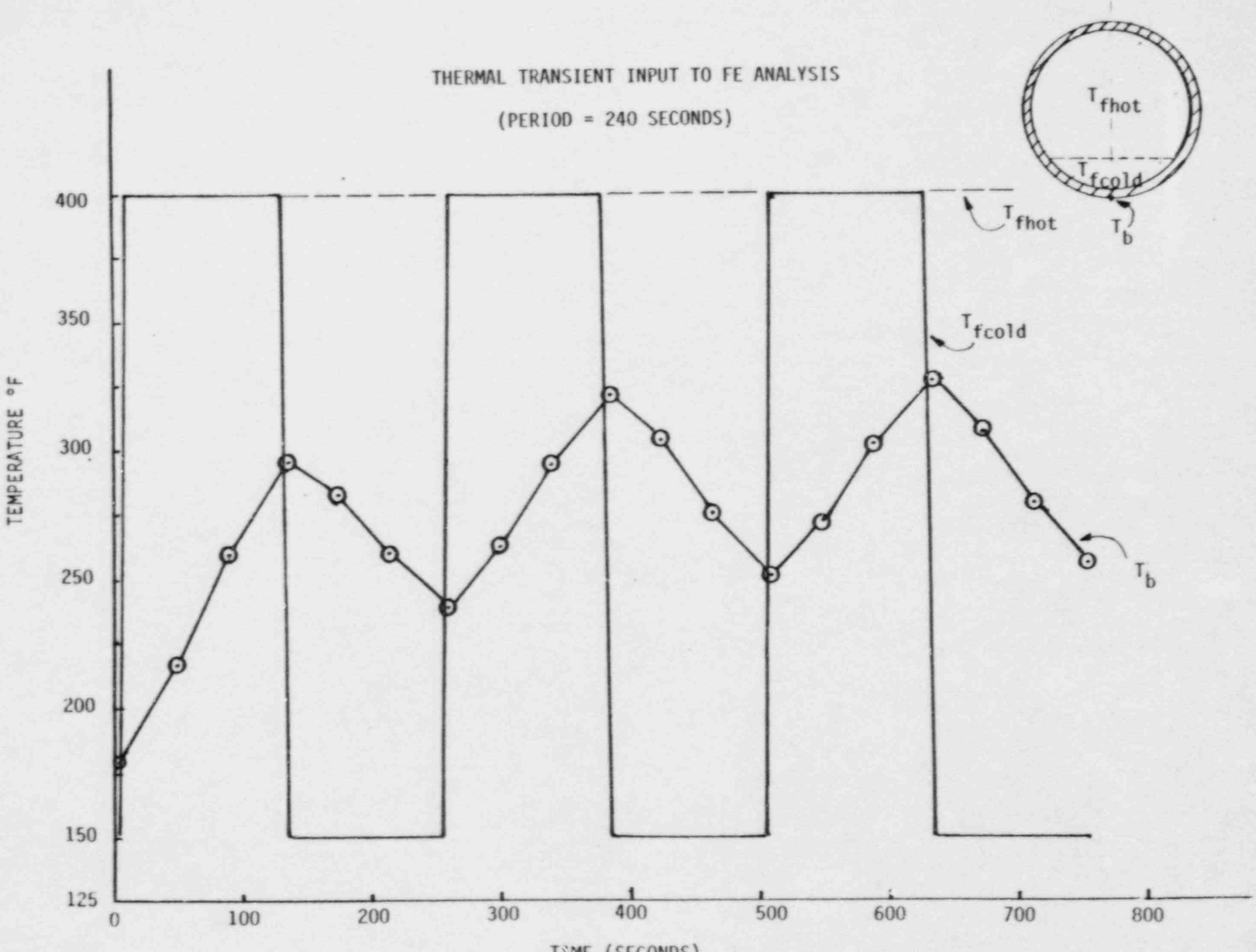


FINITE ELEMENT MODEL USED IN HEAT TRANSFER ANALYSIS

THERMAL TRANSIENT INPUT TO FE ANALYSIS

(PERIOD = 240 SECONDS)



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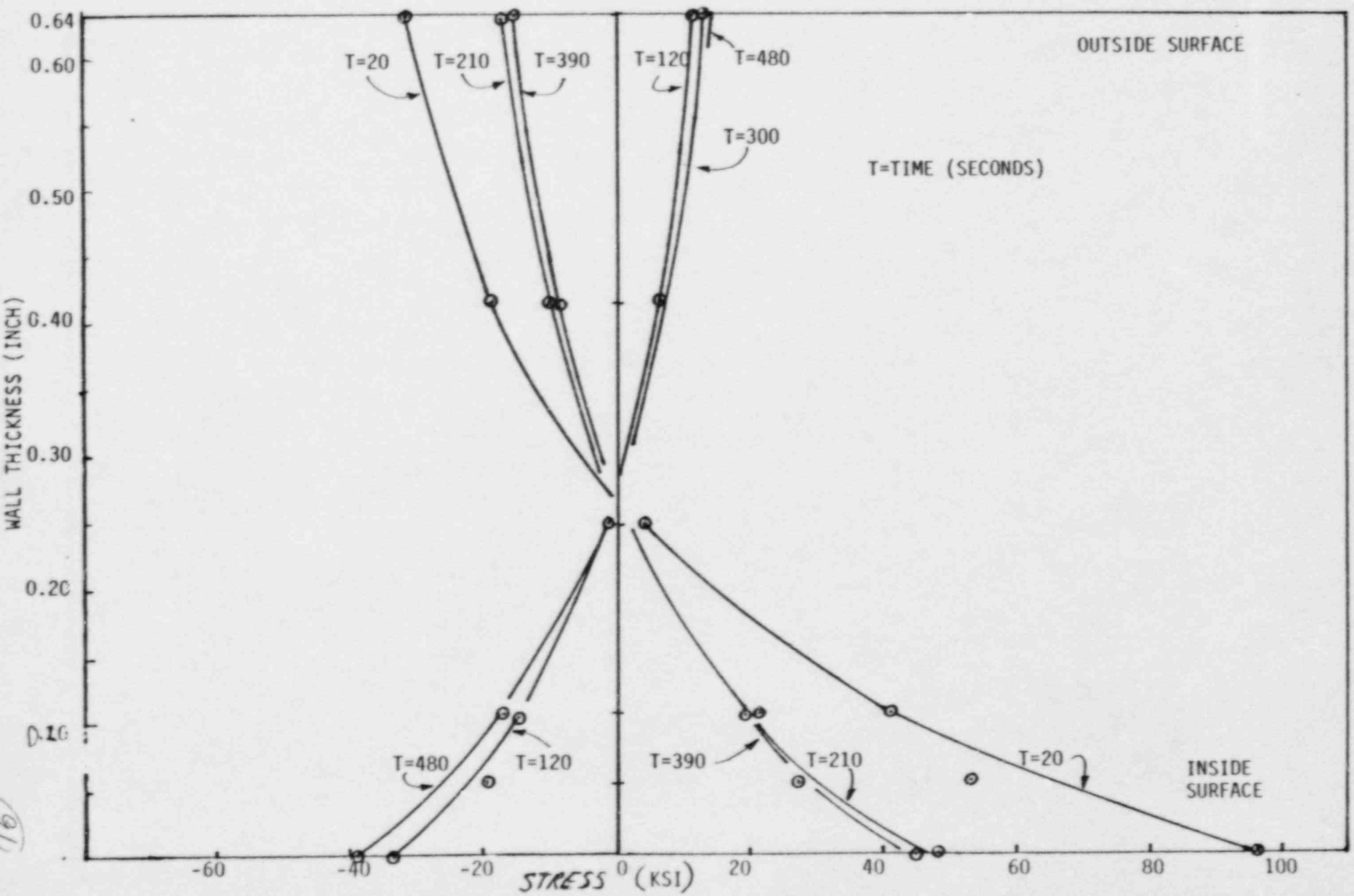
FINITE ELEMENT MODEL USED IN THERMAL STRESS ANALYSIS

THROUGH WALL STRESS DISTRIBUTION



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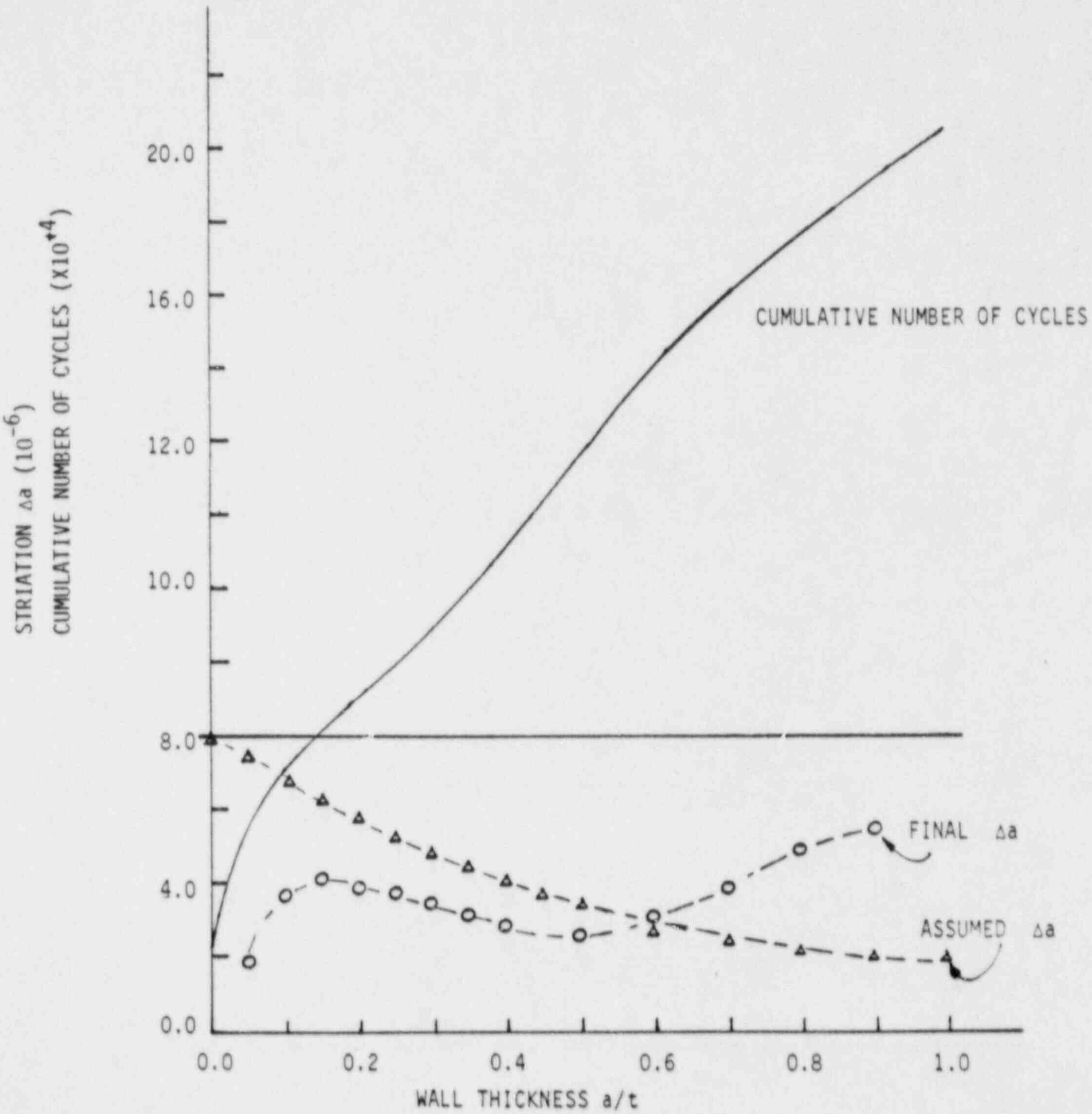
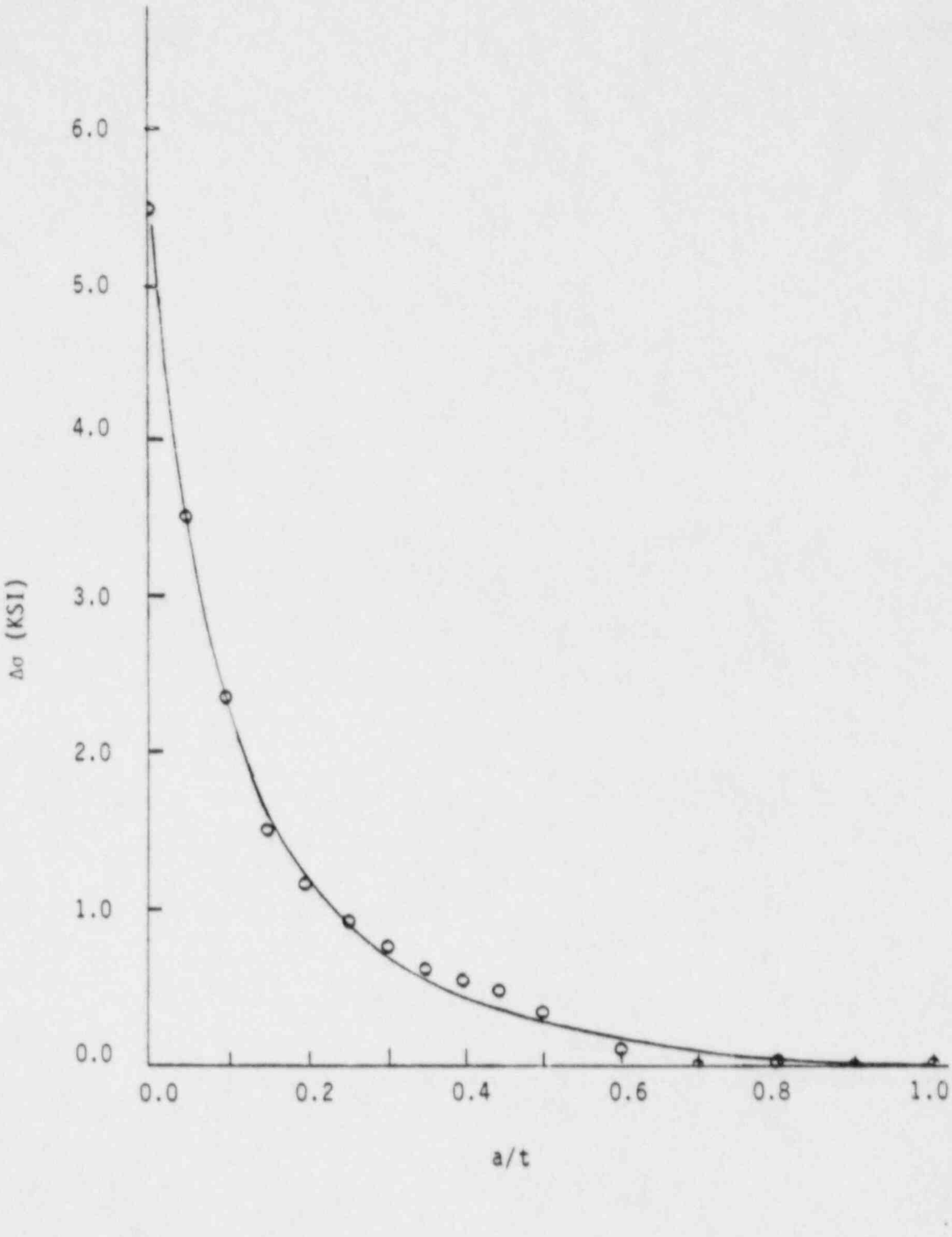
PARABOLIC DISTRIBUTION OF FATIGUE STRIATION



THROUGH-WALL STRESS DISTRIBUTION DERIVED FROM
PARABOLIC DISTRIBUTION OF STRIATION



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VI

EVALUATION OF THE EFFECT OF

REDUCED SAFETY INJECTION FLOW

CORRESPONDING TO SPILLING TO

CONTAINMENT BACKPRESSURE ON THE

JOSEPH M. FARLEY SMALL BREAK LOCA

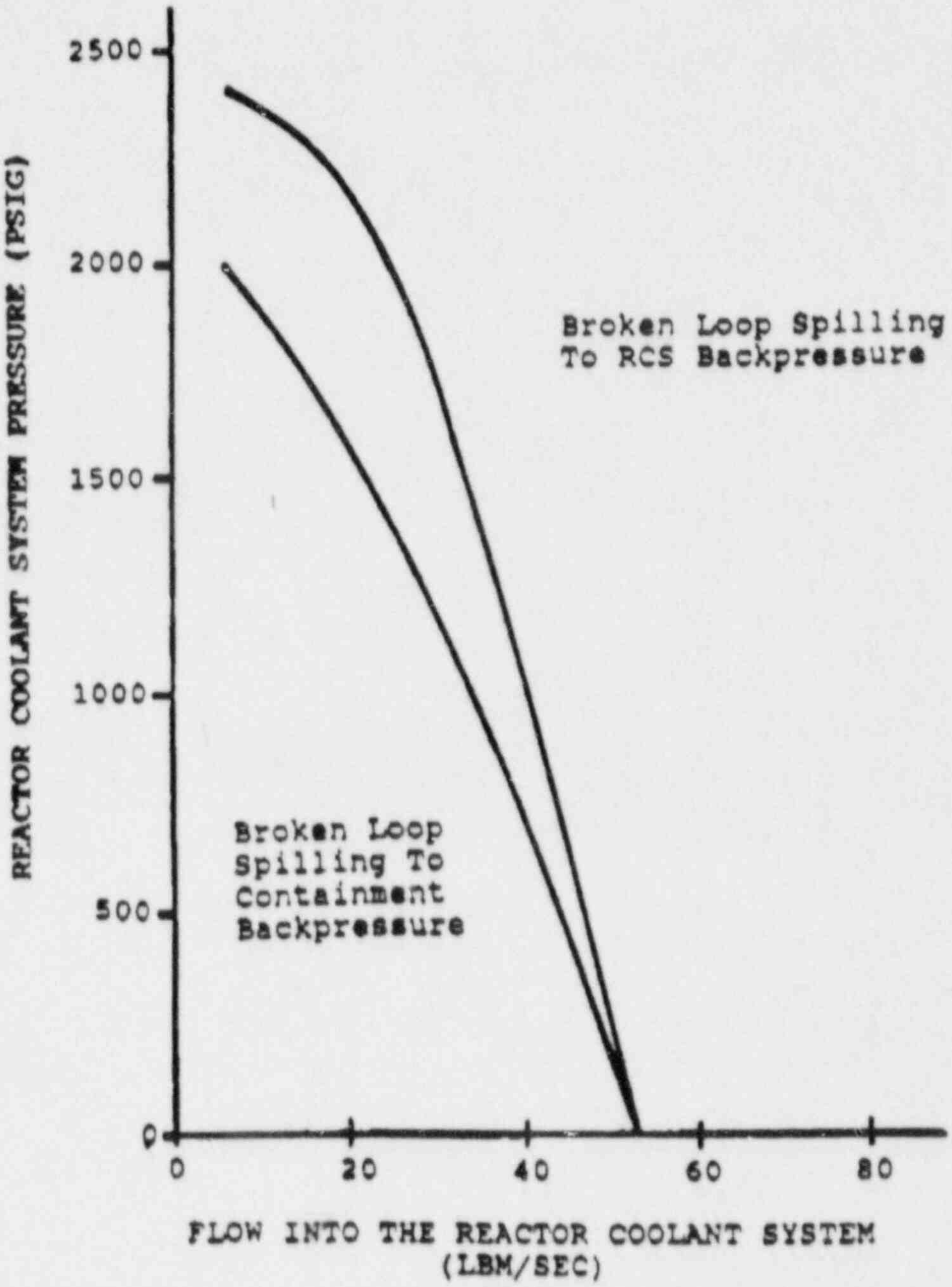
ANALYSIS

BACKGROUND

- Crack in SI line led to questions concerning Farley SBLOCA analysis of record (WFLASH)
- Review noted that the Farley WFLASH analysis inappropriately spilled the 6-inch break to RCS backpressure, not containment pressure
- Evaluation conducted to determine effect of the inappropriate spillage assumption
- This evaluation revealed an additional finding of an incorrectly reported PCT in the Farley FSAR

(95)

JOSEPH M. FARLEY ECCS HIGH HEAD INJECTION CURVES
(Minimum Safeguards, 1 Pump Operating, 1 Line Spilling)



EVALUATION RESULTS

- Increase of PCT by 45.7°F due effects of earlier core uncovery and delayed recovery time (3.84 seconds)

- Increase of PCT by 9°F due to more precise reading of computer analysis output instead of summary sheets

SUMMARY PCT TABLE

	UNIT 2	UNIT 1
FSAR	1703°F	1820°F
reporting correction	+9°F	+9°F
spillage correction	+46°F	+46°F
FSAR (proposed)	1758°F	1875°F

- Conclusion: considerable margin still exists to 2200°F 10CFR50.46 limit and to the LBLOCA analysis result of 2013°F

APCo ACTIONS

- Letter to NRC detailing evaluation and results dated January 14, 1988
- Safety Evaluation for FSAR change approved by PORC January 14, 1988
- Change to be incorporated into FSAR at next appropriate revision