CP&L
Carolina Power & Light Company
P.O. Box 1551 • Raleigh, N.C. 27602

SERIAL: NLS-91-001

JAN 07 1991

G. E. VAUGHN
Vice President
Nuclear Services Department

United States Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, DC 20555

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NO. 1
DOCKET NO. 50-325 / LICENSE NO. DPR-71
EXAMINATION / EVALUATION RESULTS FOR WELD NO. 1B21N4D-5-SW1-2 REFUELING OUTAGE 7

Reference:

1. NRC Inspection Report No. 50-325/89-35, dated December 7, 1989

Gentlemen:

Carolina Power & Light Company (CP&L) apprised the NRC Staff of the IGSCC examination/evaluation results of the indication discovered in the subject feedwater system (FWS) weld, via conference call on Thursday, December 20, 1990. This submittal is a follow-up to that conference call, and contains only that information pertinent to the ultrasonic (UT) examinations of the FWS Inconel and dissimilar metal welds, and the flaw evaluation of the subject weld. A complete summary of the NUREG 0313, Rev 2 examinations completed, as well as a synopsis of the installation/ inspection activities performed, and mitigative measures taken, as part of the Reactor Coolant Recirculation and Core Spray System piping replacement will be forthcoming in a subsequent submittal prior to Unit 1 restart.

Enclosure 1 contains (1) a description of the NUREG 0313, Rev 2, UT examinations performed on the FWS Inconel and dissimilar metal welds including the scope of those examinations, the UT Process used, and the results of those inspections, (2) a description of the inclusion of the twelve (12) FWS Inconel and dissimilar metal welds into CP&L's approved NUREG 0313, Rev 2 Inspection Program, (3) a brief description of the flaw evaluation performed for weld no. 1B21N4D-5-SW1-2, (4) a description of the monitoring of Inconel crack growth rates using CP&L's CAV System, and (5) a conclusion that provides a basis for the continued operation of BSEP Unit 1 with the Feedwater System in its present configuration. Enclosure 2 is a weld location map for the Feedwater System welds addressed by this submittal. Enclosure 3 is a copy of General Electric Ultrasonic Examination Report No. R-095, for FWS Weld No. 1B21N4D-5-SW1-2. Enclosure 4 is a copy of Structural Integrity Flaw Evaluation Report No. SIR-90-081.

A001
1/1

Please refer any questions regarding this submittal to Mr. S. D. Floyd at (919) 546-6901.

Yours very truly,

G. E. Vaughn

DBB/cwh (946BNP)

cc: Mr. S. D. Ebneter
Mr. N. B. Le
Mr. R. L. Prevatte

ENCLOSURE 1
BRUNSWICK STEAM ELECTRIC PLANT, UNIT 1
NRC DOCKET 50-325 / LICENSE NO. DPR-71
EXAMINATION / EVALUATION RESULTS FOR WELD NO. 1B21N4D-5-SW1-2
REFUELING OUTAGE 7

(1) ULTRASONIC EXAMINATIONS

Scope of Examinations

NRC Inspection Report No. 50-325/89-35, section 6.a. (Ref. 1), documented fifteen (15) dissimilar metal and Inconel welds that were potentially susceptible to IGSCC that had not been ultrasonically examined using transducers that produce refracted longitudinal (RL) sound waves. CP&L committed to examine these welds during refueling outage 7 using the appropriate techniques, thus they were added into the NUREG 0313, Rev 2 inspection scope as 'Category G' welds.

Nine (9) of the fifteen (15) welds documented by the referenced inspection report are Inconel, or Inconel to carbon steel welds in the FWS and are addressed in this submittal. Of the remaining six (6) welds, two (2) were eliminated as part of the Core Spray safe end/transition piece replacement, and four (4) are stainless steel to carbon steel dissimilar metal welds and will be addressed in the subsequent submittal as they are not considered to be germane to the examination/evaluation results of the subject weld.

The ISI weld identification numbers of the nine (9) FWS 'Category G' welds which were inspected during refueling outage 7 are as follows;

1B21N4A-2-FWRN4A45-3	1B21N4B-3-FWRN4B135-3	1B21N4C-6-FWRN4C225-3
1B21N4B-3-SW1-2	1B21N4C-6-SW1-2	1B21N4D-5-SW1-2
1B21N4B-3-SW2-3	1B21N4C-6-SW2-3	1B21N4D-5-FWRN4D315-3

(See Enclosure 2 for weld location map)

UT Process

The UT examinations of the nine (9) FWS welds identified in this submittal were performed by General Electric (GE) UT personnel who are qualified in accordance with the EPRI/BWROG/NRC requirements, including the latest requalification program. The examination of these welds incorporated the use of the fully automated GE "SMART UT" System, which uses the "Ultra Image III" computer driven data acquisition system with the ALARA remote scanning device. Manual examinations were performed as required to supplement the "SMART UT" examinations.

UT Results

As previously described in the scope of examinations, nine (9) 'Category G', FWS, Inconel or Inconel to carbon steel welds were examined. The results of these examinations are as follows;

1B21N4A-2-FWRN4A45-3 1B21N4B-3-SW1-2 1B21N4B-3-SW2-3 1B21N4B-3-FWRN4B135-3 1B21N4C-6-SW1-2 1B21N4C-6-SW2-3 1B21N4C-6-FWRN4C225-3 1B21N4D-5-FWRN4D315-3	No relevant indications were detected using 45° shear, and 45° & 60° RL transducers.

1B21N4D-5-SW1-2 No indications associated with IGSCC were recorded. However, one (1) non-geometric indication was recorded. (See Enclosure 3 for complete GE report)

NOTE: The above listed nine (9) welds, along with the remaining four (4) welds noted in the scope of examinations comprised 100% of the BSEP Unit 1, 'Category G' welds, thus no sample expansion was required.

(2) NUREG 0313, REV 2, INSPECTION PROGRAM

In accordance with NRC Inspection Report No. 50-325/89-35 (Ref 1), CP&L agreed to evaluate the dissimilar metal welds listed for inclusion in it's approved NUREG 0313 Inspection Program. CP&L has completed an evaluation of the twelve (12) FWS welds listed in the Inspection Report. Of the welds listed in the Inspection Report, nine (9) are addressed in this submittal, while the remaining three (3) were inspected using RL transducers during BSEP Unit 1 refuel outage 6.

As stated in the "Scope of Examinations", the nine (9) FWS welds which had not been examined using RL transducers were added into the refuel outage 7 inspection schedule as 'Category G' welds.

Based on the examination results of the three (3) FWS welds previously inspected during refuel outage 6, and the nine (9) FWS welds inspected during refuel outage 7, CP&L has elected to permanently include them into the NUREG 0313, Rev 2, Inspection Program as follows;

Weld Number	Category	Weld Number	Category
1B21N4A-2-SW1-2	D	1B21N4C-6-SW1-2	D
1B21N4A-2-SW2-3	D	1B21N4C-6-SW2-3	D
1B21N4A-2-FWN4A45-3	D	1B21N4C-6-FWN4C225-3	D
1B21N4B-3-SW1-2	D	1B21N4D-5-SW1-2	F
1B21N4B-3-SW2-3	D	1B21N4D-5-SW2-3	D
1B21N4B-3-FWN4B135-3	D	1B21N4D-5-FWN4D315-3	D

(3) FLAW EVALUATION FOR WELD NO. 1B21N4D-5-SW1-2

A flaw evaluation has been completed for the indication recorded in the subject weld by Structural Integrity, Associates (SIA). This evaluation was performed in accordance with ASME Code, Section XI, IWB-3640, 1986 Edition, and the requirements of NUREG 0313, Rev 2, and demonstrates that the weld can be returned to service for at least one operating cycle. In addition to the crack growth analysis, SIA also performed a leak-before-break analysis for the recorded flaw to demonstrate that in the unlikely event that the flaw would propagate through-wall, adequate margins exist between the leakage flaw size and the critical flaw size (see Enclosure 4 for complete analysis).

(4) MONITORING OF CRACK GROWTH RATES

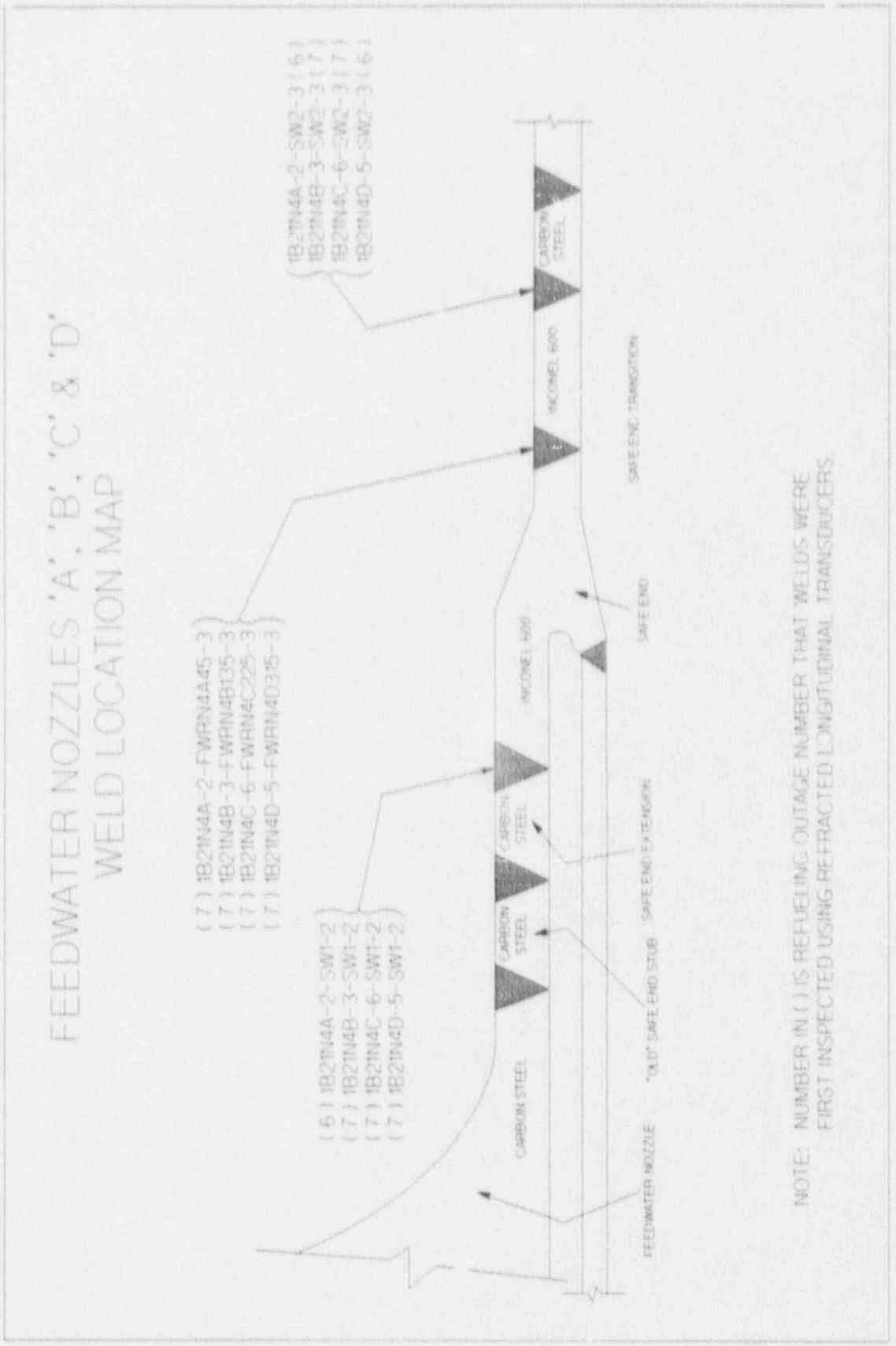
As discussed in the conference call between the Staff and CP&L on Thursday, December 20, 1990, CP&L has committed to monitor the crack growth rate of the Inconel 182 material in the BSEP Unit 1 CAV system. The CAV system crack growth data will be monitored to assure that the crack growth rate assumed in the flaw evaluation (Enclosure 4) remains conservative. CAV system data will be analyzed on a monthly basis, and any anomalies in crack growth rates will be evaluated to ensure that the FWS integrity is not compromised, and that the plant can continue to be operated safely.

(5) CONCLUSION

Carolina Power & Light Company has now completed (refuel outages 6 and 7) UT examinations of the twelve (12) FWS welds using transducers that produce refracted longitudinal sound waves. One weld (1B21N4D-5-SW1-2) contains a relevant indication while the remaining welds have been found to be free of relevant indications. The indication recorded in the subject weld has been analyzed by Structural Integrity, Associates, and found to be acceptable by evaluation. This coupled with CP&L's ability to monitor the actual crack growth rates of Inconel 182 material using the CAV System supports the position that this weld is acceptable to operate for at least one additional refueling cycle. Therefore, CP&L believes that Unit 1 can be operated safely until the next refueling outage, presently scheduled for September 1992, without adverse effect to the health and safety of the public.

ENCLOSURE 2

BRUNSWICK STEAM ELECTRIC PLANT, UNIT 1
NRC DOCKET 50-325 / LICENSE NO. DPR-71
EXAMINATION/EVALUATION RESULTS FOR WELD NO. 1B21N4D-5-SW1-2
REFUELING OUTAGE 7



ENCLOSURE 3
BRUNSWICK STEAM ELECTRIC PLANT, UNIT 1
NRC DOCKET 50-325 / LICENSE NO. DPR-71
EXAMINATION / EVALUATION RESULTS FOR WELD NO. 1B21N4D-5-SW1-2
REFUELING OUTAGE 7

GE ULTRASONIC EXAMINATION REPORT NO. R-095

GE Nuclear Energy

SUMMARY SHEET

REPORT NO.: R-095

PROJECT:
BRUNSWICK STEAM ELECTRIC PLANT
UNIT 1 - ISI-90-SN735

PROCEDURE:	GE-UT-200	REV. 2	FRR NO.	N/A
PROCEDURE:	GE-UT-102	REV. 2	FRR NO.	N/A
PROCEDURE:	GE-PT-100	REV. 0	FRR NO.	N/A

SYSTEM: FEEDWATER
WELD NO.: 1B21N4D-5-SW1-2
CONFIGURATION: SAFE-END TO PIPE

EXAM: T. WALTER/W. ARMES LVL II/II
EXAM: K. GEBETSBERGER LVL II
EXAM: H. SCHLORTT LVL II

NDE METHOD: ☐ MT ☑ PT ☑ UT ☐ VT

WELD TYPE: ☑ CIRCUMFERENTIAL ☐ LONGITUDINAL ☐ OTHER N/A

CAL SHEET NO.(S): C-122/C-123/C-124/C-125 C-126/C-127/C-142

REPORT NO.(S): R-095

DURING THE ULTRASONIC EXAMINATION OF THE ABOVE REFERENCED WELD, NO INDICATIONS ASSOCIATED WITH IGSCC WERE RECORDED BY THE "SMART UT" SYSTEM UTILIZING 45° SHEAR WAVE AND 45° AND 60° REFRACTED LONGITUDINAL WAVE SHEARCH UNITS. THE "SMART UT" SYSTEM DID RECORD ONE (1) NON-GEOMETRIC INDICATION WHICH HAS THE FOLLOWING PARAMETERS:

	DISTANCE FROM ZERO REFERENCE	TOTAL LENGTH	REMAINING LIGAMENT	SIDE OF WELD	TYPE OF REFLECTOR	SEARCH UNIT UTILIZED
1)	37.5"	1"	.46"	UPST	* PLANAR	45°S/45RL/60RL

* CIRCUMFERENTIALLY ORIENTED

THIS INDICATION HAS AN AMPLITUDE LESS THAN 100% DAC, WHICH IS NOT REPORTABLE AS PER ASME SECTION XI AND EXHIBITS NO CHARACTERISTICS OF IGSCC.

THE 45° SHEAR WAVE SEARCH UNIT ALSO RECORDED NON-RELEVANT INDICATIONS, BEAM REDIRECT AND INSIDE SURFACE GEOMETRY FROM BOTH THE UPSTREAM AND DOWNSTREAM SIDES OF THE WELD. ROOT GEOMETRY WAS ALSO RECORDED ON THE UPSTREAM SIDE OF THE WELD ONLY.

THE 45° RL SEARCH UNIT RECORDED NON-RELEVANT INDICATIONS AND INSIDE SURFACE GEOMETRY FROM BOTH SIDES OF THE WELD. SHEAR COMPONENT WAS ALSO RECORDED ON THE UPSTREAM SIDE OF THE WELD.

THE 60° RL SEARCH UNIT RECORDED NON-RELEVANT INDICATIONS AND INSIDE SURFACE GEOMETRY FROM BOTH SIDES OF THE WELD.

A MANUAL ULTRASONIC RELOOK IN THE AREA OF THE INDICATION WAS PERFORMED TO DETERMINE THE PERCENT OF DAC AT REFERENCE SENSITIVITY.

Wes Money LEVEL III DATE 12-17-90
SUMMARIZED BY

REVIEWED LEVEL III DATE 12-17-90

Mark C. Goldman LEVEL QI DATE 12-17-90
REVIEWED

FORM 184 11-6-90

GE Nuclear Energy	SUMMARY SHEET (CONTINUATION)	REPORT NO.: R-095

PROJECT:	SYSTEM: FEEDWATER
BRUNSWICK STEAM ELECTRIC PLANT UNIT 1 - SN735	WELD NO.: 1B21N4D-5-SW1-2

A LIQUID PENETRANT EXAMINATION WAS ALSO PERFORMED, WHICH RESULTED IN NO RECORDABLE INDICATIONS.

PREVIOUS DATA AND RADIOGRAPHS WERE REVIEWED PRIOR TO THIS SUMMARY.

Wes Maney LEVEL III DATE 12/17/90 SUMMARIZED BY	[signature] LEVEL III DATE 12/17/90 REVIEWED [signature] LEVEL III DATE 12/17/90 REVIEWED	PAGE 2 OF 29 FORM 186 11-6-90

GE Nuclear Energy

INDICATION PLOT SHEET

SITE: BSEP UNIT: I

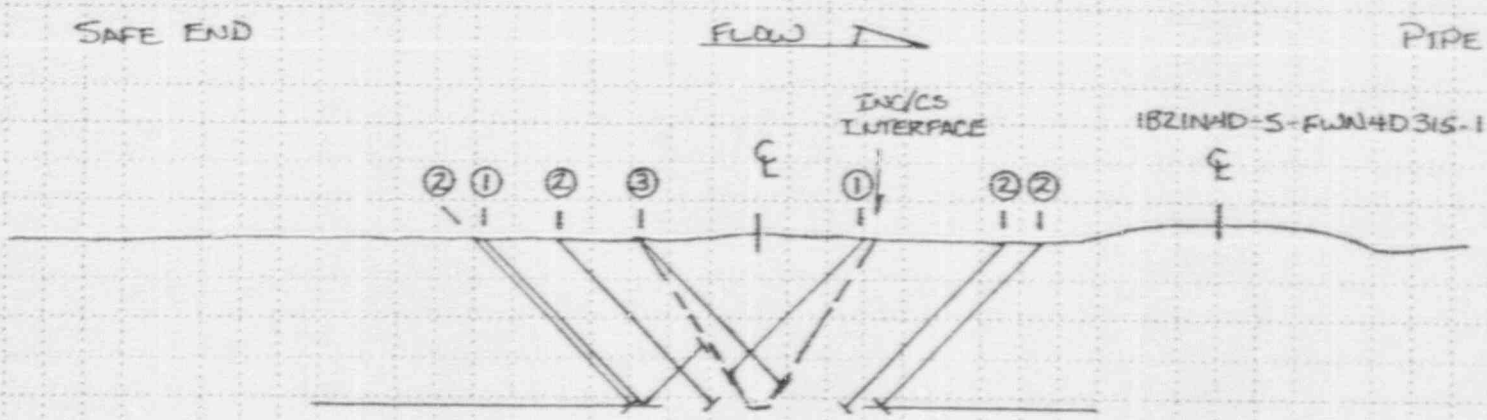
PROJECT NO: 151-90-5N735

REPORT NO. R-095

SYSTEM: FEEDWATER

COMPONENT ID NO: 1B21N4D-5-SW1-2

CONFIGURATION: SAFE END → PIPE



① NON-GEOMETRIC INDICATION #1
② INSIDE SURFACE GEOMETRY
③ ROOT GEOMETRY

45° SHEAR

Drawn By	Level	Date	Reviewed By	Level	Date	Reviewed By	Title	Date
Wes Morey	III	12-7-90	[signature]	III	12-17-90	[signature]	QC	12-17-90

FORM 137 1-13-90

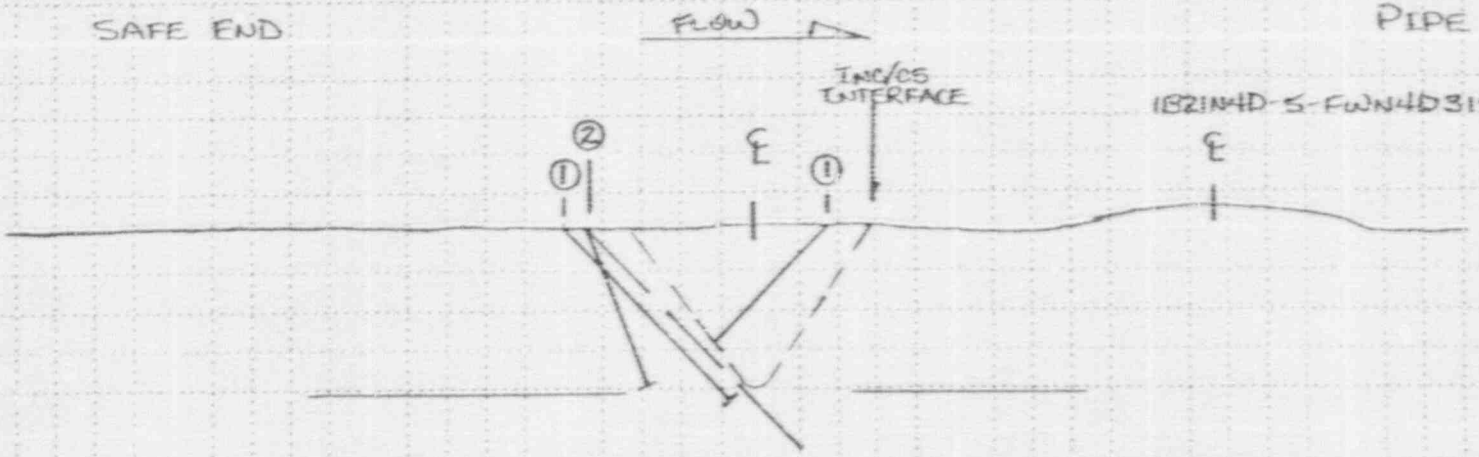
GE Nuclear Energy

INDICATION PLOT SHEET

SITE: BSEP UNIT: I
PROJECT NO: ISI-90-SN735

REPORT NO. R-095

SYSTEM: FEEDWATER | COMPONENT ID NO: 1B21N4D-S-SW1-2 | CONFIGURATION: SAFE END → PIPE



① NON-GEOMETRIC INDICATION #1
② INSIDE SURFACE GEOMETRY (SHEAR COMPONENT)

45° RL

Drawn By	Level	Date	Reviewed By	Level	Date	Reviewed By	Title	Date
Wes Money	III	12-14-90	[signature]	III	12-17-90	[signature]	QC	12-17-90

FORM 137 1-13-90

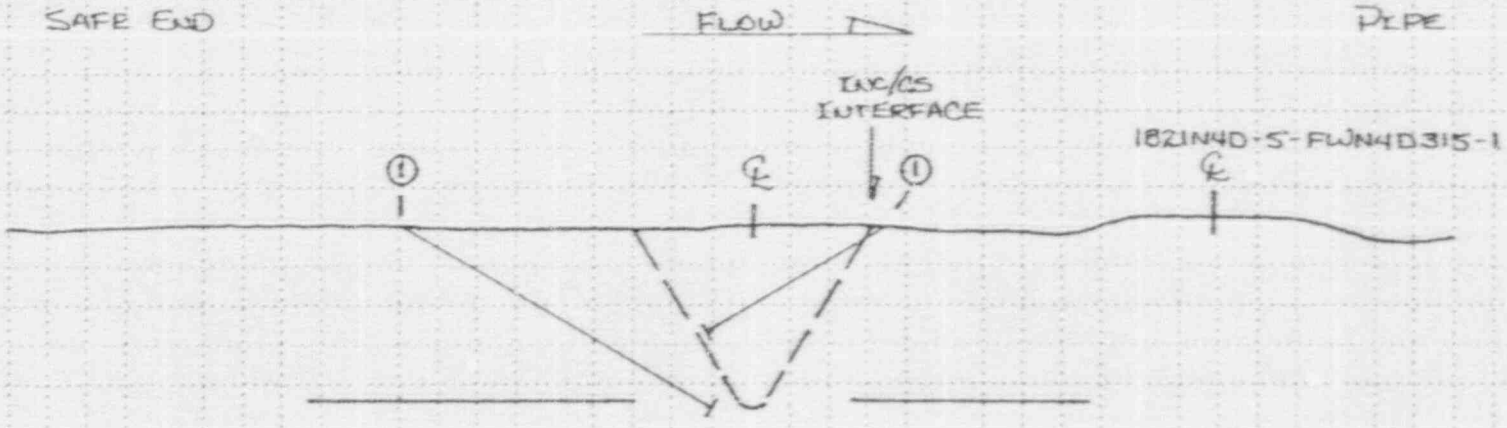
GE Nuclear Energy

INDICATION PLOT SHEET

SITE: BSEP UNIT: 1
PROJECT NO: 1S1-90-SN735

REPORT NO. R-095

SYSTEM: FEEDWATER | COMPONENT ID NO: 1B21N4D-5-SW1-2 | CONFIGURATION: SAFE END → PIPE



1 NON-GEOMETRIC INDICATION #1

60° RL

Drawn By	Level	Date	Reviewed By	Level	Date	Reviewed By	Title	Date
Wes Morey	III	12-14-90	B.L. Williams	III	12-17-90	L. Lin	QC	12-17-90

FORM 137 1-13-90

GE Nuclear Energy

WALL THICKNESS PROFILE SHEET

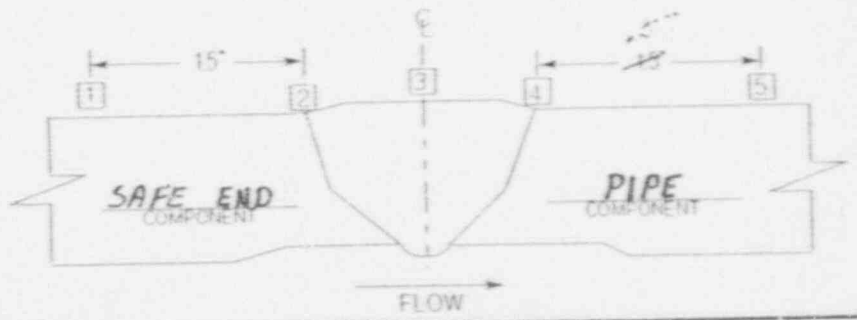
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI - 90 - SN735

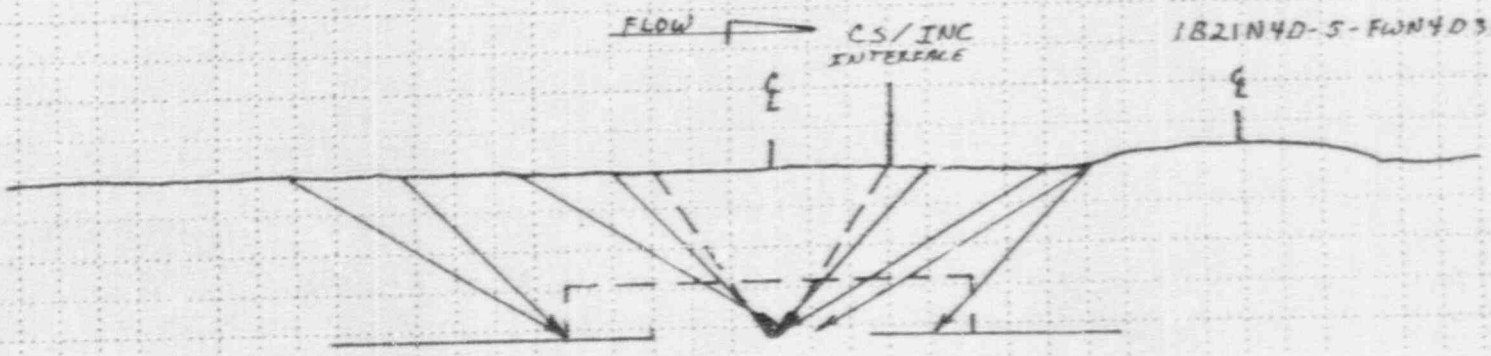
REPORT NO. R-095

POSITION	0°	90°	180°	270°
1	.84			
2	.84			
3	.84		V	A
4	.80			
5	.82			

SYSTEM ID: FEEDWATER
WELD ID NO.: 1B21N4D-5-SW1-2

CROWN HEIGHT: FLUSH
CROWN WIDTH: 1.20"
NOM. DIAMETER: 12"
WELD LENGTH: 43"





45° SHEAR, 45° RL & 60° RL COVERAGE PLOT

Examiner	Level	Date	Reviewed By	Level	Date	Reviewed By	Title	Date
H Schlott	II	12-1-90	Wes Money	III	12-7-90		QC	12-7-90

FORM 138 1-13-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: BRUNSWICK UNIT: 1

PROJECT NO: 151-90-SN735

REPORT NO. R-095

CALIBRATION SHEET NO. C-122

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21N40-5"-SWI-2

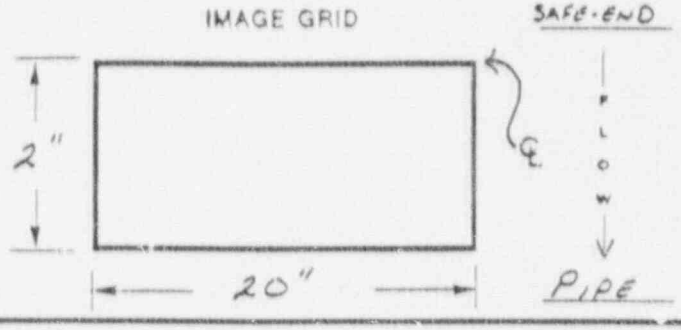
COUPLANT ULTRAGEL II BATCH NO. 8981

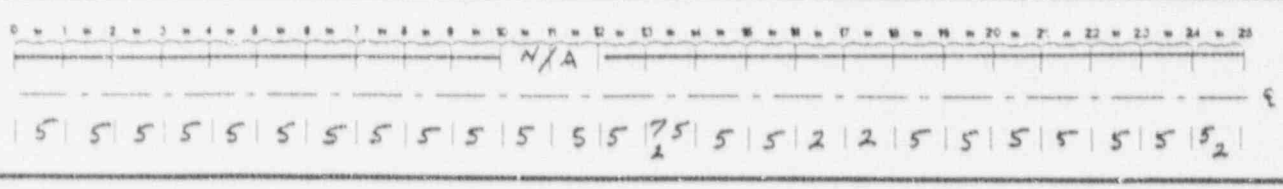
EXAM SURFACE TEMP 78 °F

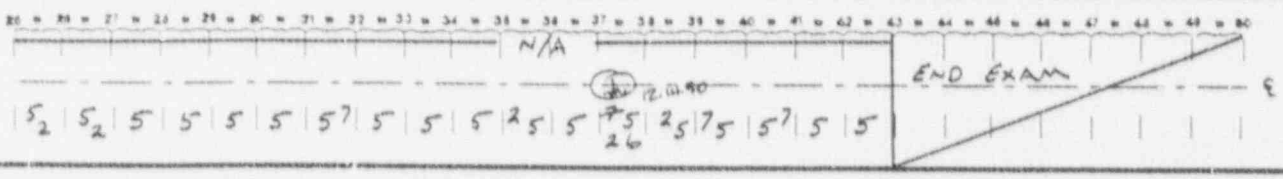
THERMOMETER S/N 1491

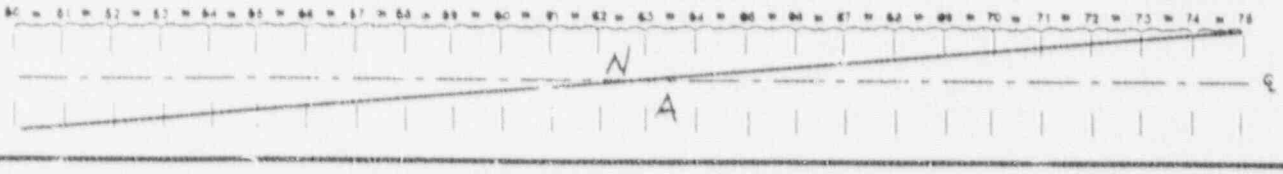
SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A

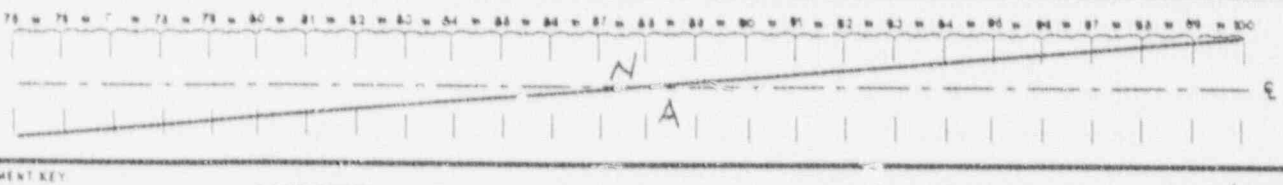
☐ CW ☐ CCW











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER BEAM REDIRECT
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.400	1.202	2.0"	28	29	0.025	01	T-023	0-325
2	20	40	↓	↓	↓	↓	↓	↓	02	↓	325-674
3	40	43	↓	↓	↓	↓	↓	↓	03	↓	674-728
4											
5						N/A					

COMMENTS 45°D SHEAR AXON SCANS. ① NO UPST EXAMS PERFORMED DUE TO DIFFERENT CAL REQUIREMENTS. ② DNST EXAM LIMITED TO A "W" OF 1.6 DUE TO THE PROXIMITY OF WELD NO. 1B21N40-5"-FWN40-315-1 WHERE THE WELD CROWN PREVENTED OPTIMUM CONTACT FROM BEING ACHIEVED.

H Schlerf — Examiner — II — Level — 12-7-90 — Date

Wes Money — Reviewed — III — Level — 12-7-90 — Date

Reviewed — QC — Title — 12-7-90 — Date

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

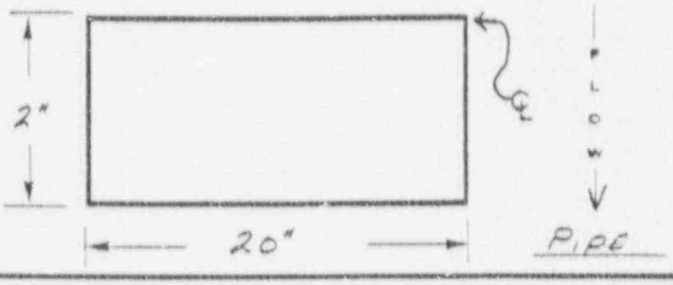
(AUTOMATED)

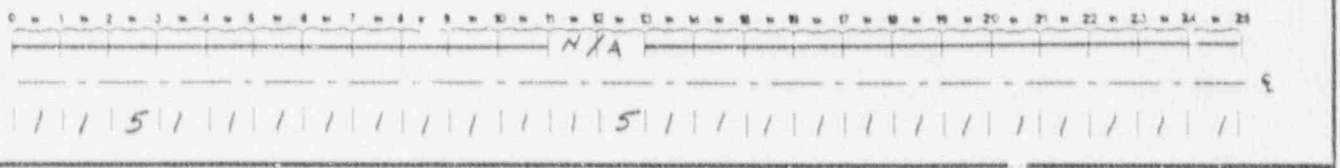
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

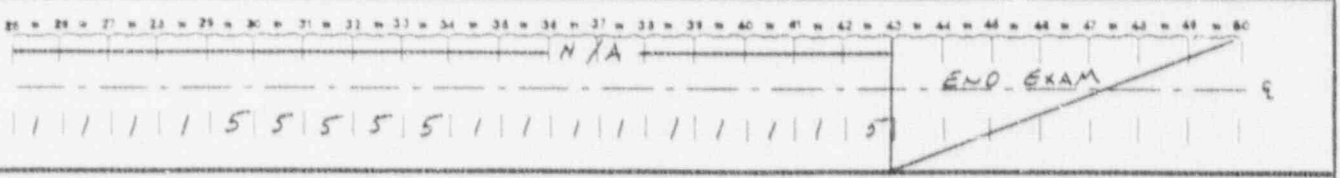
REPORT NO. R-095
CALIBRATION SHEET NO. C-122

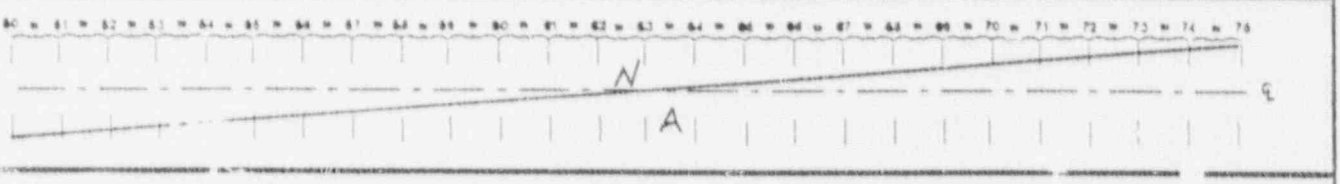
PROCEDURE GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1321N4D-S-SWI-A
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☐ CIRC ☒ TAN ☐ OTHER N/A
☒ CW ☐ CCW

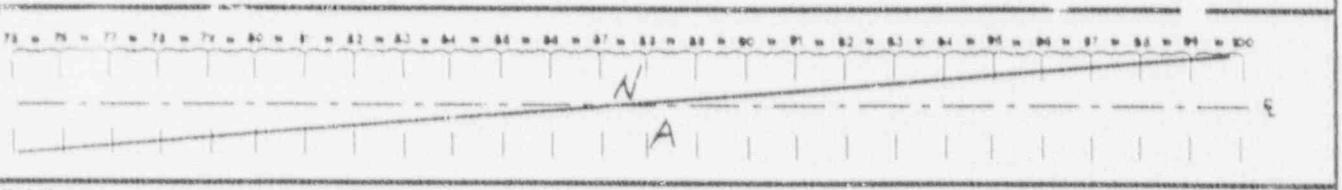
IMAGE GRID











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.400	1.207	2.0"	28	29	0-025	04	T-023	228-852
2	20	40	↓	↓	↓	↓	↓	↓	05	↓	852-1041
3	40	43	↓	↓	↓	↓	↓	↓	06	↓	1041-1103
4							N				
5							A				

COMMENTS 45° SHEAR CW SCANS. (1) NO EXAM UPST ONE TO DIFFERENT CAL REQUIREMENTS

W Schlabach	II	12-3-90	Wes Mowery	III	12-7-90
Examiner	Level	Date	Reviewed	Level	Date
			Reviewed	QC	12-17-90
				Title	Date

FORM NO. 4-07-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

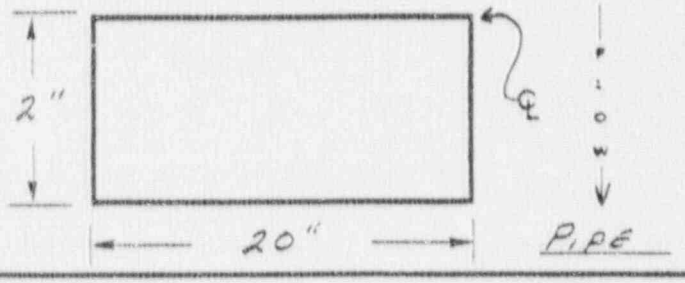
(AUTOMATED)

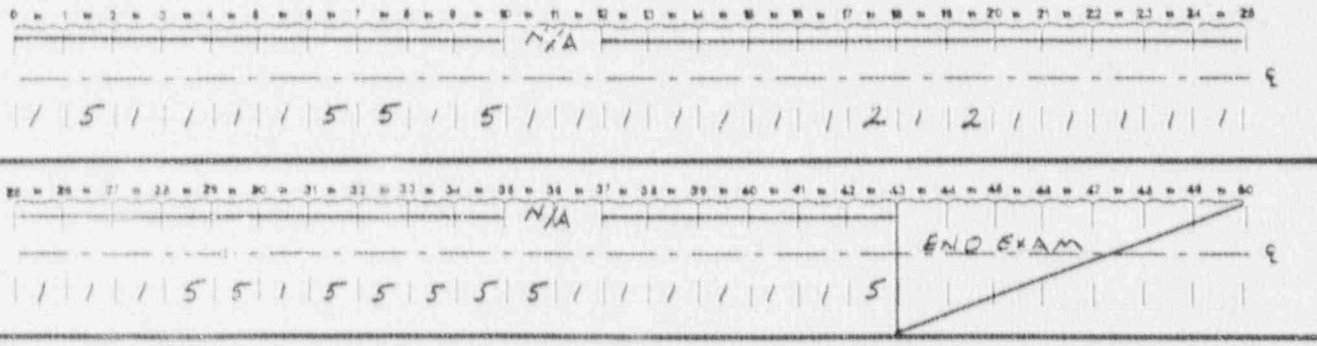
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

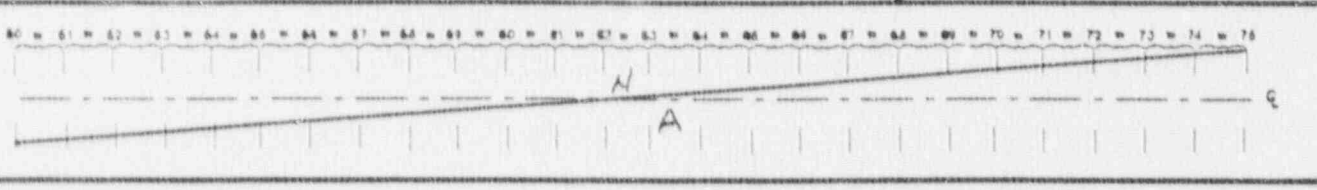
REPORT NO. R-095
CALIBRATION SHEET NO. C-122

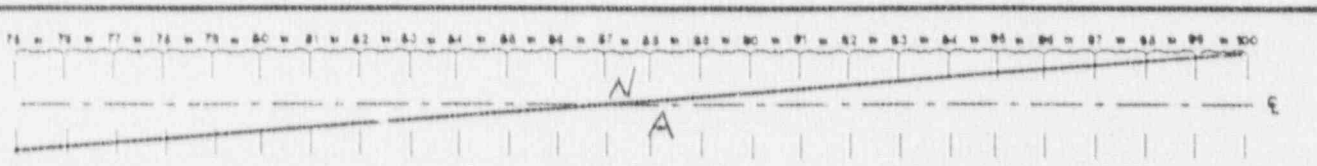
PROCEDURE: GE-UT-200 REV 2 PRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N40-S-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☐ CIRC ☒ TAN ☐ OTHER N/A
☐ CW ☒ CCW

IMAGE GRID









COMMENT KEY
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN	SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	(W) 0	20	1.202	20	28	29	0.025	07	T.023	1102 - 1207
2	(W) 20	40	↓	↓	↓	↓	↓	08	↓	1207 - 1351
3	(W) 40	43	↓	↓	↓	↓	↓	09	↓	1351 - 1406
4										
5					N/A					

COMMENTS 45° SHEAR CCW. (1) NO EXAM UPST DUE TO DIFFERENT CAL REQUIREMENTS

H Schlatt	II	12-2-90	W. Money	III	12-7-90
Examiner	Level	Date	Reviewed	Level	Date
			Reviewed	QC Title	12-12-90 Date

FORM NO. 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

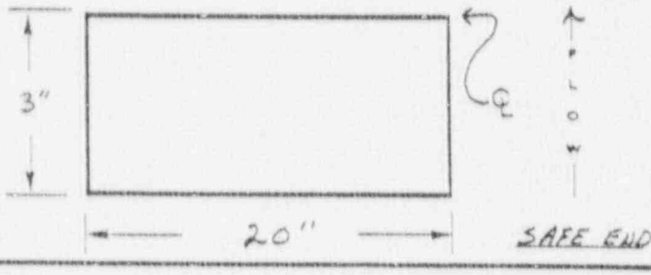
(AUTOMATED)

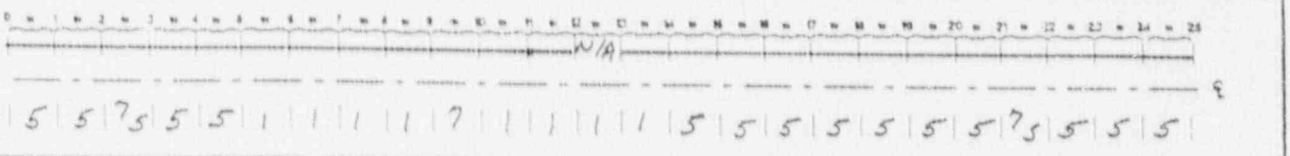
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SW735

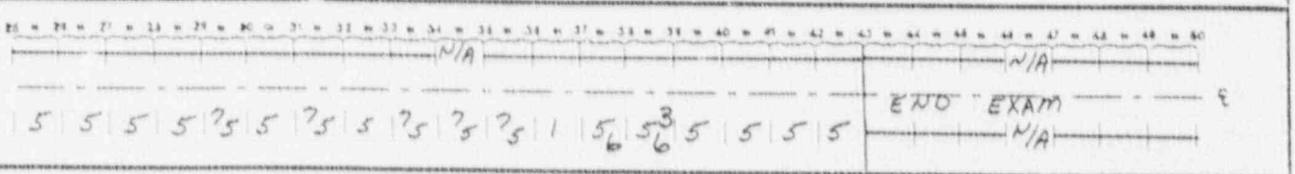
REPORT NO. R-095
CALIBRATION SHEET NO. C-123

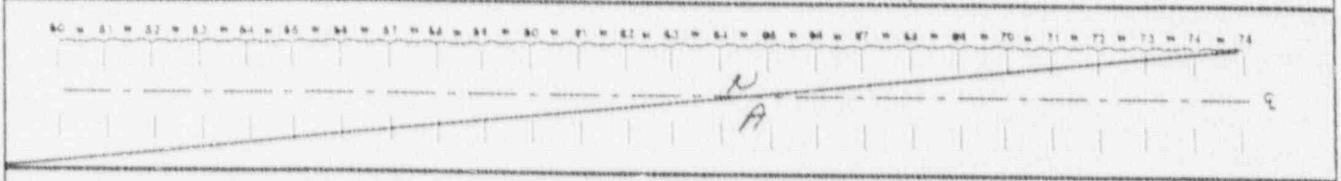
PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-S-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A
☐ CW ☐ CCW

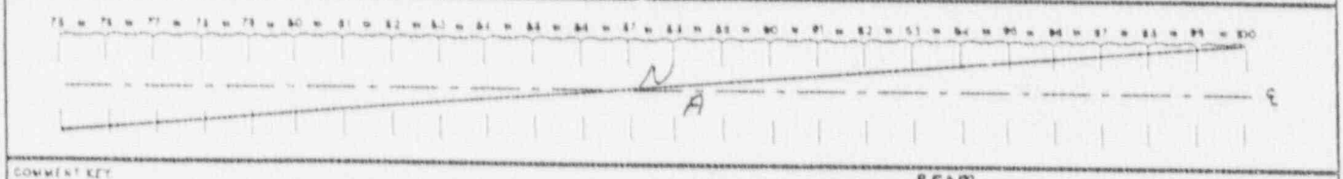
IMAGE GRID











COMMENT KEY
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER BEAM REDIRECT
8. OTHER N/A

SCAN NO	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTENUATION	THRESHOLD	DISK	FILE	TAPE	TAPE COUNTS
1	TW	0 20	4.5	6.29	2"	31	29	0.025	10	T-023	1406 - 1781
2	TW	20 40	↓	↓	↓	↓	↓	↓	11	↓	1781 - 2125
3	TW	40 43	↓	↓	↓	↓	↓	↓	12	↓	2125 - 2186
4						N/A					
5											

COMMENTS 45° S AXUP SCANS
① NO EXAM DNST. DUE TO DIFFERENT CALIBRATION REQUIREMENTS

Terri L. Watts II 12-8-90
Examiner Level Date

Reviewed III 12-7-90
Level Date

Reviewed QC 12-17-90
Title Date

FORM NO. A-(CT)-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

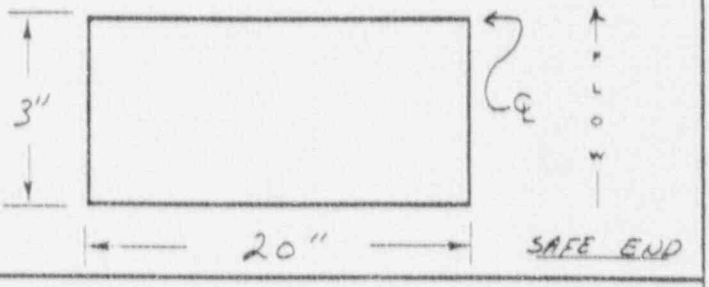
(AUTOMATED)

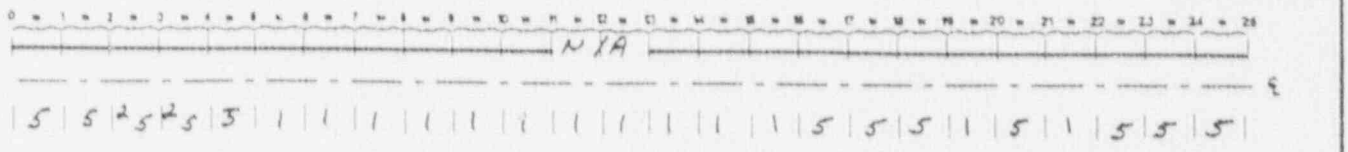
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN735

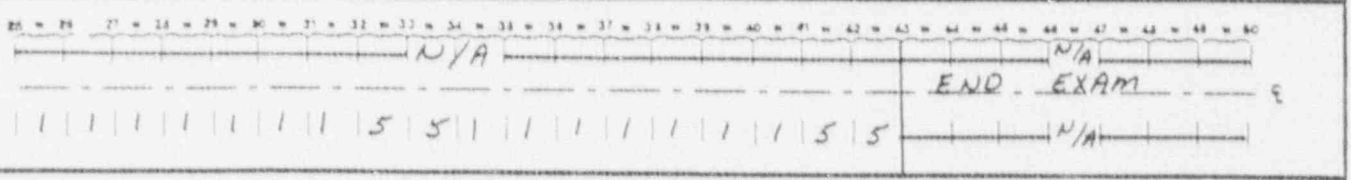
REPORT NO. R-095
CALIBRATION SHEET NO. C-123

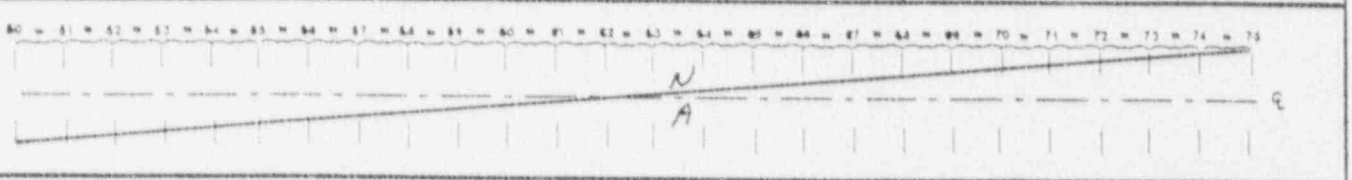
PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1821N4D-5-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☐ CIRC ☒ TAN ☐ OTHER N/A
☒ CW ☐ CCW

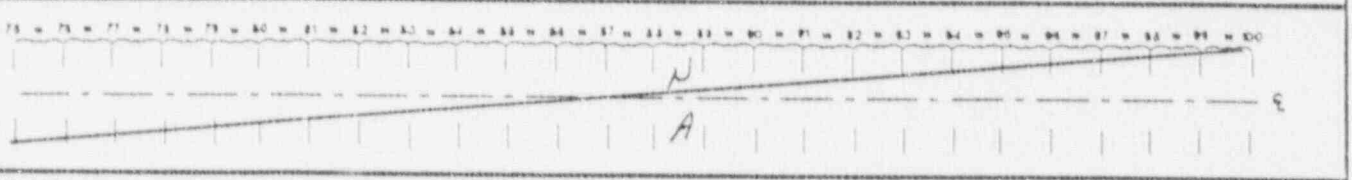
IMAGE GRID











COMMENT KEY
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	TW	0	20	.415	6.290	2"	28	29	D-025	13	T:023	2186 - 2377
2	TW	20	40	↓	↓	↓	↓	↓	↓	14	↓	2377 - 2535
3	TW	40	43	↓	↓	↓	↓	↓	↓	15	↓	2535 - 2722
4							N/A					
5												

COMMENTS 45° S CW UPST. SCANS
@ NO EXAM DUST. DUE TO DIFFERENT CALIBRATION REQUIREMENTS

Debra D. Dalton — Examiner — II Level — 12/4/90 Date

Wes Mooney — Reviewed — III Level — 12-7-90 Date

[signature] — Reviewed — QC Title — 12-17-90 Date

FORM NO. XXX-XX

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

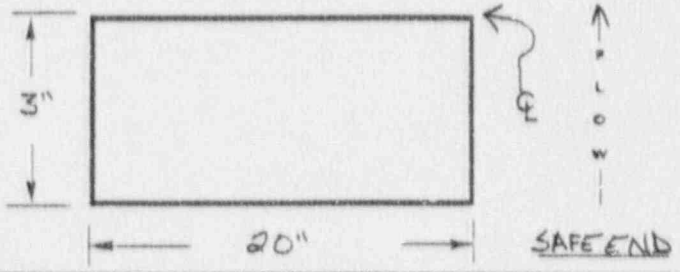
(AUTOMATED)

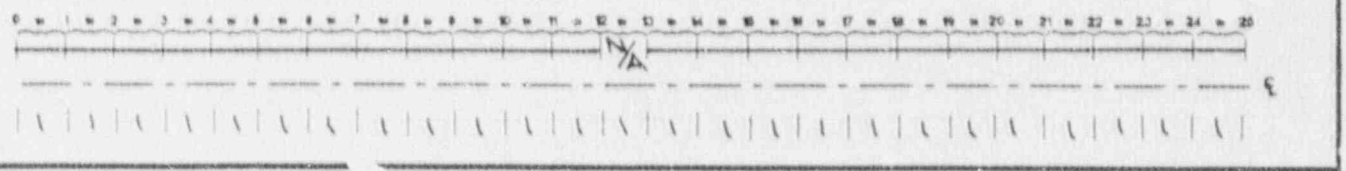
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

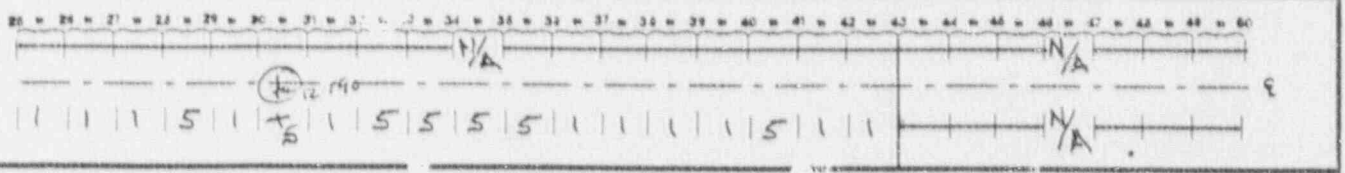
REPORT NO. R-095
CALIBRATION SHEET NO. C-123

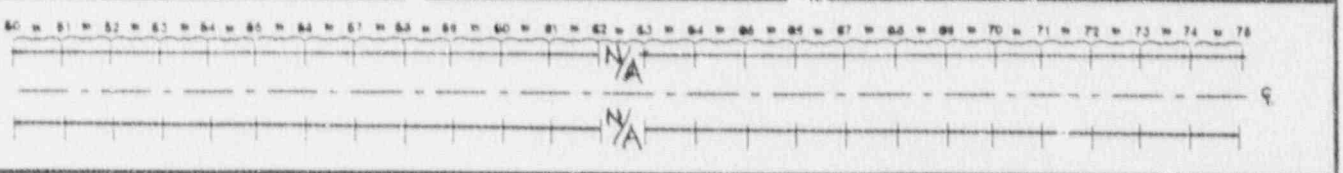
PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-5-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☐ CIRC ☒ TAN ☐ OTHER N/A
☐ CW ☒ CCW

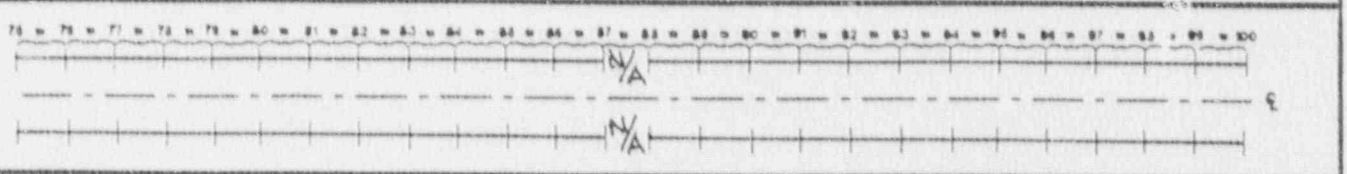
IMAGE GRID











COMMENT KEY
1. NO APPLICABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	W 0	20	4.5	4.209	2"	28	29	L-026	1	T-023	2727-2893
2	W 20	40	↓	↓	↓	27	↓	↓	2	↓	2893-3065
3	W 40	43	↓	↓	↓	27	↓	↓	3	↓	3065-3144
4											
5											

COMMENTS 45° CCW UPST. SCANS.
① NO EXAM DNST. DUE TO DIFFERENT CALIBRATION REQUIREMENTS.

Terri D. Watts II 12/3/90
Examiner Level Date

Wes Money III 12.7.90
Reviewed Level Date

[signature] QC 12-17-90
Reviewed Title Date

FORM NO. 8-07-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

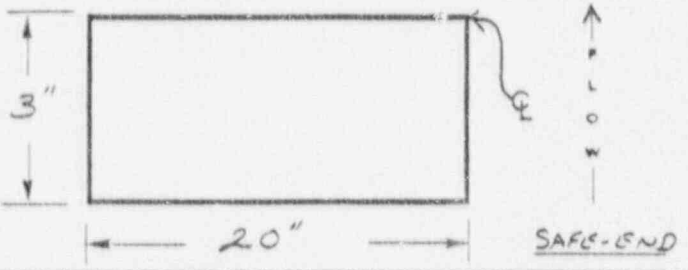
(AUTOMATED)

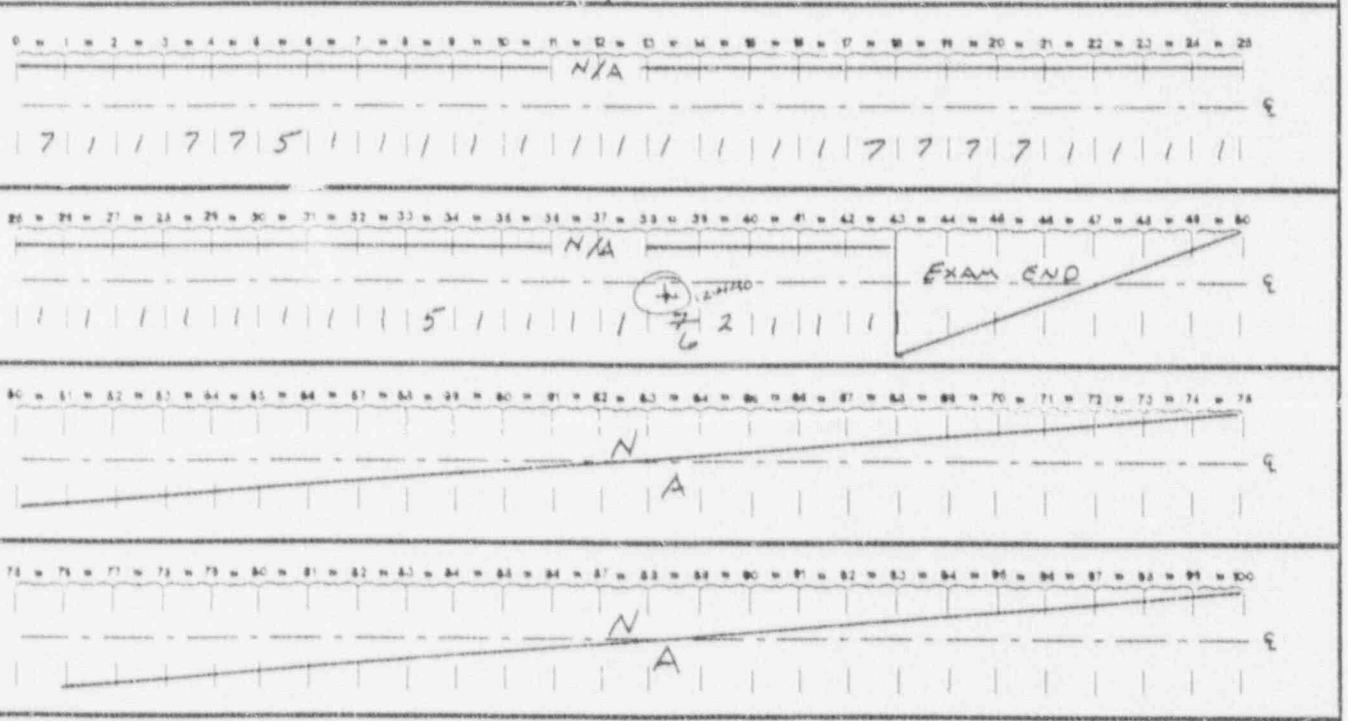
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-124

PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N40-5"-SWI-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A
☐ CW ☐ CCW

IMAGE GRID — PIPE





COMMENT KEY:
1. NO REPORTABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. WELD SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER: 3 SHEAR COMPONENT
8. OTHER: N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	TW 0	20	.400	1.200	2"	17	35	0-026	04	T-023	3147-3679
2	TW 20	40	↓	↓	↓	↓	↓	↓	05	↓	3679-4053
3	TW 40	43	↓	↓	↓	↓	↓	↓	06	↓	4053-4108
4											
5											

COMMENTS 45° IRL AXIAL SCANS
NO EXAM DNST DUE TO CAL REQUIREMENTS Different

Terri L. Watt — Examiner — II Level — 12/3/90 Date

Wm Money — Reviewed — III Level — 12.7.90 Date

Reviewed — QC Title — 12-17-90 Date

FORM NO. 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

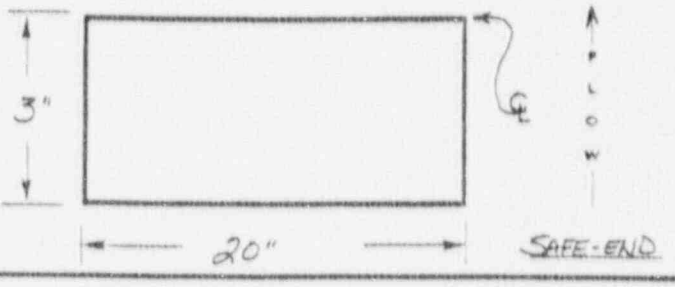
(AUTOMATED)

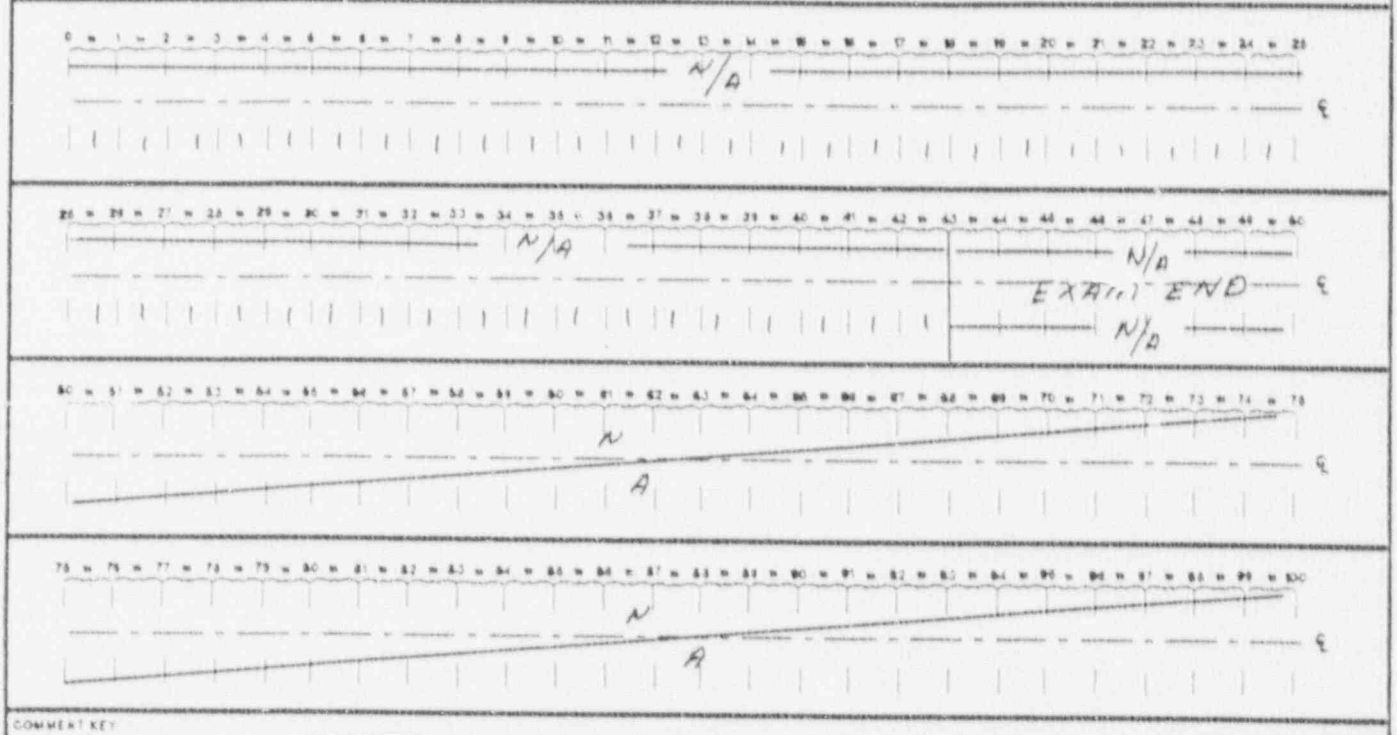
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SW735

REPORT NO. R-095
CALIBRATION SHEET NO. C-124

PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-5-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A
☒ CW ☐ CCW

IMAGE GRID





COMMENT KEY
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	400	1200	2"	17	35	D-026	07	T-023	4108 - 4179
2	20	40							08		4179 - 4258
3	40	43							09		4258 - 4279
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

COMMENTS 45° RL CW SCANS
NO EXAM DNST Due To Cal Requirements Different

Examiner	II Level	12-4-90 Date	Wes Money Reviewed	III Level	12-7-90 Date
			Reviewed	QC Title	12-17-90 Date

FORM NO. 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: BRUNSWICK UNIT: 1

PROJECT NO: ISI-90-SN735

REPORT NO. R-095

CALIBRATION SHEET NO. C-124

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21N4D-5-SW1-2

COUPLANT: ULTRAGEL II BATCH NO: B41B1

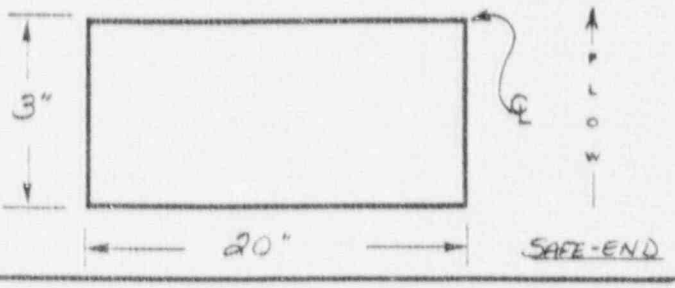
EXAM SURFACE TEMP: 78 °F

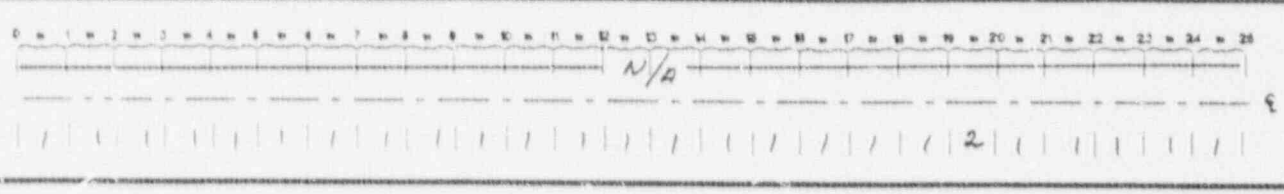
THERMOMETER S/N: 1491

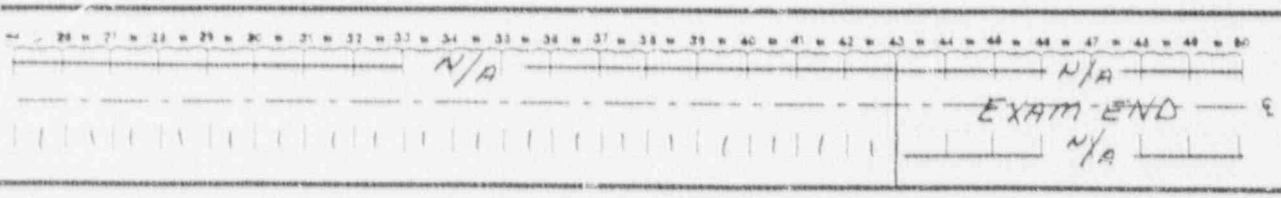
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A

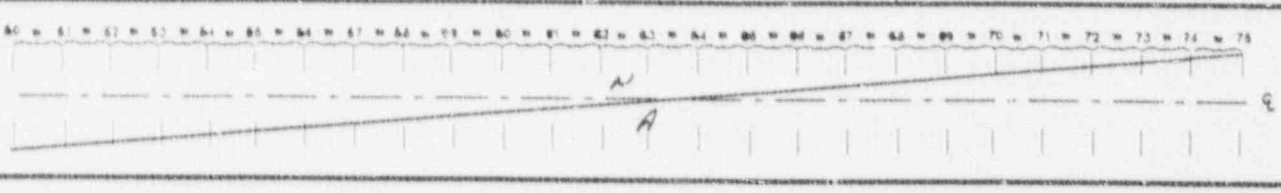
☐ CW ☒ CCW

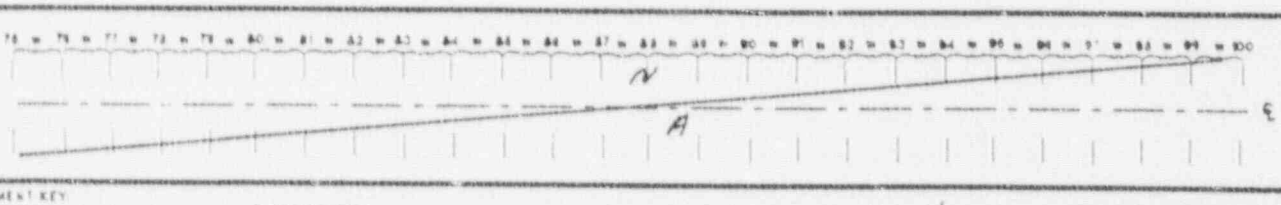
IMAGE GRID











COMMENT KEY

1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER: N/A
8. OTHER: N/A

SCAN NO	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.400	1.200	2"	17	35	D-026	10	T-023	4279 - 4361
2	20	40							11		4361 - 4429
3	40	NB							12		4429 - 4449
4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

COMMENTS 45°RL CCW SCANS

NO EXAM DONE TO Cal Requirements Different

Examiner	Level	12-4-90 Date	Reviewed	Level	12.7.90 Date
			Reviewed	QC Title	12-17-90 Date

FORM NO. 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

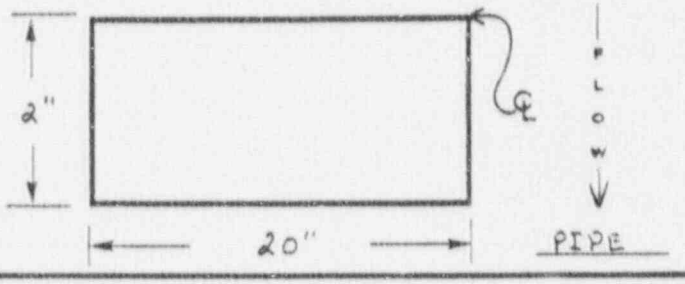
(AUTOMATED)

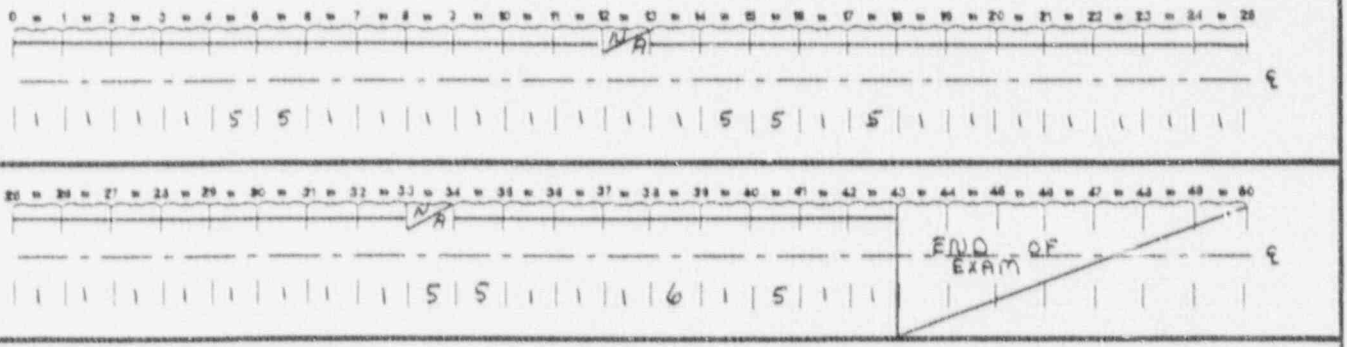
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN 735

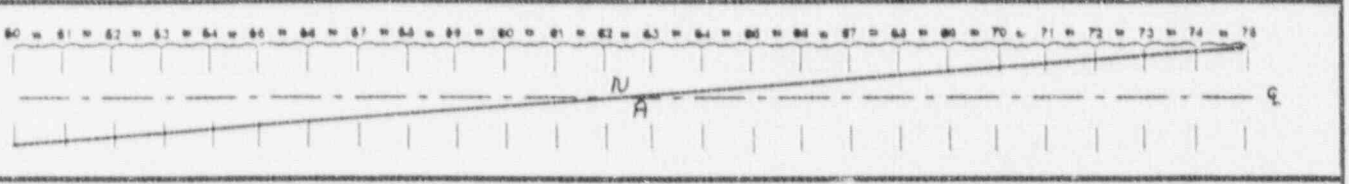
REPORT NO. R-095
CALIBRATION SHEET NO. C-125

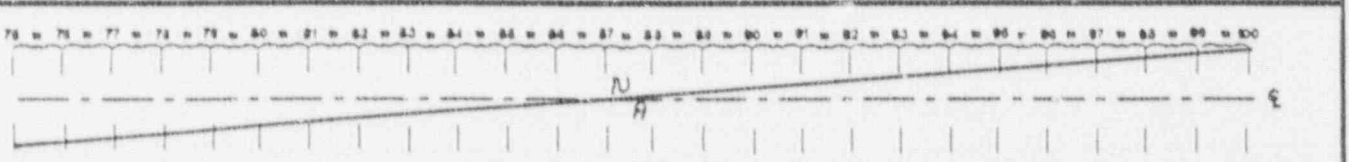
PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N40-S-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A
☐ CW ☐ CCW

IMAGE GRID









COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.397	1.250	2.0"	17	35	D-026	13	T-023	4449 - 4590
2	20	40	↓	↓	↓	↓	↓	↓	14	↓	4590 - 4731
3	40	43	↓	↓	↓	↓	↓	↓	15	↓	4731 - 4749
4											
5											

N/A

COMMENTS
45° RL RX ON ① NO EXAM UPST DUE TO DIFFERENT CAL REQUIREMENTS. ② EXAM LIMITED TO A "W" OF 1/8" DUE TO PROXIMITY OF WELD #1B21N40-S-FWN4D-315-1, WHERE THE WELD CROWN PREVENTED OPTIMUN CONTACT FROM BEING ACHIEVED ③ SCANNED BELOW REFERENCE TO MAINTAIN AVERAGE NOISE LEVEL BETWEEN 10% TO 30%.

Examiner	II Level	12-4-90 Date	Reviewed	III Level	12-7-90 Date
			Reviewed	QC Title	12-12-90 Date

FORM NO 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: BRUNSWICK UNIT: 1

PROJECT NO: ISI-90-SN 735

REPORT NO. R-095

CALIBRATION SHEET NO. C-125

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21N4D-S-SW1-2

COUPLANT ULTRAGEL II BATCH NO. 8981

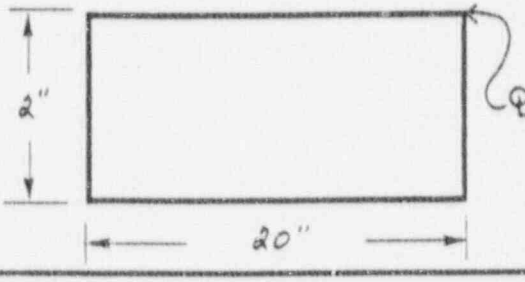
EXAM SURFACE TEMP 78 °F

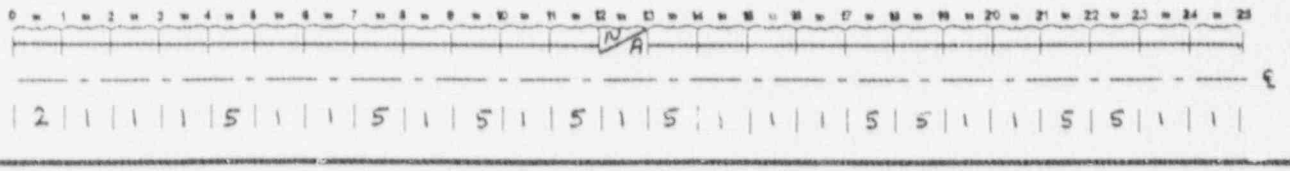
THERMOMETER S/N 1491

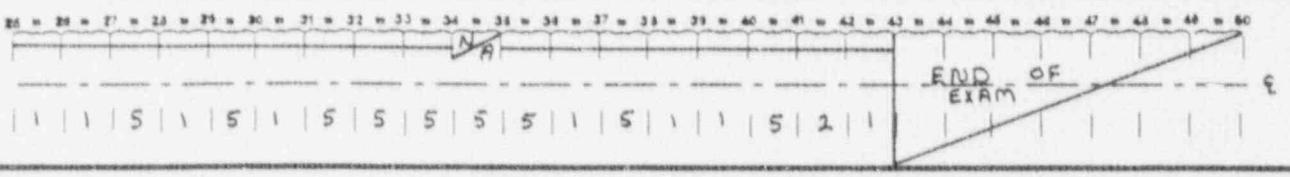
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A

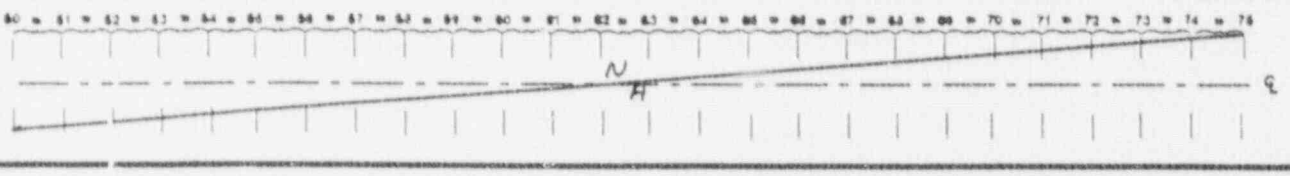
☒ CW ☐ CCW

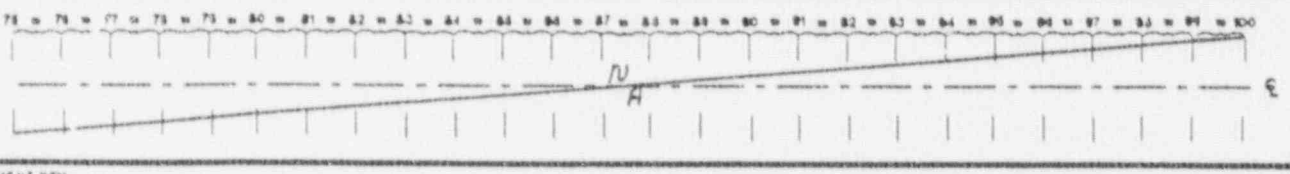
IMAGE GRID











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.397	1.250	2.0"	17	35	D-028	01	T-023	4749 - 4811
2	20	40	↓	↓	↓	↓	↓	↓	02	↓	4811 - 4900
3	40	43	↓	↓	↓	↓	↓	↓	03	↓	4900 - 4917
4											
5											

COMMENTS 45° RL CW ① NO EXAM UPST DUE TO DIFFERENT CAL REQUIREMENTS.

Examiner — II Level — 12-4-90 Date

Reviewed — III Level — 12-7-90 Date

Reviewed — QC Title — 12-7-90 Date

FORM MD 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: BRUNSWICK UNIT: 1

PROJECT NO: ISI-90-SN 735

REPORT NO. R-095

CALIBRATION SHEET NO. C-125

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21N4D-5-SW1-2

COUPLANT ULTRAGEL II BATCH NO. 8981

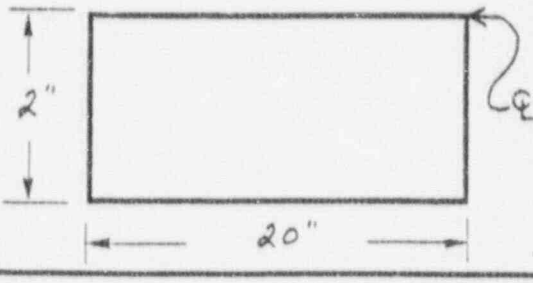
EXAM SURFACE TEMP 78 °F

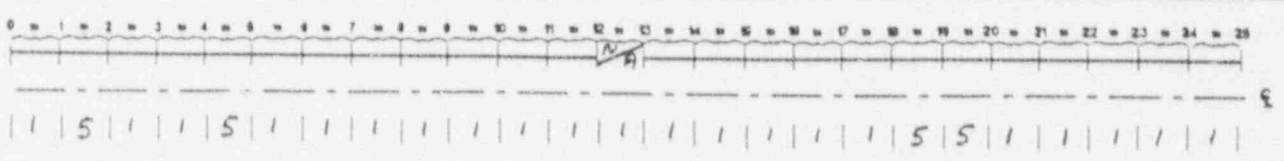
THERMOMETER S/N 1491

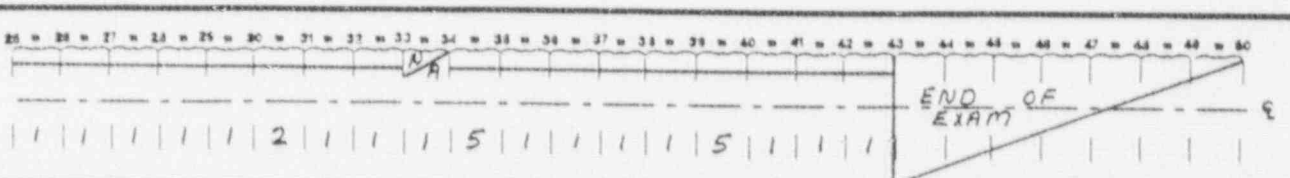
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A

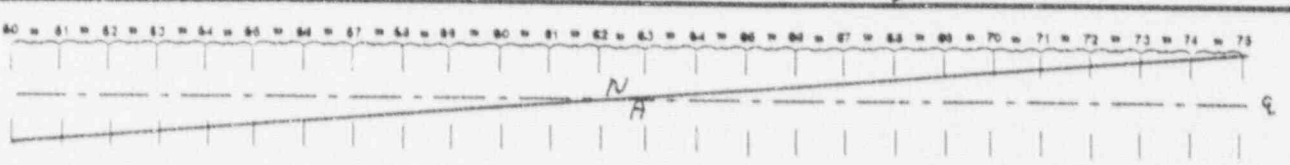
☐ CW ☒ CCW

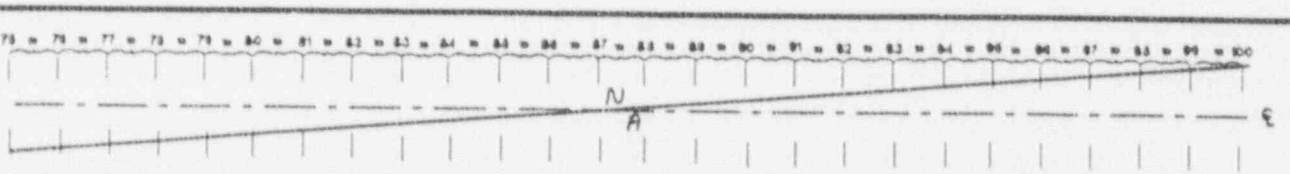
IMAGE GRID











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.397	1.25	2.0	17	35	D-028	04	1-023	4917 – 4997
2	20	40	↓	↓	↓	↓	↓	↓	05	↓	4997 – 5092
3	40	43	↓	↓	↓	↓	↓	↓	06	↓	5092 – 5110
4						N A					
5											

COMMENTS 45° RL CCW ① NO EXAM UPST. DUE TO DIFFERENT CAL. REQUIREMENTS.

Examiner — Level II — Date 12-4-90

Reviewed — Level III — Date 12-7-90

Reviewed — Title QC — Date 12-17-90

FORM MO 4-02-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

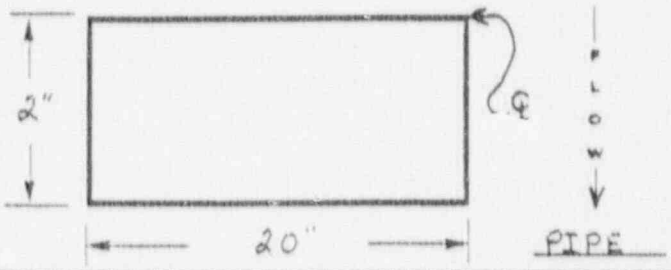
(AUTOMATED)

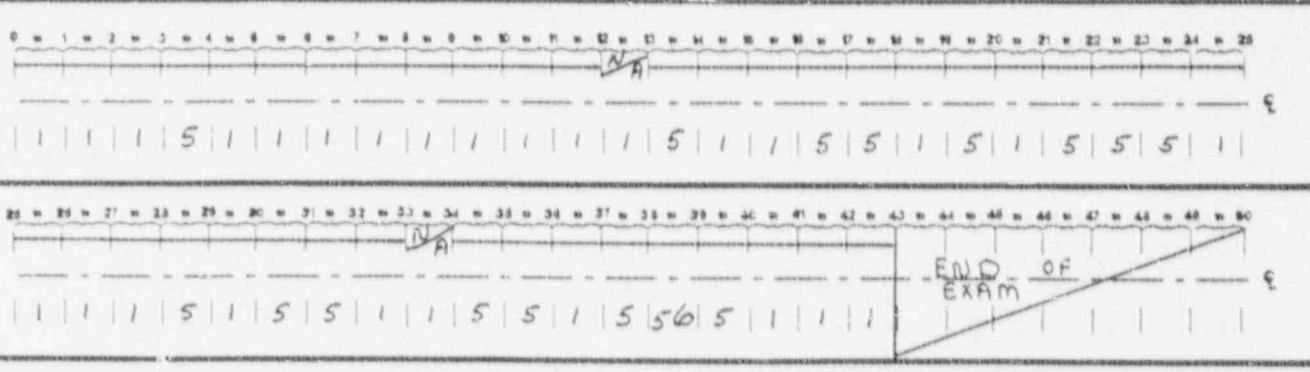
SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-126

PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1821N40-S-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A
☐ CW ☐ CCW

IMAGE GRID





COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTENUATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	40%	1:2	20"	1/2	35	0-028	07	T-023	5110 – 5195
2	20	40							08		5195 – 5300
3	40	43							09		5300 – 5315
4											
5											

COMMENTS
60° RL AXIAL ③NO EXAM UPST DUE TO DIFFERENT CAL. REQUIREMENTS. ②SCANS LIMITED TO A "W" OF 1½" DUE TO PROXIMITY OF WELD ①1821N40-S-FWN40-315-1 WHERE THE WELD CROWN PREVENTS OPTIMUM CONTACT FROM BEING ACHIEVED. ④SCANNED BELOW REFERENCE TO MAINTAIN AVERAGE NOISE LEVEL BETWEEN 10% AND 30%

Examiner	II Level	12-4-90 Date	Reviewed	II Level	12-7-90 Date
			Reviewed	QC Title	12-11-90 Date

FORM NO 4-02-490

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED

SITE: Brunswick UNIT: 1

PROJECT NO: ISI-90-SN735

REPORT NO. R-095

CALIBRATION SHEET NO. C-126

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEED WATER

WELD ID: 1B21NHD-5-SW1-2

COUPLANT ULTRAGEL II BATCH NO. 8981

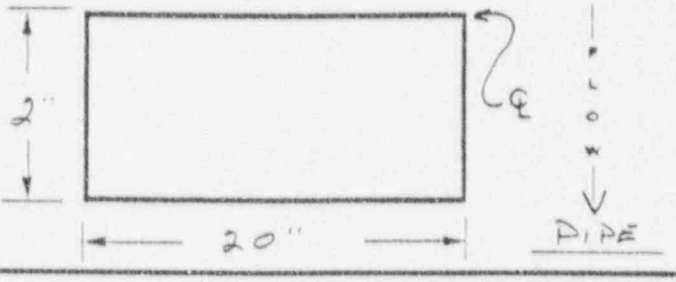
EXAM SURFACE TEMP 78 °F

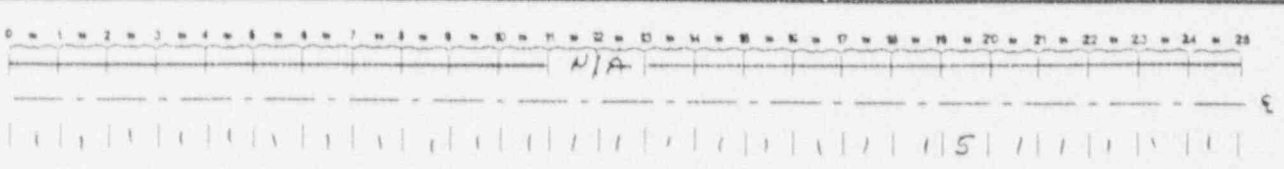
THERMOMETER S/N 1491

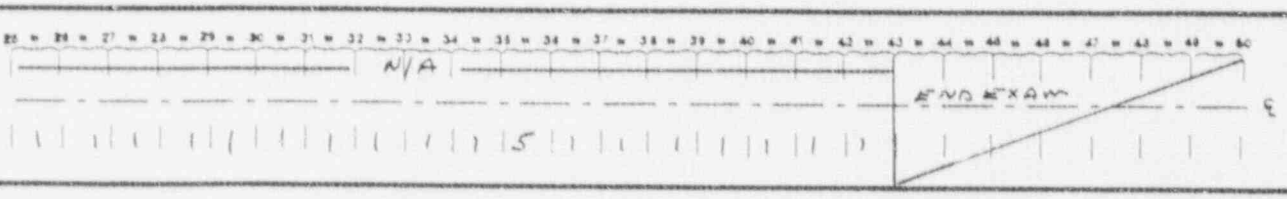
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A

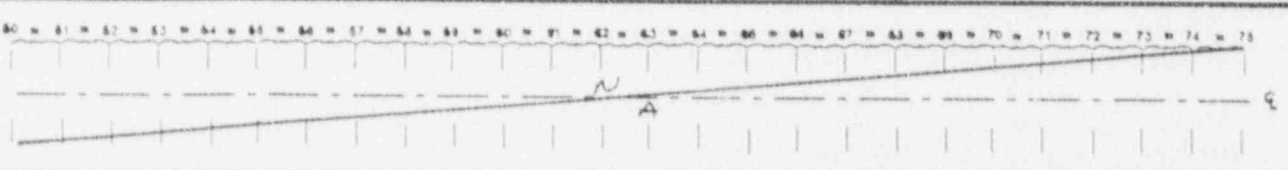
☒ CW ☐ CCW

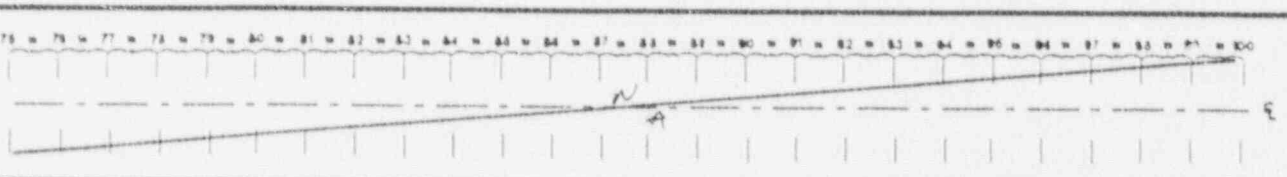
IMAGE GRID











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.402	1.2	2.0	16	35	D-028	10	T-023	5315-5400
2	20	40							11		5400-5479
3	40	43							12		5479-5499
4											
5											

COMMENTS 60° RL CW NO EXAM UPST Due to different Cal Requirements

Scanned below Reference to maintain Average Noise level between 10% and 30%

H Schlatt — Examiner — II — Level — 12-4-90 — Date

Wes Money — Reviewed — III — Level — 12-7-90 — Date

Reviewed — QC — Title — (2-7-90 — Date

FORM NO. 4-07-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: Brunswick UNIT: 1

PROJECT NO: ISI-90-SN735

REPORT NO. R-095

CALIBRATION SHEET NO. C-126

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21NHD-5-SW1-2

COUPLANT ULTRAGEL II BATCH NO. 8981

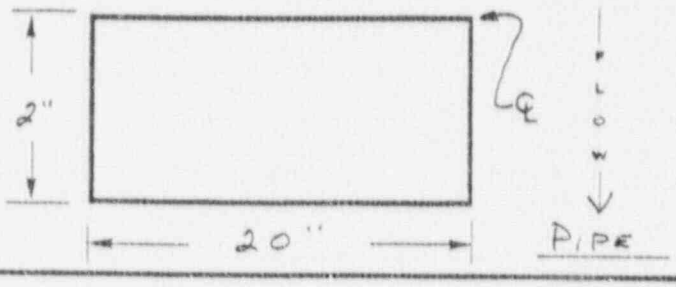
EXAM SURFACE TEMP 78 °F

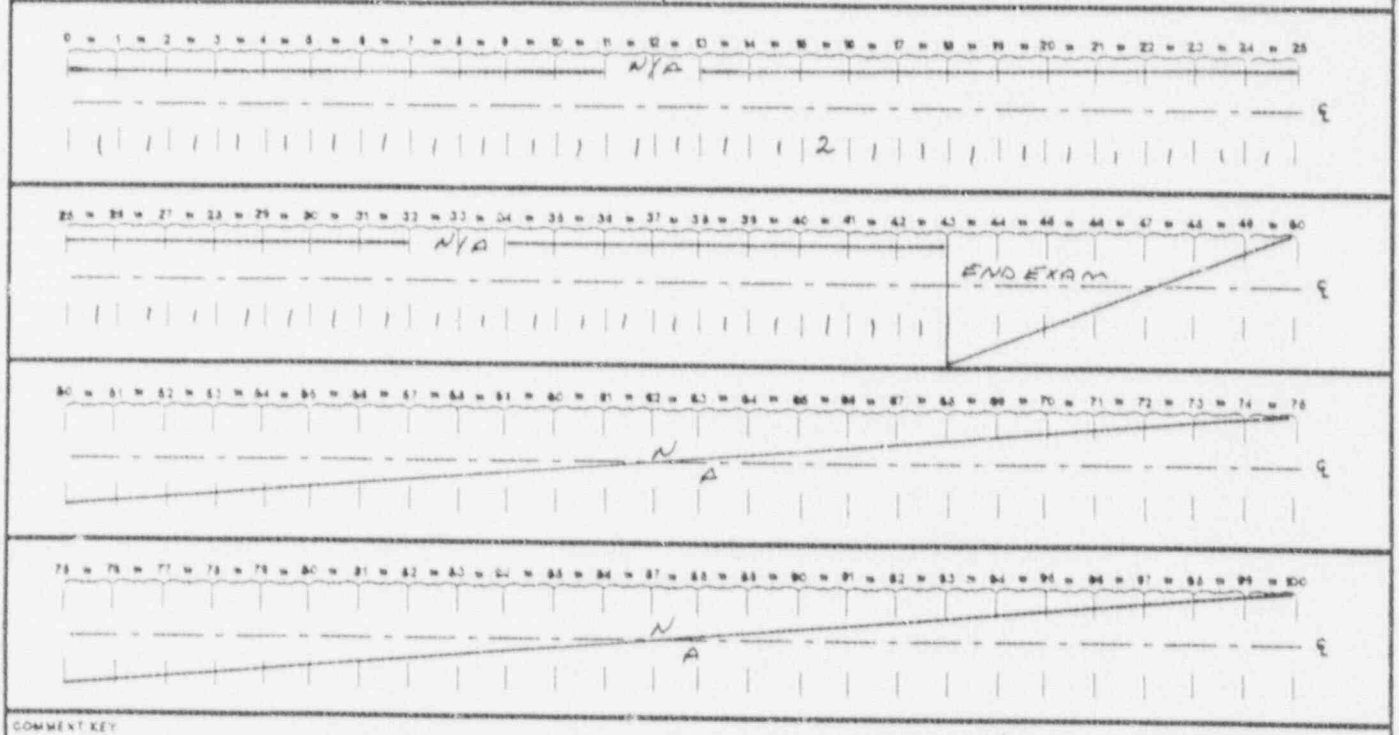
THERMOMETER S/N 1491

SCAN ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A

☐ CW ☒ CCW

IMAGE GRID





COMMENT KEY

1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	0	20	.402	1.2	2.0	16	35	D-028	13	T-023	5499 - 5573
2	20	40	↓	↓	↓	↓	↓	↓	14	↓	5573 - 5647
3	40	43	↓	↓	↓	↓	↓	↓	15	↓	5647 - 5663
4											
5											

COMMENTS 60°RL CCW No Exam UPST Due To Different Cal Requirements

Scanned Below Reference To Maintain Average Noise Level between 10% and 30%

H. Schrott — Examiner — II — Level — 12-4-90 — Date

Wes Money — Reviewed — III — Level — 12-7-90 — Date

Reviewed — QC — Title — 12-17-90 — Date

FORM NO. 4-07-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

(AUTOMATED)

SITE: BRUNSWICK UNIT: 1

PROJECT NO: 151-90-SN735

REPORT NO. R-095

CALIBRATION SHEET NO. C-127

PROCEDURE: GE-UT-200 REV 2 FRR N/A

SYSTEM: FEEDWATER

WELD ID: 1B21N40-5-SW1-2

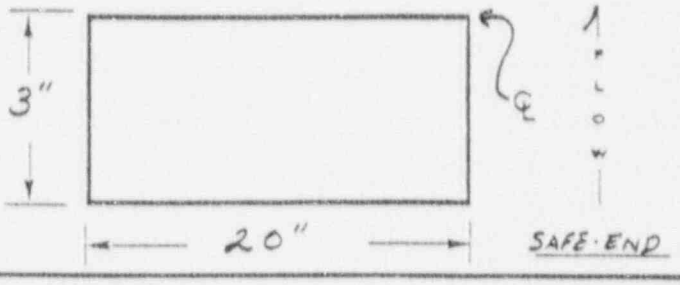
COUPLANT ULTRAGEL II BATCH NO. 8981

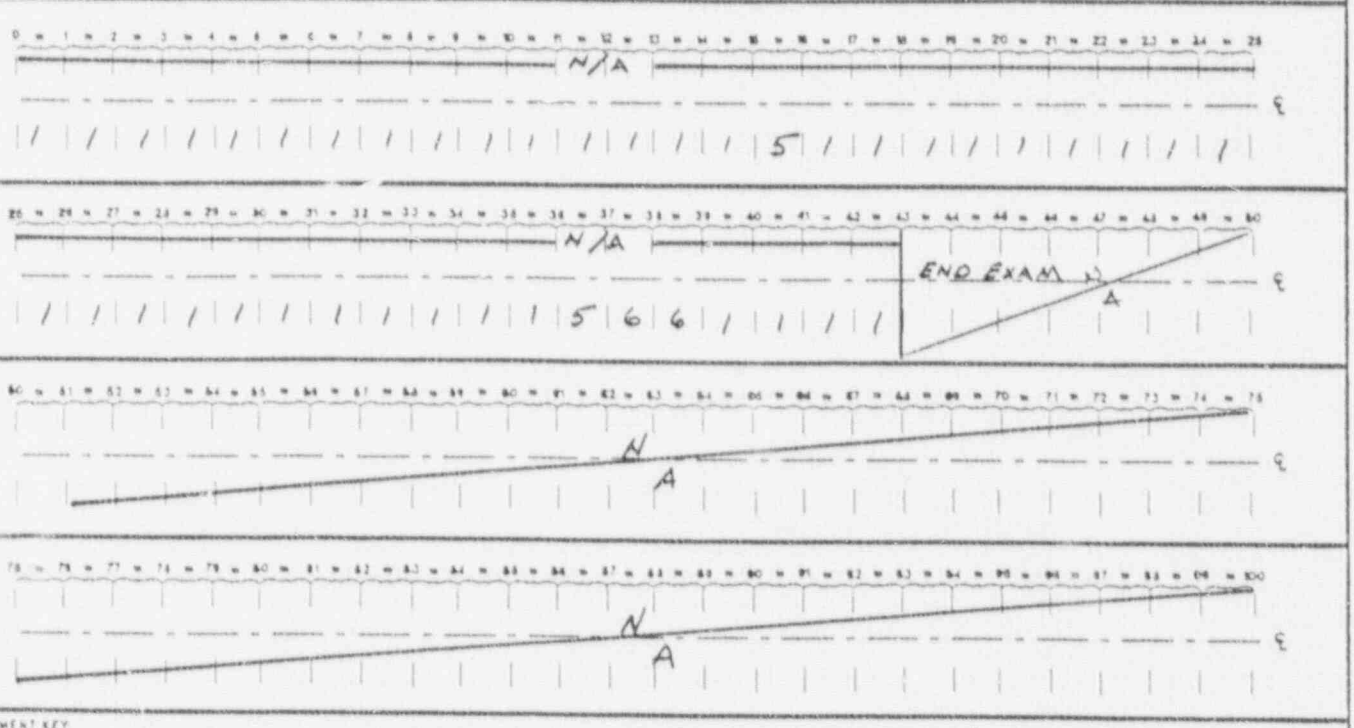
EXAM SURFACE TEMP 78 °F

THERMOMETER S/N 1491

SCAN: ☒ AXIAL ☐ CIRC ☐ TAN ☐ OTHER N/A ☐ CW ☐ CCW

IMAGE GRID





COMMENT KEY
1. NO REPORTABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1 (1) (2)	0	20	.403	1.203	2.0"	16	35%	0-029	01	T-024	0-391
2 (1) (2)	20	40	↓	↓	↓	↓	↓	↓	02	↓	391-806
3 (1) (2)	40	43	↓	↓	↓	↓	↓	↓	03	↓	806-866
4											
5											

COMMENTS 60° RL AXUPST (1) NO EXAM DNST DUE TO DIFFERENT CAL REQUIREMENTS. (2) SCANNED BELOW REFERENCE TO MAINTAIN AVERAGE NOISE LEVEL BETWEEN 10% AND 30%.

Examiner	II Level	12-4-90 Date	Wes Money Reviewed	III Level	12-7-90 Date
			Reviewed	QC Title	12-17-90 Date

FORM NO. 4-00-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

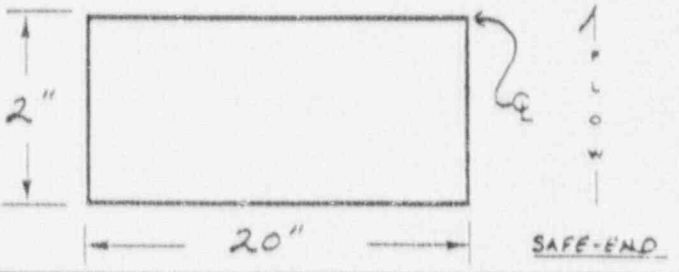
(AUTOMATED)

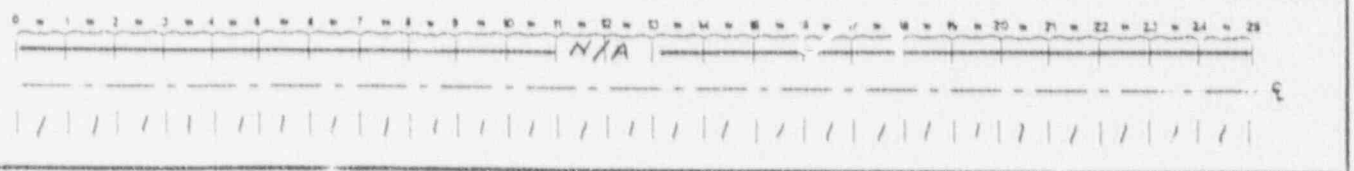
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

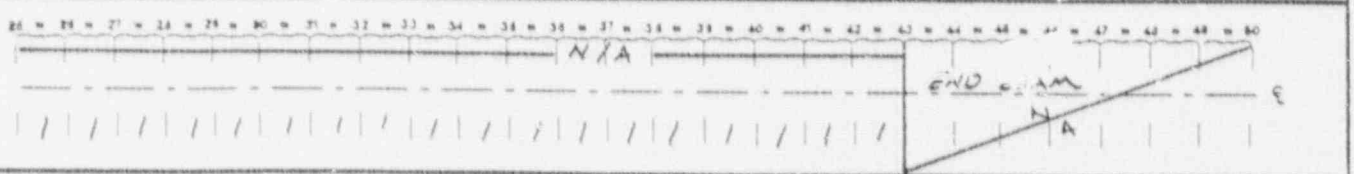
REPORT NO. R-095
CALIBRATION SHEET NO. C-127

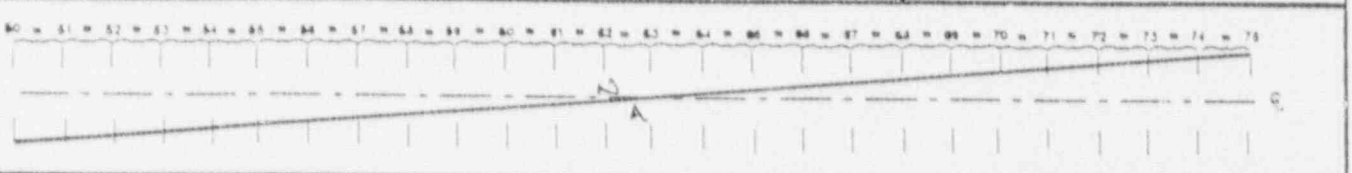
PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-5-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER
☒ CW ☐ CCW

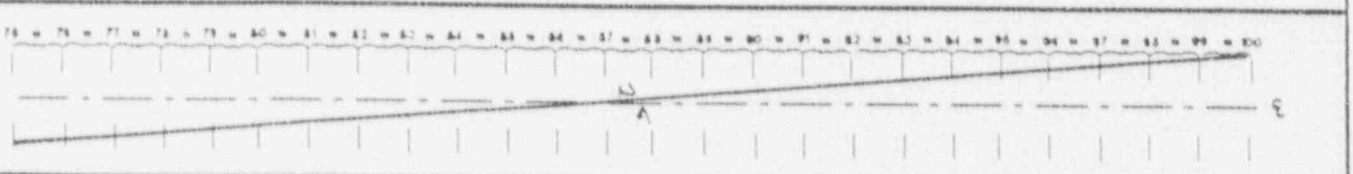
IMAGE GRID











COMMENT KEY:
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTEN-UATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1 (R)	0	20	.403	1.203	2.0"	16	35	Q-029	04	T-024	866-1011
2 (R)	20	40	↓	↓	↓	↓	↓	↓	05	↓	1011-1154
3 (R)	40	43	↓	↓	↓	↓	↓	↓	06	↓	1154-1182
4											
5											

COMMENTS 60° RL CW (1) NO EXAM DNST DUE TO DIFFERENT CAL REQUIREMENTS. (2) SCANNED BELOW REFERENCE TO MAINTAIN AVERAGE NOISE LEVEL BETWEEN 10% AND 30%

H. Schlitt — Examiner — II Level — 12.4.90 Date

Wes Money — Reviewed — III Level — 12.7.90 Date

Reviewed — QC Title — 12.17.90 Date

FORM NO. X-CC-90

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET

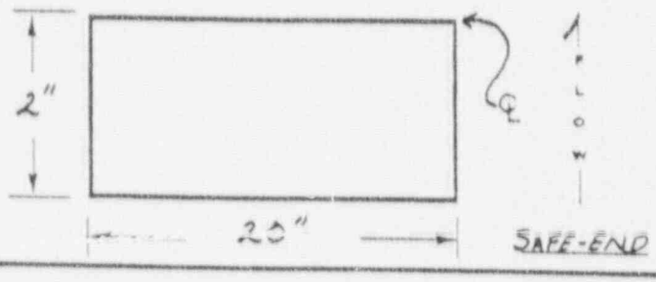
(AUTOMATED)

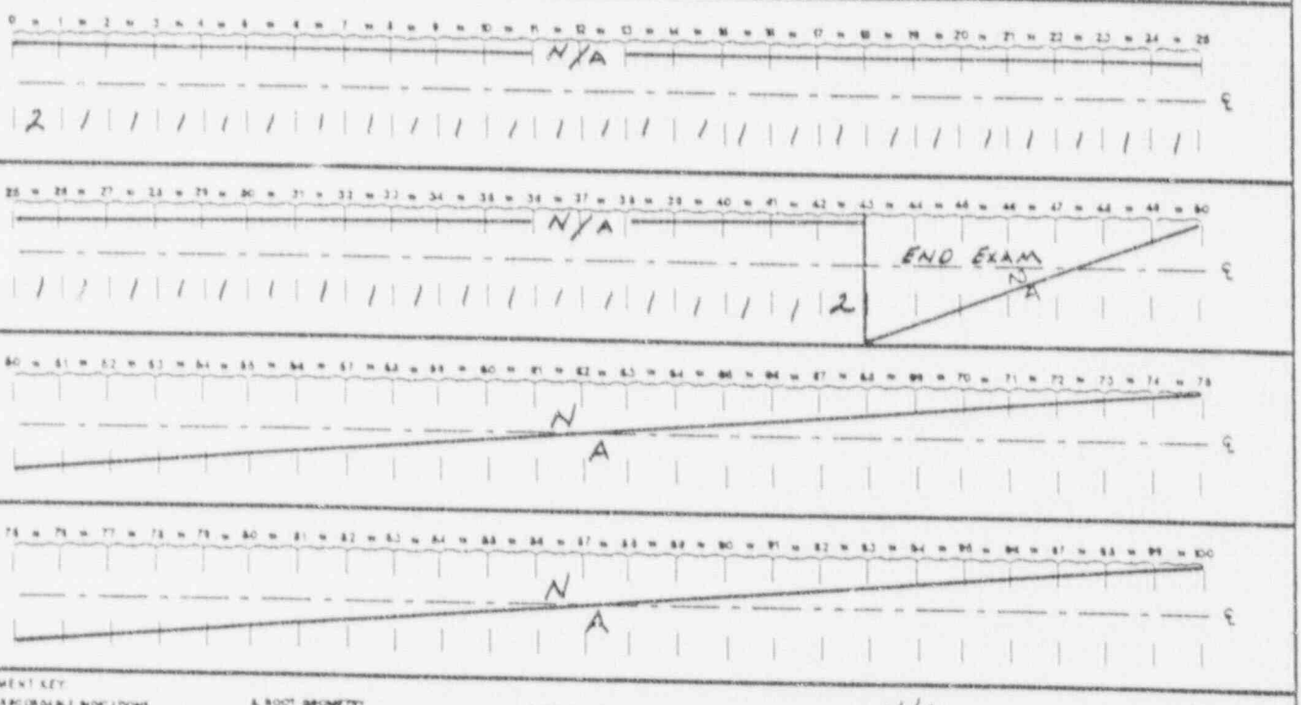
SITE: BRUNSWICK UNIT: 1
PROJECT NO: 121-80-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-127

PROCEDURE: GE-UT-200 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N40-5"-SW1-2
COUPLANT ULTRAGEL II BATCH NO. 8981
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
SCAN: ☐ AXIAL ☒ CIRC ☐ TAN ☐ OTHER N/A
☐ CW ☒ CCW

IMAGE GRID





COMMENT KEY
1. NO RECORDABLE INDICATIONS
2. NON-RELEVANT INDICATIONS
3. ROOT GEOMETRY
4. COUNTERBORE GEOMETRY
5. INSIDE SURFACE GEOMETRY
6. NON-GEOMETRIC INDICATION
7. OTHER N/A
8. OTHER N/A

SCAN NO.	SCAN IN-TO-IN		GATES IN-TO-IN		SCREEN RANGE	ATTENUATION	THRES-HOLD	DISK	FILE	TAPE	TAPE COUNTS
1	CW 0	20	.403	1.203	2.0"	16	35	0.029	7	T-024	1182-1350
2	CW 20	40	↓	↓	↓	↓	↓	↓	8	↓	1350-1550
3	CW 40	H3	↓	↓	↓	↓	↓	↓	9	↓	1550-1589
4							N				
5							A				

COMMENTS 60° RL CCW ① NO EXAM DNST. DUE TO DIFFERENT CAL REQUIREMENTS. ② SCANNED BELOW REFERENCE TO MAINTAIN AVERAGE NOISE LEVEL BETWEEN 10% AND 30%.

Examiner	II	12-4-90	Reviewed	III	12-7-90
	Level	Date		Level	Date
			Reviewed	QC	12-17-90
				Title	Date

FORM NO. A-(07)-90

GE Nuclear Energy

SCAN PARAMETER DATA SHEET

SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-122 / C-123

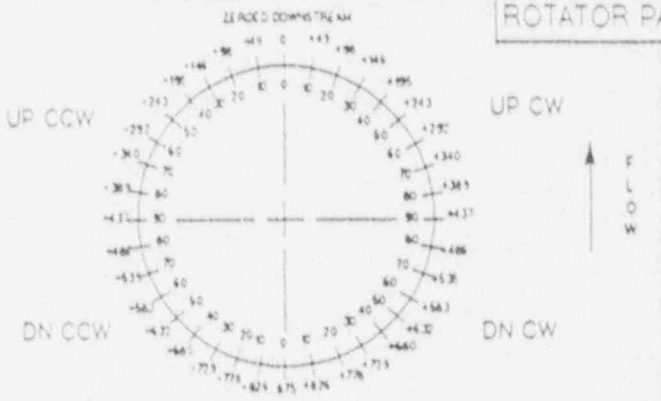
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-5-SW1-2
WELD CONFIG: SAFE END - PIPE
CIRC - 1° 786 FLOW → COUNTS
TRACK SIZE / TYPE 16" / VCR

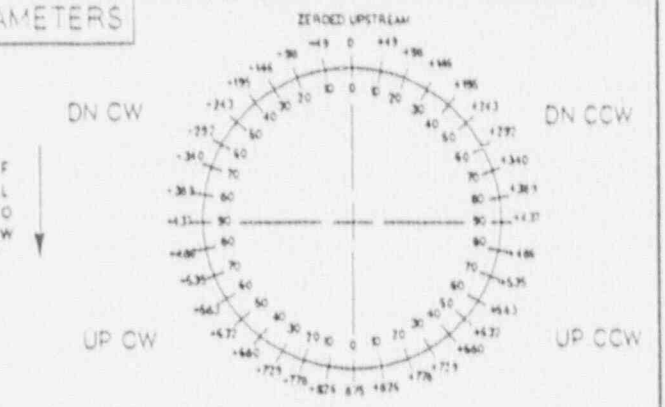
WELD DIA: 12" CIRC: 43"
TRACK LOCATION: UPSTREAM
X° LOCATION: RULE #1 / TDC
Y° LOCATION: WELD ℄
ROTATOR ZEROED BEAM DIRECTED: DOWNSTREAM
SCANNER ARM LENGTH: 12"

	CIRC (X) 18 RPM		TRA (M) 630 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
UPSTREAM							
0° - 20°	0	+15720	-1300	0	-50	+50	± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - 60° 43"	+31440	+33798	↓	↓	↓	↓	↓
60° - 80°				N			
80° - 100°				A			
DNSTREAM							
0° - 20°	0	+15720	0	+800	+825	+925	± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - 60° 43"	+31440	+33798	↓	↓	↓	↓	↓
60° - 80°				N			
80° - 100°				A			

	CIRC (X) 800 RPM		TRA (M) 3 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
CW			UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0° - 20°	0	+15720	-1300 / 0	0 / +800	+243 / +340	+536 / +632	50° - 70°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - 60° 43"	+31440	+33798	↓	↓	↓	↓	↓
60° - 80°				N			
80° - 100°				A			
CCW							
0° - 20°	0	+15720	-1300 / 0	0 / +800	-340 / -243	-632 / -536	50° - 70°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - 60° 43"	+31440	+33798	↓	↓	↓	↓	↓
60° - 80°				N			
80° - 100°				A			

ROTATOR PARAMETERS





COMMENTS: 45° S Ø DNST. AXIAL SCANS LIMITED TO A"W" OF 1.6" DUE TO THE PROXIMITY OF WELD 1B21N4D-5-FWN4D315-1, WHERE THE WELD CROWN PREVENTED OPTIMUM CONTACT FROM BEING ACHIEVED

Terri L. Wetto	II	12-2-90	Wes Morris	III	12-7-90
Operator	Level	Date	Reviewed	Level	Date
H. Schlicht	II	12-2-90	[signature]	QC	12-17-90
Examiner	Level	Date	Reviewed	Title	Date

FORM (1) 4-7-90

GE Nuclear Energy

SCAN PARAMETER DATA SHEET

SITE: BRUNSWICK UNIT: 1
PROJECT NO: 151-90-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-124 / C-125

SYSTEM: FEEDWATER
WELD ID: 1B21-N4D-S-SWI-2
WELD CONFIG: SAFE END - PIPE
CIRC - 1" 786 FLOW → COUNTS
TRACK SIZE / TYPE 16" / VCR

WELD DIA: 12" CIRC: 43"
TRACK LOCATION: UPSTREAM
X, LOCATION: RUN #1 / TDC
Y, LOCATION: WELD ℄
ROTATOR ZEROED BEAM DIRECTED: DOWNSTREAM
SCANNER ARM LENGTH: 12"

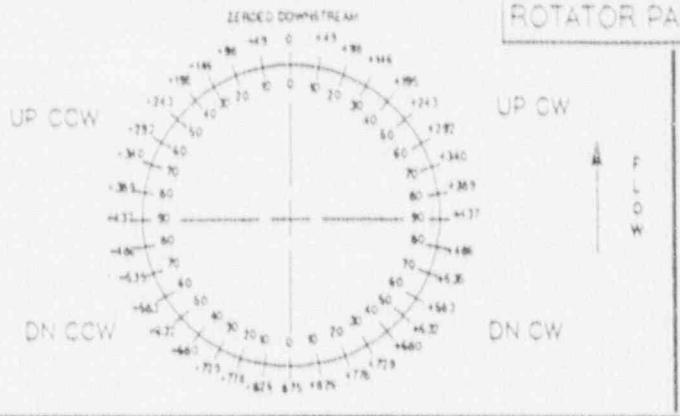
UPSTREAM	CIRC (X) 8 RPM		TRA (Y) 500 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
0° - 20°	0	+15720	-1300	0	-500	+500	±10°
20° - 40°	+15720	+31440					
40° - 60°~~45°~~	+31440	+33798					
60° - 80°							
80° - 100°							

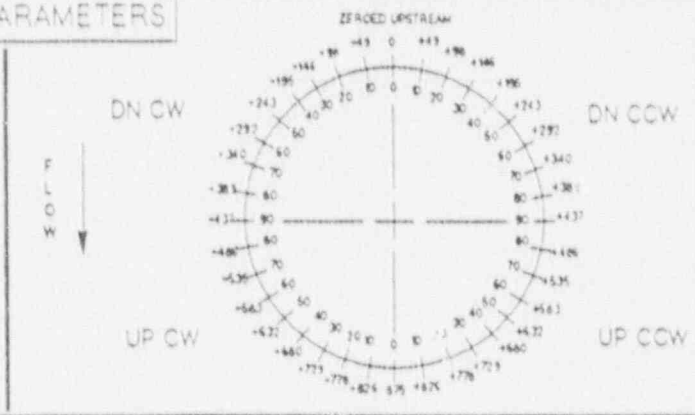
DNSTREAM							
0° - 20°	0	+15720	0	+800	+825	+925	±10°
20° - 40°	+15720	+31440					
40° - ~~60°45°~~	+31440	+33798					
60° - 80°							
80° - 100°							

CW	CIRC (X) 800 RPM		TRA (Y) 3 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
			UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0° - 20°	0	+15720	-1000/0	0/+800	+389/+486	+389/+486	90° ± 10°
20° - 40°	+15720	+31440					
40° - ~~60°45°~~	+31440	+33798					
60° - 80°							
80° - 100°							

CCW							
0° - 20°	0	+15720	-1000/0	0/+800	-486/-389	-486/-389	90° ± 10°
20° - 40°	+15720	+31440					
40° - ~~60°45°~~	+31440	+33798					
60° - 80°							
80° - 100°							

ROTATOR PARAMETERS





COMMENTS: 45° RL ① DIST. AXIAL SCAN LIMITED TO A "W" OF 16" DUE TO THE PROXIMITY OF WELD 1B21N4D-S-FWN4D316-1, WHERE THE WELD CROWN PREVENTED OPTIMUM CONTACT FROM BEING ACHIEVED.

Terri L. Watts	II	12/4/90	Wes Money	III	12790	
Operator	Level	Date	Reviewed	Level	Date	
W Schubert	II	12/4/90	Reviewed	QC	12-11-90	
Examiner	Level	Date		Title	Date	

FORM 141 4-2-90

GE Nuclear Energy

SCAN PARAMETER DATA SHEET

SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN735

REPORT NO: R-095
CALIBRATION SHEET NO. C-126/C-127

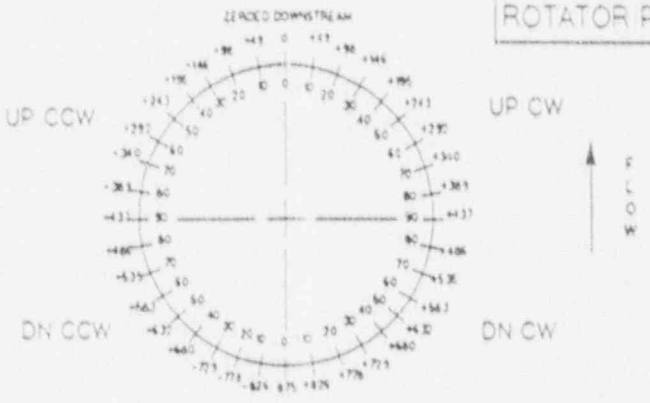
SYSTEM: FEEDWATER
WELD ID: 1B21NHD-5"-SW1-2
WELD CONFIG: SAFE-END - PIPE
CIRC - 1° 786 FLOW → COUNTS
TRACK SIZE / TYPE 16" UCR

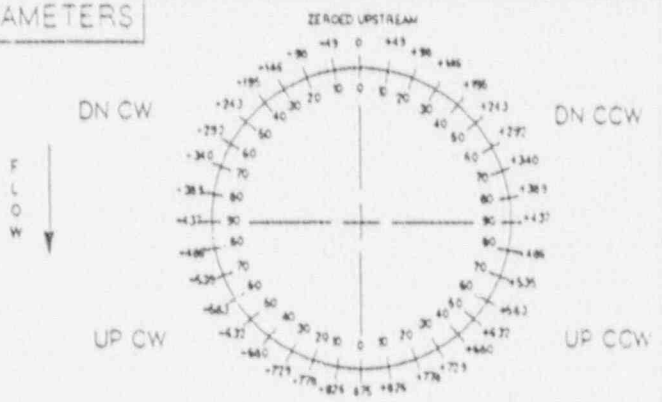
WELD DIA: 12" CIRC: 43"
TRACK LOCATION: UPST
X° LOCATION: Rule #1 / TDC
Y° LOCATION: Weld ℄
ROTATOR ZEROED BEAM DIRECTED: DNST
SCANNER ARM LENGTH: 12"

UPSTREAM	CIRC (X) 10 RPM		TRAM 550 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
0° - 20°	0	+15720	-1500	0	-50	+50	± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - ~~60°~~43	+31440	+33798					
60° - 80°							
80° - 100°							
DNSTREAM							
0° - 20°	0	+15720	0	+800	+825	+925	± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - ~~60°~~43	+31440	+33798					
60° - 80°							
80° - 100°							

CW	CIRC (X) 800 RPM		TRAM 2-3 RPM		ROT (SKEW) 250 RPM		SKEW ANGLE
			UPSTREAM	DOWNSTREAM	UPSTREAM	DOWNSTREAM	
0° - 20°	0	+15720	-800/0	0/+800	+389/+486	+389/+486	90° ± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - ~~60°~~43	+31440	+33798					
60° - 80°							
80° - 100°							
CCW							
0° - 20°	0	+15720	-800/0	0/+800	-486/-389	-486/-389	90° ± 10°
20° - 40°	+15720	+31440	↓	↓	↓	↓	↓
40° - ~~60°~~43	+31440	+33798					
60° - 80°							
80° - 100°							

ROTATOR PARAMETERS





COMMENTS: 60° RL
DNST AX EXAM Limited to A "W" of 1.6" Due To Proximity of Weld 1B21NHD-5-FWNHD-3:5-1, where the weld crown prevented optimum contact from being achieved

K Schlicht	II	12-4-90	Wes Money	III	12.7.90	Page 27 of 29
Operator	Level	Date	Reviewed	Level	Date	
K Schlicht	II	12-4-90	[illegible]	QC	12.17.90	
Examiner	Level	Date	Reviewed	Title	Date	

FORM 1A: 4-2-85

GE Nuclear Energy

ULTRASONIC EXAMINATION DATA SHEET (MANUAL PIPING)

SITE: BRUNSWICK UNIT: 1
PROJECT NO: ISI-90-SN735

REPORT NO. R-095
CALIBRATION SHEET NO. C-142

PROCEDURE: GE-UT-102 REV 2 FRR N/A
SYSTEM: FEEDWATER
WELD ID: 1B21N4D-S-SW1-2
START TIME 1030
FINISH TIME 1100

MATERIAL TYPE: ☐ CS ☐ SS ☑ OTHER INC.
EXAM SURFACE ☐ ID ☑ OD
EXAM SURFACE TEMP 78 °F
THERMOMETER S/N 1491
AXIAL SCAN SENSITIVITY 32 dB
CIRC SCAN SENSITIVITY 36 dB

L_o REFERENCE RULE #1 / TDC

W_o REFERENCE WELD ℄

1. WITH FLOW
2. AGAINST FLOW
3. CLOCKWISE
   a. upstream b. downstream
4. COUNTER CLOCKWISE
   a. upstream b. downstream
5. L-WAVE BASE METAL
6. OTHER N/A

PIPE IDENTITY
SAFE END IDENTITY

	PERFORMED		INDICATIONS	
	YES	NO	YES	NO
1	✓			✓
2		✓		✓
3a		✓		✓
3b		✓		✓
4a		✓		✓
4b		✓		✓
5		✓		✓
6		✓		✓

INDICATION NO.	L (in) FROM REF			W (in) FROM REF			MAX AMP % DAC	SWEEP READING			EXAM 1 - 6	NOMINAL SCANNING ANGLE
	L_1	L_{MAX}	L_2	W_1	W_{MAX}	W_2		SW_1	SW_{MAX}	SW_2		
NO RECORDABLE INDICATIONS											1	45°S

REMARKS 1) SUPPLEMENTAL EXAM PERFORMED FROM AN L OF 37" TO 39" FOR DATA ANALYSIS RELOOK
2) INDICATION IN QUESTION PEAKED AT 10% DAC AT AXIAL SCAN SENSITIVITY REFERENCE

Examiner	II Level	12-13-90 Date	Reviewed	III Level	12.14.90 Date	Page 23 of 29
N/A Examiner	N/A Level	N/A Date	Reviewed	QC Title	12-17-90 Date	

FORM 143 10-18-89

GE Nuclear Energy

PENETRANT EXAMINATION REPORT

SITE: BRUNSWICK UNIT: 1 REPORT NO. R-095

PROJECT NO: ISI-90-SW735 WELD / COMPONENT NO. 1B21N40-5-SW1-2

Procedure No. GE-PT-100 Rev. Ø FRR No. N/A

TECHNIQUE

MATERIAL	SURFACE CONDITION		ITEM		
☒ CS	☐ AS WELDED	☐ CLEANED	☒ PIPE	☐ FITTING	☒ WELD
☐ SS	☐ GROUND				☐ ROOT
☒ OTHER	☐ AS CAST	☒ OTHER	☐ PLATE	☐ OTHER	☐ PARTIAL
INCONEL		FLAPPED		N/A	☒ FINAL

PENETRANT MATERIAL	CLEANER	PENETRANT	DEVELOPER
MANUFACTURER	MAGNAFLUX	MAGNAFLUX	MAGNAFLUX
BRAND/TYPE	SKC-NF	SKL-HF/S	SKD-NF
BATCH NO.	90M07K	89K01K	89H09K

SURFACE TEMPERATURE: 80 °F THERMOMETER S/N: 2128

WIPERS: ☒ PAPER ☐ CLOTH ☐ OTHER N/A

			SURFACE TEMPERATURE		
			<60°	60 - 125°	>125°
PRE-CLEAN METHOD:	☒ SPRAY/WIPE	☐ SWAB/WIPE	DRYING TIME:	7 MIN	
PENETRANT APPLICATION:	☒ BRUSH	☐ SPRAY	DWELL TIME:	N/A 15 MIN	N/A
PENETRANT REMOVAL:	WIPE WITH DRY TOWEL WIPE WITH DAMP TOWEL		DRYING TIME:	7 MIN	
DEVELOPER APPLICATION:	SPRAY		DEVELOPING TIME:	15 MIN	
POST-CLEANING:	☒ SPRAY/WIPE	☐ SWAB/WIPE			

RESULTS

INDICATION NO.	LOCATION / DESCRIPTION	ACCEPTABLE	NOT ACCEPTABLE
NO	RECORDABLE	INDICATIONS	
N/A			

COMMENTS: N/A

Walter Clemons	II	10/12/90	Wes Morley	III	12-7-90
Examiner	Level	Date	Reviewed	Level	Date
N/A	N/A		Ty C	QC	12-17-90
Examiner	Level	Date	Reviewed	Title	Date

FORM 145 9-C-83

ENCLOSURE 4
BRUNSWICK STEAM ELECTRIC PLANT, UNIT 1
NRC DOCKET 50-325 / LICENSE NO. DPR-71
EXAMINATION / EVALUATION RESULTS FOR WELD NO. 1B21N4D-5-SW1-2
REFUELING OUTAGE 7

FLAW EVALUATION FOR WELD NO 1B21N4D-5-SW1-2
STRUCTURAL INTEGRITY REPORT NO. SIR-90-081

STRUCTURAL INTEGRITY ASSOCIATES, INC.

3150 Almaden Expressway
Suite 226
San Jose, CA 95118
(408) 978-8200
FAX: (408) 978-8964

Fossil Plant Operations
66 South Miller Road
Suite 10
Akron, Ohio 44313
(216) 864-8886
FAX: (216) 869-5461

December 28, 1990
NGC-90-037
SIR-90-081

Mr. Ashleigh M. Lucas
Carolina Power & Light Company
411 Fayetteville Street
Raleigh, NC 27602

Subject: Flaw Evaluation of UT Indication for Feedwater Nozzle Weld 1B21N4D-5-SW1-2 at Brunswick Unit 1

Dear Mr. Lucas:

This letter provides a summary of an evaluation performed by Structural Integrity Associates (SI) to assess the continued operation of the subject feedwater nozzle weld. The 0.38 inch deep by 1 inch long UT indication in this weld is assumed to be an IGSCC flaw for the purpose of this evaluation. In summary, it is found that the weld can be returned to service for at least one fuel cycle, since the indication is predicted to not exceed ASME Code and NRC NUREG-0313, Revision 2 allowable limits in that time.

BACKGROUND

During in-service inspection of the subject weld during the 1990 outage, a circumferential flaw indication measuring 0.38 inch deep and 1.0 inch long was identified by UT with the flaw tip in the Inconel 182 portion of the subject feedwater nozzle weld as shown in Figure 1. A fracture mechanics analysis has been performed tc demonstrate that the observed flaw will not grow to an unacceptable size during the next operating fuel cycle. The crack growth law employed in this analysis is based on conservative CAV crack growth data from Brunswick, Unit 1, without the effect of hydrogen water chemistry (HWC). In addition, a leak-before-break evaluation has been performed to demonstrate that in the event that the observed flaw should propagate through-wall, adequate margins exist between the predicted critical flaw and the leaking flaw sizes to provide a detectable leakage.

FLAW EVALUATION

The flaw evaluation was performed using the linear elastic fracture mechanics options of the pc-CRACK computer software [1]. There are two basic aspects to this evaluation: crack growth analysis and allowable flaw size determination.

Crack Growth Analysis Approach:

It is assumed for this analysis that any crack growth will be due to intergranular stress corrosion cracking (IGSCC). Fatigue cracking at this location is considered to be very unlikely since the weld is protected from any thermal transients by the presence of the thermal sleeve. Furthermore, bypass leakage of cold feedwater into the thermal sleeve annulus, which has been a problem in other BWR feedwater nozzles, is not a concern here since the thermal sleeve is welded to the safe-end, as shown in Figure 1. Even in cases where bypass leakage has occurred, cracking has not been found in the safe-end but only in the thicker nozzle region where high thermal stresses can exist. The important parameters to be considered in the crack growth analysis are the pertinent stresses, the fracture mechanics crack model and the crack growth law.

Stresses:

Since the flaw is in the circumferential direction, the axial stresses at the weld will control the crack growth. Torsional stresses are neglected, since they do not tend to open the crack. The stresses at the weld location are due to internal pressure; applied piping loads and weld residual stresses. The internal pressure used in this evaluation was conservatively assumed to be the design pressure of 1325 psig. The pressure stress shown in Table 1 was calculated using the relationship:

$$\sigma_a = \frac{p\ di^2}{(do^2 - di^2)} \qquad (1)$$

where
p = internal pressure
di = inside diameter of the pipe
do = outside diameter of the pipe

The geometric data for the pipe is provided in Table 1. The stresses due to piping loads were calculated using loads obtained from CPPD Calculation No. 5A-B21-516, Revision 0 [2]. A summary of these stresses is also shown in Table 1. For the IGSCC crack growth evaluation, the sustained stress combination of internal pressure, dead weight and thermal stresses is used, along with weld residual stresses. Since this weld has not been stress-improved, the residual stresses result from the butt welding during original construction. USNRC document NUREG-0313, Revision 2 [3] has provided a butt weld residual stress

distribution for 12-inch pipe and greater, which is used in this evaluation. This distribution is shown in Figure 2.

Crack Growth Model:

The outside diameter of the piping at the weld location is 13.75 inches with a thickness of 0.84 inch. This results in a thickness-to-inside radius (t/R) ratio of 0.139. A model consisting of a cylinder with t/R = 0.1 and a 360° circumferential crack was chosen from the pc-CRACK library and used in this analysis. This model is very conservative, considering the fact that the actual flaw only extends 1 inch around the circumference.

Crack Growth Law:

In this evaluation, a power function crack growth law of the form

$$da/dt = CK^n \qquad (2)$$

was used, where da/dt is the rate of crack growth (inches per hour), K is the applied stress intensity (ksi$\sqrt{in}$) and C and n are crack growth constants which are dependent on the material and the environment. In this evaluation, reactor environment CAV crack growth data for Brunswick Unit 1 is used together with industry crack growth data on Inconel 182 to determine the material constants. The material constants for sensitized Type 304 stainless steel, from NUREG-0313, Revision 2, are 3.59×10^{-8} and 2.161, respectively. It is assumed in this evaluation the shape of this power law relationship does not change for Inconel 182, i.e., the constant n remains the same value of 2.161. The value of C is determined using the CAV crack growth data for Brunswick Unit 1 without the effect of HWC. Crack growth data for measurements from a CAV specimen for Brunswick, Unit 1 are shown in Figure 3. The data represents all CAV data for Brunswick, Unit 1 for Inconel 182 for one set of measurements. A duplicate measurement, providing nearly identical results, was also obtained and supports these results. Without the effect of HWC, the crack growth rate is calculated from the CAV computer to be 2.45×10^{-5} in/hr using the conservative data for CAV crack measurement #1 for the 198 data points between 1200 and 1400 hours. The average stress intensity factor used to obtain this crack growth data is 26.15 ksi $\sqrt{in}$, again computed by the CAV computer. This crack growth rate of 2.45×10^{-5} in/hr at K = 26.15 ksi $\sqrt{in}$ is seen to be quite consistent with the data of Andresen [4] shown in Figure 4 for sensitized Inconel 600 and 182 in 200 ppb oxygen, water. Knowing the crack growth rate (da/dt),

the stress intensity factor and the material constant n, the value of the material constant C is calculated to be 2.12×10^{-8}. Hence the crack growth law used in this evaluation for Inconel 182 is given by:

$$da/dt = 2.12 \times 10^{-8} K^{2.161} \quad (3)$$

Crack Growth Results:

The IGSCC crack growth for a combination of sustained stresses (Dead weight + Pressure + Thermal) of 7.09 ksi and butt weld residual stress is shown in Figure 5. The crack size of the 0.38 inch deep initial flaw after 1 fuel cycle of operation (18 months or 13,140 hrs.) is calculated to be 0.42 inch. The detailed pc-CRACK computation output is attached as Appendix A. Again, this is considered to be a conservative prediction of crack growth since a 360° crack model was assumed, and the UT indication is actually only 1 inch long. Using the methods of NUREG-0313, Revision 2, the crack length is predicted to grow to only 1.22 inch, corresponding to growth in depth to 0.42 inch.

Allowable Flaw Size Determination:

The allowable flaw size is determined using ASME Code, Section XI IWB-3640 [5]. Specifically, Table IWB-3641-5 for circumferential flaws in shielded metal arc and submerged arc welds was used for this evaluation. The methodology of IWB-3640 has been incorporated into the pc-CRACK computer software, and therefore this software was used to perform the evaluation for the Inconel weld. Results of the evaluation are shown in Table 2. The results indicate that for this relatively short flaw, the allowable depth-to-thickness ratio is 0.60. The allowable flaw size is therefore 0.504 inch. As can be seen from Figure 5, the predicted flaw depth of 0.42 inches after 18 months of growth is significantly below the allowable size of 0.504 inch.

LEAK-BEFORE-BREAK CONSIDERATIONS

In the unlikely event that the observed flaw should propagate completely through-wall, a leak-before-break (LBB) analysis is performed to determine the margin of safety between the detectable leakage flaw size and the critical through-wall flaw. NUREG-1061 Volume 3 [6] and General Design Criterion 4, for leak-before-break analyses (GDC-4) [7] identify several criteria to be considered in determining the applicability of the leak-before-break approach to piping systems. One of the requirements is that the system should not be susceptible to IGSCC. Strict interpretation of this requirement would make this weld unqualified for a LBB analysis since the Inconel 182

material is susceptible to IGSCC. However, a LBB analysis is presented in this evaluation solely to supplement the crack growth evaluation presented above. In this case, the acceptance criterion is that the predicted critical through-wall flaw size (for normal operating plus SSE stresses) must be at least twice the length of that flaw which would result in detectable leakage.

Leak Rate Calculation:

Leak rates for circumferential through-wall flaws of varying length were computed by using the methods of References 8 and 9. This was done to identify the flaw length required to produce a detectable leak rate, and to assess the sensitivity to flaw size.

The crack opening area (COA) under the influence of steady-state operating stress (combined tension and bending) is computed from Reference 9 as shown in Table 3. Linear elastic methods are used in this case. This calculation is considered quite conservative since no correction for the crack tip plastic zone was included.

Given the preceding crack opening areas, the corresponding leakage rate is calculated using the methodology provided in Reference 3. The leakage rate is calculated by multiplying the crack opening area by a leakage rate constant. A conservative value for this constant of 125 gpm/in^2 is provided in Reference 8 for application to BWR piping.

Critical Flaw Size Calculation:

In this evaluation the critical flaw size is determined using the J-integral/Tearing Modulus (J/T) Elastic-Plastic Fracture Mechanics (EPFM) analytical techniques. A procedure for using this approach for the assessment of the stability of through-wall circumferential flaws in cylindrical geometries such as pipes is presented in References 10 and 11. This procedure was used for the determination of the critical flaw size using the pc-CRACK computer software.

The material properties used in the elastic-plastic fracture mechanics analyses are shown in Table 4. The elastic modulus (E), Code allowable stress (S_m), and lower bound yield strength ($\sigma_0 = \sigma_y$) and ultimate strength (σ_u) were taken from Section III of the ASME Boiler & Pressure Vessel Code for the temperatures of interest [5]. The flow stress is computed as an average of σ_y and σ_u, although this does not influence the stability analysis results. Ramberg-Osgood true stress-strain constants α and n for stainless steel were assumed for Inconel 182 since the shape of the stress-strain curve is expected to be similar to that of

Inconel 182. The stress-strain curve incorporating the $\sigma_0 = \sigma_y$ values in Table 4 is shown in Figure 6.

The EPFM J-Resistance (J-k) curve of J vs. crack extension is shown in Figure 7 for stainless steel flux welds. The power law constants, C and N, representing this curve are given in Table 4. This curve for stainless steel is from Reference 12 and represents a lower bound for low toughness submerged arc welds (SAWs). It is assumed that it is also applicable to Inconel 182 shielded metal arc welds (SMAWs), as a conservative lower bound.

Leak-Before-Break Results:

The detailed critical flaw size computation output, from pc-CRACK, is given in Appendix B. Using the conservative flux weld material J-Resistance curve described above, critical through-wall circumferential crack lengths were computed for both pure remote tension and pure bending loading of pipes. In both the tension and bending loading, the applied stress of 9.607 ksi was used, and the critical crack length results were linearly interpolated to estimate the combined tension-bending case. The 9.607 ksi total stress is comprised of 4.45 ksi pure tension (due to the design pressure of 1325 psi) and 5.157 ksi bending (due to 0.143 ksi dead-weight, 2.498 ksi thermal, and 2.516 ksi DBE or SSE stresses). The interpolated critical crack length is 14.11 inch, or approximately 35% of the pipe circumference.

Table 3 presents leak rate calculations for through-wall circumferential cracks of varying lengths. As described above, the crack opening area was conservatively calculated using linear elastic methods and taking no credit for the crack tip plasticity. Combined tension and bending loading is considered, with the pressure stress computed from the operating pressure of 1000 psi, and the previously discussed bending stresses due to dead-weight and thermal loads. The crack opening area (COA) in Table 3 is multiplied by 125 gpm/in^2 to calculate a conservative leak rate of 23.56 gpm for the crack length of 14.2 inches (approximately the critical length), and 3.22 gpm for a crack half that length. Thus, adequate leakage for detection is indicated, and leak-before-break is predicted. A further salient conclusion is that the predicted critical through-wall crack length of 14.2 inches is well in excess of the 1 inch length of the indication.

SUMMARY AND CONCLUSIONS

A flaw evaluation has been performed for the UT indication (0.38 inch deep by 1 inch long, circumferential) in feedwater nozzle weld 1B21N4D-5-SW1-2 of Brunswick Unit 1 to demonstrate that this

weld can be returned to service as-is for at least one operating cycle. The evaluation was performed using an Inconel 182 crack growth law derived from reactor coolant CAV crack growth data for Brunswick Unit 1, not taking credit for hydrogen water chemistry. A conservative crack model consisting of a 360° circumferential flaw was used for the analysis. The analysis showed that the initial flaw of 0.38 inch depth is predicted to grow to 0.42 inch after 18 months of operation. The allowable flaw size was determined per the requirements of ASME Code, Section XI IWB-3640 to be 0.504 inch deep. Thus, the flaw indication is acceptable as-is for at least one more 18-month operating cycle.

To supplement the crack growth analysis, a leak-before-break analysis was also performed to demonstrate that in the unlikely event that the existing flaw should propagate through-wall, adequate margins exist between the leakage flaw size (with leakage conservatively computed) and the critical flaw size. Furthermore, the current indication length of 1 inch is well below the predicted critical through-wall crack length of 14.2 inches, based on elastic-plastic lower bound material toughness.

Prepared by: _____ Date: 12/28/1990
N. G. Cofie

Reviewed by: J. F. Copeland Date: 12/28/90
J. F. Copeland

Approved by: A. J. Giannuzzi Date: 12/28/90
A. J. Giannuzzi

/sa
Attachments

cc: R. Johnson (BSEP) R. Hanford (Raleigh)
T. Gillman (BSEP) J. M. Brown (Raleigh)

STRUCTURAL INTEGRITY ASSOCIATES, INC.

REFERENCES

1. Structural Integrity Associates, "pc-CRACK User's Manual, Version 2.0.

2. CP&L Calculation No. SA-B21-516, Rev. 0, "Feedwater Loop B Inside Drywell".

3. NUREG-0313, Rev. 2, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping, January 1988.

4. Andresen P. L. "Effect of Dissolved Oxygen, Solution Conductivity and Stress Intensity on the Interdendritic Stress Corrosion Cracking of Inconel 182 Weld Metal", Corrosion 87, Paper No. 84, San Francisco, California, March 9-13, 1987.

5. ASME Boiler & Pressure Vessel Code, Section XI, 1986 Edition.

6. NUREG 1061, Volumes 1-5, "Report of the U. S. Nuclear Regulatory Commission Piping Review Committee", prepared by the Piping Review Committee, NRC, April 1985.

7. Stello, Jr., V., "Final Broad Scope Rule to Modify General Design Criterion 4 of Appendix A, 10 CFR Part 50", NRC SECY-87-213, Rulemaking Issue (Affirmation), Aug. 21, 1987.

8. Klecker, R., Brust, F., and Wilkowski, G., "NRC Leak-Before-Break (LBB.NRC) Analysis Method for Circumferentially Through-Wall Cracked Pipes Under Axial Plus Bending Loads", NUREG/CR-4572, BMI-2134, May 1986.

9. Paris, P.C., and Tada, H., "The Application of Fracture Proof Design Methods Using Tearing Instability Theory to Nuclear Piping Postulating Circumferential Through-Wall Cracks", NUREG/CR-3464, September 1983.

10. Kumar, V., et. al., "Advances in Elastic-Plastic Fracture Analysis," EPRI NP-3607, August, 1984.

11. Kumar, V., et. al., "An Engineering Approach for Elastic-Plastic Fracture Analysis," EPRI NP-1931, July, 1981.

REFERENCES (concluded)

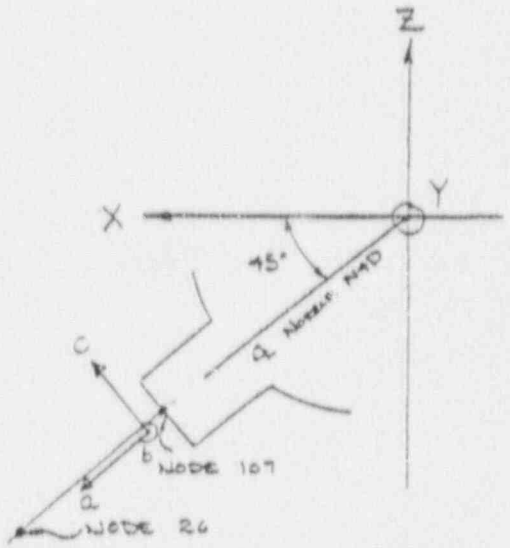
12. "Evaluation and Discussion of EPRI's High Energy Pipe Rupture Experiments", EPRI Report No. NP-5531, by Structural Integrity Associates and S. Levy, Inc., SI Report No. SIR-86-034, September 1987.

Table 1

CPL-164
BRUNSWICK-1
FEEDWATER SYSTEM - RV NOZZLE N4D
STRESSES (LOADS & MOMENTS FROM CALC. NO. SA-B21-516, REV.0)

WELD NO. 1B21N4D-S-SW1-2
NODE NO. 107

OD (IN):	13.75
T (IN):	0.84
ID (IN):	12.07
P (PSI):	1335
T (F):	562
A (IN^2):	34.069
Z (IN^3):	103.676



STRESS TYPE	Fx (LB)	Fy (LB)	Fz (LB)	Mx (FT-LB)	My (FT-LB)	Mz (FT-LB)	Fa (AXIAL) (LB)	Mb (IN-LB)	Mc (IN-LB)	TOTAL MOMENT (IN-LB)	AXIAL STRESS (PSI)
P											4450
DW	32	-629	-20	-963	-254	-728	37	-3048	-14349	14669	143
OBE	1202	6233	671	12993	3370	11630	375	40440	208085	211878	2056
DBE	1559	7483	1068	15693	4882	14137	347	58584	253116	259807	2516
THERMAL1	-1621	2763	-27	10518	4906	-15117	-1127	58872	-29024	70631	648
THERMAL2	2009	-6921	-3	-25431	-8049	-2332	1423	-96588	-235577	254609	2498

Pa, P (PSI)	Pb, DW+OBE (PSI)	Pb, DW+DBE (PSI)	Thermal (PSI)	Sustained P+DW+Th (PSI)
4450	2198	2659	2498	7097

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Table 2

to

pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.
SAN JOSE, CA (408)978-8200
VERSION 2.0

Date: 21-Dec-1990
Time: 7:11:26.33

ALLOWABLE FLAW SIZE EVALUATIONS
USING ASME SECTION XI, IWB-3640/50 PROCEDURES AND CRITERIA
FOR CIRCUMFERENTIAL CRACKS IN STAINLESS STEEL PIPING

MATERIAL IS SPECIFIED AS SHIELDED METAL ARC WELD
DEFAULT PROPERTIES:
  DESIGN STRESS = 16.95
  FLOW STRESS = 50.85

BRUNSWICK UNIT 1 FW NOZZLE WELD 1821N4D-5-SW1-2

USER SUPPLIED MATERIAL PROPERTIES:
  DESIGN STRESS = 23.30
  FLOW STRESS = 69.90

PIPE GEOMETRY:
  OUTER DIAMETER = 13.7500
  WALL THICKNESS = 0.8400
CRACK GEOMETRY:
  CRACK DEPTH = 0.3800
  CRACK LENGTH = 1.0000

THE FLAWED PIPE IS ASSUMED TO FAIL DUE TO UNSTABLE DUCTILE TEARING (EPFM)

THE ALLOWABLE FLAW SIZE IS DETERMINED USING CODE TABLES
AND DEFAULT SAFETY FACTORS FOR NORMAL OPERATING (INCL. UPSET & TEST) CONDITIONS

MEMBRANE STRESS (Pm)	=	4.4500	(SAFETY FACTOR = 2.770)
BENDING STRESS (Pb)	=	2.1980	(SAFETY FACTOR = 2.770)
EXPANSION STRESS (Pe)	=	2.4980	(SAFETY FACTOR = 1.000)
DESIGN STRESS	=	23.3000	
(Pm + Pb)/Sm	=	0.2853	
STRESS RATIO	=	0.3240	(DOES NOT INCLUDE S.F.)
M FACTOR	=	1.0000	
a/t	=	0.4524	
l/circumference	=	0.0231	
ALLOWABLE a/t	=	0.6000	

	l/circumference					
	0.00	0.10	0.20	0.30	0.40	0.50
ALLOWABLE a/t	0.6000	0.6000	0.6000	0.6000	0.6000	0.4900

STRUCTURAL INTEGRITY ASSOCIATES, INC.

Table 3

BRUNSWICK UNIT 1 FW NOZZLE WELD 1B21N4D-5-SW1-2
Leak Rate in Pipes, Circ, Thru-wall Cracks
(Water Leak)

OD	13.75	13.75	13.75	13.75	13.75	13.75
OR	6.875	6.875	6.875	6.875	6.875	6.875
Thk	0.84	0.84	0.84	0.84	0.84	0.84
IR	6.035	6.035	6.035	6.035	6.035	6.035
R, Nom.	6.455	6.455	6.455	6.455	6.455	6.455
%Circ(2a)	9	12.5	17.5	18	25	35
2a (in)	3.650216	5.069745	7.097643	7.300433	10.13949	14.19528
a (in)	1.825108	2.534872	3.548821	3.650216	5.069745	7.097643
a (rad)	0.282743	0.392699	0.549778	0.565486	0.785398	1.099557
I(theta)	0.194696	0.417685	0.961851	1.034626	2.542278	7.365272
Pressure	1000	1000	1000	1000	1000	1000
Tens Str	3359	3359	3359	3359	3359	3359
DW Str	143	143	143	143	143	143
TH Str	2498	2498	2498	2498	2498	2498
Bndg Str	2641	2641	2641	2641	2641	2641
E (psi)	28850000	28850000	28850000	28850000	28850000	28850000
COA (in^2)	0.005276	0.011274	0.025758	0.027681	0.066974	0.188447
GPM	0.66	1.41	3.22	3.46	8.37	23.56

Table 4

Material Constants Used for Inconel 182
in LBB Evaluation

E (ksi)	28,850
S_m (ksi)	16.994
σ_o (ksi) ($= \sigma_y$)	28.35
α	11.56
n	2.88
C	2.673
N	0.3162
J_{IC}	0.300
J_{max}	5
σ_u (ksi)	80.0
σ_{flow} (ksi)	54.175

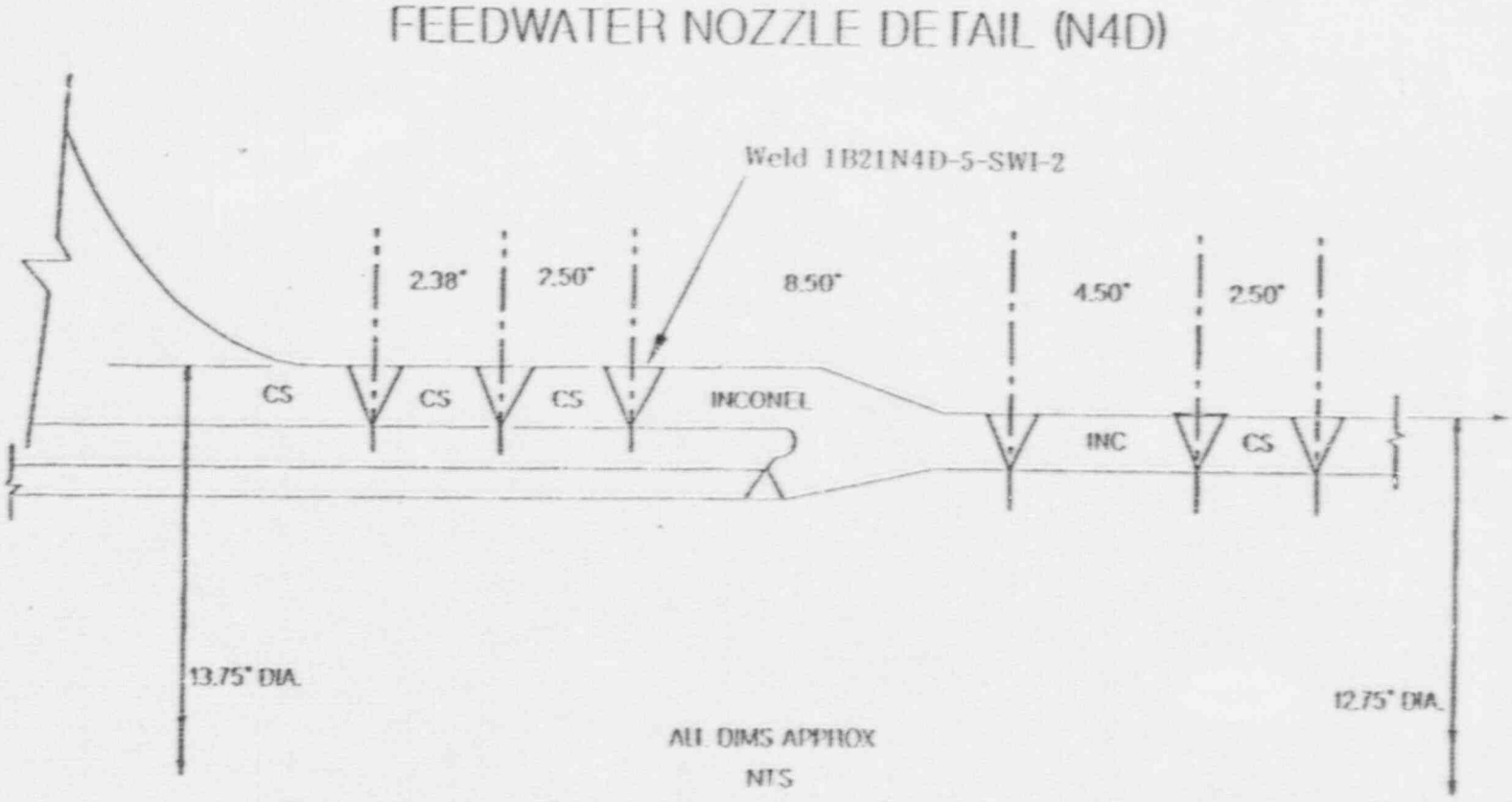

Figure 1. BSEP-1 Feedwater Nozzle Detail (N4D)

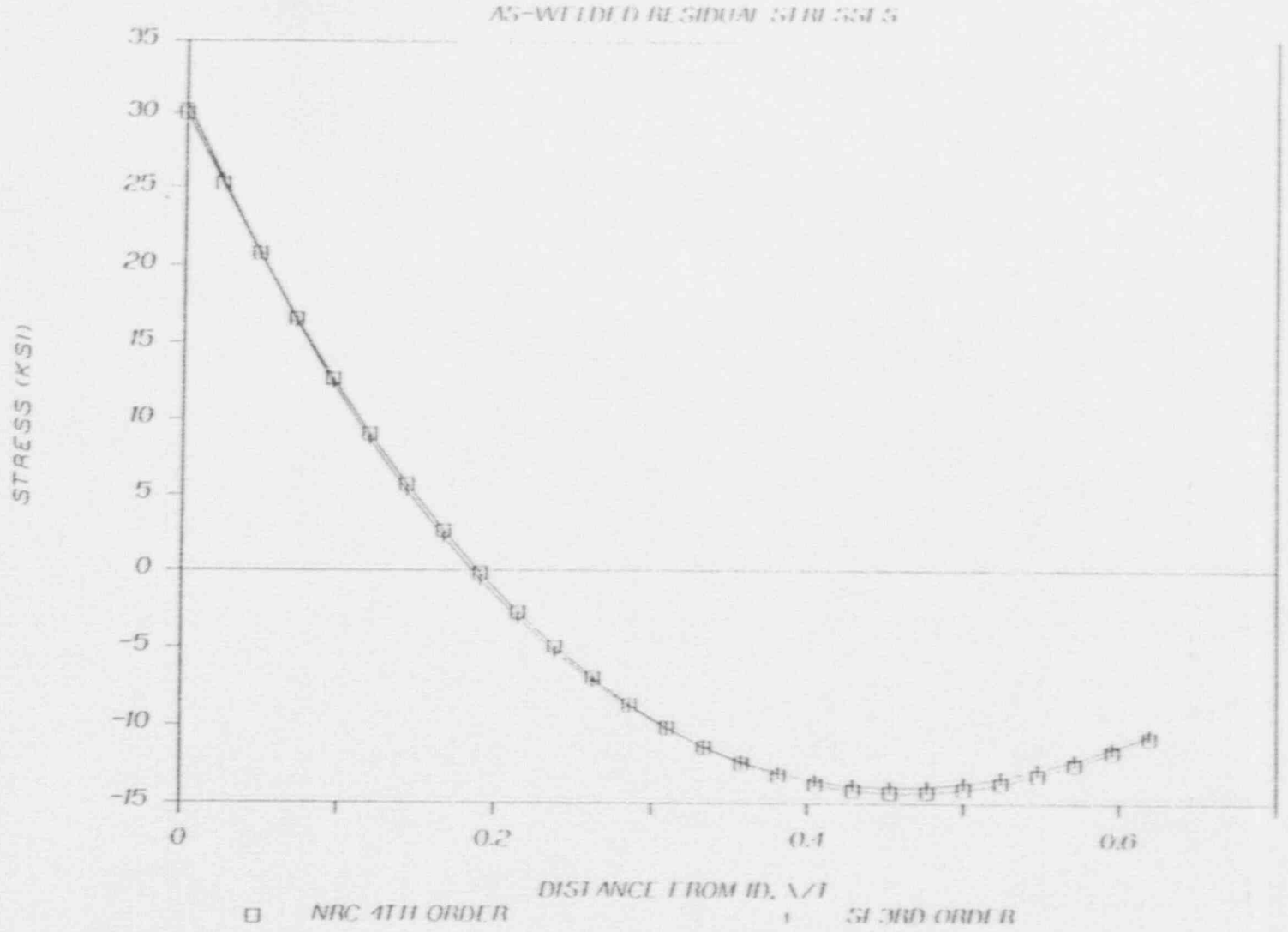

Figure 2. Through-wall Distribution of Axial Residual Stress Versus Wall Fraction for Pipe of 12-inch Size and Greater, Comparing NRC 4th Order Equation [3] with SI 3rd Order Equation

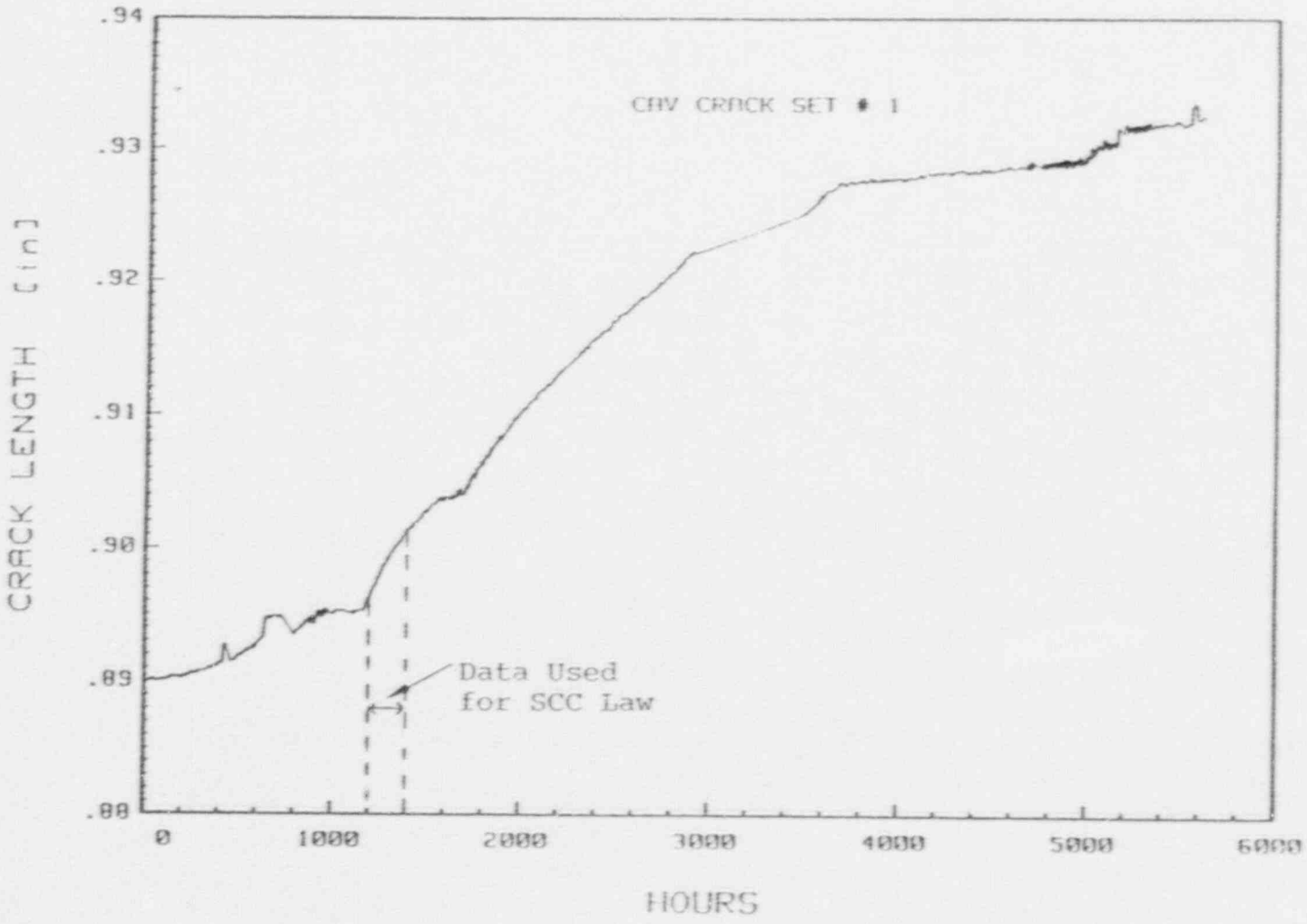

Figure 3. BSEP-1 CAV Data for Inconel 182, Showing Data Without Hydrogen Water Chemistry, Which Was Used for the SCC Growth Law Derivation.

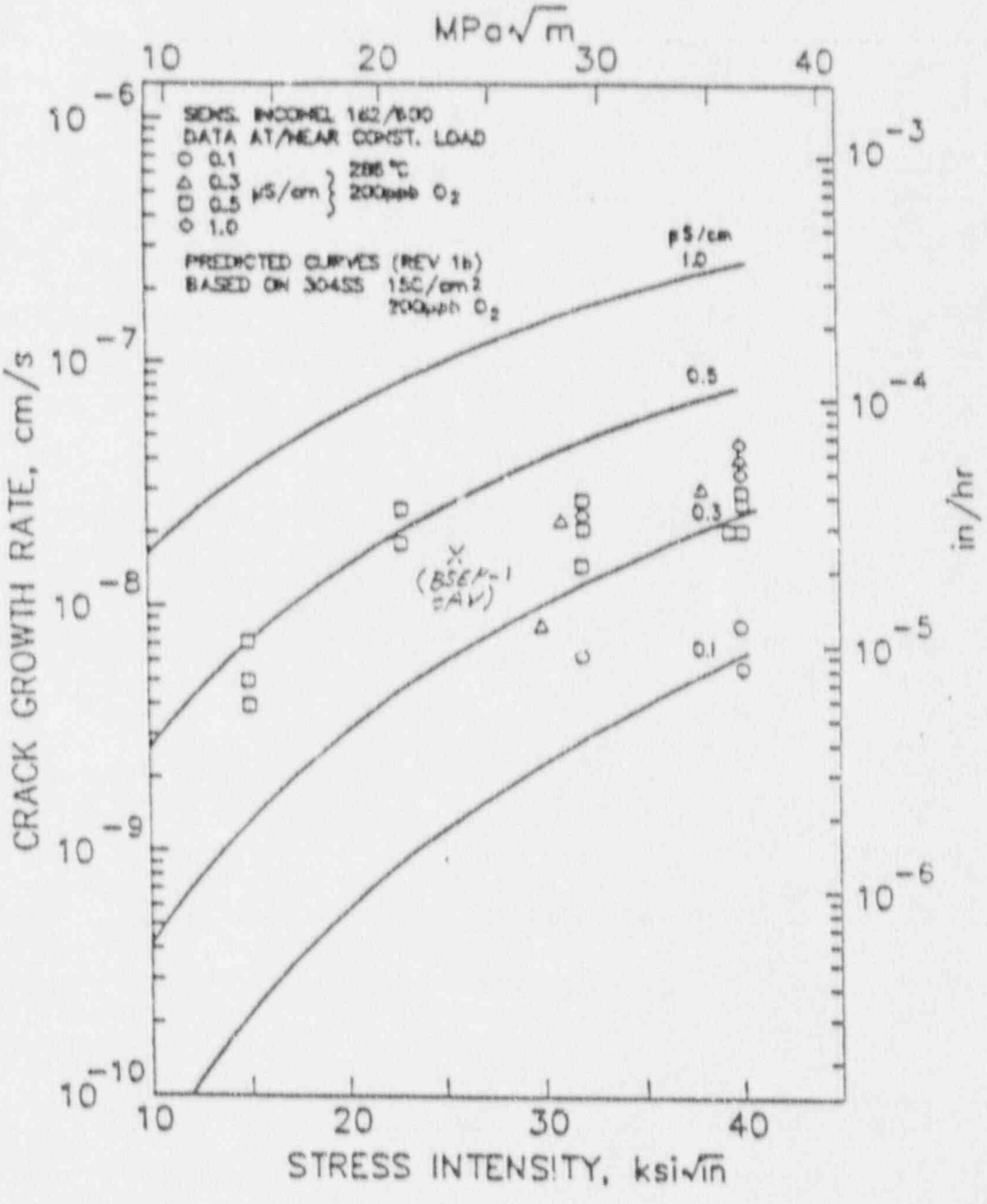

Figure 4. Comparison of the Predicted and Observed Crack Growth Rates Versus Stress Intensity for Available Data on Inconel 600 and 182 Tested at or Near Constant Load in 200 ppb Oxygen, 288°C Water [4].

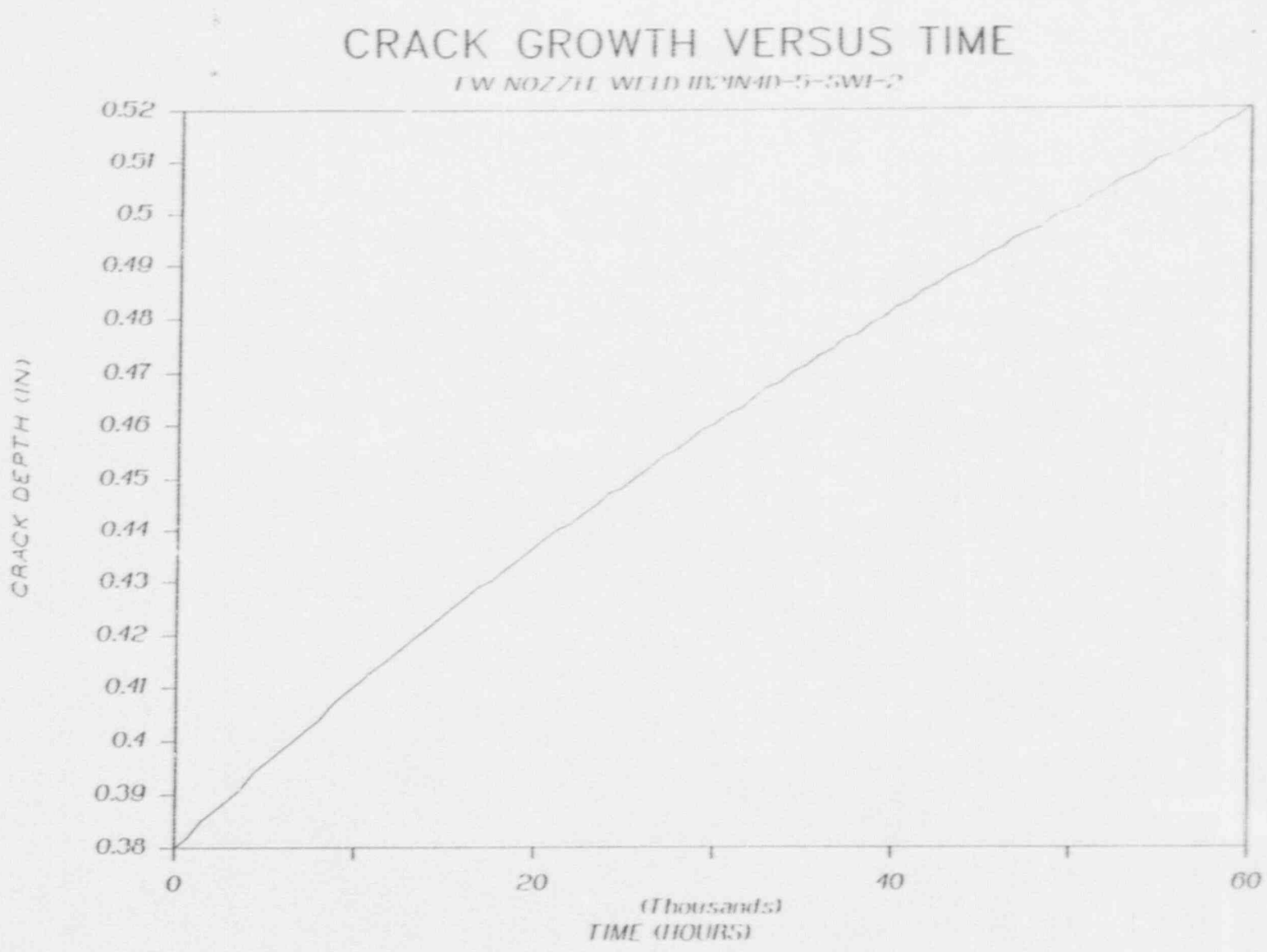

Figure 5. Predicted Stress Corrosion Crack Growth, Without Hydrogen Water Chemistry

STRUCTURAL INTEGRITY ASSOCIATES, INC.

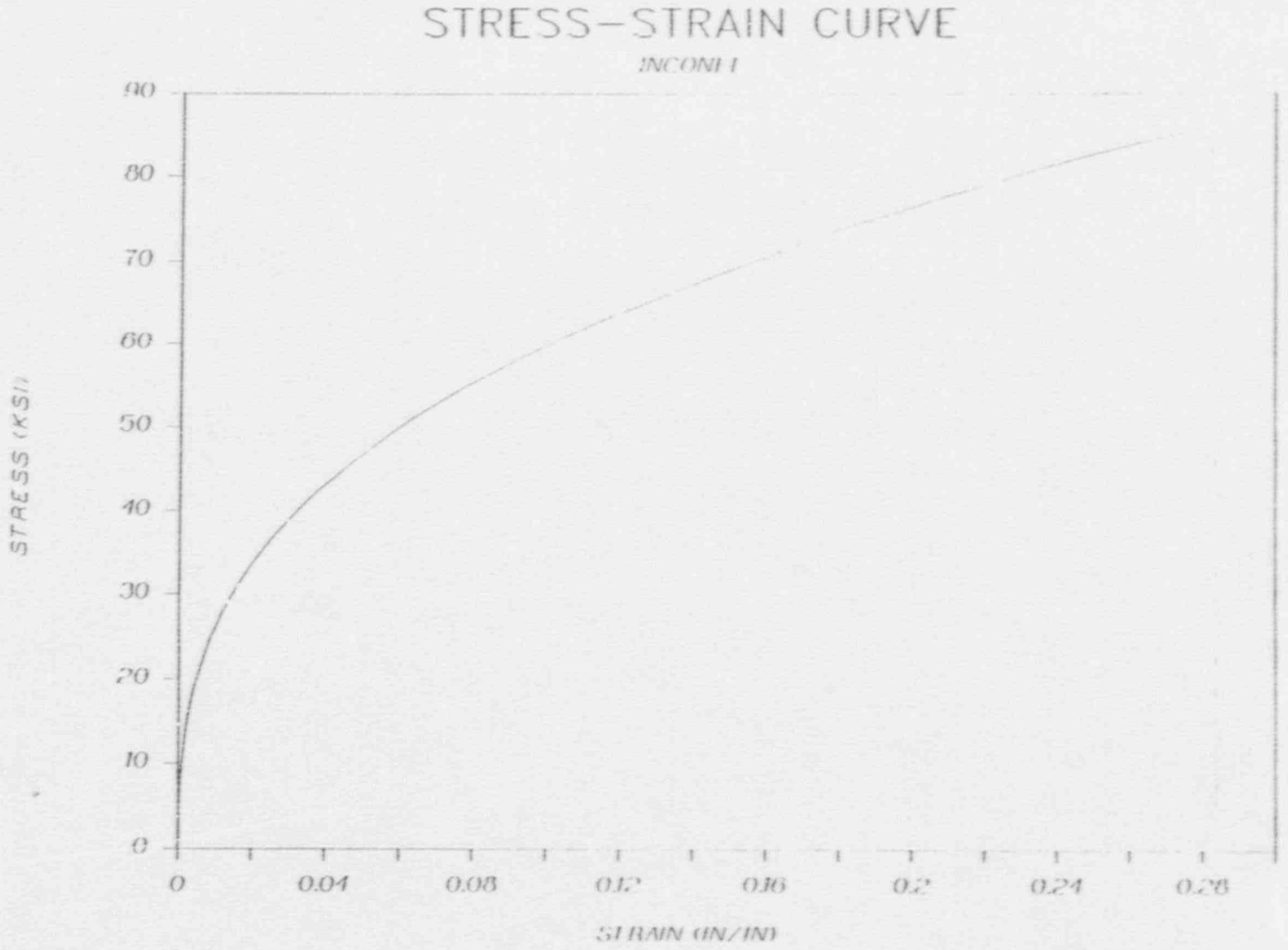

Figure 6. Ramberg-Osgood True Stress - True Strain Curve for Inconel

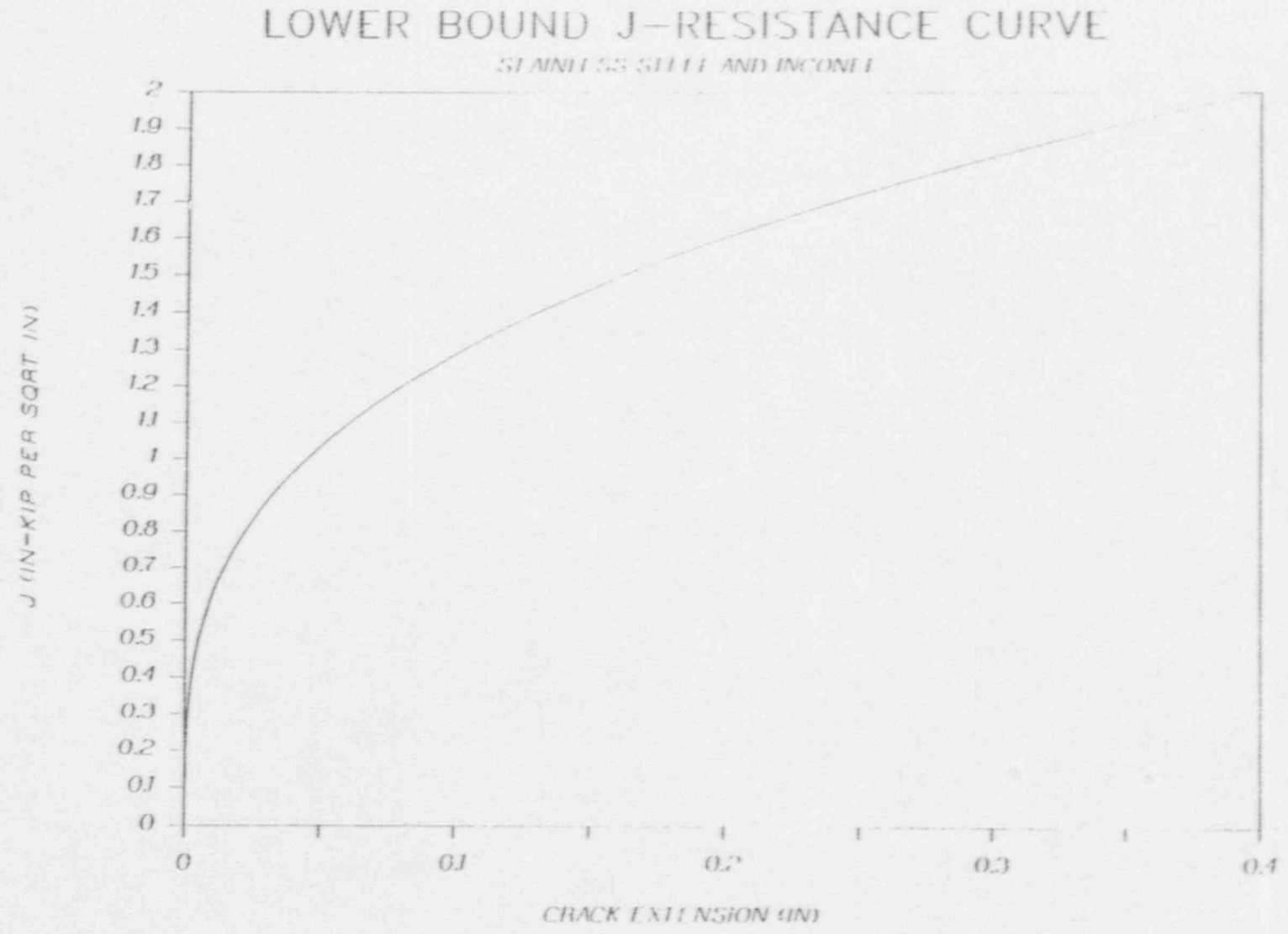

Figure 7. Lower Bound J-Resistance Curve for Austenitic Stainless Steel and Inconel Flux Welds

Appendix A

Stress Corrosion Crack Growth Analysis

tm

pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.

SAN JOSE, CA (408)978-8200

VERSION 2.0

Date: 21-Dec-1990
Time: 10:34:43.79

STRESS CORROSION CRACK GROWTH ANALYSIS

BRUNSWICK UNIT 1 FW NOZZLE WELD 1B21N4D-5-SW1-2

INITIAL CRACK SIZE= 0.3800
WALL THICKNESS= 0.8400
MAX CRACK SIZE FOR SCCG= 0.6720

STRESS CORROSION CRACK GROWTH LAW

LAW ID	C	N	Kthres	K1C
INCONEL	2.120E-08	2.1610	1.0000	1000.0000

STRESS COEFFICIENTS

CASE ID	C0	C1	C2	C3
RESIDUAL	30.6313	-266.0472	478.4576	-229.4907
MEMBRN	1.0000	0.0000	0.0000	0.0000
RESIDUALB	1.0000	-2.3810	0.0000	0.0000

CASE ID	Kmax SCALE FACTOR
RESIDUAL	1.00
MEMBRN	7.09

TIME	TIME INCREMENT	PRINT INCREMENT
60000.0	73.0	730.0

crack model:CIRCUMFERENTIAL CRACK IN CYLINDER(T/R=0.1)

CRACK SIZE	STRESS INTENSITY FACTOR CASE RESIDUAL	CASE MEMBRN	CASE RESIDUALB
0.0134	6.513	0.228	0.224
0.0269	8.614	0.324	0.312
0.0403	9.841	0.398	0.376
0.0538	10.572	0.462	0.427
0.0672	10.964	0.519	0.470
0.0806	11.105	0.571	0.507
0.0941	11.114	0.623	0.541
0.1075	10.986	0.673	0.573
0.1210	10.723	0.723	0.601

0.1344	10.347	0.770	0.627
0.1478	9.873	0.817	0.650
0.1613	9.313	0.863	0.671
0.1747	8.713	0.910	0.691
0.1882	8.079	0.960	0.712
0.2016	7.384	1.010	0.730
0.2150	6.634	1.059	0.747
0.2285	5.837	1.109	0.762
0.2419	4.997	1.158	0.776
0.2554	4.175	1.211	0.790
0.2688	3.488	1.271	0.809
0.2822	2.781	1.332	0.828
0.2957	2.056	1.394	0.844
0.3091	1.318	1.457	0.860
0.3226	0.572	1.520	0.874
0.3360	-0.179	1.584	0.886
0.3494	-0.929	1.652	0.900
0.3629	-1.683	1.721	0.912
0.3763	-2.440	1.790	0.923
0.3898	-3.196	1.861	0.933
0.4032	-3.949	1.932	0.940
0.4166	-4.696	2.004	0.947
0.4301	-5.512	2.081	0.953
0.4435	-6.355	2.161	0.958
0.4570	-7.198	2.241	0.961
0.4704	-8.039	2.322	0.963
0.4838	-8.875	2.405	0.962
0.4973	-9.703	2.488	0.960
0.5107	-10.282	2.575	0.959
0.5242	-10.586	2.666	0.961
0.5376	-10.843	2.759	0.961
0.5510	-11.053	2.852	0.959
0.5645	-11.211	2.947	0.955
0.5779	-11.317	3.042	0.950
0.5914	-11.572	3.141	0.940
0.6048	-12.398	3.248	0.921
0.6182	-13.197	3.356	0.898
0.6317	-13.966	3.465	0.873
0.6451	-14.701	3.575	0.844
0.6586	-15.399	3.686	0.812
0.6720	-16.058	3.799	0.777

TIME	KMAX	DA/DT	DA	A	A/THK
730.0	10.14	3.168E-06	0.0002	0.3823	0.455
1460.0	10.10	3.138E-06	0.0002	0.3846	0.458
2190.0	10.06	3.109E-06	0.0002	0.3869	0.461
2920.0	10.01	3.080E-06	0.0002	0.3892	0.463
3650.0	9.97	3.052E-06	0.0002	0.3914	0.466
4380.0	9.93	3.025E-06	0.0002	0.3936	0.469

5110.0	9.89	2.999E-06	0.0002	0.3958	0.471
5840.0	9.85	2.972E-06	0.0002	0.3980	0.474
6570.0	9.81	2.946E-06	0.0002	0.4001	0.476
7300.0	9.77	2.921E-06	0.0002	0.4023	0.479
8030.0	9.73	2.896E-06	0.0002	0.4044	0.481
8760.0	9.69	2.872E-06	0.0002	0.4065	0.484
9490.0	9.66	2.849E-06	0.0002	0.4086	0.486
10220.0	9.62	2.826E-06	0.0002	0.4107	0.489
10950.0	9.59	2.803E-06	0.0002	0.4127	0.491
11680.0	9.55	2.780E-06	0.0002	0.4148	0.494
12410.0	9.51	2.758E-06	0.0002	0.4168	0.496
13140.0	9.47	2.733E-06	0.0002	0.4188	0.499
13870.0	9.43	2.708E-06	0.0002	0.4208	0.501
14600.0	9.39	2.684E-06	0.0002	0.4227	0.503
15330.0	9.36	2.659E-06	0.0002	0.4247	0.506
16060.0	9.32	2.636E-06	0.0002	0.4266	0.508
16790.0	9.28	2.612E-06	0.0002	0.4285	0.510
17520.0	9.24	2.589E-06	0.0002	0.4304	0.512
18250.0	9.20	2.565E-06	0.0002	0.4323	0.515
18980.0	9.16	2.542E-06	0.0002	0.4342	0.517
19710.0	9.12	2.519E-06	0.0002	0.4360	0.519
20440.0	9.09	2.496E-06	0.0002	0.4379	0.521
21170.0	9.05	2.474E-06	0.0002	0.4397	0.523
21900.0	9.01	2.452E-06	0.0002	0.4415	0.526
22630.0	8.97	2.430E-06	0.0002	0.4432	0.528
23360.0	8.94	2.409E-06	0.0002	0.4450	0.530
24090.0	8.90	2.388E 06	0.0002	0.4468	0.532
24820.0	8.87	2.368E-06	0.0002	0.4485	0.534
25550.0	8.83	2.348E-06	0.0002	0.4502	0.536
26280.0	8.80	2.328E-06	0.0002	0.4519	0.538
27010.0	8.76	2.308E-06	0.0002	0.4536	0.540
27740.0	8.73	2.289E-06	0.0002	0.4553	0.542
28470.0	8.69	2.270E-06	0.0002	0.4570	0.544
29200.0	8.66	2.252E-06	0.0002	0.4586	0.546
29930.0	8.63	2.234E-06	0.0002	0.4602	0.548
30660.0	8.60	2.216E-06	0.0002	0.4619	0.550
31390.0	8.57	2.198E-06	0.0002	0.4635	0.552
32120.0	8.53	2.181E-06	0.0002	0.4651	0.554
32850.0	8.50	2.164E-06	0.0002	0.4667	0.556
33580.0	8.47	2.147E-06	0.0002	0.4682	0.557
34310.0	8.44	2.130E-06	0.0002	0.4698	0.559
35040.0	8.41	2.114E-06	0.0002	0.4713	0.561
35770.0	8.38	2.098E-06	0.0002	0.4729	0.563
36500.0	8.35	2.083E-06	0.0002	0.4744	0.565
37230.0	8.33	2.067E-06	0.0002	0.4759	0.567
37960.0	8.30	2.052E-06	0.0001	0.4774	0.568
38690.0	8.27	2.037E-06	0.0001	0.4789	0.570
39420.0	8.24	2.022E-06	0.0001	0.4804	0.572
40150.0	8.21	2.008E-06	0.0001	0.4819	0.574
40880.0	8.19	1.993E-06	0.0001	0.4833	0.575
41610.0	8.16	1.979E-06	0.0001	0.4848	0.577
42340.0	8.13	1.966E-06	0.0001	0.4862	0.579
43070.0	8.11	1.953E-06	0.0001	0.4876	0.581
43800.0	8.08	1.940E-06	0.0001	0.4891	0.582

44530.0	8.06	1.927E-06	0.0001	0.4905	0.584
45260.0	8.03	1.914E-06	0.0001	0.4919	0.586
45990.0	8.01	1.901E-06	0.0001	0.4933	0.587
46720.0	7.98	1.888E-06	0.0001	0.4946	0.589
47450.0	7.96	1.876E-06	0.0001	0.4960	0.591
48180.0	7.94	1.864E-06	0.0001	0.4974	0.592
48910.0	7.94	1.865E-06	0.0001	0.4987	0.594
49640.0	7.94	1.867E-06	0.0001	0.5001	0.595
50370.0	7.95	1.869E-06	0.0001	0.5015	0.597
51100.0	7.95	1.871E-06	0.0001	0.5028	0.599
51830.0	7.96	1.873E-06	0.0001	0.5042	0.600
52560.0	7.96	1.875E-06	0.0001	0.5056	0.602
53290.0	7.96	1.877E-06	0.0001	0.5069	0.604
54020.0	7.97	1.879E-06	0.0001	0.5083	0.605
54750.0	7.97	1.882E-06	0.0001	0.5097	0.607
55480.0	7.98	1.886E-06	0.0001	0.5111	0.608
56210.0	8.02	1.904E-06	0.0001	0.5124	0.610
56940.0	8.05	1.923E-06	0.0001	0.5138	0.612
57670.0	8.09	1.941E-06	0.0001	0.5153	0.613
58400.0	8.12	1.960E-06	0.0001	0.5167	0.615
59130.0	8.16	1.980E-06	0.0001	0.5181	0.617
59860.0	8.20	1.999E-06	0.0001	0.5196	0.619
60000.0	8.21	2.003E-06	0.0001	0.5199	0.619

END OF pc-CRACK

Appendix B

Determination of Critical Through-Wall Flaw Size for Leak-Before-Break Evaluation

tm

pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.

SAN JOSE, CA (408)978-8200

VERSION 2.0

Date: 21-Dec-1990
Time: 7:54: 2. 1

INSTABILITY EVALUATION

BRUNSWICK UNIT 1 FW NOZZLE WELD 1B21N4D-5-SW1-2

crack model:THROUGH WALL CRACK IN CYLINDER UNDER REMOTE TENSION

MATERIAL PROPERTIES:-
FLOW STRESS(SIGMAf)= 54.1750
YIELD STRESS(SIGMAo)= 28.3500
YIELD STRAIN(EPSILONo)= 9.827E-04
YOUNG MODULUS= 2.885E+04
POISSON RATIO= 0.3000

RAMBERG-OSGOOD STRESS-STRAIN LAW:-
ALPHApl= 11.5600
Npl= 2.8800

GEOMETRIC PROPERTIES:-
OUTSIDE DIAMETER= 13.7500
WALL THICKNESS (t)= 0.8400

OTHER CONDITIONS:-
PLANE STRAIN <1> OR
PLANE STRESS <2>= 2
dA= 2.028E-01

LOADING CONDITIONS:-
LOAD= 327.2979
STRESS= 9.6070

HALF CRACK LENGTH(a)= 1.0000
(2a/circumference)= 0.0493

a/t(a/b)	F	H
0.0000	1.0000	5.7306
0.0625	1.0640	4.3876
0.1250	1.2206	4.2469
0.2500	1.7117	3.5995
0.3750	2.8526	2.5974
0.5000	3.9936	1.5953

MATERIAL J-R CURVE:INCONEL
J= 2.6730 * (da)^ 0.3162
Jic= 0.3000
Jmax= 5.0000

INCREMENTATION:-
CRACK INCREMENT= 0.2028
NUMBER OF INCREMENTS= 100

INCREMENT CRACK SIZE

STRESS= 9.6070

CRACK SIZE	Jappl	Tappl	Tmat	dA
1.0000	0.0433	0.5025	61806.2832	0.0000
1.2028	0.0537	0.6153	38865.9221	0.0000
1.4056	0.0664	0.7218	24560.7813	0.0000
1.6084	0.0813	0.8126	15855.6173	0.0000
1.8112	0.0980	0.9154	10569.9355	0.0000
2.0139	0.1169	1.0322	7221.5296	0.0000
2.2167	0.1382	1.1652	5029.1467	0.0000
2.4195	0.1623	1.3385	3555.5334	0.0000
2.6223	0.1899	1.4918	2531.0316	0.0000
2.8251	0.2206	1.6828	1829.0175	0.0000
3.0279	0.2554	1.8999	1333.4600	0.0000
3.2307	0.2946	2.1473	979.2015	0.0000
3.4335	0.3389	2.4297	723.2572	0.0015
3.6363	0.3890	2.7533	536.6920	0.0023
3.8391	0.4458	3.1248	399.6843	0.0035
4.0418	0.5102	3.5526	298.4474	0.0053
4.2446	0.5835	4.0467	223.2630	0.0081
4.4474	0.6670	4.6190	167.1998	0.0124
4.6502	0.7623	5.4011	125.2629	0.0189
4.8530	0.8737	6.6020	93.2597	0.0291
5.0558	1.0099	7.3652	68.1773	0.0460
5.2586	1.1619	8.4181	50.3513	0.0717
5.4614	1.3355	9.6474	37.2547	0.1114
5.6642	1.5346	11.0663	27.5878	0.1729
5.8670	1.7629	12.7076	20.4390	0.2681
6.0697	2.0250	14.6112	15.1443	0.4156
6.2725	2.3264	16.8251	11.2182	0.6446

BY INTERPOLATION

Jcrit= 2.0512
Tcrit= 14.8034
Acrit= 6.0874
Acrit - dA= 5.6545
w= 11.8424

MATERIAL J-R CURVE: INCONEL

da	Jmat	Tmat
0.0020	0.3746	582.1897

0.0028	0.4172	461.1879
0.0040	0.4647	365.3351
0.0056	0.5176	289.4042
0.0078	0.5764	229.2547
0.0110	0.6420	181.6066
0.0154	0.7150	143.8617
0.0217	0.7964	113.9616
0.0305	0.8870	90.2759
0.0429	0.9879	71.5131
0.0604	1.1002	56.6499
0.0849	1.2254	44.8758
0.1193	1.3648	35.5489
0.1678	1.5201	28.1604
0.2359	1.6930	22.3076
0.3317	1.8856	17.6712
0.4663	2.1000	13.9984
0.6556	2.3389	11.0890
0.9218	2.6050	8.7843
1.2960	2.9013	6.9586
1.8221	3.2314	5.5123
2.5618	3.5990	4.3666
3.6018	4.0084	3.4591
5.0640	4.4644	2.7401
7.1199	4.9722	2.1706

END OF pc-CRACK

tm

pc-CRACK

STRUCTURAL INTEGRITY ASSOCIATES, INC.

SAN JOSE, CA (408)978-8200

VERSION 2.0

Date: 21-Dec-1990
Time: 8:48:24.42

INSTABILITY EVALUATION

BRUNSWICK UNIT 1 FW NOZZLE WELD 1B21N4D-5-SW1-2

crack model:THROUGH WALL CRACK IN CYLINDER UNDER REMOTE BENDING

MATERIAL PROPERTIES:-
FLOW STRESS(SIGMAf)= 54.1750
YIELD STRESS(SIGMAo)= 28.3500
YIELD STRAIN(EPSILONo)= 9.827E-04
YOUNG MODULUS= 2.885E+04
POISSON RATIO= 0.3000

RAMBERG-OSGOOD STRESS-STRAIN LAW:-
ALPHApl= 11.5600
Npl= 2.8800

GEOMETRIC PROPERTIES:-
OUTSIDE DIAMETER= 13.7500
WALL THICKNESS (t)= 0.8400

OTHER CONDITIONS:-
PLANE STRAIN <1> OR
PLANE STRESS <2>= 2
dA= 2.028E-01

LOADING CONDITIONS:-
LOAD= 1060.8260
STRESS= 9.6070

HALF CRACK LENGTH(a)= 1.0000
(2a/circumference)= 0.0493

a/t(a/b)	F	H
0.0000	1.0000	8.3623
0.0625	1.0589	6.3423
0.1250	1.1838	5.6635
0.2500	1.5175	4.3380
0.3750	2.1278	3.1355
0.5000	2.7381	1.9330

MATERIAL J-R CURVE:INCONEL
J= 2.6730 * (da)^ 0.3162
Jic= 0.3000
Jmax= 5.0000

INCREMENTATION:-
CRACK INCREMENT= 0.2028
NUMBER OF INCREMENTS= 100

INCREMENT CRACK SIZE

STRESS= 9.6070

CRACK SIZE	Jappl	Tappl	Tmat	dA
1.0000	0.0284	0.3082	154515.2647	0.0000
1.2028	0.0347	0.3576	99773.2108	0.0000
1.4056	0.0421	0.3996	65772.1967	0.0000
1.6084	0.0503	0.4337	44675.1280	0.0000
1.8112	0.0593	0.4709	31364.0503	0.0000
2.0139	0.0690	0.5118	22589.6766	0.0000
2.2167	0.0796	0.5567	16603.1041	0.0000
2.4195	0.0910	0.6262	12403.8482	0.0000
2.6223	0.1040	0.6903	9309.8402	0.0000
2.8251	0.1182	0.7562	7052.9928	0.0000
3.0279	0.1338	0.8289	5394.4662	0.0000
3.2307	0.1509	0.9093	4159.0612	0.0000
3.4335	0.1697	0.9984	3228.1500	0.0000
3.6363	0.1903	1.0973	2519.7001	0.0000
3.8391	0.2129	1.2073	1975.9330	0.0000
4.0418	0.2378	1.3299	1555.4902	0.0000
4.2446	0.2652	1.4670	1228.3410	0.0000
4.4474	0.2955	1.6204	972.4009	0.0000
4.6502	0.3289	1.8186	771.2436	0.0013
4.8530	0.3665	2.1827	610.5914	0.0019
5.0558	0.4115	2.4870	475.2314	0.0027
5.2586	0.4628	2.7839	368.5931	0.0039
5.4614	0.5202	3.1146	286.2061	0.0056
5.6642	0.5845	3.4885	222.4852	0.0082
5.8670	0.6564	3.9123	173.0781	0.0118
6.0697	0.7372	4.3938	134.6897	0.0170
6.2725	0.8278	4.9425	104.8128	0.0245
6.4753	0.9298	5.5693	81.5304	0.0354
6.6781	1.0447	6.2874	63.3710	0.0512
6.8809	1.1744	7.1124	49.2004	0.0742
7.0837	1.3211	8.0630	38.1413	0.1077
7.2865	1.4874	9.1616	29.5131	0.1567
7.4893	1.6764	10.4350	22.7861	0.2287
7.6921	1.8917	11.9152	17.5472	0.3351
7.8949	2.1375	13.6411	13.4732	0.4931

BY INTERPOLATION

Jcrit= 2.1304
Tcrit= 13.5911

Acrit=	7.8890
Acrit - dA=	7.4010
w=	8.0707

MATERIAL J-R CURVE: INCONEL

da	Jmat	Tmat
0.0020	0.3746	582.1897
0.0028	0.4183	458.7269
0.0040	0.4670	361.4464
0.0057	0.5214	284.7959
0.0081	0.5822	224.4003
0.0114	0.6500	176.8126
0.0162	0.7257	139.3166
0.0229	0.8103	109.7723
0.0325	0.9047	86.4933
0.0461	1.0101	68.1510
0.0653	1.1278	53.6985
0.0925	1.2592	42.3108
0.1311	1.4059	33.3381
0.1857	1.5697	26.2682
0.2632	1.7526	20.6976
0.3730	1.9568	16.3084
0.5285	2.1848	12.8499
0.7489	2.4394	10.1249
1.0612	2.7236	7.9777
1.5037	3.0410	6.2859
2.1307	3.3953	4.9529
3.0193	3.7909	3.9026
4.2784	4.2326	3.0750
6.0626	4.7258	2.4229
8.5908	5.0000	1.9091

END OF pc-CRACK