FIELD APPLICATION OF A NON-POST WELD HEAT TREAT WELD OVERLAY TO AN ALLOY STEEL REACTOR PRESSURE VESSEL NOZZLE

By

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Mercury Company
Vernon, Vermont

Presented at EPRI Seminar on
Repair Welding Alternative for
Nuclear Power Plant Components
Charlotte, North Carolina
March 11, 1987

5245R


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ABSTRACT

Ultrasonic inspection of the core spray nozzle to safe-end welds at Vermont Yankee revealed indications representative of Intergranular Stress Corrosion Cracking (IGSCC).

In order to minimize plant downtime, a weld overlay was applied to the two affected welds.

This report will discuss the qualification and application of a weld overlay process that was applied to SA508 CL 2, reactor pressure vessel nozzles without a subsequent post-weld heat treat, resulting in a significant time saving for the repair.

ACKNOWLEDGEMENTS

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Dr. Wylie J. Childs - Electric Power Research Institute

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Mr. William D. Fields - Vermont Yankee Nuclear Power Corporation

Mr. Richard G. Mossey - Vermont Yankee Nuclear Power Corporation

Mr. Paul Norris - Georgia Power Company

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1.0 INTRODUCTION

The two core spray nozzles (called the N5 nozzles) are located on the shell portion of the reactor vessel, 180 degrees apart, as shown on Figure 1. The nozzles and safe ends are sized for a ten-inch connection, with a reducer being used to mate with the eight-inch core spray piping (Figure 2).

The nozzle is fabricated from SA508 CL 2, low alloy steel; the safe end is fabricated from SB166, Alloy 600 (Inconel 600). Both components are forgings. The nozzle is clad with Inconel 182 weld metal to allow the safe end to be welded to the nozzle without a subsequent post-weld heat treatment. The safe end is welded to the clad nozzle using Inconel 82 weld metal. The details of the weld joint are shown in Figure 2.

In 1985, IGSCC was detected in a similarly designed weld joint in a boiling water reactor. Inspections at other facilities have also revealed the presence of IGSCC.

During the 1985-1986 refueling outage at Vermont Yankee, the two core spray nozzle to safe-end welds were inspected. Probable IGSCC indications were detected.

The following sections of this paper will address the inspection methodology and findings, review the repair options considered, and discuss the planning and execution of the weld overlay repair applied to the welds.

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2.0 INSPECTION METHODOLOGY AND FINDINGS

Both welds were examined ultrasonically using manual and automated techniques intended for use with multiple Inconel weld layers. Automated examination showed three closely spaced indications parallel with the weld longitudinal axis on the N5B nozzle. The N5A nozzle showed no indications. Manual examination for reflectors perpendicular to the weld axis of N5B showed seven indications, with a concentration of indications at the area showing the circumferential indications. N5A showed seven randomly spaced axial indications.

Initially both nozzle to safe-end welds were examined using nominal Section XI manual examination techniques employing refracted longitudinal beams. Using this method, no indications were noted. Due to the high "noise" level experienced during the examination overall, confidence in the technique is low.

Utilizing the automated system and the same transducers used during the manual examination, several areas containing coherent reflectors were discriminated in the overall "noise" of the examination. Evaluation as to the nature of the reflectors was not conclusive. The reflectors were located very close to the nominal alloy steel/Inconel interface, and the signal to noise ratio was quite low. Additionally, the location of the reflectors raised questions since the reflectors did not appear to connect with the ID. Refracted longitudinal waves do not respond well to corner reflectors and, as such, some portion of a flaw face can produce the maximum response; however, other non-IGSCC conditions respond in a similar manner. This contributed to the incomplete evaluation of these first examinations.

In parallel with the core spray nozzle examinations, work was in progress to optimize examination of the N2 nozzle to safe-end welds. This effort had shown that a particular series of focused refracted longitudinal wave probes were effective in examining multiple stainless steel weld butters and clads. These transducers had also been utilized for Inconel weld

examinations at other reactors. Though not directly proven on Vermont Yankee's N-5 configuration, it was decided that these transducers would be used as an aid in evaluation.

The large "footprint" of these transducers (2.2" x 2.2") prohibited scanning normal to the weld. By machining the transducer contact surfaces, it was possible to scan parallel with the weld. Manual examination with these transducers showed the axial indications in areas around the circumference. Several of these axial indications were located at areas which contained circumferential indications from the first automated examination series. Several additional axial indications were identified.

The applications difficulties associated with IGSCC detection in metallurgical and geometric configurations, such as the Vermont Yankee N-5, complicate the detection and discrimination process; and finite sizing of each indication was not considered feasible. Qualitative evaluation of the detection data would indicate indications were contained in the inner one-third of the thickness; however, the lack of qualified techniques for this configuration prevents quantitative sizing results.

3.0 MANAGEMENT DECISIONS

The results of the UT inspections showed the existence of rejectable IGSCC. Continued operation was not permissible without repair or replacement of the defective welds. New safe ends had been procured as a contingency measure, so replacement was a possible option.

Due to the vessel configuration required by the recirculation system piping replacement activity, the N5 nozzles could not be inspected until late in the refueling outage, precluding repair or replacement in parallel with the recirculation piping.

After studying the evolutions necessary to replace the safe ends, it was concluded that at least a month of critical path outage time would be required. It was also felt that the weld overlay repair could be performed with little to no impact on schedule, once the welding procedures were developed.

Approximately a month existed before the plant would be in a condition to allow the overlay to begin. Although it was an aggressive schedule, all parties felt that the necessary front end work could be accomplished within the month.

4.0 WELD PROCEDURE QUALIFICATION

In addition to the standard weld procedure qualification requirements, it was necessary to demonstrate that the welding procedure provided the necessary tempering of the alloy steel base metal, allowing the post-weld heat treatment step to be eliminated from the repair process.

The ASME Code had introduced several years earlier the "half-bead" repair approach for weld repair of pressure vessel defects using the manual stick welding process without post-weld heat treatment, and in early 1986, the issuance of Code Case N-432 allowed the use of automatic TIG weld repair of pressure vessel defects, also without PWHT. Both of these processes were specified for repair of cavities, where a defect was ground out and the vessel thickness restored by depositing weld metal.

Utilizing the concepts addressed by ASME in the vessel cavity repair procedures, a program was undertaken to develop an automatic weld overlay process for reactor pressure vessel nozzles without PWHT.

The initial work was performed by Georgia Power Company and Structural Integrity Associates under an EPRI project funded by the BWR Owners Group for IGSCC Research.

This information was available to Vermont Yankee through the courtesy of Georgia Power and EPRI.

Using the Georgia Power welding parameters as a starting point, a program was initiated to develop plant-specific procedures for Vermont Yankee.

Samples of carbon steel pipe were overlay welded and then cross-sectioned to check for iron-dilution of the Inconel overlay as well as determine the hardness recovery due to weld heat tempering.

A high degree of iron dilution was detected (on the order of 50 percent) in the first overlay layer. However, since no evidence of micro- or

macro-fissuring was detected in any samples, it was decided not to pursue refinement of first layer parameters.

Hardness surveys after one, two, and three layers demonstrated adequate tempering of the base metal hardness.

A nozzle safe-end mockup was fabricated. It consisted of a SA508 CL 2 nozzle forging, clad with Inconel 182 welded to an Inconel 600 forging using Inconel 82 weld wire, essentially duplicating the core spray nozzle configuration at Vermont Yankee. A weld overlay was applied using the parameters selected for the overlay process. All steps of the repair were followed.

A grooved sample of SA508 CL 2 material was welded as shown in Figure 3. Side bends, tensile specimens, Charpy specimens, and hardness traverses were performed, all with satisfactory results. Once again, no evidence of micro-fissioning was detected at the overlay/base metal interface.

Specimens were sent to two facilities for testing. All results were consistent except for one area. One of the labs reported that the hardness at the toe of the overlay exceeded the target value of Rc 35; however, a review of the microstructure showed satisfactory results. A review of the cross sections showed that the bead overlap between the first and second layer were quite low, leading to the conclusion that the results were an anomoly of the test sample. The other samples and the actual installation, maintained a 1/16" to 1/8" overlap spacing.

Thus, the weld procedure qualification program demonstrated that the selected welding parameters produced a final configuration with the desired metallurgical conditions.

5.0 WELD PROCEDURE DEVELOPMENT

Arc Automatic Pipe Welding Systems equipment was selected due to the features of double down technique and dual optics.

Utilizing the welding parameters provided through the courtesy of Georgia Power and EPRI as a starting point, several passes were welded on carbon steel pipe in the 5G position. The welding parameters were adjusted until an optimum weld bead contour was achieved for each of the three layers. The weld bead contour samples were cross-sectioned and etched to determine depth of penetration for each layer. The primary concerns were iron dilution, micro-fissuring, and amount of tempering taking place. The weld parameters were finalized to achieve 12 K joules/in for the first layer, 16 K joules/in for the second, 20 K joules/in for the third, and 21 K joules/in maximum for the remaining layers. All welding operations for the overlay procedure qualification were performed in the 5G position.

A weld procedure test coupon was fabricated to resemble the actual core spray nozzle configuration and materials. It consisted of a SA508 CL 2 nozzle blank-machined for buttering, weld-buttered with Inco 182, post-weld heat treated at 1200°F, remachined for V-groove butt weld, then welded to SB166 Inconel 600 forging with Inco 82. Upon completion of the butt weld, a 300°F preheat was established on the overlay test coupon with resistance heaters. The first layer was welded and a cross-section sample was removed from the 9 o'clock location. A filler plug was welded into the sample hole and Layers 2 and 3 were completed. Resistance heaters were placed on the test coupon with top and bottom control then heated to 500°F and held for two hours and 45 minutes.

When the test coupon had cooled, an additional sample was removed from the coupon at the 3 o'clock location. The sample hole was plugged and the weld test coupon prepared for water backing. Water was pumped through the coupon at approximately 3 gpm to maintain the interpass temperature less than 110°F for the fourth and remaining layers. After completion of welding the weld test coupon was machined to provide the utility with the UT calibration standard. In addition to the standard weld procedure test samples, overlay

cross section was removed from the 3 o'clock position. Hardness surveys were performed transverse to the overlay fussion line on the first layer, third layer temper heat treatment, and final layer cross sections. These hardness surveys demonstrated adequate tempering of the base metal, and metalographic surveys showed no evidence of micro-fissuring.

Therefore, the weld procedure development program indicated the selected weld parameters would produce the required metallurgical conditions.

6.0 ENGINEERING DESIGN

The weld overlay was designed to be a "full structural" overlay, using the design rules of the ASME Code, Section XI, Subsection IWB-3640. The term "full structural" means that no credit is taken for any remaining uncracked thickness of the nozzle. All loads are assumed to be resisted only by the weld overlay.

The welding process used was the machine gas tungsten arc method. The welding parameters were developed and controlled to use the heat of welding to provide the tempering of the alloy steel nozzle to avoid the need for a post-weld heat treatment.

The basic repair strategy was to lower the water level for a short period to allow the first few weld layers to be applied to the nozzle (the temper-bead phase of the repair) followed by refilling of the vessel and application of the weld overlay phase of the repair.

The weld procedure development process established how thick the temper bead portion was required to be, recognizing that a 1/8-inch minimum thickness was required by the ASME Code. (The qualification process showed that the 1/8-inch minimum was sufficient to achieve the required tempering of the base metal.)

The completed weld overlay is shown in Figure 4.

7.0 JOB EXECUTION

Radiological surveys at the N5 nozzles showed a 50-100 mR/hr field at the elbow, 300-500 mR/hr in the biological shield blockout, and hot spots reading 3-10 R/hr on contact. General area at the platform was 100-250 mR/hr.

Lead blanket shielding was placed on the core spray pipe and elbow, up to and including portions of the safe end. The radiation dose rate was reduced to 25 mR/hr contact at the elbow and 50-150 mR/hr general area at the platform. Lead plate wrapped in poly was used to shield the hot spots, to the extent possible.

The area on top of the biological shield had a dose rate of 10-15 mR/hr. This low background area was used by personnel in between wire and tungsten changes.

The existing N5 nozzle to safe-end weld was etched to identify the actual location and width. Reference marks were punched at 90° quadrants around and on both sides of the weld to identify the overlay limits and provide the location of nozzle to weld interface for future safe-end replacement. The surface to be overlayed was prepared, cleaned, and visually examined. The automatic weld travel ring was mounted and the weld lead installed and adjusted for the first portion of the weld overlay. The weld surface received the final cleaning to removal all surface contamination, thermocouples were attached and a 300°F minimum preheat was established.

The double down welding was performed entirely with remote video. Minor weld bead adjustments, wire, and tungsten changes were performed by an inside drywell operator.

The first three layers of the overlay were initiated at the center of the existing nozzle to safe-end weld and progressed outward to the overlay limits. Each layer ended on the last bead of the preceding layer with 50%-70% overlap. Starts and stops were staggered to the extent possible to produce a reasonably smooth surface.

Removal of the automatic weld bead and travel ring was required for the overlay temper heat treatment. Thermocouples were attached and additional resistance heaters were wrapped around the overlay with top and bottom control. The overlay was heated between 450°F to 500°F and maintained for a minimum of two (2) hours then allowed to cool until a delta T of 150°F between vessel water and nozzle temperature was achieved. The reactor vessel was then filled until the core spray nozzles were flooded.

The resistance heaters and thermocouples were removed and the overlay surface was prepared for welding. Subsequent overlay weld layers were welded using the double down technique with 60%-70% overlap. Each layer started and ended on the extreme passes of the preceding layer. Surface oxide was removed from every other weld layer after the third, by power brushing followed by solvent wipe. It was evident after the seventh layer that a final surface machining would be required in order to perform the final ultrasonic examinations. Layers eight and nine were added to increase the overlay thickness. Surface profile measurements were taken to insure the overlay thickness requirements had been achieved prior to machining. A stripping technique was used to add weld metal to the low areas.

A clam shell pipe lathe was adapted to machine the overlay surface. The lathe was mounted on the safe end and aligned to the axis using the overlay reference punch marks. A flat surface was machined across the overlay to produce a profile of less than 1/64" gap under a 1" straight edge and better than 250 MMS finish without violating the .535" minimum thickness.

Final liquid penetrant examinations were performed and accepted and the overlays were released for volumetric UT examination. The project was completed from start to finish in fourteen (14) days.

8.0 POST-INSTALLATION UT DEVELOPMENT

Following installation, ultrasonic examinations of the overlay were conducted to verify integrity of the overlay with respect to bond between the nozzle and overlay and the overall volumetric integrity of the overlay.

Calibration standards were fabricated which duplicated the safe-end nozzle and overlay configuration as installed.

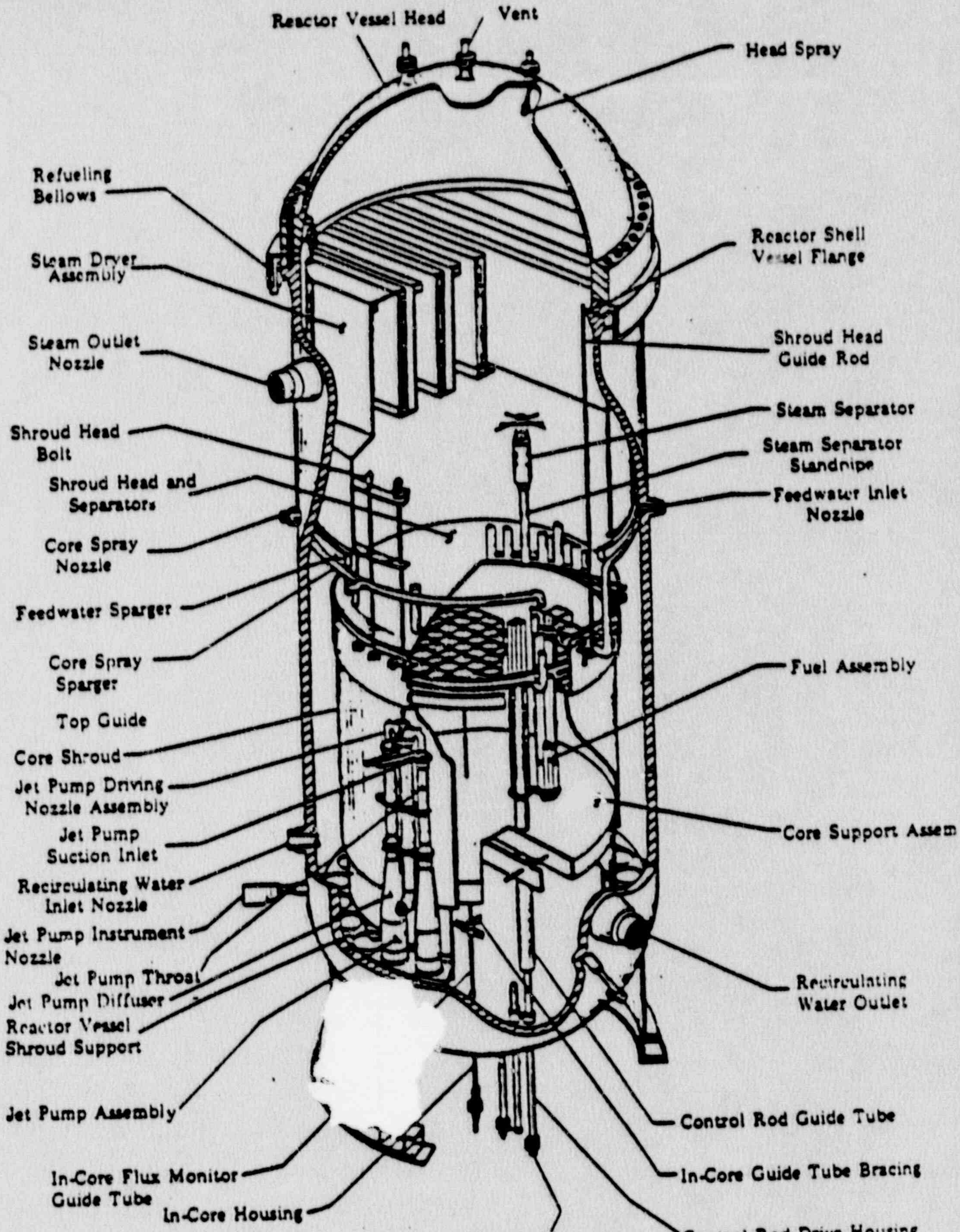
Qualifications of the technique were performed on mockups representing the safe-end, nozzle and overlay geometry and metallurgy.

Inspection methodology developed under the BWROG-II Program at EPRI was utilized. The overall surface finish and flatness requirements for finished overlays were enhanced beyond the EPRI Program recommendations to aid in examination.

9.0 CLOSURE

The non-PWHT weld overlay process provides a viable alternative for flawed pipe repair at reactor pressure nozzles. It is particularly beneficial when repairing stainless steel welds, since PWHT would result in potential sensitization of the stainless steel.

Once the welding parameters are developed, the process can be applied easily and quickly.



Reactor Vessel Head
Vent
Head Spray
Refueling Bellows
Reactor Shell Vessel Flange
Steam Dryer Assembly
Steam Outlet Nozzle
Shroud Head Guide Rod
Steam Separator
Shroud Head Bolt
Steam Separator Standpipe
Shroud Head and Separators
Feedwater Inlet Nozzle
Core Spray Nozzle
Feedwater Sparger
Core Spray Sparger
Fuel Assembly
Top Guide
Core Shroud
Jet Pump Driving Nozzle Assembly
Core Support Assem
Jet Pump Suction Inlet
Recirculating Water Inlet Nozzle
Jet Pump Instrument Nozzle
Jet Pump Throat
Jet Pump Diffuser
Recirculating Water Outlet
Reactor Vessel Shroud Support
Jet Pump Assembly
Control Rod Guide Tube
In-Core Flux Monitor Guide Tube
In-Core Guide Tube Bracing
In-Core Housing
Control Rod Drive
Control Rod Drive Housing

Figure 1

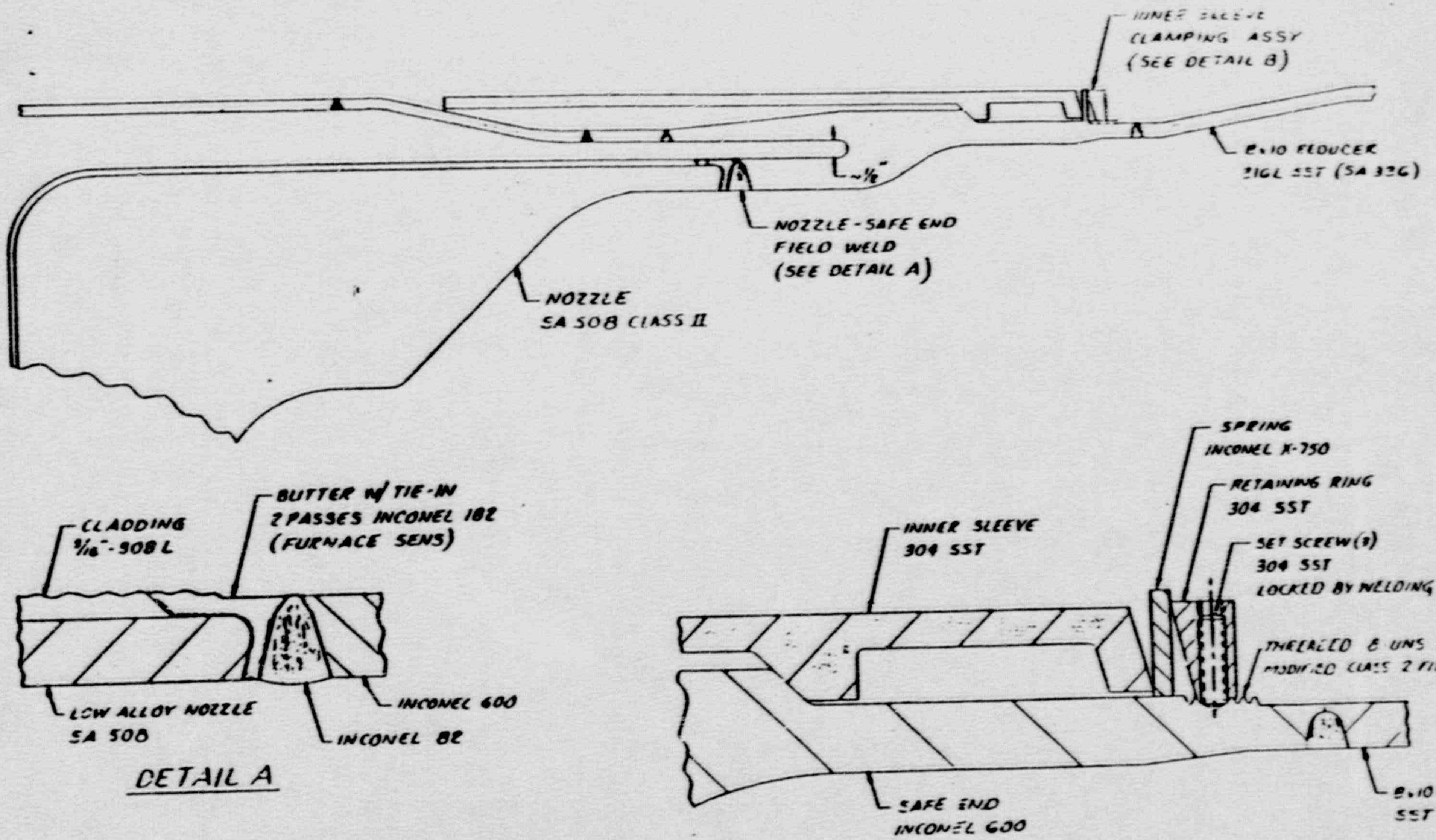
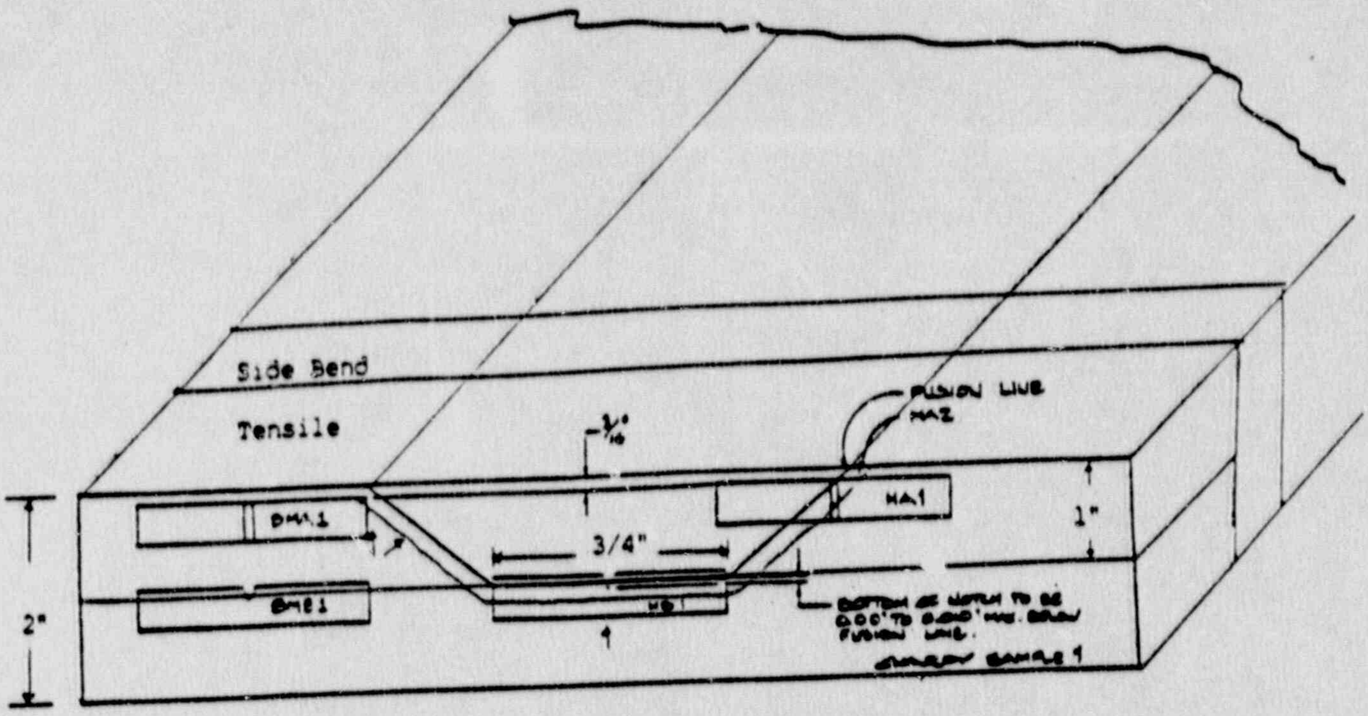
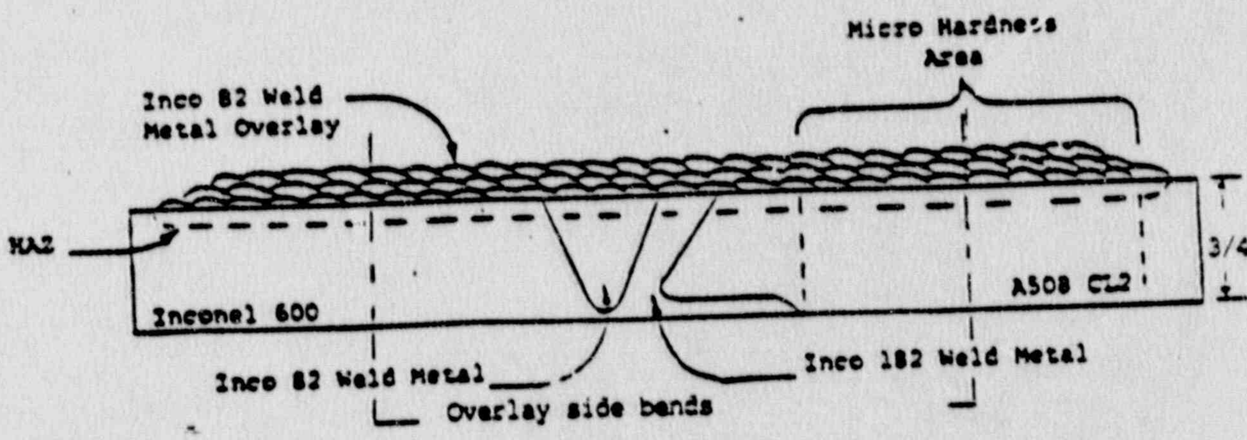


FIGURE 2

EXISTING CORE SPRAY
SAFE END/NOZZLE ARRANGEMENT



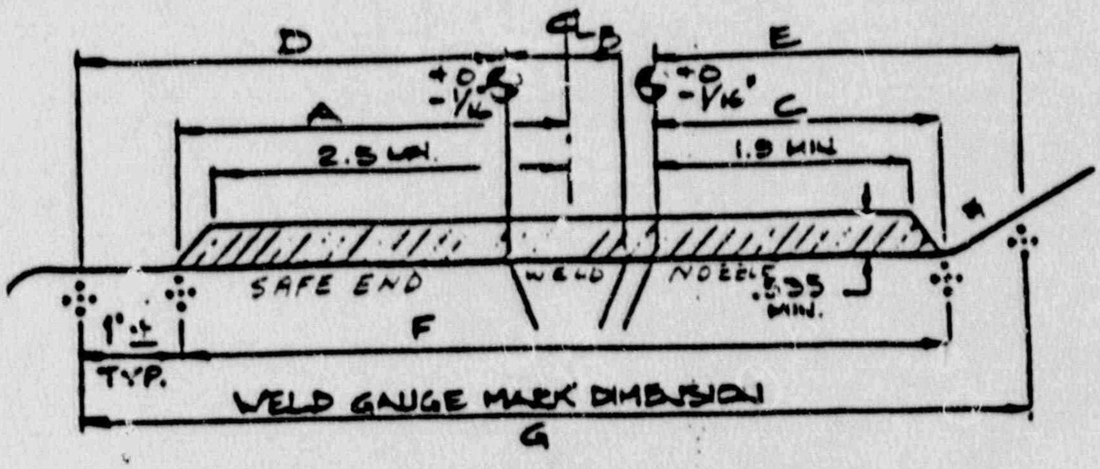
4 side bends = No defects
2 red. section T.S. = 87.7 Ksi + 88.1 Ksi, break in base
hardness survey = 500 gm HV ≤ 35 Rc



8 side bend of overlay/base = no defect > 1/16"
2 reduced section tensiles with overlay removed to base = 88.1 + 87.7 Ksi/
break in base of P-3
3 charpies of overlay/P-3 haz = 120 ft. lbs. avg. + .0745 avg. mils. l.e.
hardness survey of P-3/overlay haz body @ 30 Rc

Mechanical Test Program

Figure 3



G	WELD GAUGE DATA		
Location	Initial	Post Weld	Δ
0	8.462	8.447	-.015
90	8.350	8.347	-.003
180	8.323	8.302	-.021
270	8.313	8.315	+.002

DIMENSIONAL DATA						
Location	A	B	C	D	E	F
0	3.120	.781	2.513	3.750	3.531	6.475
90	3.120	.781	2.505	3.749	3.516	6.366
180	3.108	.781	2.512	3.739	3.533	6.310
270	3.120	.781	2.500	3.745	3.483	6.352

FIGURE 4

WELDING PROCEDURE SPECIFICATION CP/OL

MACHINE GAS TUNGSTEN ARC WELDED OVERLAY

OF ASME SECTION IX P-3 Gr3, P-43 & ENiCrFe-3

MATERIAL USING A MODIFIED POST WELD HEAT TREATMENT,

TEMPER BEAD AND WATER BACKING TECHNIQUE

IMPACT TESTED FOR MATERIALS 5/8" & GREATER

THICKNESS RANGE: 1/8" TO MAX. TO BE WELDED

Job Number 70430

FOR INFO ONLY

								Welding Procedure Specification
2	6/4/86	PCM	[illegible]					MERCURY COMPANY OF NORWOOD INC A Fischbach Company
1	5/30/86	PCM	[illegible]					
0	5/28/86	PCM	[illegible]					
REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	WPS-CF/OL Sh. 1 of 14

LIST OF REVISIONS

REVISION	DATE	DESCRIPTION
0	5-28-86	First Issue
1	5-30-86	Minor Change: Pg. 13 of 14 changed voltage secondary and changed oscillation
2	6-4-86	Increase Interpass Temp. In WPS to 200°F.

								Welding Procedure Specification
2	6/4/86	PCM	[signature]					MERCURY COMPANY OF NORWOOD INC
1	5/30/86	PCM	[signature]					
0	5/28/86	PCM	[signature]					A Fischbach Company
REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	WPS-CF/OL Sh. 1a of 14

FORM 237 1000

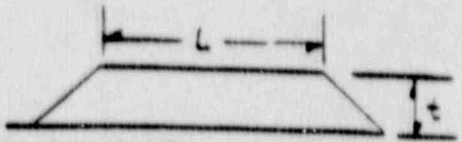
WELDING PROCEDURE SPECIFICATION
(WPS)

Welding Procedure Specification CF/OL
Welding Process G.T.A.W. Type Machine
Supporting Procedure Qualification Record CI1586 - CH1586 - CF/OL1586

JOINTS (QW402)

Joint Design Overlay
Backing Yes
Backing Material P-43 & P-3 Material
Root Opening N/A
Other

SKETCH



L & t As Required
For Bead Placement See Tech. Sheet 11

BASE METALS (QW403)
Specification Type & Grade SB166
to Specification Type & Grade SA508 CL2
P-No. 43 Gr. No. N/A to P-No. 3 Gr. No. 3
Other
Thickness Range:
Base Metal: Groove All Thicknesses Fillet N/A
Deposited Weld Metal 1/8" To Max. To Be Welded
Other
Pipe Dia. Range: Groove All Diameters Fillet N/A
Other

Filler Metals (QW404)
F-No. F-43 Other
A-No. See SFA Spec Other
Spec. No. (SFA) SFA 5.14
AWS No. (Class) ERNiCr-3
Size of Filler Metals .035" Dia.

Electrode - Flux (Class) N/A
Flux Tradename N/A
Consumable Insert None
Other Pass Deposit Less Than 1/2" (1/16" Nominal)

REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD
2	6/4/86	PCM	[signature]				
1	5/30/86	PCM	[signature]				
0	5-28-86	PCM	[signature]				

Welding Procedure Specification

MERCURY COMPANY OF NORWOOD INC
SUBSIDIARY OF FISCHBACH & MOORE INCORPORATED

WPS CF/OL Sh. 2 of 14

WELDING PROCEDURE SPECIFICATION
(WPS)

Welding Procedure Specification CF/OL
Welding Process G.T.A.W. Type Machine
Supporting Procedure Qualification Record No. CI1586-CH1586-CF/OL1586

POSITIONS (QW405)
Position of Groove All Positions
Welding Progression See Technique Sheet
Positions of Fillet N/A

POSTWELD HEAT TREATMENT (QW407)
Temperature Range 450°F-500° F
Time Range 2 Hrs. Minimum
Upon completion of Layer 3.

PREHEAT (QW406)
Preheat Temp. Min. 300°-400° F
Interpass Temp. Max. 400° F Max.
Preheat Maintainence 1 Hr. Prior To Welding
Other Maintain for 3 layers until PWHT is initiated. 70-200°F after P.W.H.T.

GAS (QW408)
Shielding Gas Argon
Percent Composition 100% Weld Grade
Flow Rate 20-45 CFH
Gas Backing None
Trailing Shielding Gas None

*** ELECTRICAL CHARACTERISTICS (QW409)** (See Specific Technique Sheets Attached)
Current A.C. or D.C. Direct Polarity Straight
Amps 210 Pr. 110BG-250Pr.160 BG Volts 9-9.8 Pr., 8.8 BG
Other See Technique Sheet Other See Technique Sheet
Tungsten Electrode Size & Type 1/8" EWTH-2
Mode of Metal Transfer for GMAW N/A
Electrode Wire Feed Speed
Other Pulse ARC Mode

TECHNIQUE (QW410)
String or Weave Bead String
Orifice or Gas Cup Size 3/8" To 3/4"
Initial and Interpass Cleaning Brushing Or Grinding
Other
Method of Back Gouging None
Osillation 0"-For First Three Layers, 0-3/8" For Remaining Layers
Contact Tube to Work Distance N/A
Multiple or Single Pass Per Side Multiple
Multiple or Single Electrode Single Solid Continuous
Peening None
Other Travel Speed - Actual 6 - 6 1/2 IPM; water backed after P.W.H.T.

REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD
2	6/4/86	PCM	[signature]				
1	5/30/86	PCM	[signature]				
0	3/28/86	PCM	[signature]				

Welding Procedure Specificati

MERCURY COMPANY OF NORWOOD INC

WPS-CF/OL Sh. 3 of 14

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD

(PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86

Welding Process G.T.A.W.

Procedure Qualification Record No. C115B6 Date 5-28-86

JOINTS (QW402)

Joint Design Overlay

Root Opening None

Backing P-3 & P-43 material

Other See attached sketch Sh. 11

BASEMETALS (QW403)

Material Spec. SB166 to SA508 CL2

Type of Grade NA

P-No. 43 to P-No 3

Thickness 3/4" Dia 13-1/2" O.D.

Weld Metal Deposit

Other

FILLER METALS (QW404)

Weld Metal A No. * See SFA Spec.

Filler Metal F No. F-43

SFA Specification* SFA 5.14

AWS Classification ERNiCr-3

Size of Electrode .035"

Other

POSITION (QW405)

Position of Groove 5G

Weld Progression Double Down

Other

PREHEAT (QW406)

Preheat Temp. 300°F min. thru Layer 3

Interpass Temp. 400°F max. thru Layer 3

Other Pipe still air cooled to below 100°F, water added to I.D. at approx. 3 GPM interpass maintained below 110°F 4th thru

POSTWELD HEAT TREATMENT (QW407)

Temperature * 500°F

Time 2 hrs. 45 min.

Heat-Up-Rate NA

Cooldown Rate NA

Other *PWHT upon completion of Layer 3

No PWHT after Layers 4-11

GAS (QW408)

Shielding Gas Argon @ 20 CFH

Composition 100% Weld Grade

Gas Backing None

Other

ELECTRICAL CHARACTERISTICS (QW409)

Current Direct

Polarity Straight

Amps See Tech. Shts. Volts See Tech. Shts

Other

TECHNIQUE (QW410)

Travel Speed See Tech. Shts.

String or Weave Bead String

Oscillation None

Multi or Single Pass (Per side) Multiple

Single or Multiple Electrodes Single

Other Solid Continuous

Form 213-

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD (PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86
Welding Process GTAW
Procedure Qualification Record No. CI1586 Date 5/28/86

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
#1	.979	.759	.743	65,200	87.7 KSI	Ductile BM
#2	.980	.754	.739	65,100	88.1 KSI	Ductile BM

GUIDED BEND TEST (QW-160)

FIG. NO. TYPE	RESULTS	FIG. NO. TYPE	RESULTS
Side 1	Acceptable	NA	NA
Side 2	Acceptable	NA	NA
Side 3	Acceptable	NA	NA
Side 4	Acceptable	NA	NA

TOUGHNESS TEST (QW-170)

SPECIMEN NO.	NOTCH LOCATION	NOTCH TYPE	TEST TEMP.	IMPACT VALUES	LATERAL EXP % SHEAR	LATERAL EXP MILS	DROP WEIGHT BREAK	DROP WEIGHT NO BREAK
SEE ATTACHED SUPPLEMENT SHEET 10								

OTHER TEST

Type of Test L.P. examination good, (2) Macro tests good
Deposit Analysis NA
Other

Welders Name C. Roy Clock No. NA Stamp No. M-147
Who by virtue of these test meets welder performance requirements
Welding witnessed by M.F. Trombley II Mercury Quality Control
Test Conducted by: Dirats Labratories Lab. Test No. 02129
We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

DATE 5-28-86

Mercury Company of Norwood, Inc.
By: P.C. McAuliffe P.C. McAuliffe M.W.S.

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD
(PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86

Welding Process GTAW - SMAW

Procedure Qualification Record No. CH1586 Date 5/28/86

JOINTS (QW402)

Joint Design Single Vee

Root Opening 1/8"

Backing None

Other

BASEMETALS (QW403)

Material Spec. SB166

Type of Grade NA

P-No. P-43 to P-No P-43

Thickness 5/8" Dia Plate

Weld Metal Deposit GTAW 3/8" SMAW 1/4"

Other

FILLER METALS (QW404)

Weld Metal A No. See SFA Spec.

Filler Metal F No. F-43

SFA Specification GTAW SFA 5.14, SMAW 5.11

AWS Classification * GTAW ERNiCr-3

Size of Electrode GTAW-1/8", SMAW 3/32"

Other * SMAW - ENiCrFe-3

POSITION (QW405)

Position of Groove 3G

Weld Progression Upward

Other

PREHEAT (QW406)

Preheat Temp. 50°F min.

Interpass Temp. less than 350°F

Other

POSTWELD HEAT TREATMENT (QW407)

Temperature None

Time NA

Heat-Up-Rate NA

Cooldown Rate NA

Other

GAS (QW408)

Shielding Gas Argon @ 20 CFH

Composition 100% Weld Grade

Gas Backing Argon @ 10 CFH

Other

ELECTRICAL CHARACTERISTICS (QW409)

Current Direct

Polarity GTAW-Straight SMAW-Reverse

Amps GTAW 130 Volts 12

Other SMAW 85 amps , 23 volts

TECHNIQUE (QW410)

Travel Speed GTAW 2-1/2 IPM, SMAW 6 IPM

String or Weave Bead String & weave

Oscillation GTAW 0"-1/4", SMAW - less than 3 times core diameter

Multi or Single Pass (Per side) Multiple

Single or Multiple Electrodes Single

Other No Peening

Form 113-1

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD (PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86

Welding Process GTAW - [illegible]

Procedure Qualification Record No. CH15B6 Date 5/28/86

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
#1	1.003	.523	.525	48,300	92.1 KSI	Ductile BM
#2	1.000	.501	.501	45,900	91.6 KSI	Ductile BM

GUIDED BEND TEST (QW-160)

FIG. NO. TYPE	RESULTS	FIG. NO. TYPE	RESULTS
Side 1	Acceptable	NA	NA
Side 2	Acceptable		
Side 3	Acceptable		
Side 4	Acceptable		

TOUGHNESS TEST (QW-170)

SPECIMEN NO.	NOTCH LOCATION	NOTCH TYPE	TEST TEMP.	IMPACT VALUES	LATERAL EXP % SHEAR	LATERAL EXP MILS	DROP WEIGHT BREAK	DROP WEIGHT NO BREAK
NA	NA	NA	NA	NA	NA	NA	NA	NA

OTHER TEST

Type of Test NA

Deposit Analysis NA

Other

Welders Name D. Goyetche Clock No. NA Stamp No. M-454

Who by virtue of these test meets welder performance requirements

Welding witnessed by M.F. Trombley II Mercury Quality Control

Test Conducted by: Dirats Labratories Lab. Test No. 01248

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section I of the ASME Code.

Mercury Company of Norwood, Inc.

DATE 5-20-86

By: P.C. McAuliffe P.C. McAuliffe M.W.S.

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD
(PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86

Welding Process GTAW-SMAW

Procedure Qualification Record No. CF/OL1586 (Groove) Date 5/28/86

JOINTS (QW402)

Joint Design Single Vee

Root Opening 1/8"

Backing None

Other Consumable Insert

BASEMETALS (QW403)

Material Spec. SB 166 to SA 508

Type of Grade NA CL 2

P-No. 43 to P-No 3

Thickness .750" Dia 13.500" O.D.

Weld Metal Deposit .750"

Other Buttering 3/8"

FILLER METALS (QW404)

Weld Metal A No. See SFA Spec.

Filler Metal F No. GTAW-F43, SMAW-F43

SFA Specification GTAW SFA 5.14, SMAW SFA 5.11

AWS Classification *GTAW ERNiCr-3

Size of Electrode GTAW .035" SMAW 1/8"

Other *SMAW ENiCrFe-3

POSITION (QW405)

Position of Groove * 5G

Weld Progression 360° Orbital - GTAW

Other SMAW buttering 1G - Progression forward.

PREHEAT (QW406)

* Preheat Temp. Buttering 300°F

* Interpass Temp. Buttering less than 400°F

Other *GTAW 50°F min.

**GTAW interpass less than 350°F

POSTWELD HEAT TREATMENT (QW407)

Temperature 1200°F

Time 17 Hrs.

Heat-Up-Rate 600°F

Cooldown Rate 400°F

Other *After buttering of P-3 material

GAS (QW408)

Shielding Gas Argon @ 20 CFH

Composition 100% Weld Grade

Gas Backing Argon @ 15 CFH

Other

ELECTRICAL CHARACTERISTICS (QW409)

Current Direct

Polarity GTAW-Straight, SMAW-Reverse

Amps * Volts *

Other SMAW 90 amps, 23 volts

*GTAW-170 PR - 120 BG AMPS, 9.5 PR-8.5 BG Volts

Max. Joule/In. for SMAW 20,700

TECHNIQUE (QW410)

Travel Speed GTAW 3 IPM, SMAW 6 IPM

String or Weave Bead String

Oscillation None

Multi or Single Pass (Per side) Multiple

Single or Multiple Electrodes Single

Other GTAW - Solid continuous

Form 213

MERCURY COMPANY OF NORWOOD INC

PROCEDURE QUALIFICATION RECORD (PQR)

Welding Procedure Specification CF/OL Rev. 0 Date 5/28/86

Welding Process GTAW

Procedure Qualification Record No. CF/OL1586 (Groove) Date 5/28/86

TENSILE TEST (QW-150)

SPECIMEN NO.	WIDTH	THICKNESS	AREA	ULTIMATE TOTAL LOAD LB.	ULTIMATE UNIT STRESS PSI	CHARACTER OF FAILURE & LOCATION
#1	.755	.571	.431	37,500	87.0 KSI	Ductile BM
#2	.756	.573	.433	37,600	86.8 KSI	Ductile BM

GUIDED BEND TEST (QW-160)

FIG. NO.	SB166 (P-43)	FIG. NO.	SA 508 C12 (P-3)
TYPE	RESULTS	TYPE	RESULTS
Side 1	Acceptable	Side 1	Acceptable
Side 2	Acceptable	Side 2	Acceptable
Side 3	Acceptable	Side 3	Acceptable
Side 4	Acceptable	Side 4	Acceptable

TOUGHNESS TEST (QW 170)

SPECIMEN NO.	NOTCH LOCATION	NOTCH TYPE	TEST TEMP.	IMPACT VALUES	LATERAL EXP		DROP WEIGHT	
					% SHEAR	MILS	BREAK	NO BREAK
NA	NA	NA	NA	NA	NA	NA	NA	NA

OTHER TEST

Type of Test L.P. Examination good (2) Macro tests good

Deposit Analysis NA

Other

Welders Name C. Roy Clock No. NA Stamp No. M-147

Who by virtue of these test meets welder performance requirements

Welding witnessed by M.F. Trombley II Mercury Quality Control

Test Conducted by: Dirats Labratories Lab. Test No. 02181

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

Mercury Company of Norwood, Inc.

DATE 5/28/86

By: P.C. McAuliffe M.W.S.

WELDING PROCEDURE SPECIFICATION CF/OL

SUPPLEMENT SHEET

TOUGHNESS TEST (QW-170)

The toughness test was performed on the SA508CL2 material for Welding Procedure Specification CI Rev. 0.

Specimen No.	Notch Location	Notch Type	Test Temp.	Impact Values	% Shear	Lateral Exp. Mils.	Dropweight Break/No Break
1	BM	V	40 F	85 ft lbs	50%	66	NA
2	BM	V	40 F	103 ft lbs	65%	67	NA
3	BM	V	40 F	80 ft lbs	50%	59	NA
4	HAZ	V	40 F	104 ft lbs	85%	76	NA
5	HAZ	V	40 F	106 ft lbs	70%	71	NA
6	HAZ	V	40 F	111 ft lbs	85%	69	NA

REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD
2	6/4/86	PCM	FB				
1	5/30/86	PCM	FB				
0	5/28/86	PCM	FB				

Welding Procedure Specification

MERCURY COMPANY OF NORWOOD INC

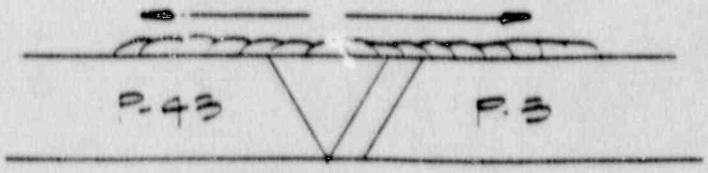
A Fischbach Company

WPS-CF/OL

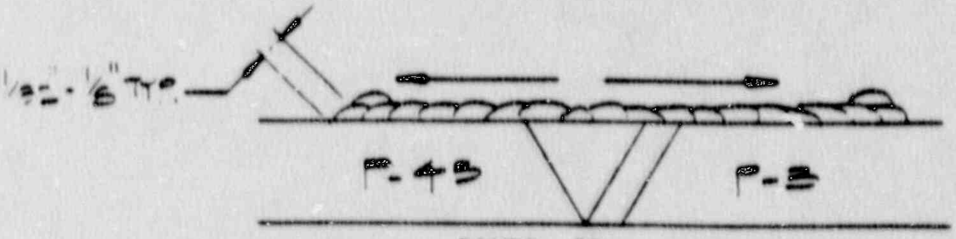
FORM 237 10/?

WELDING PROCEDURE SPECIFICATION CF/OL

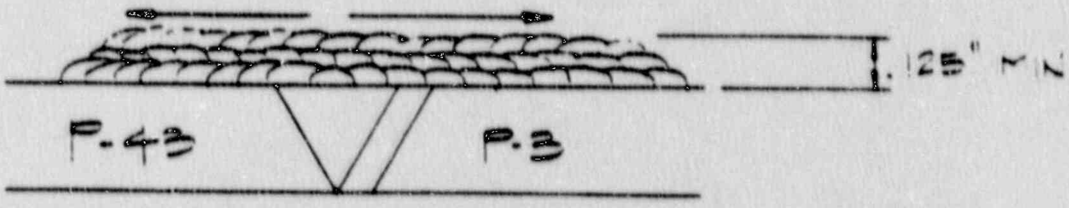
BEAD PLACEMENT OF OVERLAY LAYERS 1-3



LAYER #1
Begin at center of existing weld.
Weld progression may be either direction.



LAYER #2
Place edge beads as shown.
Progression of subsequent beads may be either direction from center of weld.



LAYER #3
Weld progression may begin at either edge.

Preheat/interpass Layer 1-3 = 300/400°F.
P.W.H.T. after Layer 3 = 450-500°F for 2 hr. min.
Subsequent layers run using parameters enclosed with water in ID and a preheat/interpass of 70/200°F.

								Welding Procedure Specification
								Attachment to PQR
2	6/4/86	PCM						MERCURY COMPANY OF NORWOOD INC A Fischbach Company
1	5/30/86	PCM						
0	5/28/86	PCM						
REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	WPS-CF/OL Sh. 11 of 14

TECHNIQUE SHEET OVERLAY PARAMETERS

This Technique Sheet provides direction for the parameters to be followed for the first three layers of weld overlay, with no variation.

Layer 1

Current: 210 AMPS Primary
Pulse Arc Mode
120 AMPS Secondary
Voltage: 9.8 Volts Primary
9.8 Volts Secondary
Oscillation: None
Filler Metal Size: .035" Dia. ERNiCr-3
Torch Angle: 90 degree
Shielding Gas: 100% Weld Grade Argon at 30 CFH
Wire Feed: 39 IPM Primary
30 IPM Secondary
Travel Speed: 8.5 IPM Actual
Bead Placement: 50% - 70% Overlap
Preheat: 300 degree F. Min. shall continue into P.W.H.T.
Interpass: 400 degree F. Max.
Welding Progression: Double Down Technique
Heat Input: 12,442 Joules/in Max.

Layer 2

Current: 230 AMPS Primary
Pulse Arc Mode
140 AMPS Secondary
Voltage: 9.8 Volts Primary
9.8 Volts Secondary
Oscillation: None
Filler Metal Size: .035" Dia. ERNiCr-3
Torch Angle: 90 degree
Shielding Gas: 100% Weld Grade Argon at 30 CFH
Wire Feed: 63 IPM Primary
51 IPM Secondary
Travel Speed: 7 IPM Actual
Bead Placement: 50%-70% Overlap Max. on edge beads, 1/32"-1/8" from base metal
Preheat: 300 degree F. Min. shall continue into P.W.H.T.
Interpass: 400 degree F. Max.
Welding Progression: Double Down Technique
Heat Input: 16,749 Joules/in Max.

REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	
								Welding Procedure Specification
2	6/4/86	PCM	[signature]					MERCURY COMPANY OF NORWOOD INC A Fischbach Company
1	5/30/86	PCM	[signature]					
0	5/28/86	PCM	[signature]					
REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	WPS-CF/OL Sh. 12 of 14

TECHNIQUE SHEET (page 2)

Layer 3

Current: 240 AMPS Primary

Pulse Arc Mode

140 AMPS Secondary

Voltage: 9.8 Volts Primary

9.8 Volts Secondary

Oscillation: None

Filler Metal Size: .035" Dia. ERNiCr-3

Torch Angle: 90 degree

Shielding Gas: 100% Weld Grade Argon at 30 CFH

Wire Feed: 69 IPM Primary

56 IPM Secondary

Travel Speed: 6 IPM Actual

Bead Placement: 50%-70% Overlap Max. on edge beads

Preheat: 300 degree F Min. shall continue into P.W.H.T.

Interpass: 400 degree F Max.

Welding Progression: Double Down Technique

Heat Input: 20,188 Joules/in Max.

Layers 2 & 3 shall not make contact with the base metal.

Note: All starts and stops to be staggered.

Upon completion of Layer 3, the overlay shall be Post Weld Heat Treated at a temperature of 450 degree F. - 500 degree F. for a minimum time of 2 hours. Upon completion of P.W.H.T., the pipe will be still air cooled to 100 degree F. prior to the addition of water. After the addition of water preheat is 70 degree F min., 200 degree F. max.

The attached parameter sheets provide ranges for layer 4 through the final layer. Minor variations may be made providing the general parameter ranges and maximum heat input (joules/in.) are not exceeded. The weld progression may be 360 degree orbital or continue with the Double Down Technique.

The heat input controls as delineated herein enhances the impact properties of the material being welded. The P.Q.R. limits the heat input required to complete the weld as shown by the following formula for the machine G.T.A.W. process.

REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD
2	6/4/86	PCM	[illegible]				
1	5/30/86	PCM	[illegible]				
0	5/28/86	PCM	LPC				

Welding Procedure Specification

MERCURY COMPANY OF NORWOOD INC

A Fischbach Company

WPS-CF/OL

Sh. 13 of 14

TECHNIQUE SHEET (page 3)

$$\text{Heat Input (Joules/Inch)} = \frac{\left[\left(PA \times PV \times \frac{A}{A+B}\right) + \left(SA \times SV \times \frac{B}{A+B}\right)\right] 60}{\text{Travel Speed (I.P.M.)}}$$

PA=Primary Amps
PV=Primary Volts
SA=Secondary Amps (Background)
SV=Secondary Volts (Background)
A=Time at High Pulse
B=Time at Low Pulse

FILLER METAL ERNiCr-3	.035" Dia.
PA	210-240
SA	120-160
PV	9.7-9.8
SV	- -

TRAVEL SPEED 6-8.5 IPM
MAXIMUM JOULE INPUT 21,000

								Welding Procedure Specification
2	6/4/86	PCM	[signature]					MERCURY COMPANY OF NORWOOD INC A Fischbach Company
1	5/30/86	PCM	[signature]					
0	5/28/86	PCM	[signature]					
REV	DATE	CHKD	APPVD	REV	DATE	CHKD	APPVD	WPS-CF/OL Sh. 14 of 14

FORM 237 1080

Reactor Nozzle To Safe-End
Structural Overlay
Test Program

Reactor Nozzle To Safe-End Structural Overlay Test Program

Index

ABSTRACT

Reactor Nozzle to Safe-End Structural Overlay Test Program

This report details the SA568 Cl. 2 nozzle mock-up, welding instructions and the results of non-destructive examinations and mechanical testing to qualify an overlay procedure to meet Code Case N-432. Additionally, an actual overlay done conventionally without preheat or post heat was performed to compare data to that of the Code Case qualification. The overlay was done in both a water backed (heat sink) condition and a non-water backed condition.

The results of the test program yielded welding procedure qualifications meeting Code Case N-432 and equivalent results for an in-situ nozzle to safe-end overlay using conventional (non-Code Case) techniques in the heat sink and non-water backed conditions. Additionally, a random occurring weldability problem was observed and traced to filler material surface quality, providing additional information to prevent weld defects.

cc: File 8500-1
Contract N61122

February 4, 1988

REACTOR NOZZLE TO SAFE-END STRUCTURAL OVERLAY TEST PROGRAM

BACKGROUND INFORMATION:

In the mid to late 1970's, intergranular stress corrosion cracking (IGSCC) was found in existing nuclear power plant reactor piping systems. This corrosion process was to be mitigated by several means, one of which was the applying of a overlay over the affected joint area with the piping system full of water. The application of the overlay performed two functions; (1) to effectively double the wall thickness at the joint location and (2) due to weld shrinkage, place the inside surface of the pipe in compression which would close the corrosion crack openings and/or reverse the tensile stresses present to slow down the IGSCC process.

The IGSCC problem was due to the selection of type 304 stainless steel material which was of the high carbon, i.e. .04% carbon or higher variety. This material was easily sensitized when welded upon and IGSCC cracking was found in the HAZ of this piping materials. Additionally, stainless steel safe-ends were attached to the reactor nozzles which had similar chemistry. Some of these safe-ends were later replaced with Inconel or with low carbon grade stainless steel. However, even some of the replacement safe-ends exhibited IGSCC as well and had to be replaced after being in service. Inconel 182 filler materials (nozzle weld prep butter) also has exhibited IGSCC, plus furnace sensitized Inconel safe end forgings.

As an alternate to replacement, a full structural overlay across the nozzle to safe end joint was deemed possible after research had been performed by the EPRI Foundation. The EPRI funded program was designed to find an alternate GTAW mechanized technique that would give the same equivalent results (metallurgically) as the half bead repair technique would on the reactor steels (SA533B or SA508-Cl. 2). This alternate technique was needed so that repairs to reactor shells and/or nozzles could be done remotely under high radiation fields.

BWR core spray/inlet nozzles typically have high radiation fields due to the crud trap nature of the small annulus space formed by the thermal sleeve and nozzle. Two plants, Hatch Unit 2 and Vermont Yankee had IGSCC UT indications in the core spray safe end to nozzle welds. Rather than change these safe-ends out,

the Utilities opted to go with a structural overlay utilizing the alternate half bead technique. In order to do so, Code Case N432 was passed by the ASME Code to allow this alternate mechanized GTAW technique.

As this was just another method to fix the IGSCC problem, CBI Services deemed it necessary to have this method qualified and available for future repair alternates to offer utilities with this problem. Presently, only two companies have qualified the procedure, one being GE and the other being CBI.

This report deals exclusively with the actual Code Case N-432 qualifications and a proposed alternate method which will give the Utilities more flexibility in performing this fix. Code Case N-432 requires both preheat and post heat during the welding process for the first six layers deposited. The alternates investigated in this report are a non water backed, non preheated, non post heated condition and a water backed non post heated condition to compare with the Code Case qualification. The water backed qualification allows the Utility the greatest flexibility in that the reactor annulus and recirculation piping system could remain full and/or flowing which allows in vessel operations to be performed simultaneously with the remote overlay operation. It also eliminates the need for the attachment of thermocouples and preheating devices or for the preheating and post heating cycles. Eliminating the need to preheat/post heat would minimize outage time required to perform the structural overlay.

THE TEST PROGRAM

The test program was designed to qualify welding procedures in the 5G position utilizing existing SA508 Cl. 2 nozzle forging material which had been procured from a scrapped reactor. As this material had been procured to nuclear specifications, it was assumed to be typical of what would be found in existing reactors. To meet the Code Case requirements of minimum post weld heat treat time applied to the nozzle prior to the repair, the reactor nozzle was given an additional 24 hours of PWHT at 1150 F. (This particular nozzle was cut out of an existing reactor. It is assumed that at least 10 hours of PWHT at 1150 F had been applied during the original fabrication cycle.) The nozzle chosen also had been utilized for an Induction Heating Stress Improvement (IHSI) mockup. This induction heating was

concentrated in the stainless steel safe-end area rather than in the nozzle forging. This induction heat treatment is thought to have no effect on the actual nozzle properties in the regions tested. Please refer to the work orders in Appendix IV which show test specimen location.

The purpose of the test was threefold:

1. Produce a welding procedure qualification meeting the ASME Code Case N-432 which would establish base line material properties.

2. Produce a non-water backed and a water backed overlay which, when tested, the material properties could be compared to the base line established in the Code Case qualification.

3. Provide sufficient technical data to allow in-service repairs on nozzle to safe-end welds by overlaying with and without water in the affected nozzle/safe-end.

To do the comparison, a Code Case groove weld was made in one region of the nozzle forging and a full thi ess structural overlay was built-up across the nozzle to s -end joint. The overlay was blended smoothly into the 45 sl e region of the nozzle forging. Please refer to Appendix II for the nozzle assembly drawings for details. As the Code Case requires the procedure qualification to be done utilizing the equipment planned for the repair, the use of fiberoptic video monitoring was used to produce both the groove and overlay welds.

Code Case N-432 Groove Weld

A 1" deep, 60 , with a .25" root opening groove was machined 360 in the nozzle forging after trimming excess material from the nozzle forging and PWHT for 24 hours at 1150 F plus or minus 25 F. Once machined, the forging was nondestructively tested and positioned for welding. Preheaters were installed inside the bore of the nozzle, and thermocouples attached outside in the "3T" band of the groove. After preheating of the nozzle to the required 300 F, it was allowed to "soak" for one hour prior to start of welding. Welding was performed per the instructions in W.O. H5173 (Appendix IV). Using ERNiCr-3 (Inconel) filler.

It was interesting to note that during the first six layers deposited, no real problems were encountered. It was feared that the sidewalls of the groove could not be easily welded (especially using remote video). Because the torch was motorized, it could be easily positioned to have the arc impinge on the sidewall. Additionally, positioning of the filler was also easily done with it being motorized as well. These features are necessary for ease of operation in a high radiation field. With these features, the six layers required by Code Case N-432 were deposited easily and the 60 groove shape was maintained allowing conventional split weave beading to complete the joint. (See photos 5 thru 7, Appendix III).

During the welding of the groove, some difficulty was incurred on passes 53 and 54 at the 90 location. The passes exhibited poor wetting into the side walls and heavy oxides were produced. The location was ground and liquid penetrant examined. No indications were found. As the spool of wire being used for filler was almost empty, another filler spool was used for the next passes without incident. Upon UT examination after groove completion, this location exhibited indications of non-fusion. This location was marked for further examination by sectioning and microscopic examination. This exam revealed inclusions between beads and internally within the beads. This defect was caused by an intermittent filler material quality problem. (See weld overlay for additional details and photos 25 and 26 Appendix III).

Upon completion of welding, the nozzle was post heated at 500 F for 2 hours minimum prior to cooling to ambient. After cooling to ambient for 48 hours minimum, the groove weld was liquid penetrant and ultrasonic inspected. With the exception of the UT indications at 90 , no defects were found.

<u>Weld Overlay</u>

In order to do a wet/dry overlay, the nozzle was re-configured to have a partial thermosleeve detail. (See Nozzle Mock-up Drawing Appendix II). With this configuration, one half (0 -90 -180) would be filled with water (both stagnate and flowing at +40 F) and the other half (0 -270 -180) dry. This configuration would allow the welding to be affected by a severe (water backed) quench rate and a moderate quench rate (steel mass effect - increasing interpass temperature), both conditions without the benefits of preheat or post heat.

The nozzle assembly was instrumented with thermocouples at the 90 and 270 center lines at the I.D. surface of the nozzle bore. Additionally, an O.D. surface thermocouple was placed on the 45 slope of the nozzle and both the flowing water and stagnate water were monitored. (See photos 10 thru 17 for plumbing and thermocouple installation.)

To do the overlay welding, passes were alternated from clockwise to counter-clockwise to eliminate the variable of pass direction so impact specimens could be taken from the highest heat input (vertical up) locations - wet or dry.

Welding was performed per the instructions of W.O. H5224. Temperatures were monitored to determine peak temperature per pass and location. It became evident that the stagnate water (which was to represent water in the reactor annulus) could not be maintained at +40 F due to its small volume. Therefore, tap water was allowed to flow at the minimum rate which would allow the water temperature contacting the I.D. surface of the nozzle reach equilibrium. Cold water (+40 F) was circulated in the thermal sleeve to cool the annulus water to the equilibrium point. The actual water temperature contacting the steel ranged from +45 F to 65 F, for the majority of the overlay welding.

During the first two beads being deposited on the first layer, heavy oxides were formed and wetability was very poor. As the beads were being deposited on the stainless steel safe-end, wetability should have been very good. A review of the weld parameters, equipment set-up, Argon supply, etc. was made prior to proceeding. At this point, it was noticed that the spool of filler material had seams or laps present on the exposed wraps. The spool of wire was replaced with another which did not exhibit this condition. Welding resumed using the same parameters, etc. with excellent results.

Upon completion of the first layer, a liquid penetrant exam was performed. The first two beads exhibited several indications. These indications were ground into and additional ones found. The entire volume represented by these two beads were then ground out, (See photo 19, Appendix III) and replaced with good material.

Now that the weldability (poor wetting - heavy oxide) problem had been traced to wire surface quality, a stepped up visual inspection of wire surface quality was instituted to prevent additional repairs. This inspection noted several spools of the same heat/lot to have this surface problem where as the majority did not. The surface problem was very intermittent without any pattern. An entire spool might be defective or only a few inches, a few wraps be defective and those inches or wraps would be found any where on the spool. Cross sections of good and bad wire (same heat/lot) were cut, mounted and polished for microscopic examination which confirmed the problem. (See photos 25 and 26, Appendix III).

In order to produce a smooth transition from the nozzle shape to the safe-end, it was necessary to "step" each layer into the existing radius joining the 45 sloped nozzle reinforcement and the weld prep extension. This transition is necessary so the overlay will not induce piping reactions into the radiused region of the nozzle causing fatigue. This meant that the last layer would have to have a temper bead technique which could soften the toe tie in area. Temper beads were deposited 1/32 to 1/16" from the toe tie in without the use of filler and decreasing heat input. This technique is the same as "Flame Softening" except thru the use of the mechanized GTAW process. (See W.O. H5224, Appendix IV for details).

Upon overlay completion and grinding for ISI UT inspection, the overlay was ultrasonic and liquid penetrant inspected. No defects were found.

Test Results:

Code Case Groove Weld: PQR 7673 (Appendix V) lists all mechanical results including hardness, nil ductility temperature, tensile strength levels, etc. The results meet the requirements of Code Case N-432. A 1" deep (or less) weld repair could be made utilizing a welding procedure which incorporates these techniques.

Weld Overlay: PQR 7718 (Appendix V) list all mechanical results for the non-water backed overlay. PQR 7719 lists the results for the water-backed overlay. Both PQR's exhibit good notch toughness levels in the HAZ. This toughness level is similar to that of the HAZ impact strength of the Code Case Groove.

The non-water backed overlay exhibited lower hardness levels in the toe tie region than either the Code Case groove or water backed overlay, which exhibited hardness of 380 to 410 Hv-10. The non-water backed overlay also exhibited a hard zone in the HAZ at a location slightly removed from the toe tie. In general this region was 400 to 435 Hv-10. This area became suspect when etched for determining the HAZ region. As the welds were made 360 orbital and no similar condition was found on the water backed hardness samples, it is thought that the interpass temperature may have allowed a greater portion of the HAZ to transform into a harder microstructure.

As the Code Case groove had also exhibited hardness in excess of 400 Hv-10, a small sample was "temper beaded" to see the effects of this technique. A supplement to W.O. H5173 was prepared to perform this technique and testing. After temper beading, the toe of the groove hardness dropped approximately 30 to 50 Hv-10. A suspect region further away from the nozzle surface however, increased in hardness by the same amount. (See W.O. 5173 Appendix IV).

In reviewing all hardness data, it appears the HAZ will range from 375 to 400 Hv-10 with some locations reaching 435 Hv-10. These hardness ranges are probably typical of the SA508-Cl. 2 material when welded in this manner. Forgings, especially in this shape, are noted for non-uniform properties. Specimen location may account for some of the scatter seen in the hardness results, but the fact remains that the hardest location is not at the toe of the weld within 1mm of the surface but at a depth of 3/16 to 1/4" within 1 to 2mm of the fusion line.

Conclusions:

1. Mechanized orbital GTAW welding can be performed on SA508-Cl. 2 nozzle materials with and without preheat or post heat and achieve/maintain material properties which are notch tough and ductile at NDT plus 60 F.

2. An additional heat sink of water backing during welding appears to have no adverse affects and may be more beneficial as lower hardness (ave) was achieved versus the with and without preheat conditions.

3. Equivalent results were obtained in comparing the three conditions which should allow the use of any method investigated to overlay the nozzle to safe-end joint.

4. No HAZ cracking was observed in any cross-section, tensile, or bend specimen despite hardnesses exceeding 425 Hv-10, indicating a lack of sufficient hydrogen being absorbed during the welding. The use of the GTAW process provides the lowest hydrogen levels of the commonly used process (SMAW, SAW, GMAW), plus the use of Inconel filler allows any remaining hydrogen to be absorbed in the weld deposit rather than into the HAZ.

5. Notch toughness at +20 F in the HAZ equaled or exceeded forging base material toughness at that location and depth. (Base material toughness varies with depth from quenched surface and location within the forging envelope).

6. Filler material can vary within a single heat/lot and within a single spool due to drawing process control problems. Wire surface quality has to be smooth and without laps, tears, seams, etc. or weldability problems of poor wetting, heavy oxides (slagging) and inclusions will occur.

7. Full structural overlays covering the nozzle to safe-end weld can be temper-beaded at the toe tie in points without the use of filler and obtain similar hardness and impact strength levels to that of Code Case N-432.

8. Hardness levels or 350 Hv 10 mean average were not achieved using either stringer beads or weave beads with temper techniques. Typical 380-400 Hv-10 mean average was achieved is probably more realistic than the 350 Hv-10 levels desired.

9. Code Case N-432 requirements to use stringer beads does not yield superior HAZ impact or hardness levels when compared to a weave technique.

Recommendations:

1. These techniques should be used with caution. Welders should be trained on mock-ups to assure the technique used can be done under simulated plant conditions prior to doing the actual work.

2. Even though in-plant dry well conditions are usually hot (+80 F) and dry, reactors filled with water tend to have condensation form on the outside surfaces. Surfaces to be welded upon should be wiped with Acetone to remove surface moisture prior to welding, when using the non-preheated condition.

3. These water backed and non-preheated conditions should be done using ERNiCr-3 (Inconel) filler only. The use of ER309L, etc. is not recommended due to the coefficient of linear expansion of the austenitic stainless steel filler materials. Overlay deposits of these types can cause thermal fatigue.

NOZZLE TO SAFE-END

STRUCTURAL OVERLAY QUALIFICATION TEST PROGRAM

1.0 Purpose of Test:

The purpose of this test program is to qualify a non-water-backed and water-backed structural overlay procedure which could be utilized in the reinforcement of ASME Section III, Class 1, reactor nozzles and safe-ends which have in-service generated flaws in the weld joining the nozzle to the safe-end.

2.0 Objectives of Test:

The objectives of this test program is to:

1) Produce a procedure qualification meeting ASME Code Case N-432 to establish base-line material properties.

2) Produce a non-water-backed and water-backed overlay, which upon destructive testing, will yield similar material properties.

3) Serve as a model for future qualifications.

4) Provide sufficient technical data to allow in-service repairs to nozzle to safe-end welds by structurally reinforcing the affected area by overlay welding with and without water in the affected nozzle/safe-end.

3.0 References:

3.1 ASME Code Case N-432

3.2 ASME Section XI, 1986 Edition, No Addenda

3.3 ASME Section III, 1986 Edition, No Addenda

3.4 ASME, Section V, 1986 Edition, No Addenda

3.5 ASME Section IX, 1986 Edition, No Addenda

3.6 "Alternatives to 1/2 Bead Repair Technique (GTAW)" by P.J. Alberry and J. G. Feldsten - Maintenance Welding in Nuclear Power Plants/III, conference paper November 1985.

3.7 Test Assembly Drawing

3.8 73-C124 Nozzle FN2-1-5 Certified Test Report

3.0 References: (Continued)

3.9 Drawing ER420 Rev. 1, Contract 34541 - Safe-End Details

3.10 Nozzle to Safe-End Weld Sequence and Parameters.

4.0 Test Materials:

The materials to be utilized in this test program are:

1) An SA508 Class II forging which was salvaged from a cancelled 238" boiling water reactor. This forging has the following fabrication history:

a) Weld prep buttered by the SMAW process using Inconel 182 electrodes.

b) Nozzle to shell welded complete into the shell ring.

c) The nozzle and butter have been PWHT'd at 1150°F for a total time of 10 - 14 hours. (Fabrication records destroyed - Typical time for manufacturing cycle).

d) Additional SMAW Inconel butter applied and new weld prep made (20°J prep).

e) Safe-end to nozzle weld made by orbital GTAW process using Inconel 82 filler.

f) Weld joining safe-end to nozzle has been IHSI treated for test/qualification purposes.

2) An A312 type 304L "Built Up," "Tuning Fork" design safe-end.

3) Inconel 82 filler materials, .023", .035" and .045"Ø.

5.0 Post Weld Heat Treatment:

As most reactors in operation to which this test program could be applicable have nozzles with fabrication histories which have 20 to 30 hours total PWHT time, the test assembly shall be PWHT at 1150°F ± 25°F for 24 hours mininum prior to any welding. This heat treatment should also relax any induced stresses by the IHSI testing.

6.0 Consideration of Restraint:

Both Code Case N-432 and ASME Section III, NB-4321(c) require consideration of restraint in procedure qualification. The location of the groove weld meets C.C. N-432 requirements for self restraint by having sufficient material thickness surrounding the cavity to be welded.

Code Case N-432, para. 2.1(e) allows the assembly to qualify weld buildup procedures provided the cavity is not less than the thickness of the weld buildup or 1 in whichever is greater. As most safe-ends are 1 to 1-3/16" thick, and standard designed overlays are slightly less than wall thickness (for thru-wall cracks -360°), A 1" minimum depth groove shall be used.

As the overlay will be applied to a full scale mock-up containing actual materials and typical geometry,restraint that will be encountered on nozzles in service should be similar.

To minimize any stiffening effects of the wet/dry interface divider plate, the plate shall be made from thin guage material which allows the nozzle and safe-end to band in due to the expected weld shrinkage. (See Assembly Drawing).

7.0 Test Specimen Locations:

All destructive test specimens shall be as located on the test assembly drawings. It must be noted that test specimens may or may not comply with ASME Section III, NB-4334.2(a) due to the orientation of the groove weld and overlay reinforcement weld. For purposes of this test program, the test samples are taken at similar depths from the O.D. surface of the forging and transverse to the axis of the welds.

8.0 Reference Nil Ductility Transition Temperature RT NDT:

For the forging involved, the actual nil ductility transition temperature as established by the nozzle forger using drop weight test is -30°F. Per Code Case N-432, the test temperature for Charpy "V" notch impact testing shall be (RT NDT +60°F), +30°F.

9.0 Remote Sensing:

As most in-service nozzles and safe-ends are in high radiation fields which require video remote controlled welding, all welding will be performed using pulsed GTAW welding equipment with remote viewing of the arc and deposit using closed circuit video systems. A Dimetrics Gold Track II welding system utilizing a "G" weld head and color video system shall be used to deposit all welds.

10.0 Test Program Operation Sequence:

10.1 Test assembly preparation for Welding:

10.1.1 Burn excess shell material from forging.

10.1.2 Machine excess forging material to required dimensions.

10.1.3 Machine Code Case cavity in forging hub to required dimensions.

10.1.4 PWHT assembly for 24 hours minimum at 1150°F ± 25°F.

10.1.5 Clean all surfaces of scale, rust, etc. by wire brushing or sandblasting. Care must be taken to protect the Inconel weld and stainless safe-end from iron contaminated brushes or sandblast effects. Use only stainless steel brushes on the safe-end and weld.

10.1.6 Layout reference lines for specimen removal and dimensional checks.

10.1.7 Take as-builts of test assembly prior to welding.

10.1.8 Install wet/dry divider plate and thermocouples.

10.2 Code Case N-432 Welding:

10.2.1 The groove shall be welded with stringer bead welding with heat inputs ranging from 20 to 40 K Joules/in. of deposit. Additionally, the wire feed speeds shall be controlled to allow deposits to be made within the 1.25 to 2.0 megajoule range.

10.2.2 The groove shall be filled with the required layer sequence of C.C. N-432, Fig. 1, using parameters meeting the Kilo Joule/ Mega Joule heat input limitations.

10.2.3 As more than 6 layers may be required for actual overlay, a minimum of 8 layers shall be deposited in the groove.

10.2 Code Case N-432 Welding: (Continued)

10.2.4 Preheat and post heat requirements shall be met using electrical heaters and recording instruments to monitor preheat, interpass and post heat temperatures. Thermocouples shall be attached by the thermal discharge method.

10.3 Non-Water-Backed And Water-Backed Overlay Welding:

10.3.1 After completion of the post heat operations, the assembly shall be filled with water internally and cooled to +40°F ± 5°F by circulating the water and/or adding ice.

10.3.2 Once the assembly has been cooled to +40°F, water in the annulus space between the thermal sleeve and nozzle wall shall be allowed to become stagnent, water may be flowed through the thermal sleeve and safe-end as necessary to maintain +40° ± 5°F for the water backed portion only during welding.

10.3.3 Overlay welding shall be accomplished using a weave technique and heat inputs ranging from 20 to 40 KJoules/in. Additionally, wire feed speeds shall be controlled to make deposits within a 1.25 to 2.0 Megajoule range. Weld beads shall be alternately deposited. Clockwise, counter clockwise 360°, to allow impact specimens to be taken from the vertical position.

10.3.4 Care shall be taken to deposit the overlay in such a manner to produce a smooth transition in the crotch section of the forging.

10.3.5 Temperature monitoring of forging shall be done during all welding.

11.0 Required Non-Destructive Examinations*

* All nondestructive examinations shall be performed to meet ASME Section V, 1986 Edition, No Addenda Techniques.

11.1 Code Case Groove Weld:

11.1.1 Magnetic Particle:

MT inspect the groove surfaces and 1" either side of the groove prior to welding.

11.1 Code Case Groove Weld: (Continued)

11.1.1 Magnetic Particle:

MT inspect the groove surfaces and 1" either side of the groove prior to welding.

11.1.2 Liquid Penetrant:

a) PT inspect the groove surfaces plus 1" either side of the groove prior to welding.

b) PT first layer deposited in groove.

c) PT final surface of completed weld prior to destructive sample removal.

11.1.3 Ultrasonic:

a) UT inspect the groove and machined hub area to a depth of 2" from the machined surface using focused longitudinal inspection techniques.

b) UT inspect the final weld.

11.2 Non-Water-Backed And Water-Backed Overlay Weld:

11.2.1 Magnetic Particle:

MT surface of SA508 Cl II forging which is to be overlayed plus 1".

11.2.2 Liquid Penetrant:

a) PT entire surface of forging and safe-end to be overlayed plus 1" prior to overlaying.

b) PT first layer deposited plus 1" additional.

c) PT final surface deposited plus 1" additional.

11.2.3 Ultrasonic:

a) UT inspect the volume to be overlayed using focused longitudinal inspection techniques.

b) UT inspect the final deposit.

11.3 Surfaces to be inspected may be ground, cleaned, buffed as necessary to obtain meaningful examinations.

11.4 Acceptance criteria for the examinations shall meet ASME Section III, Subsection NB-5000 for the method used.

12.0 Destructive Examinations:

12.1 Code Case Groove Weld:

12.1.1 Tensile Tests:

a) 2 transverse .505"Ø tensiles.
b) 2 all weld metal .505"Ø tensiles

12.1.2 Bend Tests:

a) 4 transverse side bends

12.1.3 Drop Weight Tests:

a) 6 - P-2 specimens for base metal (assumed to be -30°F per CTR)

12.1.4 Charpy "V" Notch Impacts:

All impact specimens shall be removed from the maximum depth practical and tested at T NDT +60°F temperature for HAZ and unaffected base material. A minimum of 3 HAZ and 3 base metal specimens shall be tested.

12.1.5 Hardness tests (Vickers Hv 10):

a) A minimum of 3 cross sections shall be cut and prepared for hardness surveys.

b) Each cross section shall have a minimum of 3 hardness transverses in the HAZ, 2 at the surface (left and right of groove centerline) and 1 at the deepest point of the repair.

12.2 Non-Water-Backed And Water-Backed Overlay Weld: (Tests required for each condition)

12.2.1 Tensile Tests:

a) 2 transverse all weld metal .505"Ø tensiles of the overlay deposit.

12.2 Non-Water-Backed and Water-Backed Overlay Weld: (Continued)

12.2.2 Bend Tests:

a) 4 transverse side bends. Centerline of bends to include the HAZ of the SA508 Cl. II forging at the toe of the overlay.

12.2.3 Charpy "V" Notch Impacts:

a) All impact specimens shall be removed at the maximum depth possible and tested at T NDT +60°F temperature. A minimum of 3 HAZ and 3 base metal specimens shall be tested.

12.2.4 Hardness Tests (Vickers Hv 10):

a) A minimum of 3 cross sections shall be cut and prepared for hardness surveys.

b) Each cross section shall have a minimum of 3 hardness transverses in the HAZ. One shall be taken near the toe of the overlay, near the surface of the overlay. One shall be taken near the bottom of the overlay, in the curved crotch section of the forging. One shall be taken at random at the bottom of the overlay near the HAZ of the nozzle butter.

13.0 Metallurgical Examinations:

Random microstructure examinations of the SA508 Cl II forging shall be performed on the HAZ of both the Code Case groove and weld overlay welds. The examinations shall be done on each cross section prepared for hardness testing. A minimum of 3 examinations per cross section is required. The exams shall be located near the required hardness transverses. Magnification shall be sufficient to identify the HAZ micro-structure present.

Photographs shall be taken of the typical micro-structures.

14.0 Acceptance Criteria of Test Program

14.1 Code Case N-432 Welding:

14.1.1 Mechanical Testing data shall meet the requirements of C.C. N-432 applicable Section III and IX welding procedure qualification requirements.

14.1.2 HAZ hardness shall meet 350 Hv10 or lower, as measured and calculated for mean hardness level. Peak hardness shall not exceed 390.

14.2 Non-Water-Backed and Water-Backed Overlay Welding

14.2.1 Mechanical test data shall meet the requirements of 14.1.1.

14.2.2 HAZ hardness shall meet the requirements of 14.1.2.

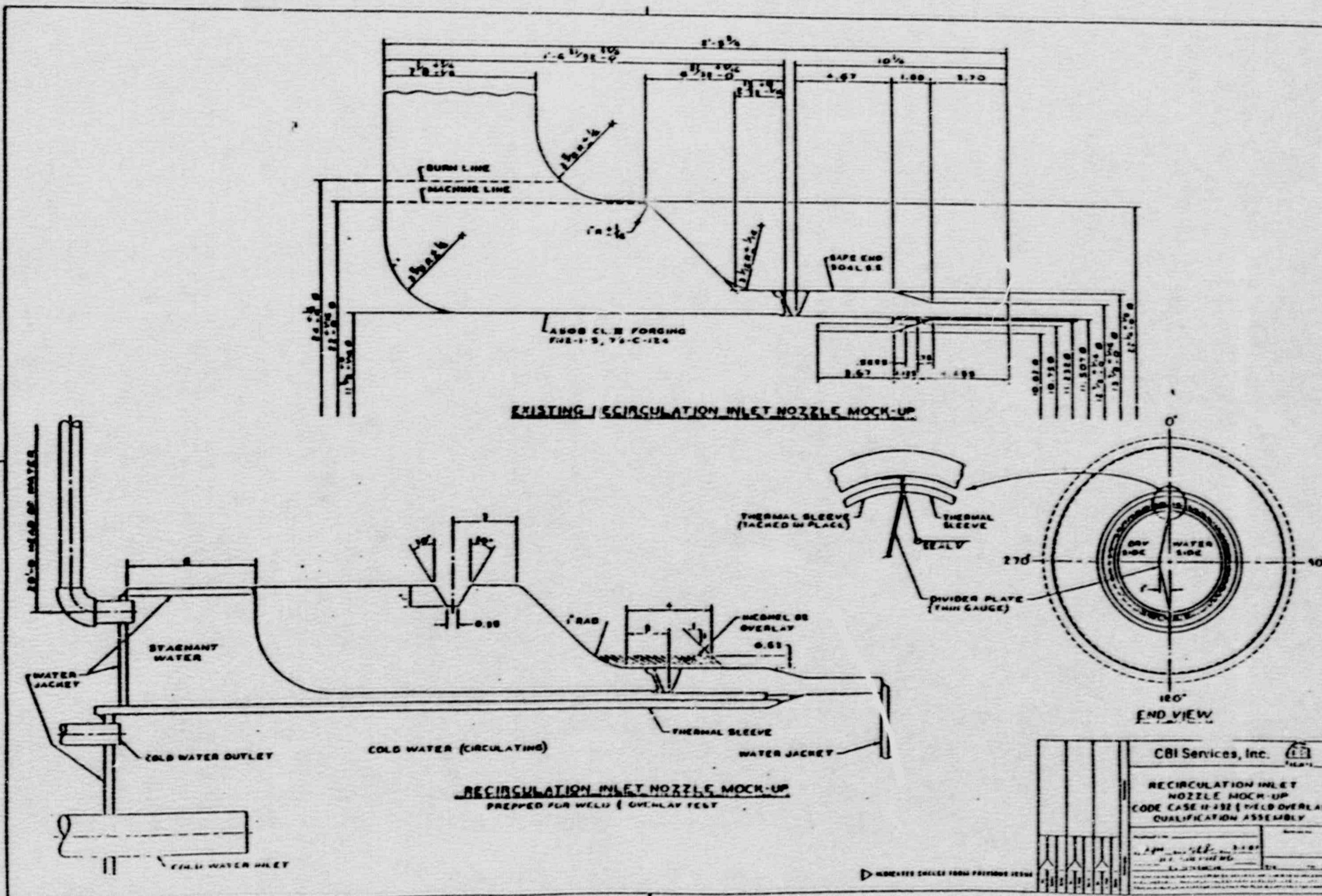
Appendix II

List Of Drawings

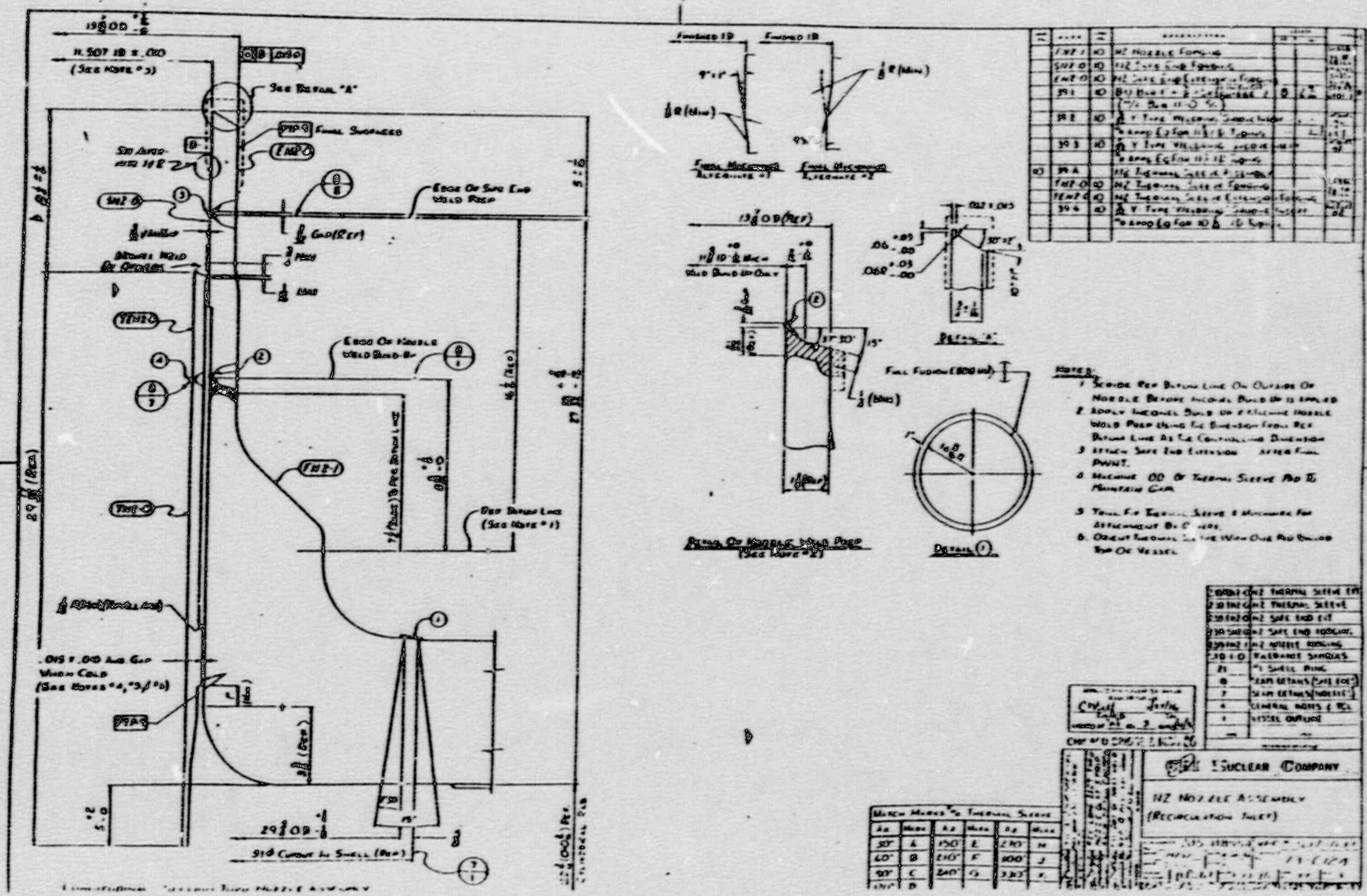
1. Recirculation Inlet Nozzle Mock-up
   Code Case N-432 & Weld Overlay Qualification Assembly

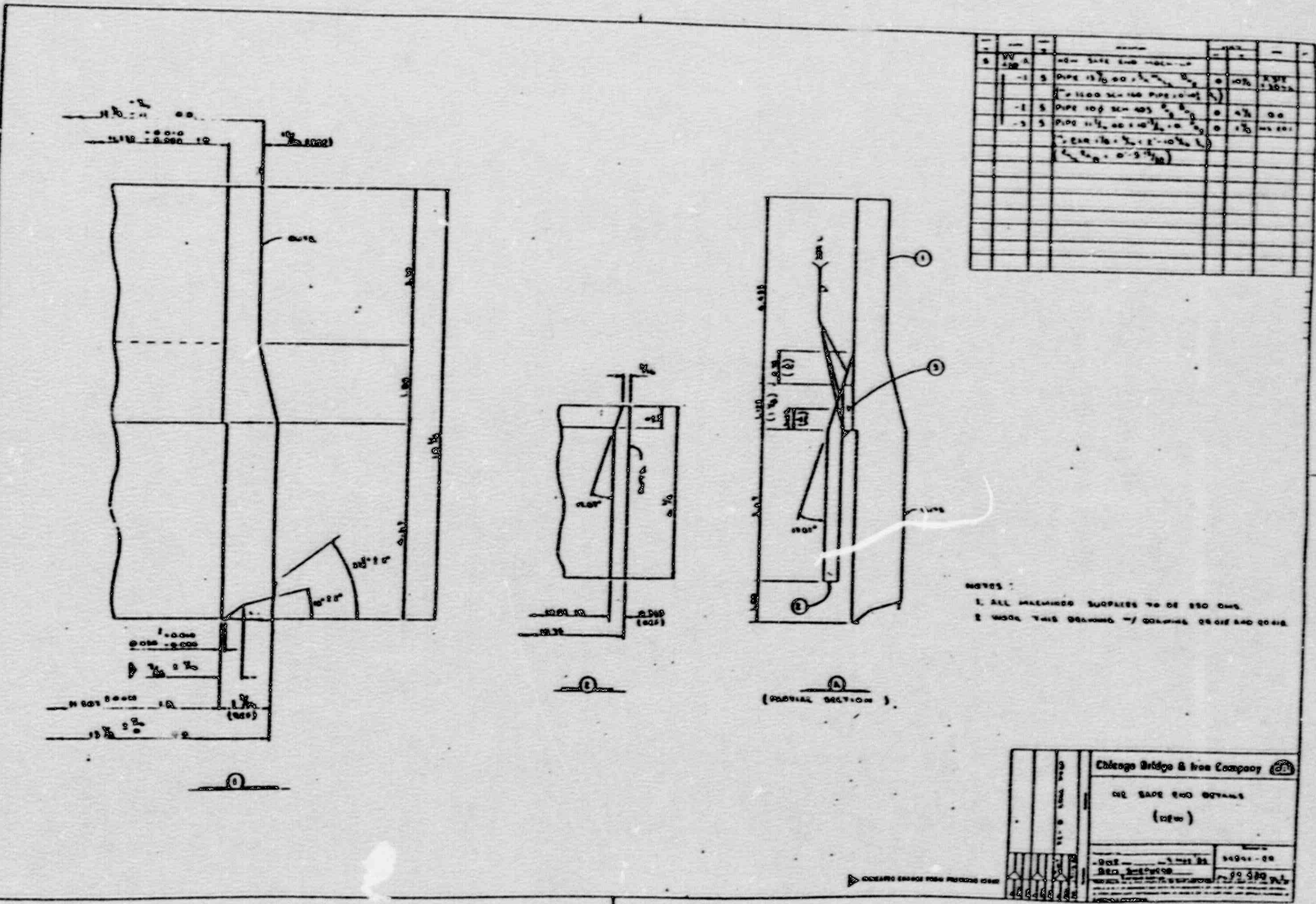
2. N2 Nozzle Assembly Contract 73-6124

3. N2 Safe-End Details   Dwg. ER420   Contract 34541



BURN LINE
MACHINE LINE
A508 CL. II FORGING
SAFE END
304L S.S.
EXISTING RECIRCULATION INLET NOZZLE MOCK-UP
THERMAL SLEEVE (TACKED IN PLACE)
THERMAL SLEEVE
SEAL
DIVIDER PLATE (THIN GAUGE)
DRY SIDE
WATER SIDE
0°
90°
180°
270°
END VIEW
STAGNANT WATER
WATER JACKET
COLD WATER OUTLET
COLD WATER (CIRCULATING)
INCONEL 82 OVERLAY
THERMAL SLEEVE
WATER JACKET
COLD WATER INLET
RECIRCULATION INLET NOZZLE MOCK-UP
PREPPED FOR WELD & OVERLAY TEST
CBI Services, Inc.
RECIRCULATION INLET
NOZZLE MOCK-UP
CODE CASE N-432 & WELD OVERLAY
QUALIFICATION ASSEMBLY


See Detail "A"
Final Surfaced
Edge Of Safe End Weld Prep
Edge Of Nozzle Weld Build-Up
Ref Datum Line (See Note # 1)
.015 ± .00 Avg Gap When Cold
Finished ID
Final Machining Alternate #1
Final Machining Alternate #2
Detail "A"
Detail Of Nozzle Weld Prep (See Note # 2)
Full Fusion (800 Ib)
Detail (1)
NOTES:
1 Scribe Ref Datum Line On Outside Of Nozzle Before Inconel Build Up Is Applied
2 Apply Inconel Build Up & Machine Nozzle Weld Prep Using The Dimension From Ref Datum Line As The Controlling Dimension
3 Attach Safe End Extension After Final PWHT.
4 Machine OD Of Thermal Sleeve And To Maintain Gap
5 Tack Fit Thermal Sleeve & Machine For Attachment By C
6. Orient Thermal Sleeve With Ove And Toward Top Of Vessel
N2 Thermal Sleeve
N2 Safe End Ext
N2 Safe End Forging
N2 Nozzle Forging
Tolerance Symbols
Shell Ring
Seam Details (Safe End)
Seam Details (Nozzle)
General Notes & TCL
Vessel Outline
Match Marks To Thermal Sleeve
Nuclear Company
N2 Nozzle Assembly
(Recirculation Inlet)



NOTES :

Chicago Bridge & Iron Company

Appendix III

List Of Photos

Photos

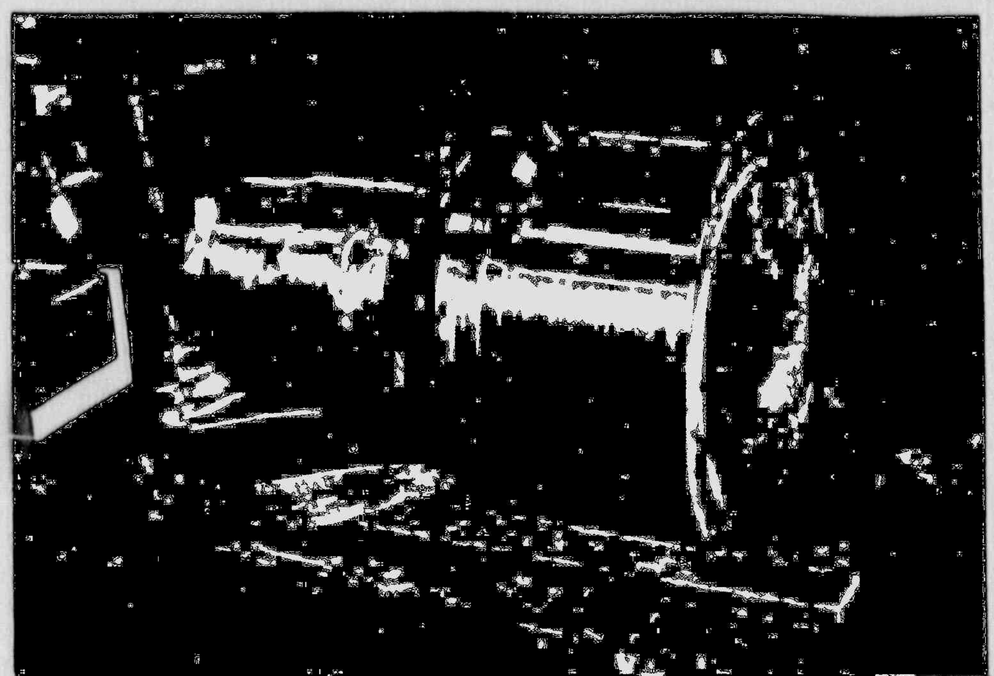


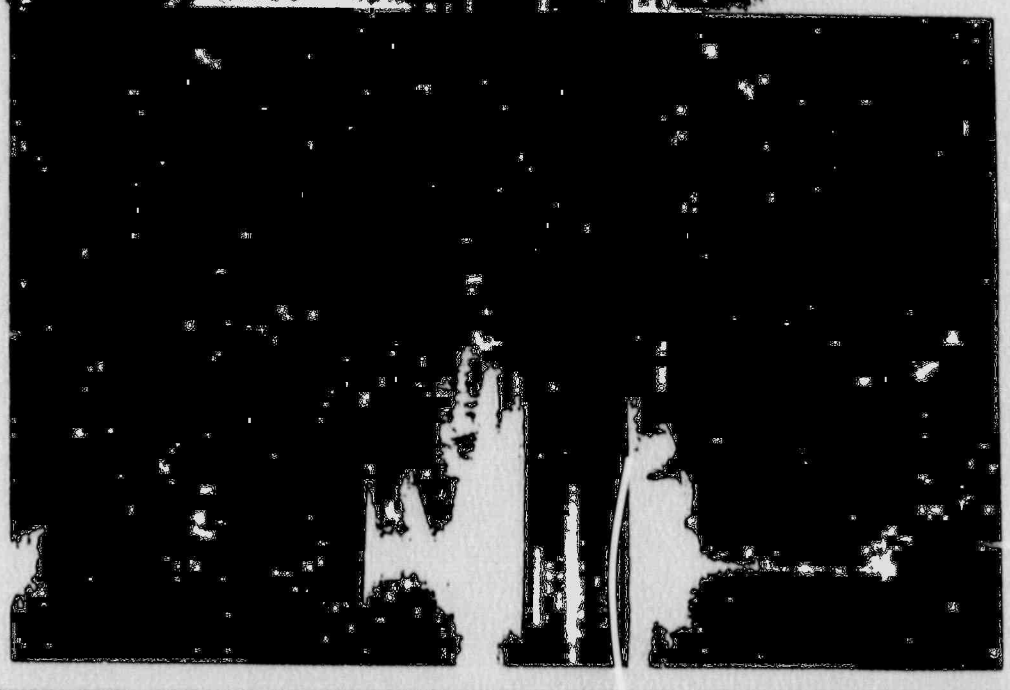
Photo 1

Photo 2

Photo 3

Photo 4

Photo 5



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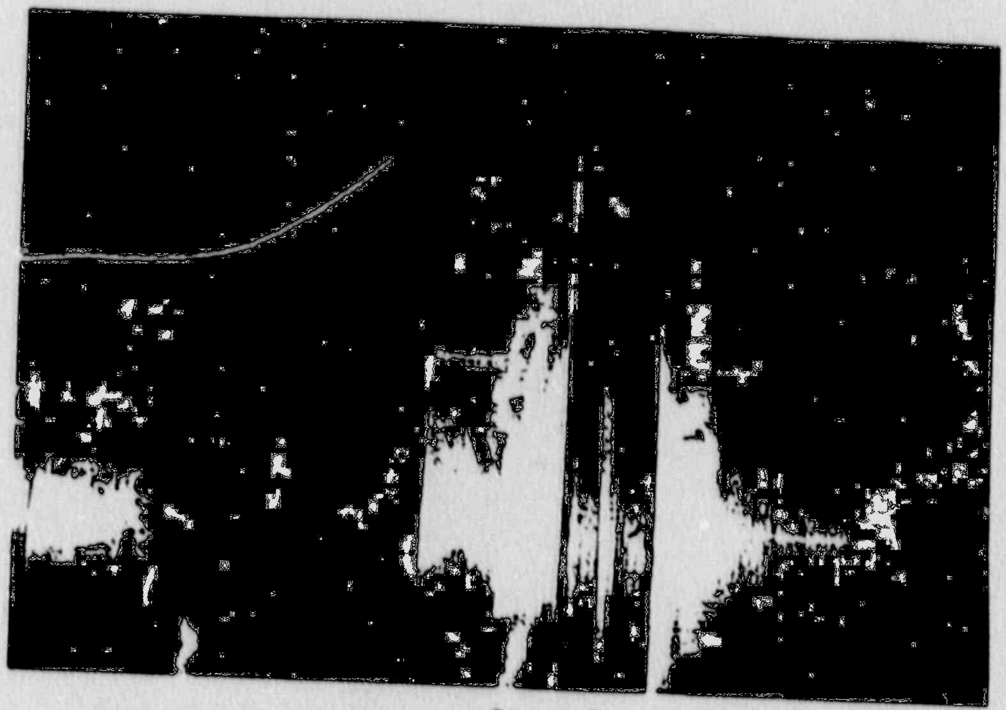

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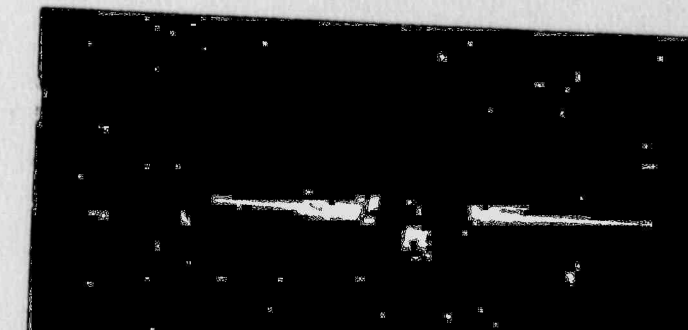

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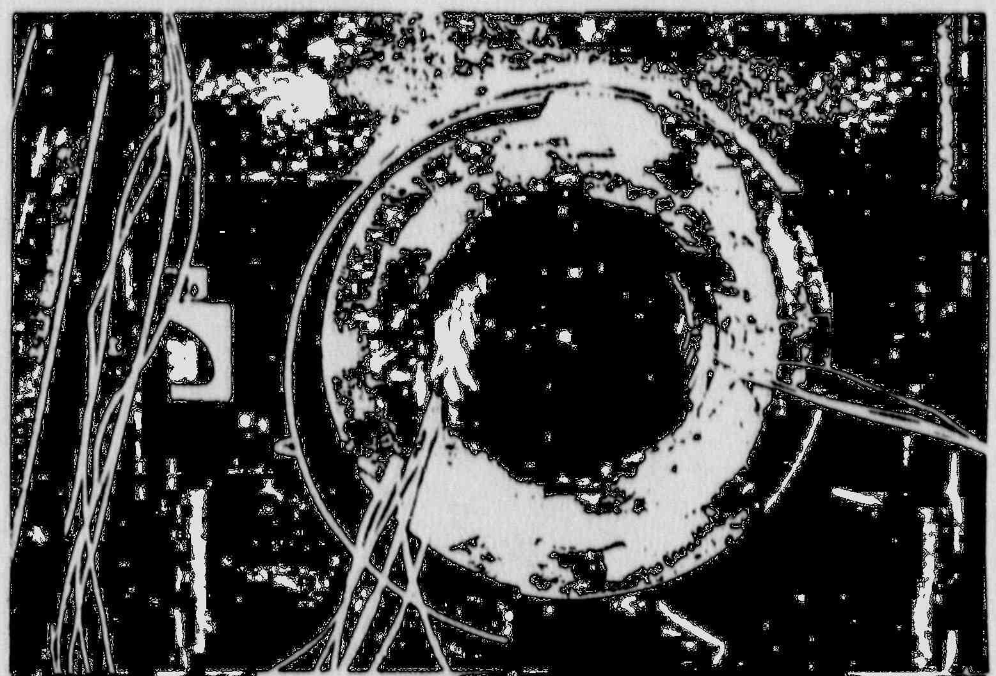
Photo 9



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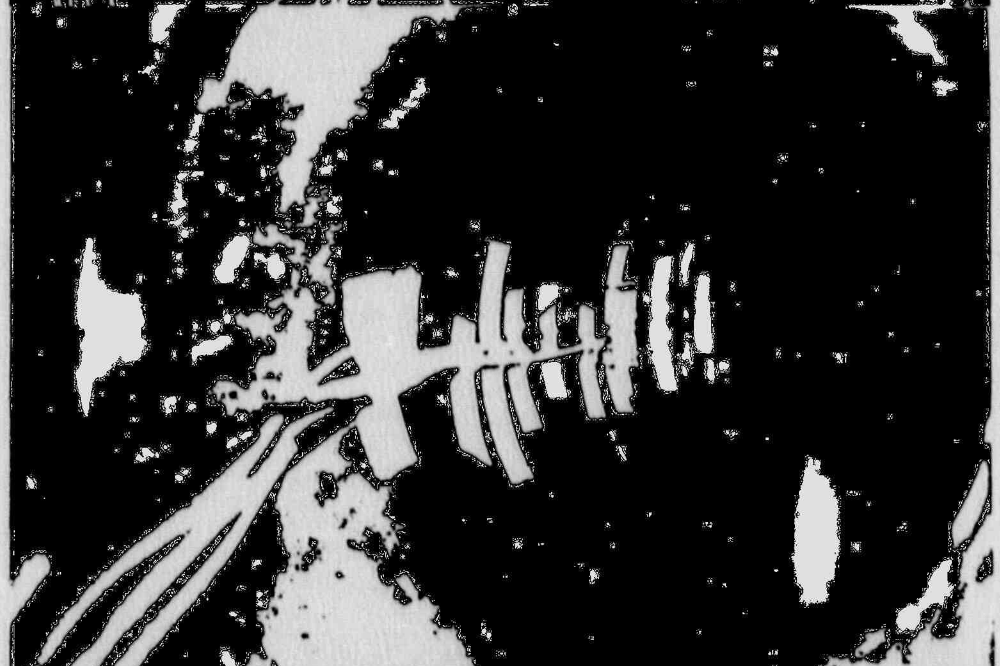

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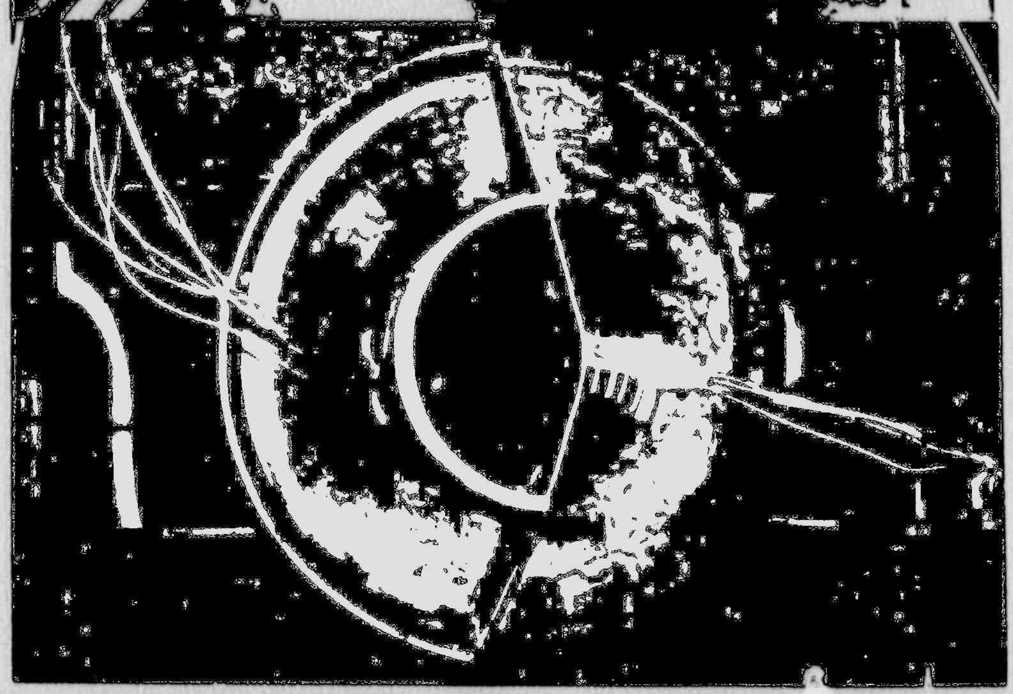

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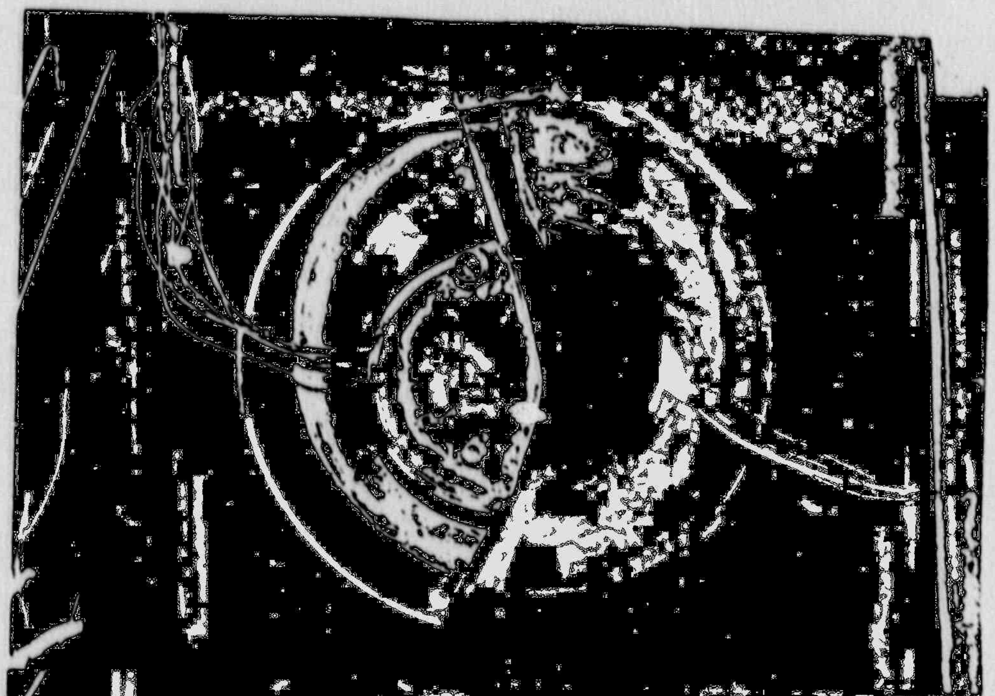
Photo 13



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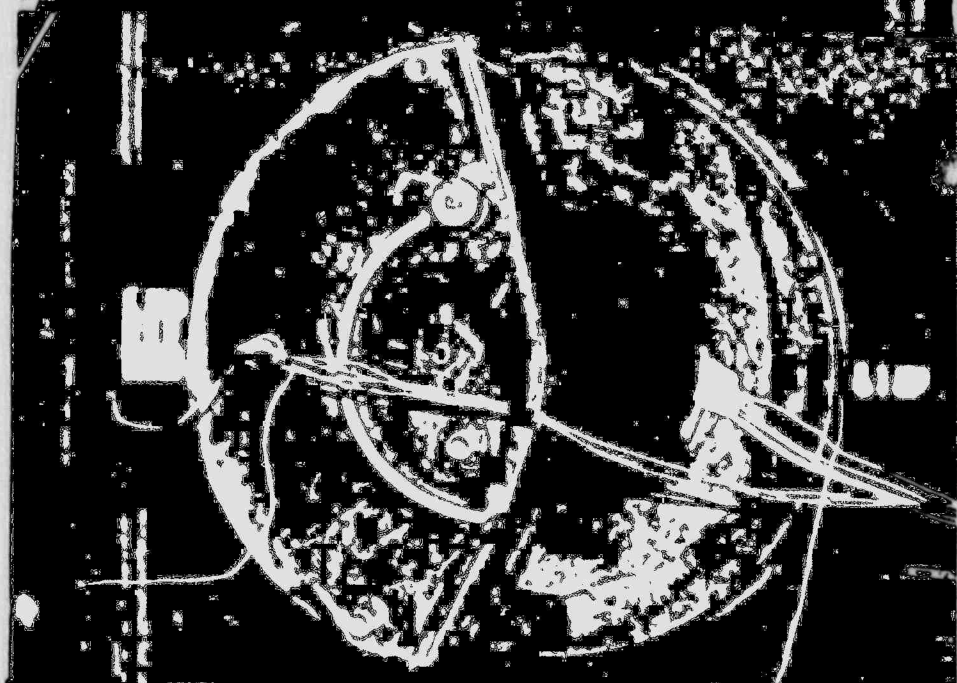
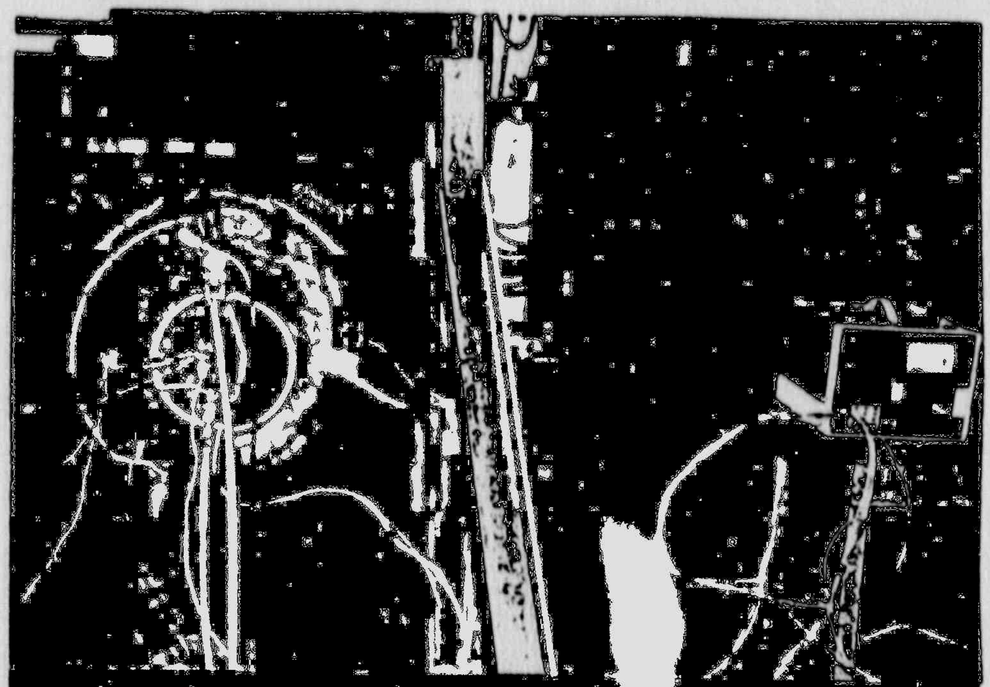


Photo 15

Photo 16



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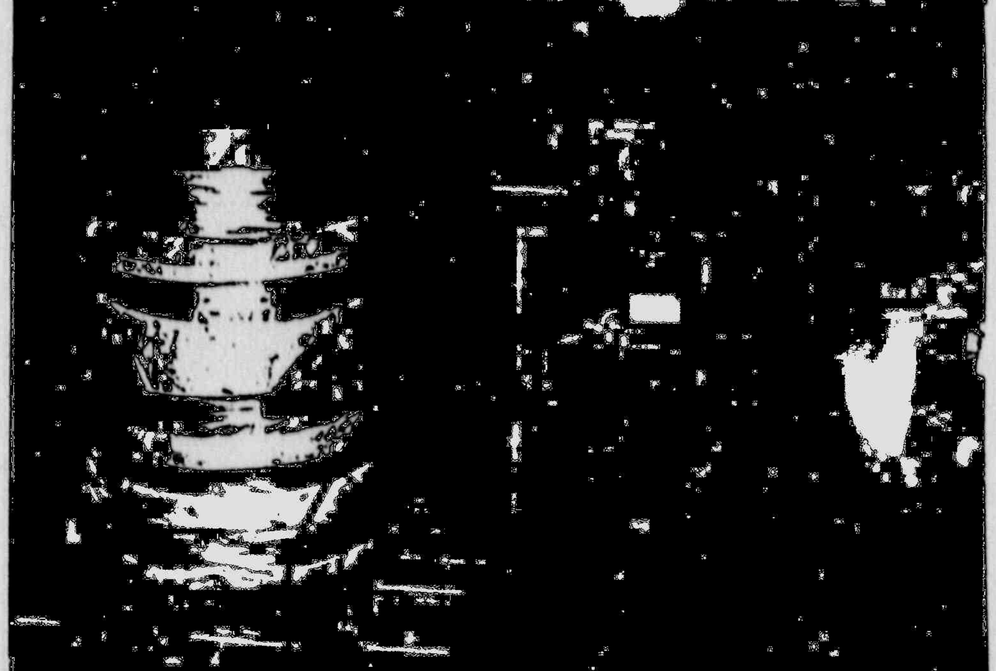

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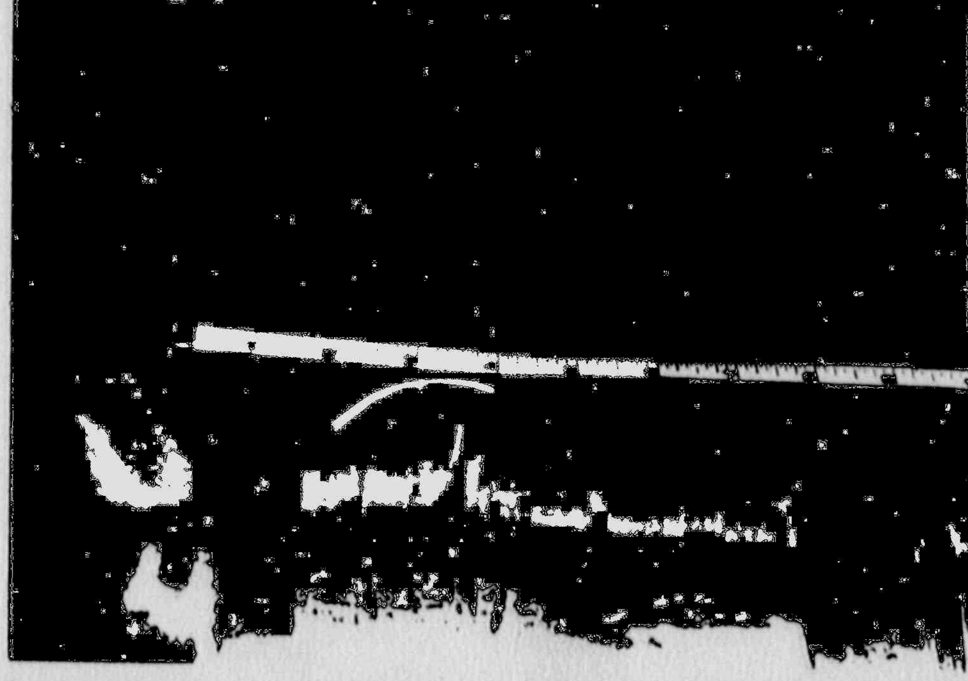

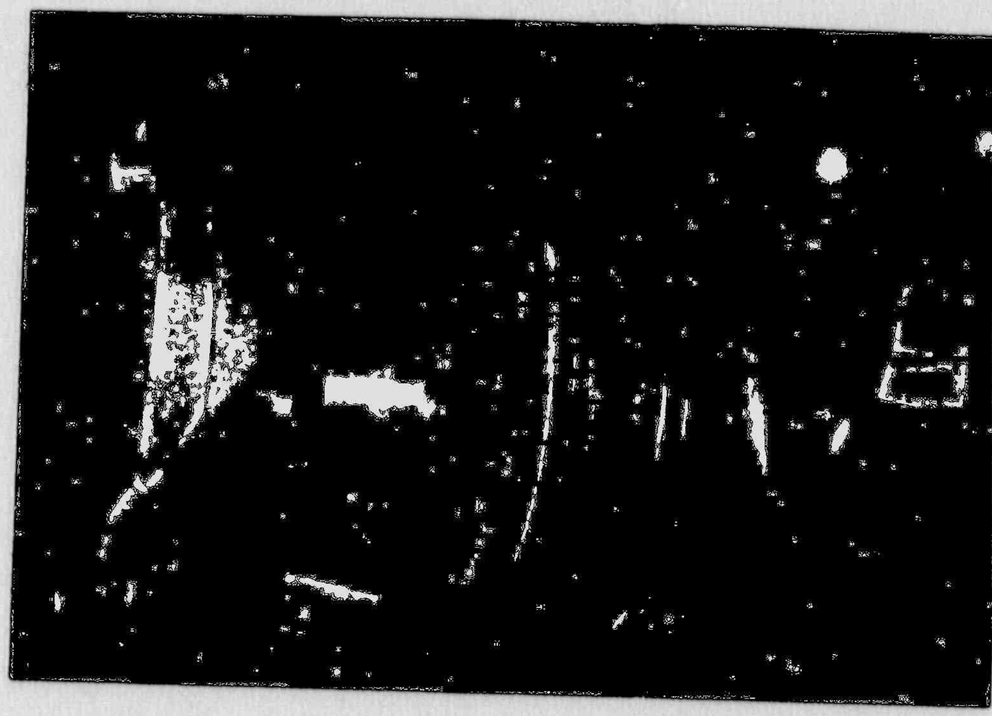

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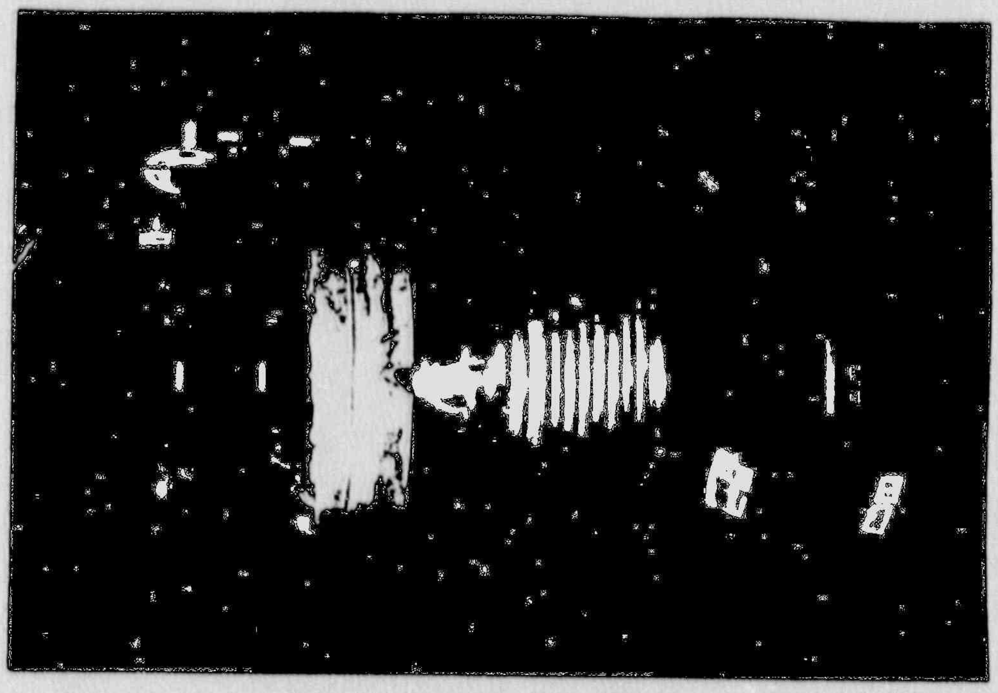
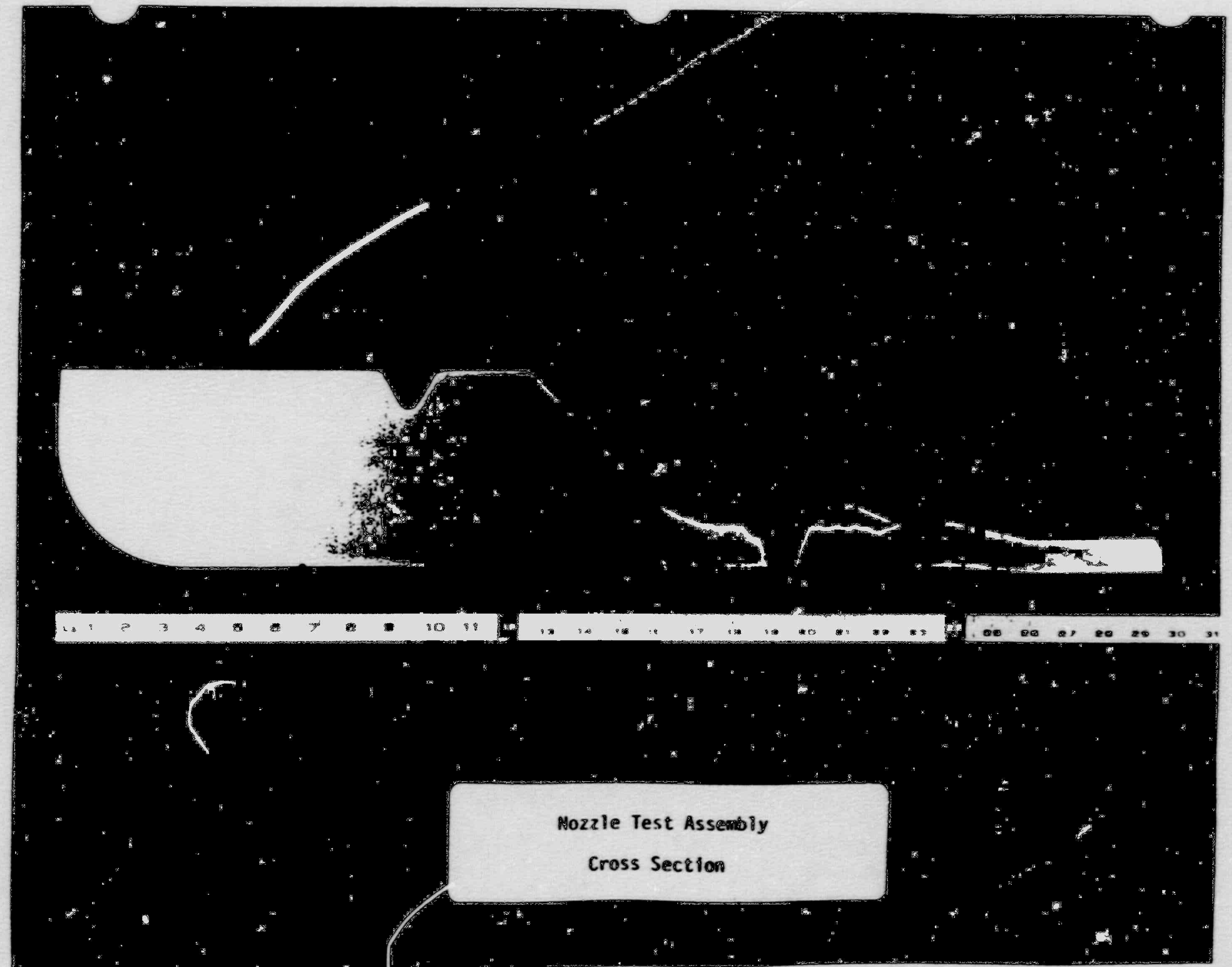


Photo 20

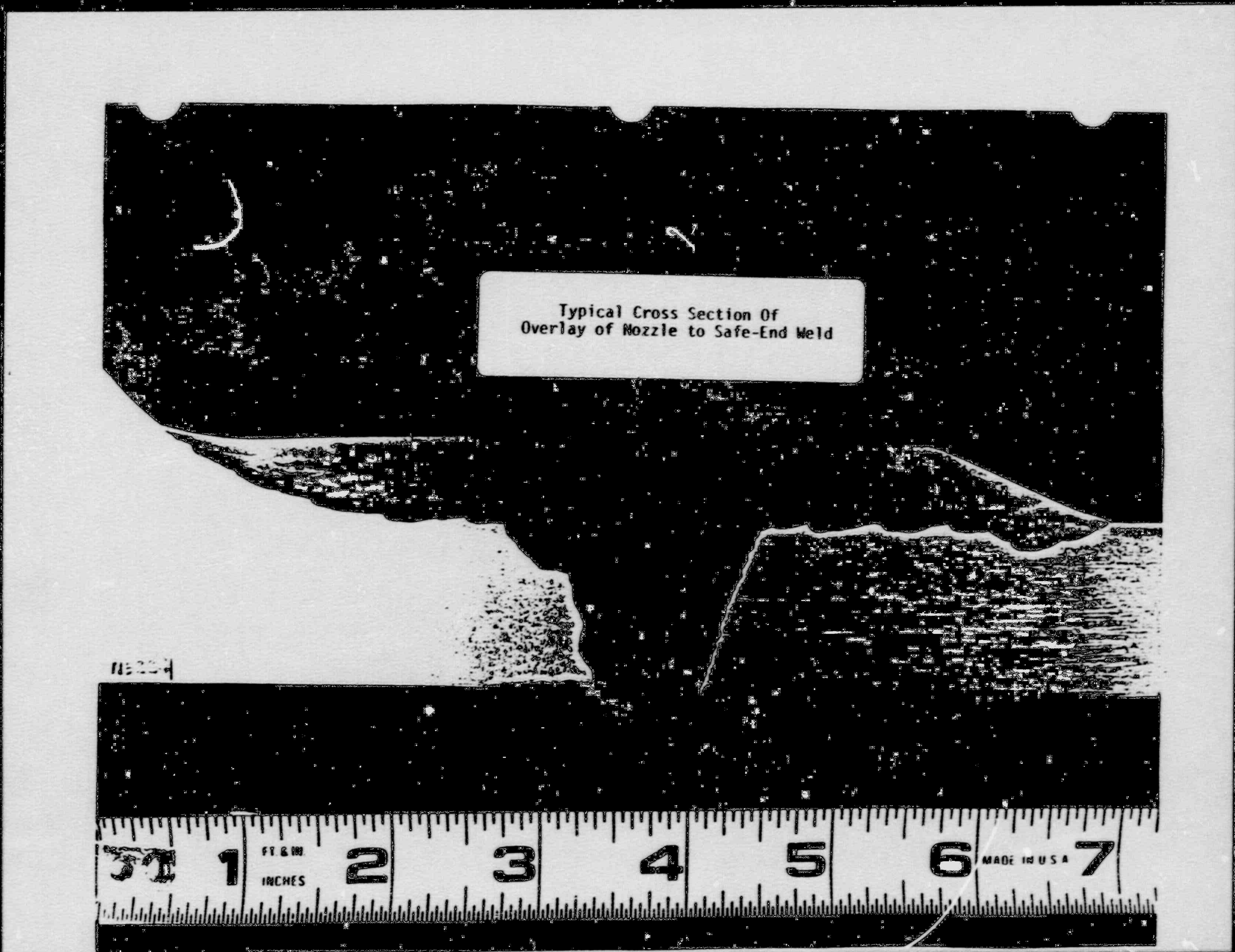
Photo 21



Nozzle Test Assembly

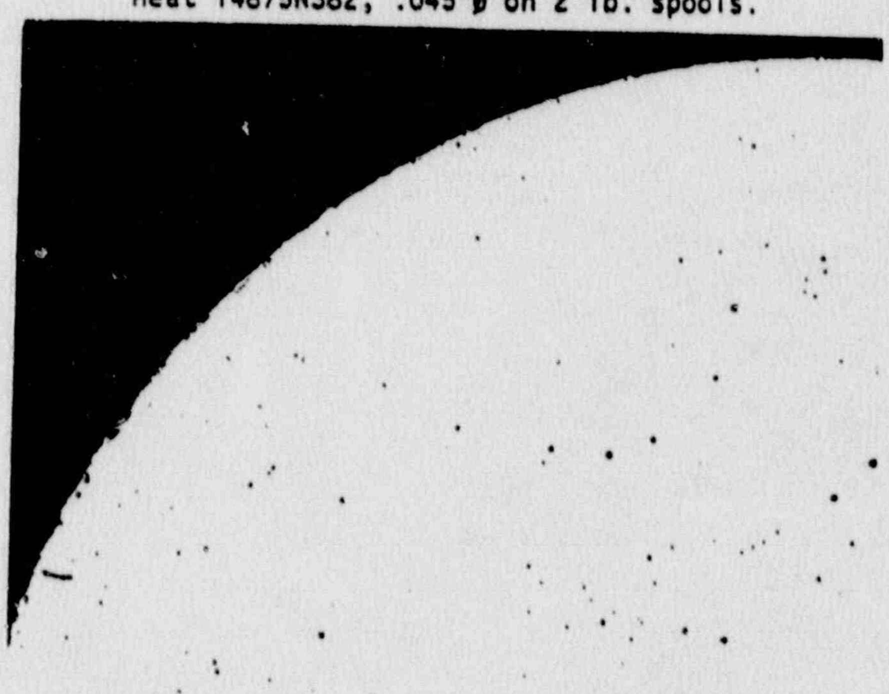
Cross Section


Typical Code Case Groove
Cross Section Showing
6 Layer Butter


Typical Cross Section Of
Overlay of Nozzle to Safe-End Weld
FT & IN
INCHES
MADE IN U S A

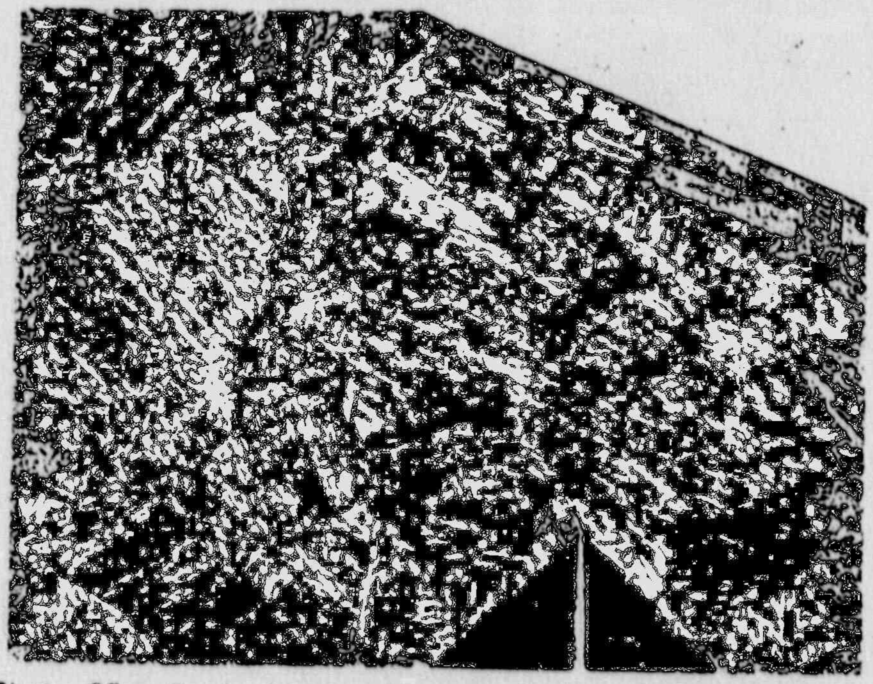
200X
No etch

Photo 25: Cross section of GTAW filler metal which caused unacceptable weld beads (heavy oxide, humped bead shape & inclusions). We believe the rough surface prevented sufficient cleaning of the wire during manufacture. The wire is ARCOS Type 382, Heat Y4875N382, .045"Ø on 2 lb. spools.



200X
No etch

Photo 26: Same heat of filler metal as above but from a different spool which had acceptable welds. Notice smooth surface.



Nital Etch
400X

W/O H5173

Specimen A

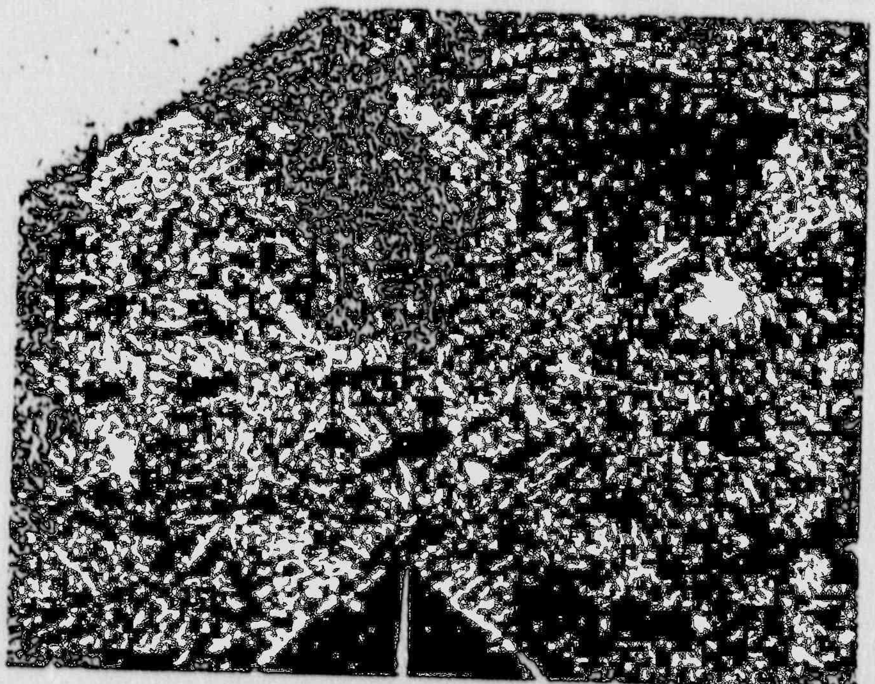
Photo 27: Typical HAZ microstructure near the surface of the code case repair groove weld (Identified as "right side" in hardness report). Weld/Fusionline is in upper right corner. The vickers hardness number of the impression in the photo is 408 HV 10kg.

Nital Etch
400X

W/O H5173

Specimen A

Photo 28: Same as above but on the other side of the groove(ID as " left side" in hardness report). The vickers hardness number of the impression in the photo is 386 HV 10kg.

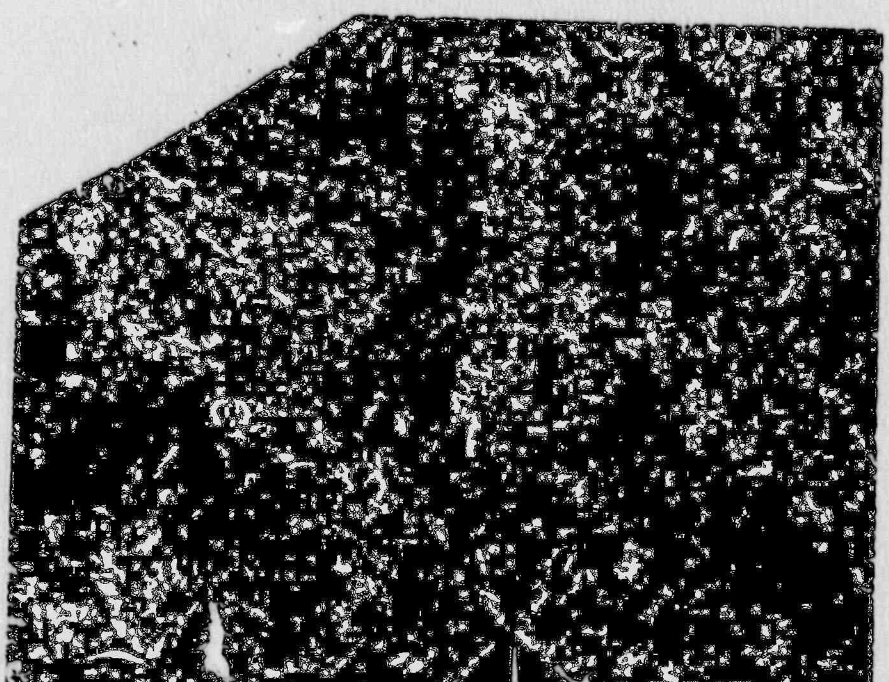


Nital Etch
400X

W/O H5173-Supp.

Specimen A - 1
(Before Temper
Bead)

Photo 29: Typical HAZ microstructure near the surface of the code case repair groove weld (ID is "leftside" in hardness report) before welding the temper beads. The weld/fusionline is in upper left corner. The vickers hardness number of the impression in the photo is 401 HV 10kg.

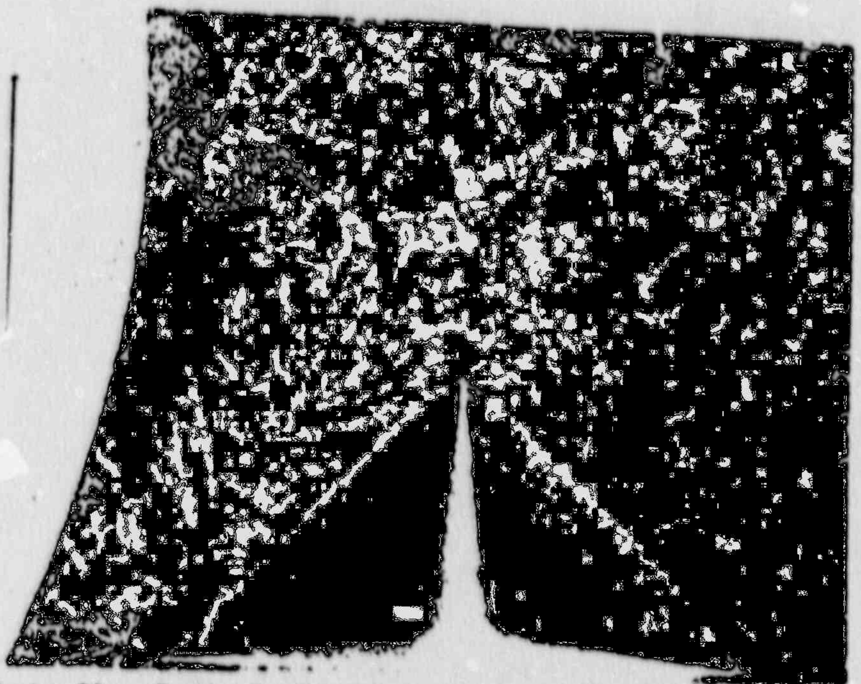


Nital Etch
400X

W/O H5173-Supp.

Specimen A-1
(After Temper
Bead)

Photo 30: Same location as above but after welding the temper beads. The vickers hardness number of the impression in the photo is 345 HV 10kg.

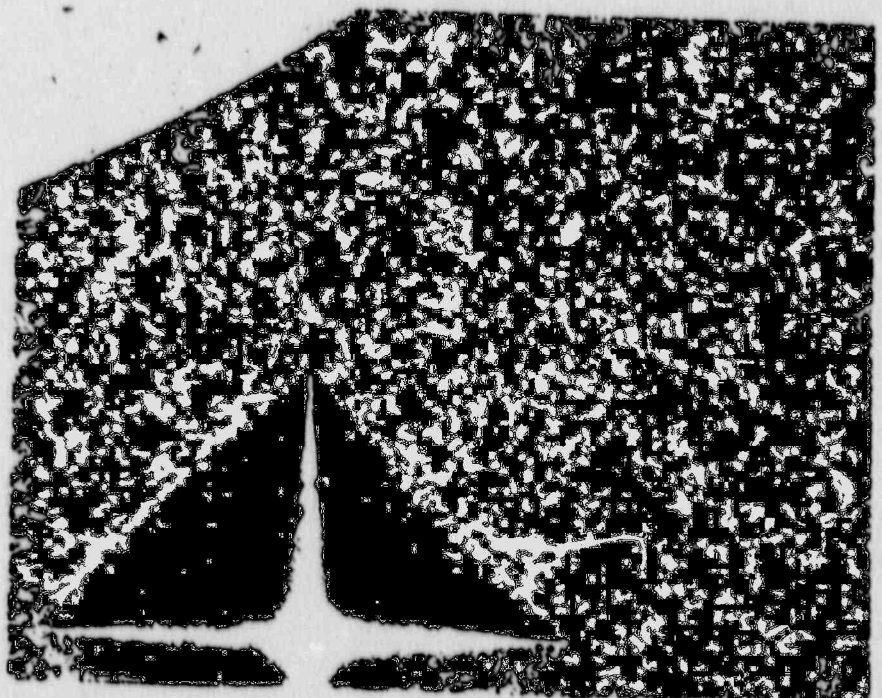


Nital Etch
400X

W/O H5224

Specimen D2

Photo 31: Typical HAZ microstructure near the surface of the SA508-CL2 at the toe of the overlay weld (Identified as "toe" in the hardness report). Weld/Fusionline is in upper left corner. Hardness number of the impression in the photo is 350 HV 10kg.



Nital Etch
400X

W/O H5224

Specimen D2

Photo 32: Same as above but at location "A-1" which has a harder HAZ. The vicker hardness number of the impression in the photo is 434 HV 10kg.

Appendix IV

List of Data

1. Material Test Report For Nozzle FN2-1-5
   Contract C73-C124 (2 pages)

2. Material Test Report For ERNiCr-3
   Electrode (Arcos) (1 Page)

3. Work Order H5173 Code Case Groove

4. Work Order H5224 Nozzle to Safe-End Overlay
   (Water Backed and Non-Water Backed)

5. Non-Destructive Examination Reports

   5.1 PT of overlay area prior to overlay.

   5.2 MT of Code Case groove prior to welding.

   5.3 UT of Code Case groove prior to welding.
   UT of overlay area prior to overlay.

   5.4 PT of finished groove and overlay after welding and blend grinding.

   5.5 UT of Code Case groove after welding and grinding .
   UT of overlay after welding and grinding.

S.O. No ¹¼-½ MATERIAL TE EPORT DATE August 8, 19 74

Purchaser ⌄ B I Nuclear Co. Purchaser's Order No. M10312-3 73-C124

Distributor Distributor's Order No.

ITEM NO.	QTY.	PRODUCT	SPEC.	HEAT OR CODE NO.	FORGING NO.	HEAT TREATMENT: L/F approved procedure HT-12, Rev. 4 Mod. 3	FCE. CHARTS ATTACHED YES	NO
2	2	N2 Nozzle Mark: FN2-1-4 & FN2-1-5	SA508-2 & CBIN Specs. MS-52.1 Rev. 7 & QAS -51, Rev.4	Q2QL4W Supplier Ht. No. 212800	573C 1 & 2	1650°F ±25°F for 7½ hr Air Cool 1560°F ±25°F for 7½ hr Water Quench 1290°F ±25°F for 7½ hr Air Cool Test were stress relieved as follows: 1150°F ±25°F for 50 hrs. L/F approved procedure SPWHT-101, Rev. 4		X

CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES

FORGING NO.	HEAT NO.	C	MN	P	S	SI	CR	NI	MO	V		Grain Size	NDT REPORTS ATTACHED U.T.	M.P.	D.P.	REMARKS
573C	Q2QL4W	.20	.69	.007	.012	.28	.37	.82	.63	.02	Ladle		X	X		Dropweight Testing
-1		.183	.720	.008	.015	.276	.37	.855	.57	.017	Check	7				Four (4) specimens -
-2		.183	.720	.008	.014	.276	.37	.86	.57	.018	Check	7 - 8				Two (2) each @180°
-3		.192	.730	.008	.014	.276	.37	.855	.58	.018	Check	7 - 8				apart. No-break @-10°F
-4		.180	.720	.010	.015	.276	.38	.86	.57	.018	Check	7 - 8				to qualify -20°F NDT.
573C-1	Minimum RT_{NDT} @ - 30°F															Testing in accordance
573C-2	Minimum RT_{NDT} @ - 30°F															with approved test pls
																1944-02 Rev. 1

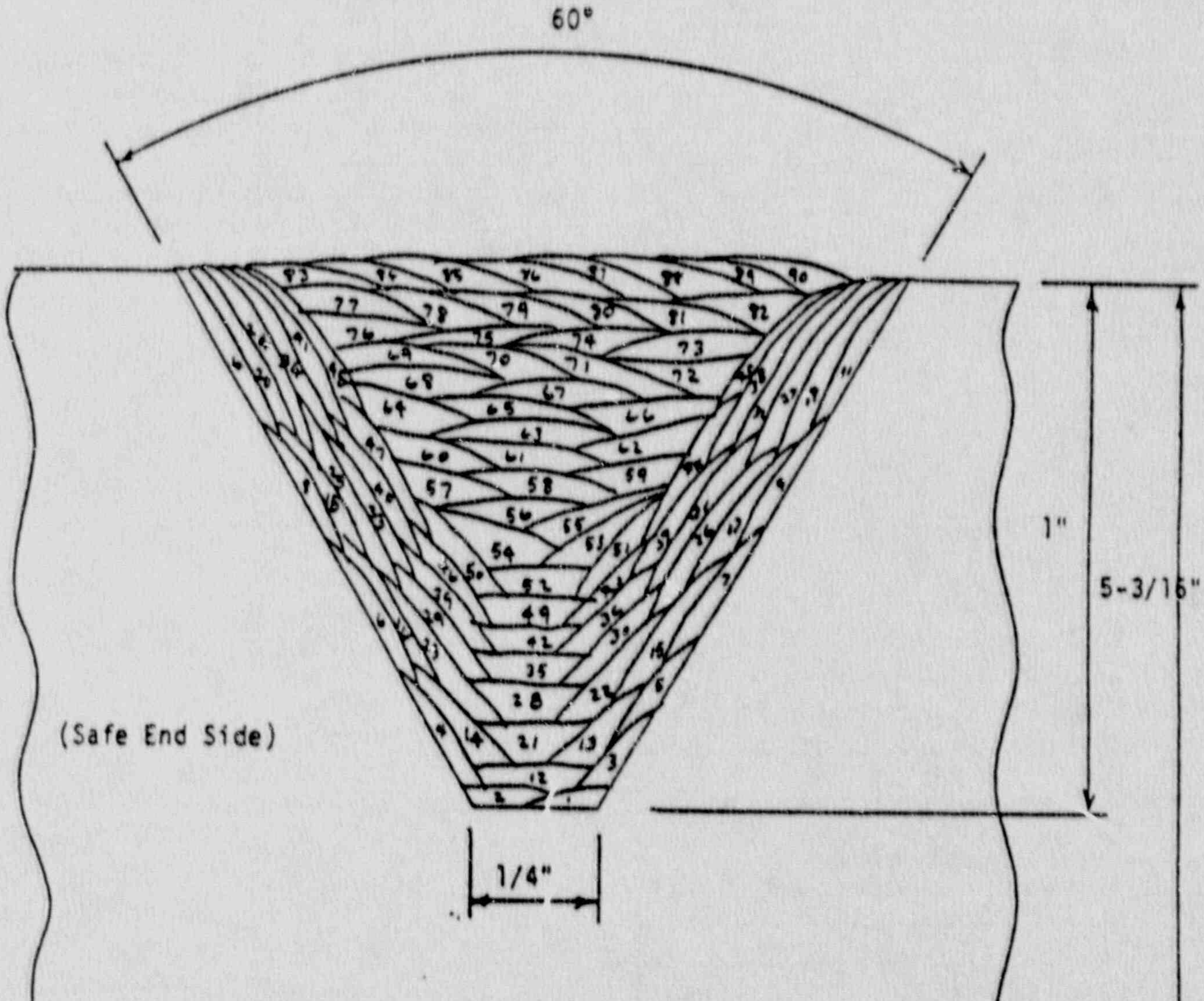
FORGING NO.	HEAT NO.	TEST TEMP.	TENSILE PSI x 1000	YIELD PSI x 1000	ELONG. % in 2"	R.A. %	B.H.N.	Impact Testing V-Notch @ +40°F to Qualify -20°F RT_{NDT}: ENERGY (ft-lbs)	LATERAL EXP. (in")	% SHEAR
573C-1	Q2QL4W	R.T. 0	86,190	64,389	26.0	70.7		84-91-73	.066-.068-.060	80-70-70
		180	82,625	65,000	26.0	67.6		83-82-73	.064-.063-.059	70-70-60
		0	Actual NDTT @ - 30°F					62-65-92	.050-.053-.064	55-60-75(V @ +30°F)
		180	Actual NDTT @ - 30°F					69-73-87	.055-.057-.062	60-55-75(V @ +30°F)
-2		0	91,767	70,980	24.0	70.0		72-68-82	.062-.057-.066	70-80-90
		180	88,500	68,000	25.5	67.9		67-79-83	.055-.060-.064	70-80-90
		0	Actual NDTT @ - 30°F					66-80-82	.054-.058-.060	60-70-70(V @ +30°F)
		180	Actual NDTT @ - 40°F					70-74-75	.054-.057-.058	60-55-65(V @ +20°F)

Lenape Forge certifies that all applicable requirements of SA508-2 & CBIN Spec. MS-52.1 Rev.7 & QAS-51, Rev.4 have been complied with.

We hereby certify the above results to be correct as contained in the records of the Company.

SHEET 2 of ___
W/O No. H5173

WORK ORDER



5G POSITION

S.O. No '44-4

MATERIAL TE   EPORT

DATE August 8, 19 74

Purchaser . B I Nuclear Co.

Purchaser's Order No. M10;12-3   73-C124

Distributor

Distributor's Order No.

ITEM NO.	QTY.	PRODUCT	SPEC.	HEAT OR CODE NO.	FORGING NO.	HEAT TREATMENT: L/F approved procedure HT-12, Rev. 4 Mod. 3	FCE. CHARTS ATTACHED YES	FCE. CHARTS ATTACHED NO
2	2	N2 Nozzle Mark: FN2-1-4 & FN2-1-5	SA508-2 & CBIN Specs. MS-52.1 Rev. 7 & QAS -51, Rev.4	Q2QL4W Supplier Ht. No. 212800	573C 1 & 2	1650°F ±25°F for 7½ hr Air Cool 1560°F ±25°F for 7½ hr Water Quench 1290°F ±25°F for 7½ hr Air Cool Test were stress relieved as follows: 1150°F ±25°F for 60 hrs. L/F approved procedure SPWHT-101, Rev. 4		X

CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES

FORGING NO.	HEAT NO.	C	MN	P	S	SI	CR	NI	MO	V		Grain Size	NDT REPORTS ATTACHED U.T.	M.P.	O.P.	REMARKS
573C	Q2QL4W	.20	.69	.007	.012	.28	.37	.82	.6,	.02	Ladle		X	X		Dropweight Testing
-1		.133	.720	.008	.015	.276	.37	.855	.57	.017	Check	7				Four (4) specimens -
-2		.183	.720	.008	.014	.276	.37	.86	.57	.018	Check	7 - 8				Two (2) each @180°
-3		.192	.730	.008	.014	.276	.37	.855	.58	.018	Check	7 - 8				apart. No-break @-10
-4		.180	.720	.010	.015	.276	.38	.86	.57	.018	Check	7 - 8				to qualify -20°F RT.
573C-1	Minimum	RT NDT @	- 30°F													Testing in accordance
573C-2	Minimum	RT NDT @	- 30°F													with approved test pl 1944-02 Rev. 1

FORGING NO.	HEAT NO.	TEST TEMP.	TENSILE PSI x 1000	YIELD PSI x 1000	ELONG. % in 2"	R.A. %	B.H.N.	Impact Testing V-Notch @ +40°F to Qualify -20°F RT_{NDT} ENERGY (ft-lbs)	LATERAL EXP. (in")	% SHEAR
573C-1	Q2QL4W	R.T. 0	86,190	64,389	26.0	70.7		84-91-73	.066-.068-.060	80-70-70
		180	82,625	65,000	26.0	67.6		83-82-73	.064-.063-.059	70-70-60
		0	Actual NDTT @ - 30°F					62-65-92	.050-.053-.064	55-60-75(V @ +30°F)
		180	Actual NDTT @ - 30°F					69-73-87	.055-.057-.062	60-55-75(V @ +30°F)
-2		0	91,767	70,980	24.0	70.0		72-68-82	.062-.057-.066	70-80-90
		180	88,500	68,000	25.5	67.9		67-79-83	.055-.060-.064	70-80-90
		0	Actual NDTT @ - 30°F					66-80-82	.054-.058-.060	60-70-70(V @ +30°F)
		180	Actual NDTT @ - 40°F					70-74-75	.054-.057-.058	60-65-65(V @ +20°F)

Lenape Forge certifies that all applicable requirements of SA508-2 & CBIN Spec. MS-52.1 Rev.7 & QAS-51, Rev.4 have been complied with.

We hereby certify the above results to be correct as contained in the records of the Company.

ARCOS DIV. OF HOSKINS MFG. CO.
P.O. DRAWER 308 MT. CARMEL, PA 17851

Date October 23, 1984

CERTIFICATION OF TESTS

K3-51776-
Customer's Order No. 43701D
Arcos S. O. No. 18313
Shipping Date October 23, 1984
ASME CERTIFICATE QSC-448
Expiration date: October 23/87
ITEM NO. 1

Chicago Bridge & Iron
c/o Copper Nuclear Station
2 Miles South of Brownville
Brownville, Nebraska 58321

Size .045 x 2k#sp Grade ARCOS 382
Lot No./Alloy No. Y4875N382
Lbs./No. Pieces 430#

SPECIFICATION: ASME SFA 5.14 Class ERNiCr-3; ASME Section II, Part C; ASME B & PVC Section III, 1983 Edition, Subsection NB2400 and 10CFR21 applies. WMS-4N (43700) Rev. 0; QAS-311 Rev. 15

Element	WIRE TEST RESULTS
Carbon	.02
Manganese	2.9
Silicon	.15
Sulphur	.009
Phosphorus	.00
Chromium	18.7
Nickel	74.3
Molybdenum	.054
Titanium	.38
Columbium +Ta	2.3
ir	
Aluminum	
Copper	.07
Iron	1.7
Tantalum	.00
Cobalt	.01
n	
Vanadium	.094
Zinc	
Zirconium	
Ferrite	Total Others <.50
X-Ray	

Charpys: As Welded / Heat Treated — As Welded / Heat Treated

Tensiles: Yield / Tensile / Elong. — Yield / Tensile / Elong. / Red. of Area
As Welded:
Heat Treat:
Hardness:
Bends:

We hereby certify that the above material has been tested in accordance with the listed specification and is in conformance with requirements.

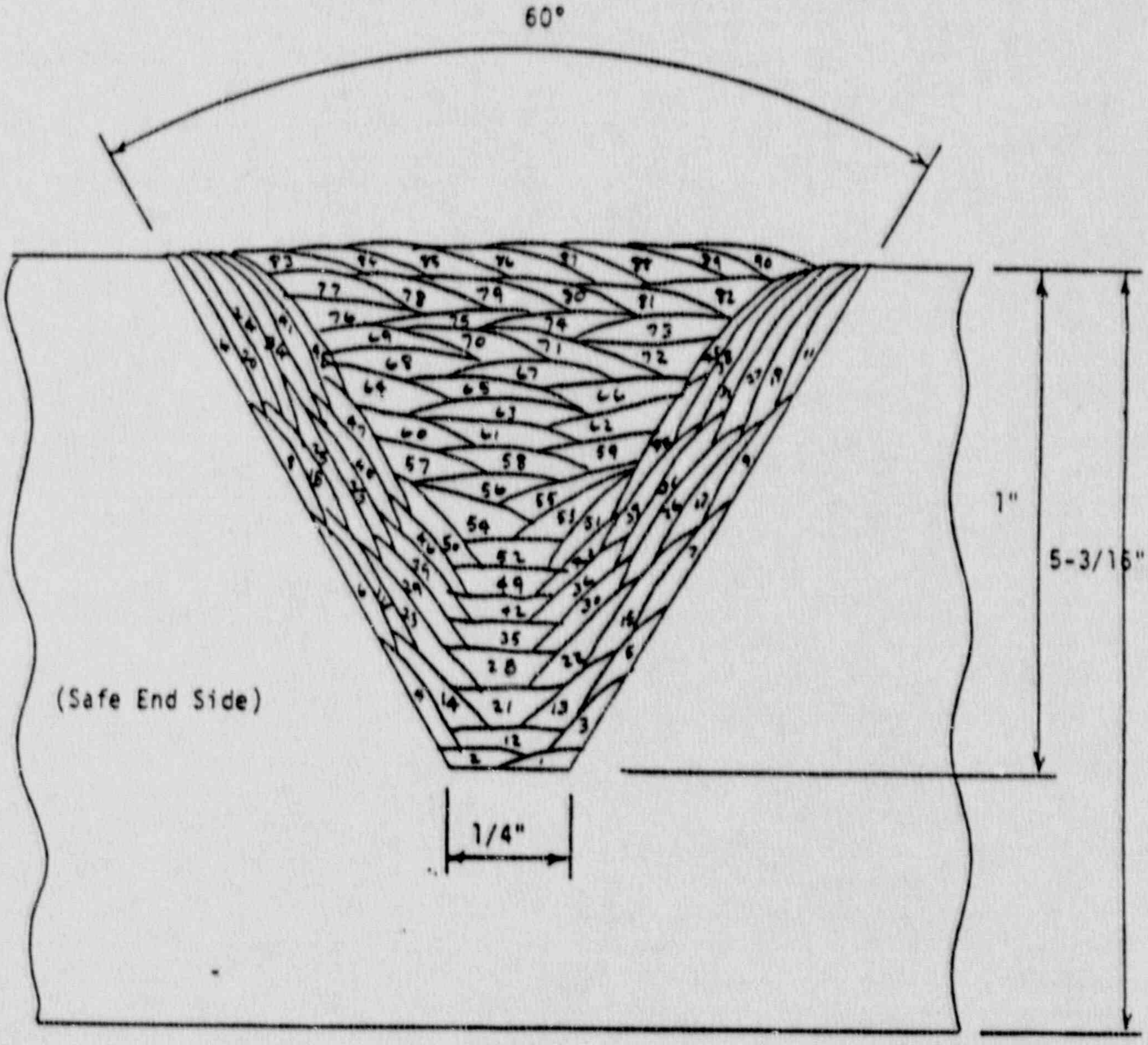
ARCOS

11/12/84
11/13/84

Quality Control Section

WORK ORDER

SHEET 2 of ___
W/O No. H5173



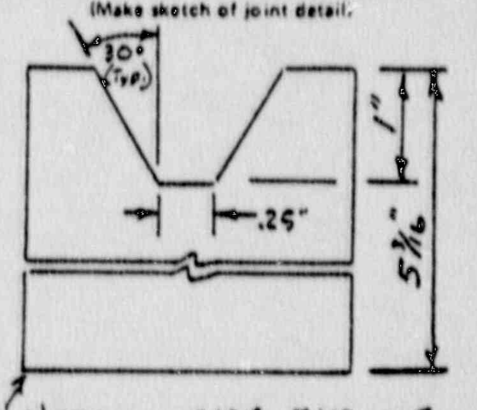
5G POSITION

CBI WORK ORDER AND REPORT FORM IMPACT

*Sheet 1 of ____
*W/O No. H5173

Location: HOUSTON Contract No. N61122 Mat'l Test No. — *PQR No. 7673
*Mat'l: A508 *Grade: CL. 2 *H.T. ____ *Rem Addr. ____ *Thk: 5.19 in
*Mill: LENAPE FORGE *Ctry: USA *Mat'l (2): ____ *Thk: ____ in / mm
*Process: GTA *Current/Polarity: DC/SP *Joint Type: — *Weld Tech: Std-Imp-Hd-H & I *Wash Dv. —
*Electrode AWS: ERNiCr-3 *FN: 382 *Mfr: ARCOS Ctry: USA Batch No. X4875N382
*Flux or Gas: ARGON *Mfr: — Ctry: — Moisture AR — % AB — %
*Rootpass: — *Preheat: 300°F *IPT: 350°F *PWHT Temp: 500°F *Time: 2.0 Hr *Position: 5G

Grain Dir:
Welder: JED, JDM
Plates Req: 1
GWPS: GTAW
Edge Coating: NONE
(Make sketch of joint detail)



HEAT NO C124 FN2-1-5

Side	Pass	Dia.	Amps	Volts	Pass Dir.	BOR 5/12"	IPM	Remarks

SEE FOLLOWING PAGES FOR PARAMETERS USED.
SEE "NOZZLE TO SAFE-END STRUCTURAL OVERLAY QUALIFICATION TEST PROGRAM" FOR DETAILS.
SUMMARY:
NOZZLE ASSY. PWHT AT 1150°F/24 HRS PRIOR TO WELDING.
WELDING PERFORMED @ GOLD TRACK II GTAW PULSED ARC SYSTEM @ REMOTE VIDEO.
BUTTER GROOVE @ 6 LAYERS & FILL REMAINDER FLUSH @ MINIMUM 8 LAYERS.
STRINGER BEADS – 20 TO 40 KJ/IN. & WIRE FEED SPEED @ 1.25 TO 2.0 MEGAJOULES.
NDE PER TEST PROGRAM.

Total Passes Side 1 ____ Side 2 ____ Heat Input Last Pass ____ KJ/in.

CHARPY V-NOTCH IMPACT TEST ✓ Spec Size: (10) 7.5 - 6.7 - 5 - 3.3 - 2.5 mm

*Notch Location	Side	Depth	Spec Orient	Spec No.	Spec Mark	*Test °F Temp	*Ft. Lbs.			*Lat. Exp.			*% Shear		
HAZ	1	*	L	6	1 2 3 A	+20	70	62	84	37	66	63	45	40	50
HAZ	1	*	L	–	4 5 6	+20	88	91	93	59	55	56	70	65	70
HAZ	1	1/16	L	3	1 2 3 AA	+20	73	79	72	63	56	46	60	60	60
BM	1	**	L	6	1 2 3 B	+20	122	120	104	76	69	63	60	60	50
BM	1	**	L	–	4 5 6	+20	94	106	113	63	68	72	70	70	70
BM	1	1/4T	L	3	1 2 3 BB	+20	43	48	60	36	65	60	60	50	50
BM	1	1/4T	L	3	1 2 3 BBA	+20	43	51	45	33	62	37	40	35	35

*) MAX PRACTICAL DEPTH OF GROOVE (3/16" TO 1/4 OF CV)
**) 5229-B
**) 5229-B
NOTE: CV TEST TEMP. EQUALS T NDT +60°F.

TENSION TESTS 4 - .505

	*Orient	*UTS ksi	*YS ksi	*El %	*RA %
R	L-T-ST-R	—	—	—	—
	L-T-ST-R				
WM	1	104.1	75.1	40	59
	2	103.9	74.5	41	45

JT	*UTS ksi	*YS ksi	*El %	*FAILURE
				P-H-W
1	88.0	68.2	30	P-H-W
2	87.1	66.7	21	P-H-W
				P-H-W

*Bends: 4S R ____ F ____ L 4 OK ____ NG
NDT: -40°F *H* ____ WM* ____

FERRITE NO. ____
Mfr ____ CB ____

CHEMISTRY:

	*Plate	*Weld
CB		
C		
Mn		
Si		
P		
S		
Ni		
Cr		
Mo		
Nb		
V		
Cu		
Al		
Ti		
N		
Other		

HARDNESS: ✓
Maximum Value
1st Side 2nd Side
*RC
Plate
Hma
Hmp
WM
(HV 10)
Plate
Hma SEE
Hmp ATTACHED
WM RESULTS
*Brinell
Plate
HAZ
WM

*Purpose of Test: CODE CASE N-432 PQR PER "NOZZLE TO SAFE-END STRUCTURAL OVERLAY QUALIFICATION TEST PROGRAM"

Evaluation of Results: TEST RESULTS MEET CC N-432.
UT/PT (AFTER COMPLETED WELD AT AMBIENT 48 HRS) - OK.
BM CV #B1 TO 6 DISREGARDED DUE TO LOCATION.
SOME PASSES WERE BELOW 20 KJ/IN.

Complete Work Order By: ____ Date ____
By: [illegible signature] Date: [illegible] REV ____

See standard 801-4-2 for instructions for completing this form.

* Indicates data to be keypunched.

File 622-508-1
No. 822-17

2 PAGES [illegible]

Printed in USA

WL 110 (FRONT) REV SEP 81

SHEET 3 of ____
W/O No. H5173

WORK ORDER

CBI

Low Pulse Frequency = 1.5

Low Pulse Width = 60%

Synchronization	Pulse Arc	Voltage control	Continuous
Upslope time	3 Sec.	Downslope time	10 Sec.
Wire Start Delay	5 Sec.	Travel Start Delay	4 Sec.

Number	1-4	5-6	7-9	10-11	12	13-16	17-18	19-20	21-23	24
Primary Weld Current (amps.)	200	200	200	200	200	200	200	200	200	200
Background Current (amps.)	100	100	100	100	100	100	100	100	100	100
Out Dwell (primary)(sec. x 1)	--	--	--	--	--	--	--	--	--	--
Excursion time (sec. x 1)	--	--	--	--	--	--	--	--	--	--
In Dwell (primary) (sec x 1)	--	--	--	--	--	--	--	--	--	--
Oscillation (in.)	--	--	--	--	--	--	--	--	--	--
Primary Wire Feed (IPM)	31	31	31	31	31	31	31	31	31	31
Background Wire Feed (IPM)	21	21	21	21	21	21	21	21	21	21
Travel (IPM) (Torch Speed)	4.23	4.14	4.05	3.97	4.23	4.14	4.05	3.97	4.14	3.97
Primary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Background Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	20.16	20.58	21.02	21.48	20.16	20.58	21.02	21.48	20.58	21.4[illegible]
Energy Density (MJ/in^3)	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93

ER NiCr 3 .045"Ø FILLER METAL.
EWTh-2 1/8"Ø ELECTRODE.
No 10 & 12 CUP.
40 CFH ARGON FLOW RATE.

WORK ORDER

SHEET 4 of ____
W/O No. H5173

Pass Number	25-27	28	29	30	31-34	35	36	37-38	39	40-41
Primary Weld Current (amps.)	200	210	215	210	200	200	200	200	200	200
Background Current (amps.)	100	110	115	110	100	100	100	100	100	100
Out Dwell (primary)(sec x .1)	-	-	-	-	-	-	-	-	-	-
Excursion time (sec. x .1)	-	-	-	-	-	-	-	-	-	-
In Dwell (primary)(sec. x .1)	-	-	-	-	-	-	-	-	-	-
Oscillation (in.)	-	-	-	-	-	-	-	-	-	-
Primary Wire Feed (IPM)	31	31	31	31	31	31	31	31	31	31
Background Wire Feed (IPM)	21	21	21	21	21	21	21	21	21	21
Travel (IPM) (Torch Speed)	4.05	4.25	4.92	4.92	4.92	4.74	4.92	5.09	4.92	5.09
P[illegible]ary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
[illegible]ground Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	21.02	21.31	18.94	18.41	17.33	17.96	17.33	16.74	17.33	16.74
Energy Density (MJ/in^3)	1.93	2.05	2.12	2.05	1.93	1.93	1.93	1.93	1.93	1.93

Pass Number	42	43-48	49-56	57	58	59	60	61-62	63	64
Primary Weld Current (amps.)	210	200	210	200	210	200	220	220	220	220
Background Current (amps.)	110	100	110	100	110	100	110	110	110	110
Out Dwell (primary)(sec. x 1)	-	-	-	-	-	-	-	-	-	-
Excursion time (sec. x 1)	-	-	-	-	-	-	-	-	-	-
In Dwell (primary) (sec x 1)	-	-	-	-	-	-	-	-	-	-
Oscillation (in.)	-	-	-	-	-	-	-	-	-	-
Primary Wire Feed (IPM)	31	31	31	31	35	30	35	35	35	38
Background Wire Feed (IPM)	21	21	21	21	25	20	25	25	25	28
Travel (IPM) (Torch Speed)	4.74	4.92	4.92	4.48	4.48	4.92	4.64	4.91	4.64	4.64
[illegible]rimary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Backoround Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
He[illegible]nput (Kilojoules/in.)	19.08	17.33	18.41	19.00	20.18	17.33	20.18	19.08	20.18	20.18
[illegible]nergy Density (MJ/in^3)	2.05	1.93	2.05	1.93	1.79	2.00	1.84	1.84	1.84	1.68

SHEET 5 of ___
W/O No. H5173

WORK ORDER

Pass Number	65-68	69-76	77-82*	83-90						
Primary Weld Current (amps.)	220	225	225	220						
Background Current (amps.)	110	115	115	110						
Out Dwell (primary)(sec x .1)	-	-	-	-						
Excursion time (sec. x .1)	-	-	-	-						
In Dwell (primary)(sec. x .1)	-	-	-	-						
Oscillation (in.)	-	-	-	-						
Primary Wire Feed (IPM)	40	45	45	40						
Background Wire Feed (IPM)	30	35	35	30						
Travel (IPM) (Torch Speed)	4.56	4.47	4.38	4.64						
ary Arc Volts	9.0	9.0	9.0	9.0						
b..ground Arc Volts	8.5	8.5	8.5	8.5						
Heat Input (Kilojoules/in.)	20.57	21.58	22.02	20.18						
Energy Density (MJ/in^3)	1.59	1.44	1.44	1.59						

*Passes 78 & 79 - 2/3 of circum. downhill side.

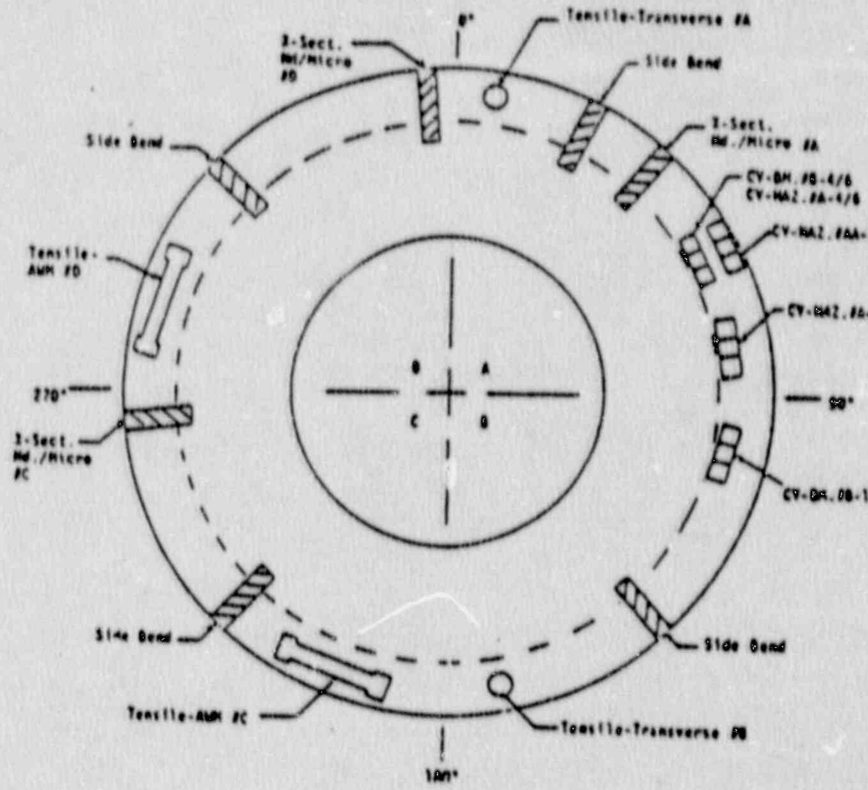
Pass Number										
Primary Weld Current (amps.)										
3ackground Current (amps.)										
Jut Dwell (primary)(sec. x 1)										
Excursion time (sec. x 1)										
n Dwell (primary) (sec x 1)										
scillation (in.)										
rimary Wire Feed (IPM)										
ackground Wire Feed (IPM)										
ravel (IPM) (Torch Speed)										
rimary Arc Volts										
ackground Arc Volts										
nput (Kilojoules/in.)										
ergy Density (MJ/in^3)										

TEST SPECIMEN CUTTING SKETCH

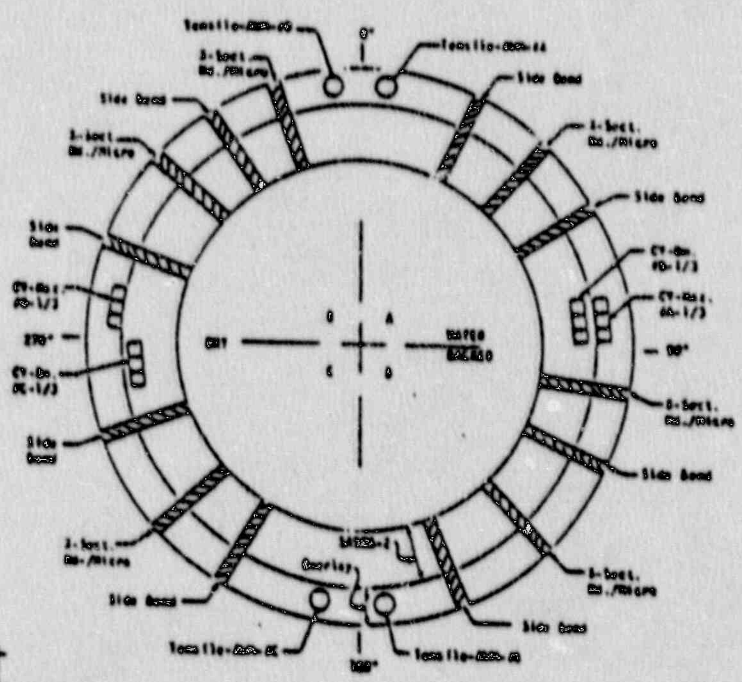
W/O H5173 & H5224

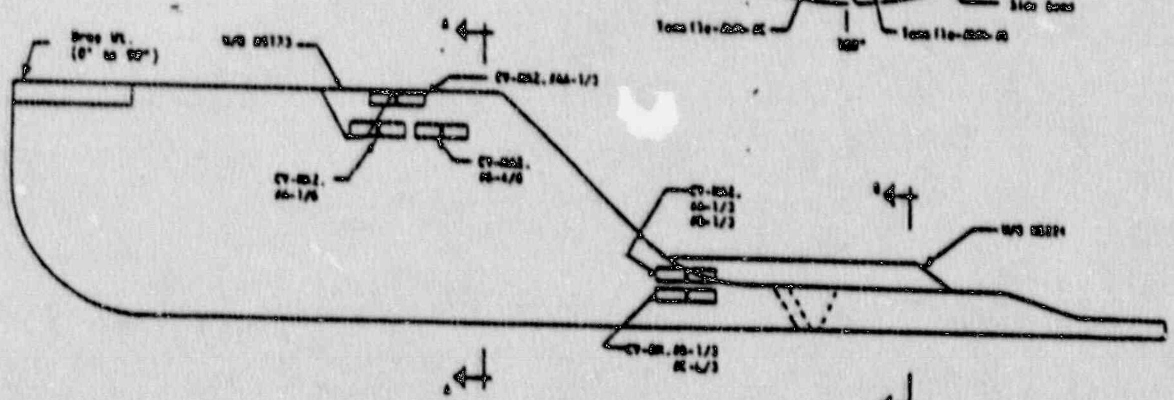
______ of ______

SECTION A-A
(W/O H5173)



SECTION B-B
(W/O H5224)

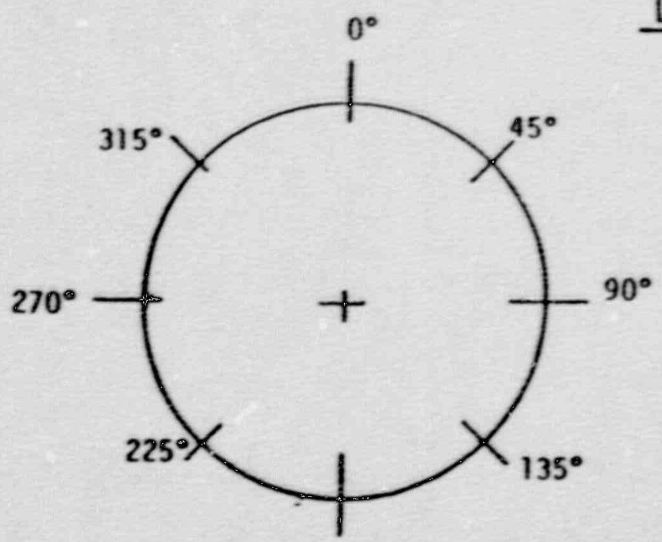




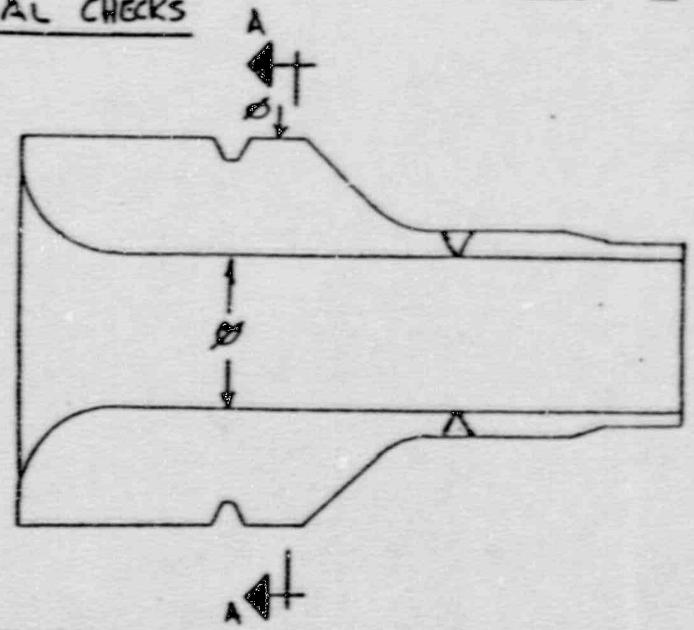
NOZZLE ASSEMBLY-LONGITUDINAL SECTION

W/O H517:

DIMENSIONAL CHECKS



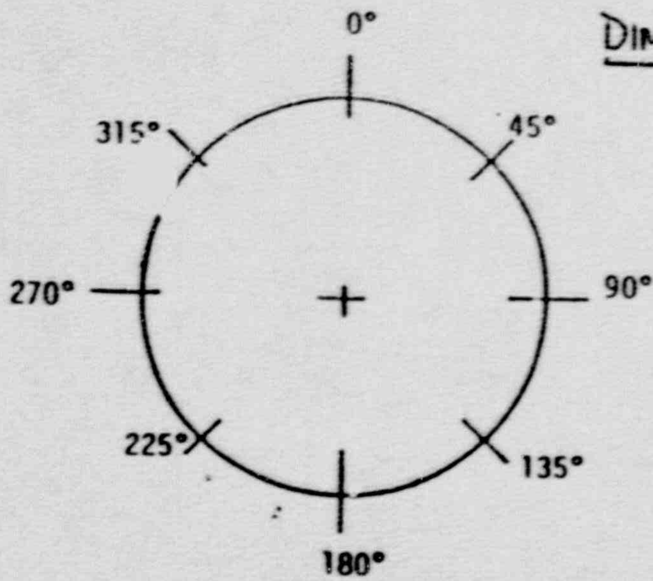
SECTION A-A



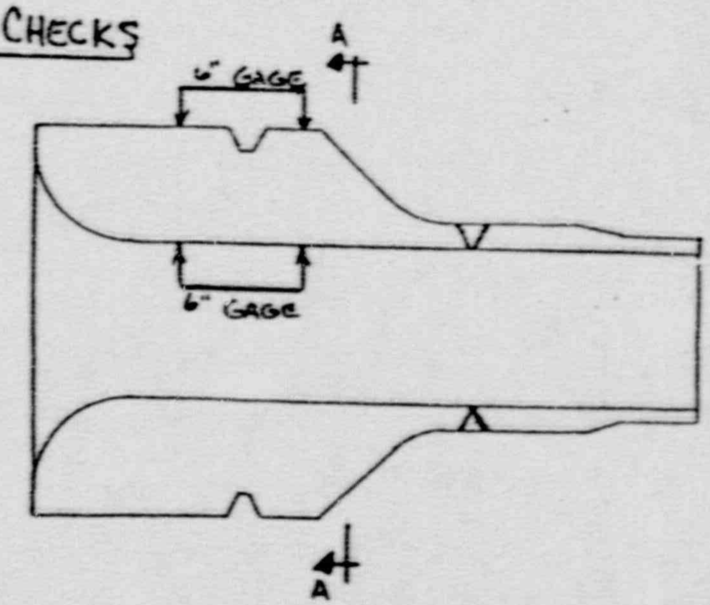
PIPE OR COMPONENT	LOCATION / DIMENSION	0°	45°	90°	135°	180°	225°	270°	315°					
BEFORE WELDING	I. DIAMETER	11.597"	11.597	11.594	11.596									
	O. DIAMETER	22.067"	22.068	22.067	22.069									
AFTER WELDING	I. DIAMETER	11.595	11.594	11.594	11.591									
	O. DIAMETER	22.040	22.042	22.042	22.040									
	.....													

W/O H517

DIMENSIONAL CHECKS



SECTION A-A

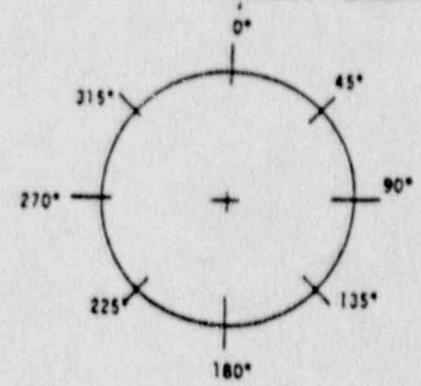


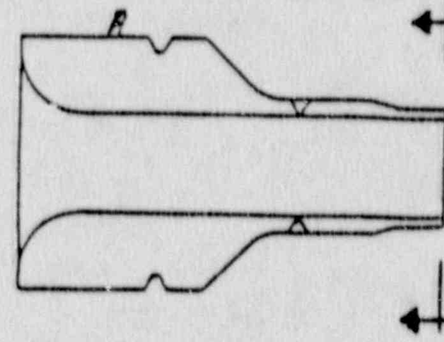
PIPE OR COMPONENT	LOCATION / DIMENSION	0°	45°	90°	135°	180°	225°	270°	315°					
OUTSIDE	BEFORE WELDING	6.025	6.022	6.015	6.022	6.029	6.025	6.025	6.023					
	AFTER WELDING	6.014	6.015	6.015	6.019	6.024	6.022	6.022	6.016					
INSIDE	BEFORE WELDING	6.011	6.020	6.025	6.023	6.013	6.022	6.022	6.011					
	AFTER WELDING	6.006	6.016	6.022	6.019	6.010	6.016	6.018	6.007					

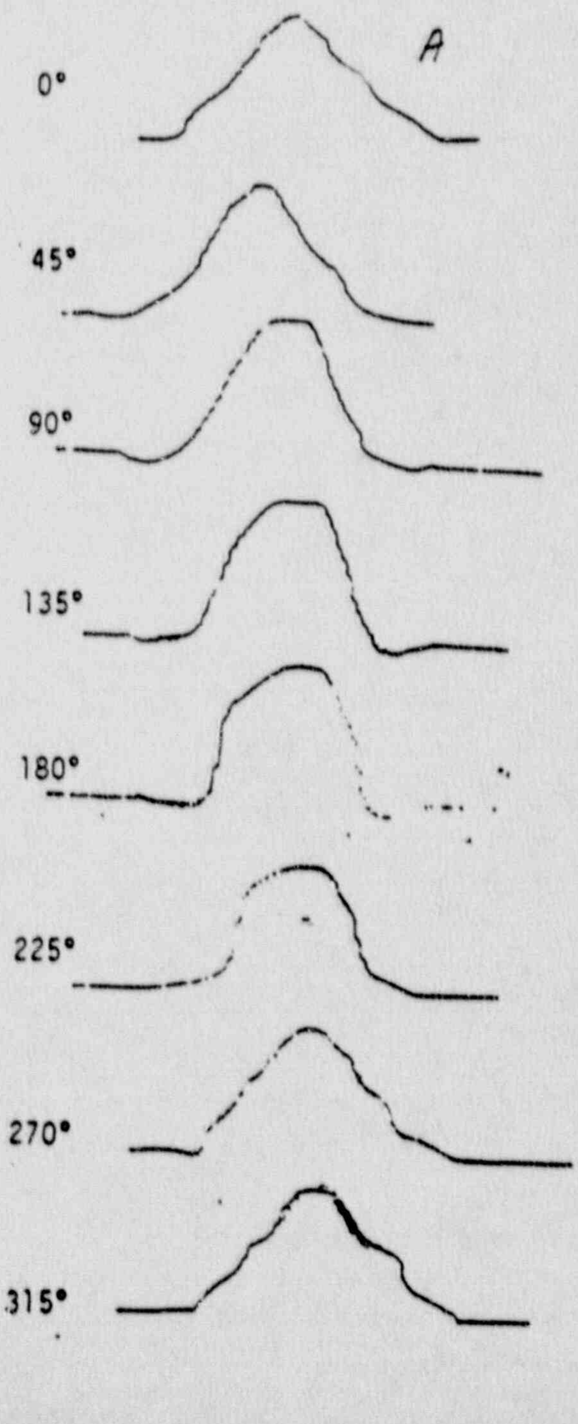
W/O H5173

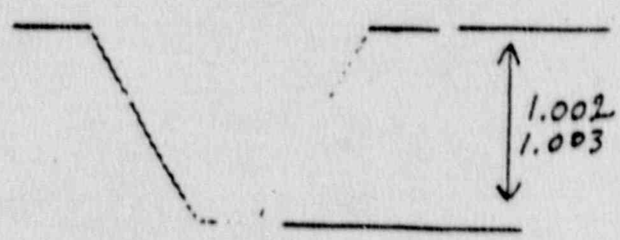
CONTOUR GAGE TRACING

LOCATION After 6 Layers & Prior to Welding.





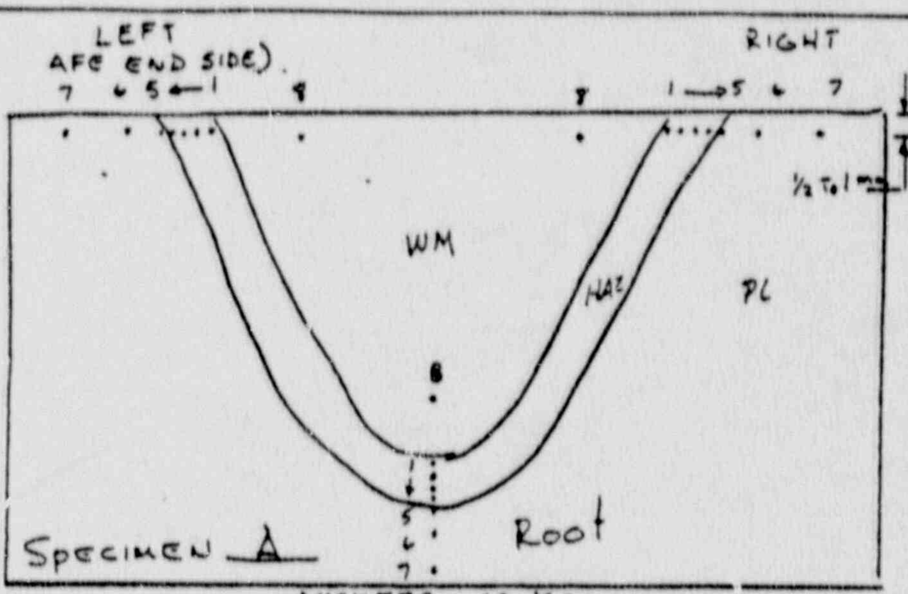




TYPICAL - 0° - 360°

MACHINED GROOVE

METALLURGICAL LABORATORY
HARDNESS TEST REPORT



Work Order No.: H5173
Material: SA 508-2
Thickness: 5 3/16"
Electrode: ER NiCr-3
PWHT: 500°F / 2Hrs
Position: 5G
Test By: AEH
Date: 2-17-87
Location: Houston

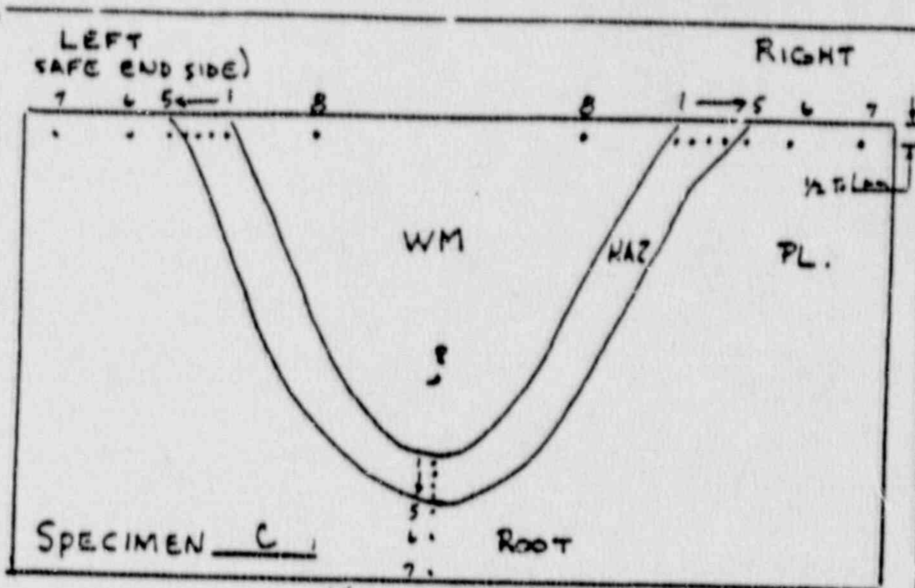
VICKERS 10 Kg

AREA	LEFT SIDE	RIGHT SIDE	ROOT		
1	386	408	315		
2	362	417	300		
3	255	312	227		
4	224	261	198		
5	183	188	180		
6	184	184	181		
7	179	185	184		
8	177	183	222		

TRAVERSE SPACING
1 To 5 = ½ mm
5 To 6 = 1 mm
6 To 7 = 6 To 10 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT



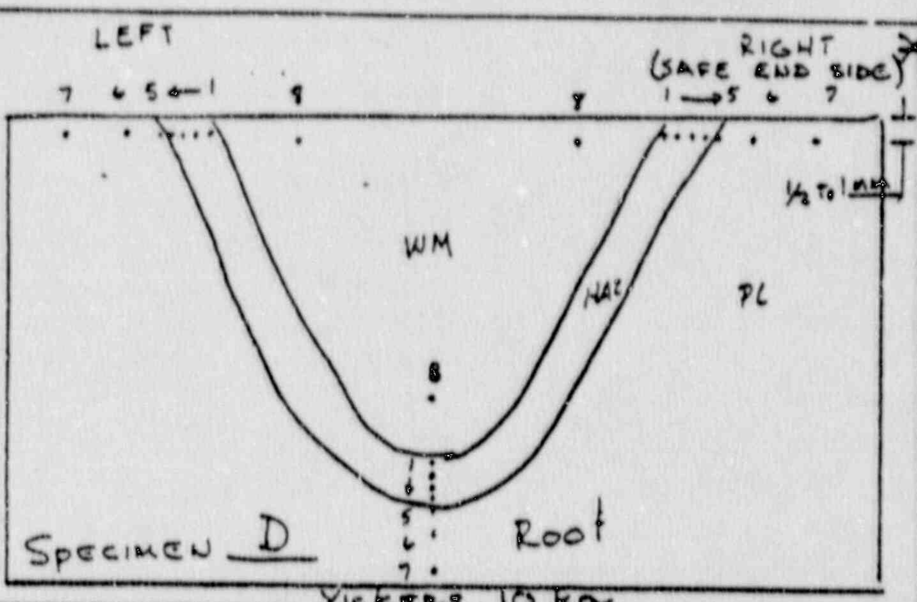
Work Order No.: H5173
Material: SA508-2
Thickness: 5 3/16"
Electrode: ERNiCr-3
PWHT: 500°F / 2 HRS.
Position: 5G
Test By: AEH
Date: 2-17-87
Location: HOUSTON

VICKERS 10 Kg.

AREA	LEFT (SAFE END SIDE)	RIGHT	ROOT
1	379	306	297
2	396	292	288
3	281	239	248
4	241	208	208
5	194	177	179
6	179	177	178
7	178	174	177
8 (WM)	174	172	213

TRAVERSE SPACING
1 TO 5 = ½ mm
5 TO 6 = 1 mm
6 TO 7 = 6 TO 10 mm

METALLURGICAL LABORATORY
HARDNESS TEST REPORT



Work Order No.: H5173
Material: SA 508-2
Thickness: 5 3/16"
Electrode: ERNiCr-3
PWHT: 500°F /24 HRS
Position: 5G
Test By: ACH
Date: 2-17-87
Location: HOUSTON

VICKERS 10 Kg

AREA	LEFT SIDE	*RIGHT SIDE	ROOT		
1	384	390	308		
2	400	395	336		
3	327	300	264		
4	230	243	211		
5	211	200	183		
6	185	183	187		
7	187	180	189		
8	175	175	208		

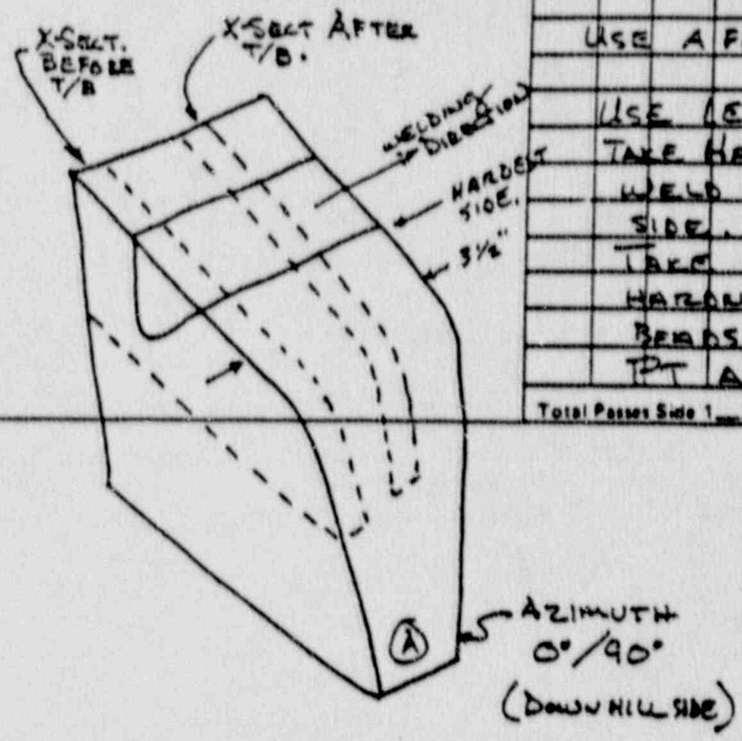
TRAVERSE SPACING
1 To 5 = 1/2 mm
5 To 6 = 1 mm
7 To 7 = 6 To 10 mm

CBI WORK ORDER AND REPORT FORM NONIMPACT

*Sheet ____ of ____
*W/O No. H5173 SUPPLEMENT

Location HOUSTON Contract No. N61122 *Mat'l Test No. — *POR No. —
Mat'l A508 *Grade 2 *H.T. ____ *Rem Addr. — *Thk 5.19 in.
*Mill LENAPE FORGE *Ctry ____ *Mat'l (2) ____ *Thk ____ in./mm
*Process GTA (A) *Current/Polarity DC/SP *Joint Type G *Weld Tech: Std-Imp-Hd-H & I *Wash Dir. —
*Electrode AWS ENiCr-3 *TN 382 *Mfr ARCOS Ctry USA Batch No. Y4875N382
*Flux or Gas ARGON *Mfr — Ctry — Moisture AR — % AB — %
*Rootpass — *Preheat 020 °C *IPT 100 °C *PWHT Temp — °F/°C *Time — Hr *Position *

Grain Dir:
Welder: ____
Plates Req: ____
GWPS ____
Edge Coating ____
(Make sketch of joint detail)



Side	Pass	Dia.	Amps	Volts	Pass Dir.	BOR 5/12"	IPM	Remarks

*) 45° ANGLE-VERTICAL DOWN.
SEE PARAMETERS ON PAGE 2.
USE A FLAT TRACK.
USE LEFTOVER FROM QUAL. "A"
TAKE HARDNESS TO DETERMINE HARDEST SIDE.
WELD TEMPER BEADS ON THE HARDEST SIDE.
TAKE ANOTHER X SECTION TO DETERMINE HARDNESS AFTER WELDING TEMPER BEADS.
PT AFTER WELDING. OK ✓

Total Passes Side 1 ____ Side 2 ____ Heat Input Last Pass ____ KJ/in.

TENSION TESTS:

	*Orient	*UTS ksi	*YS ksi	*El %	*RA %
R	L-T-ST-R				
	L-T-ST-R				
Wm.					

Jt.	*UTS ksi	*YS ksi	*El %	*FAILURE
				P-H-W
				P-H-W
				P-H-W
				P-H-W

*Bends ___ S ___ R ___ F ___ L ___ OK ___ NG
NDT R* ___ c H* ___ c WM* ___ c
FERRITE NO. ____
Mfr ____ CB ____

CHEMISTRY:

	*Plate	*Weld
CE		
C		
Mn		
Si		
P		
S		
Ni		
Cr		
Mo		
Nb		
V		
Cu		
Al		
Ti		
N		
Other		

HARDNESS: Maximum Value

	1st Side	2nd Side
*RC		
Plate		
Hma		
Hmp		
WM		
See (HV10) ATTACHED. - BEFORE & AFTER		
Plate		
Hma		
Hmp	SEE ATTACHED	
WM	REPORT.	
*Brinell		
Plate		
HAZ		
WM		

File No. ____

Purpose of Test: EVALUATE TEMPER BEADS ON HARDNESS. USING LEFT OVER TEST WELD.

Evaluation of Results:

SOME SOFTENING AT SURFACE AFTER TEMPER BEADS.

Complete Work Order By: Date: 3-16-87
By: A.E.H. Date: 3-12-87 REV 0

See standard 801-4-2 for instructions for completing this form.

* Indicates data to be keypunched.

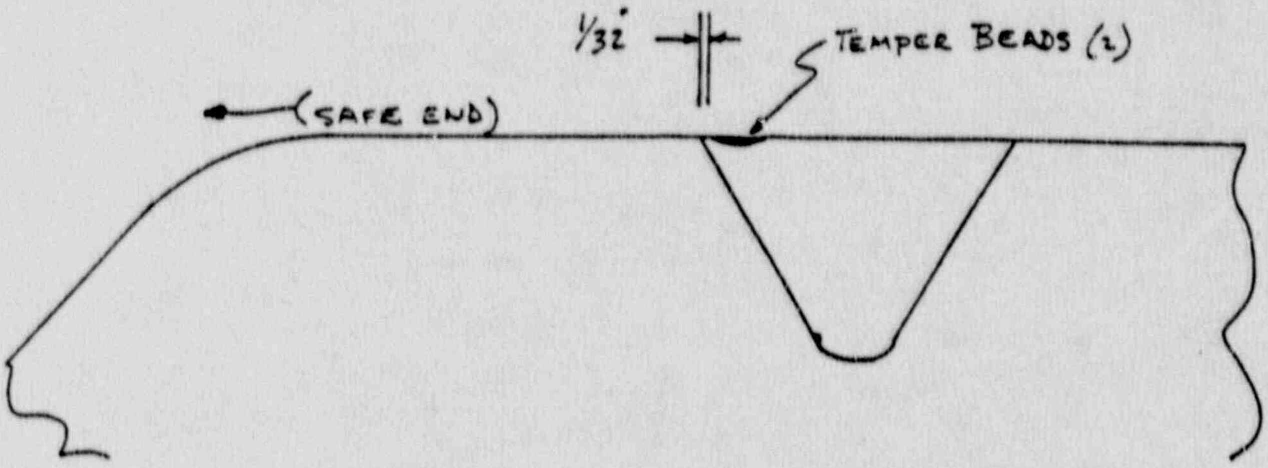
Printed in USA

WL 159 (FRONT) REV SEP 81

CBI

WORK ORDER

SHEET 2 of ___
W/O No H5173
SUPPLEMEN



Synchronization	PULSE ARC.	Voltage control	SAMPLED
Upslope time	3 SEC.	Downslope time	10 SEC.
re Start Delay	—	Travel Start Delay	4 SEC.

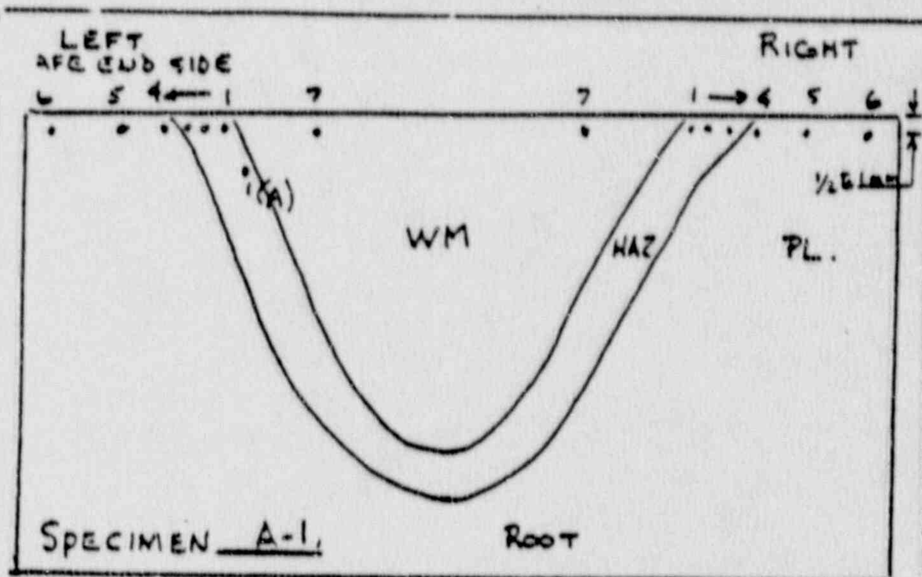
Pass Number	1	2	—	—	—	—	—	—	—	—
Primary Weld Current (amps.)	180	120								
Background Current (amps.)	90	60								
Out Dwell (primary)(sec. x 1)	-	-								
Excursion time (sec. x 1)	-	-								
In Dwell (primary) (sec x 1)	-	-								
~~Oscillation (in.)~~ LPW	60	60								
~~Primary Wire Feed (IPM)~~ LPF	1.5	1.5								
Background Wire Feed (IPM)	—	—								
Travel (IPM) (Torch Speed)	2.4	2.4								
Primary Arc Volts	9.0	9.0								
Background Arc Volts	8.5	8.5								
Heat Input (Kilojoules/in.)	31.4	20.93								
Energy Density (MJ/in^3)	—	—								

SHEET 3 of ___

METALLURGICAL LABORATORY HARDNESS TEST REPORT

BEFORE WELDING TEMPER BEADS

Work Order No.:	H5173 (SUPP)
Material:	SA508-2
Thickness:	5 3/16"
Electrode:	ERNiCr-3
PWHT:	NONE
Position:	5G (36-45°)
Test By:	RCW / AEH
Date:	3/16/87
Location:	HOUSTON



VICKERS 10 KG.

AREA	LEFT (SAFE END SIDE)	RIGHT	A		
1	401	360	371		
2	300	286			
3	248	249			
4	195	226			
5	186	182			
6	183	184			
7 (WM)	171	161			

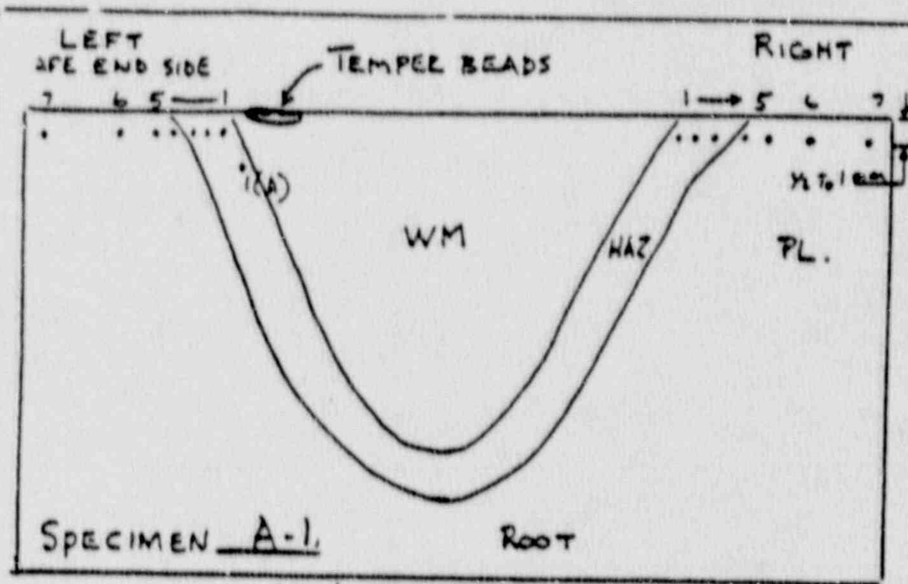
TRAVERSE SPACING
1 TO 4 = 1/2 mm
4 TO 5 = 1 mm
5 TO 6 = 6 TO 10 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SHEET 4 :

AFTER WELDING TEMPER BEADS



Work Order No.: H5173 (supp)
Material: SA 508 - 2
Thickness: 5 3/16"
Electrode: ERNiCr-3
PWHT: NONE
Position: 5G (36-45°)
Test By: AEH
Date: 3-16-87
Location: HOUSTON

VICKERS 10 Kg

AREA	LEFT (SAFE END SIDE)	RIGHT	A		
1	365	322	412		
2	267	286			
3	231	247			
4	189	203			
5	185	185			
6	182	184			
7	173	175			

TRAVERSE SPACING
1 To 5 = ½ mm
5 To 6 = [illegible] mm
6 To 7 = 6 To 10 mm

CBI WORK ORDER AND REPORT FORM IMPACT

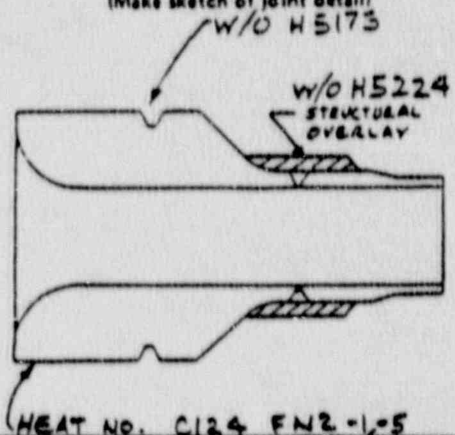
*Sheet 1 of ____
*W/O No. H5224

Location HOUSTON Contract No. N61122 *Mat'l Test No. — *POR No. 7717 & 7718
*Mat'l A508 *Grade 2 *H.T. QT *Rem Addr. ____ *Thk 1.20 in
*Mill LENAPE FORGE *Ctry USA *Mat'l (2) A312-304L *Thk 1.20 in
*Process GTA (A) *Current/Polarity DC/SP *Joint Type OL *Weld Tech.: Std-Imp-Hd-H & I *Wash Dir. —
*Electrode AWS ERNiCr-3 *TN 382 *Mfr ARCOS Ctry USA Batch No. Y4875N382
*Flux or Gas ARGON *Mfr — Ctry — Moisture AR — % AB — %
*Rootpass — *Preheat ≤40 °C *IPT — °C *PWHT Temp — °C *Time — Hr *Position 5G

Grain Dir:

Welder: JDM, JED, AEH
Plates Req:

GWPS GTAW
Edge Coating —
(Make sketch of joint detail)



Side	Pass	Dia.	Amps	Volts	Pass Dir.	BOR S/12"	IPM	Remarks

SEE FOLLOWING PAGES FOR PARAMETERS USED.
SEE "NOZZLE TO SAFE-END STRUCTURAL OVERLAY QUALIFICATION PROGRAM" FOR DETAILS.
SUMMARY:
NOZZLE ASSY PWHT AT 1150°F/24 HRS PRIOR TO WELDING.
WELDING PERFORMED W/ GOLD TRACK II GTAW PULSED ARC SYSTEM W/ REMOTE VIDEO
WEAVE BEADS 20 TO 40 KJ/IN.
5 WIRE FEED @ 1.25 TO 2.0 MEGAJOULES.
ALTERNATED WELDING DIRECTION EACH PASS.
1/2 OF JOINT H_2O BACKED @ 20' HEAD PRESS. FOLLOWED BY H_2O @ 40°F IS CIRCULATING INSIDE T/S.
USE PER TEST PROGRAM.

Total Passes Side 1 ____ Side 2 ____ Heat Input Last Pass ____ KJ/in.

CHARPY V-NOTCH IMPACT TEST ✓ Spec Size: (10) - 7.5 - 6.7 - 5 - 3.3 - 2.5 mm

	*Notch Location	*Side	*Depth	*Spec Orient	Spec No.	Spec Mark	*Test (F) Temp C	*Ft. Lbs.			*Lat. Exp.			*% Shear		
H_2O Backed	HAZ	1	*	L	3	1,2,3 A	+20	95	76	95	60	57	65	50	40	55
	BM	1	1/4T	L	3	1,2,3 B	+20	43	48	60	36	45	40	40	50	50
Dry	HAZ	1	*	L	3	1,2,3 D	+20	111	89	98	75	63	72	50	40	70
	BM	1	1/4T	L	3	1,2,3 C	+20	43	51	45	33	42	37	40	35	35

*) MAX. PRACTICAL DEPTH OF OVERLAY (3/16" TO ℄ OF CV).

NOTE: CV TEST TEMP EQUALS T NDT +60°F.

TENSION TESTS: 4 - .250" ⌀

*Orient		*UTS ksi	*YS ksi	*El % (1")	*RA %	#
[redacted] H_2O BACKED [redacted]		95.0	62.5	39	62	A
		99.2	69.8	32	54	B
Wm. TRANSVERSE	DRY	97.4	67.1	30	49	C
		97.2	65.2	29	65	D

	*UTS ksi	*YS ksi	*El %	*FAILURE
				P · H · W
				P · H · W
	4 DRY			P · H · W
	4 H_2O BACKED			P · H · W

*Bends: 8 S R ___ F ___ L 8 OK ___ NG
NDT(s) -40 °C H* — C WM* — C

FERRITE NO. —
Mfr — CB —

CHEMISTRY:

	*Plate	*Weld
CE	— —	
C		
Mn		
Si		
P		
S		
Ni		
Cr		
Mo		
Nb		
V		
Cu		
Al		
Ti		
N		
Cb		

HARDNESS —
Maximum Value
1st Side 2nd Side
*RC
Plate
Hmz
Hmp
WM
3 — HV 10
Plate
Hmz SEE
Hmp ATTACHED
WM REPORTS
*Brinell
Plate
HAZ
WM

File No. 622-508-1
633-304L-1
822-17
PAGE 1, 2 & 3 ONLY

Purpose of Test: NOZZLE TO SAFE-END STRUCTURAL OVERLAY QUALIFICATION TEST PROGRAM" BY LES

Evaluation of Results:

SATISFACTORY.
HAD SOME IN PROCESS DEFECTIVE WELDING DUE TO BAD WIRE WHICH WAS REMOVED & REWELDED.

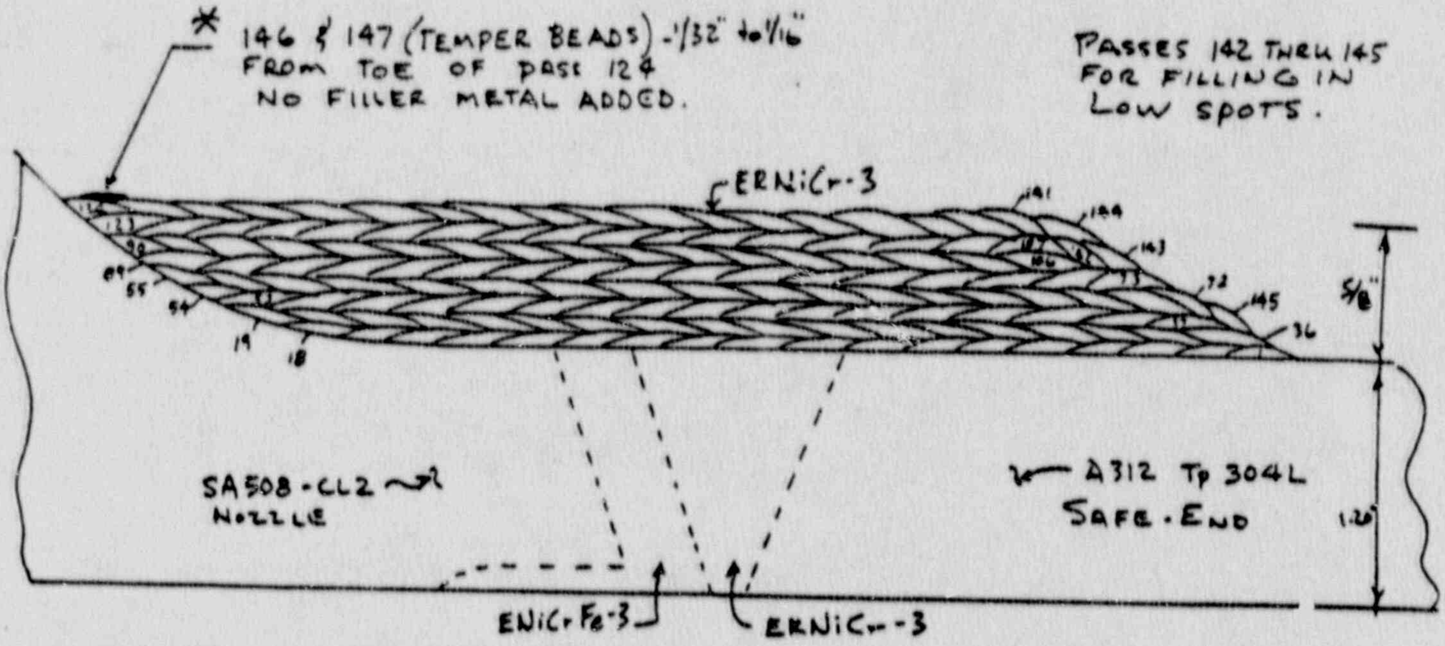
Complete Work Order By: Date:
By: JOHN D. MATHEWS, AEH Date: 11-2-86 REV B

See standard 801-4-2 for instructions for completing this form.

* Indicates data to be keypunched.

CBI WORK ORDER

W/O No H5224
SHEET 2 of ___



Synchronization	SYN PULSE	Voltage control	CONTINUOUS
Upslope time	5 SECS.	Downslope time	10 SECS.
Wire Start Delay	7 SECS.	Travel Start Delay	6 SECS.

Pass Number	1	2-4	5	6-18	19-36	37-54	55-72	73-89	90	91-104
Primary Weld Current (amps.)	220	220	220	220	220	220	220	220	220	220
Background Current (amps.)	110	110	110	110	110	110	110	110	110	110
Out Dwell (primary)(sec. x 1)	4	4	4	4	4	4	4	4	4	.3
Excursion time (sec. x 1)	.3	.2	.2	.2	.2	.2	.2	.2	.2	.2
In Dwell (primary) (sec x 1)	4	4	4	.3	.3	.3	.3	.3	.3	4
Oscillation (in.)	.20	.24	.24	.24	24	.24	.24	.24	.24	.24
Primary Wire Feed (IPM)	40	40	35	35	33	35	35	35	35	35
Background Wire Feed (IPM)	30	30	25	25	25	25	25	25	25	25
Travel (IPM) (Torch Speed)	2.55	2.55	2.55	2.56	2.38	2.62	2.64	2.66	2.68	2.68
Primary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Background Arc Volts	8.5	8.5	8.5	8.5	8.5	[illegible]	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	36.04	38.39	38.39	37.64	40.33	36.12	36.38	36.08	35.76	35.76
Energy Density (MJ/in^3)	1.57	1.64	1.89	1.87	2.00	1.87	1.87	1.87	1.87	1.87

ERNiCr-3 .045" Ø FILLER WIRE
EWTh-2 1/8" Ø ELECTRODE
No. 12 CUP
40 CFH ARGON FLOW RATE.

CBI WORK ORDER

W/O No H5224
SHEET 3 of ___

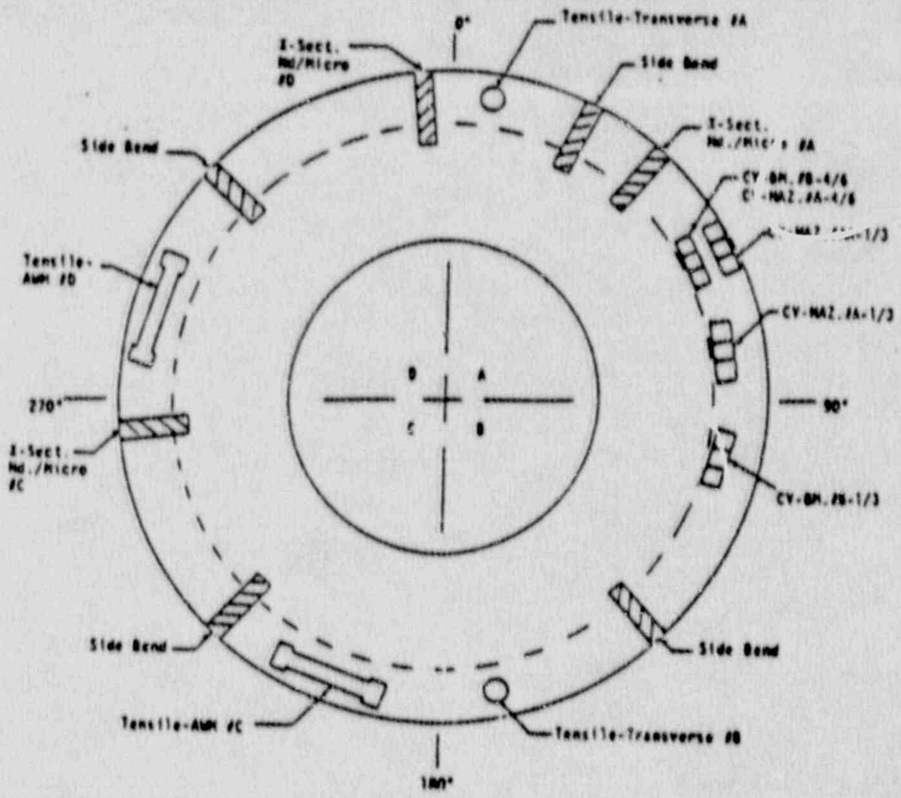
Synchronization	SYN PULSE	Voltage control	CONTINUOUS
Upslope time	5 SECS.	Downslope time	10 SECS.
Wire Start Delay	7 SECS.	Travel Start Delay	6 SECS.

Pass Number	107-123	124-145	146*	147*						
Primary Weld Current (amps.)	220	220	180	120						
Background Current (amps.)	110	110	90	60						
Out Dwell (primary)(sec. x 1)	.3	.3	.3	.3						
Excursion time (sec. x 1)	.2	.2	.2	.2						
In Dwell (primary) (sec x 1)	.4	.4	.4	.4						
Oscillation (in.)	.24	.24	.24	.24						
Primary Wire Feed (IPM)	35	35	—	—						
Background Wire Feed (IPM)	25	25	—	—						
Travel (IPM) (Torch Speed)	2.71	2.72	2.72	2.72						
Primary Arc Volts	9.0	9.0	9.0	9.0						
Background Arc Volts	8.5	8.5	8.5	8.5						
Heat Input (Kilojoules/in.)	35.47	35.19	28.79	19.19						
Energy Density (MJ/in^3)	1.87	1.87	—	—						

TEST SPECIMEN CUTTING SKETCH

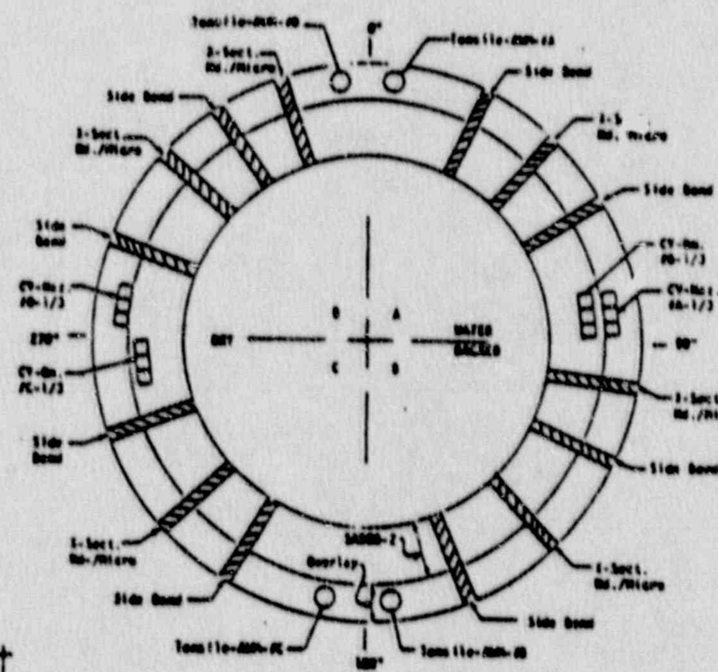
W/O H5173 & H5224

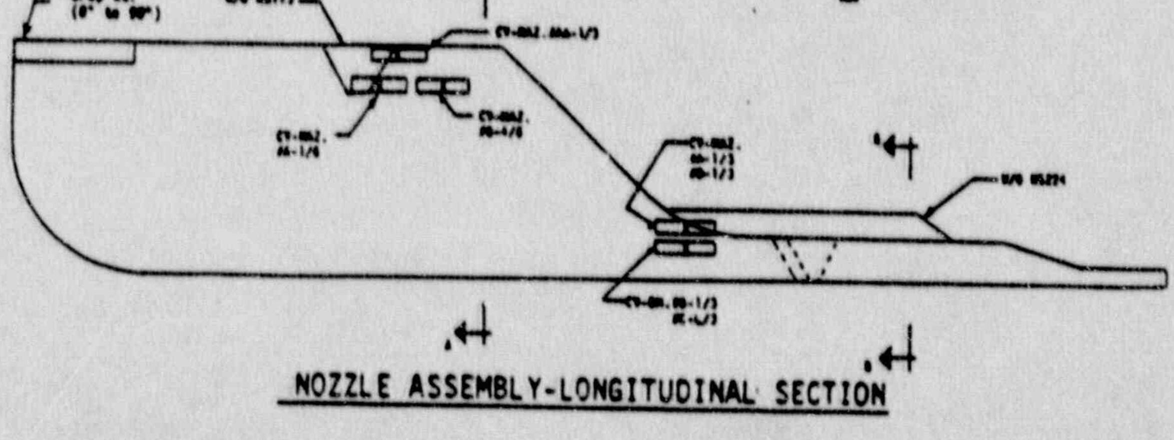
______ of ______



SECTION A-A
(W/O H5173)

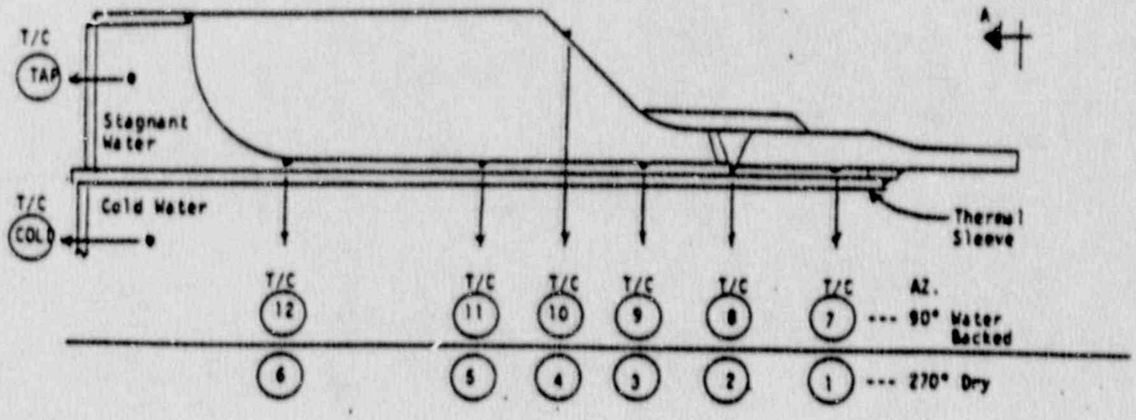
SECTION B-B
(W/O H5224)

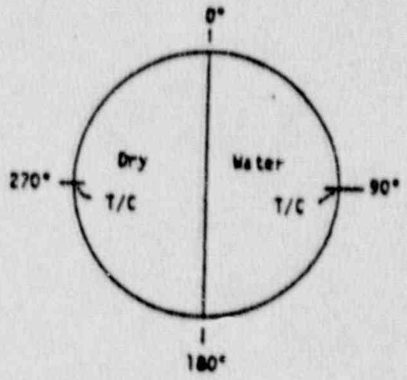




NOZZLE ASSEMBLY-LONGITUDINAL SECTION

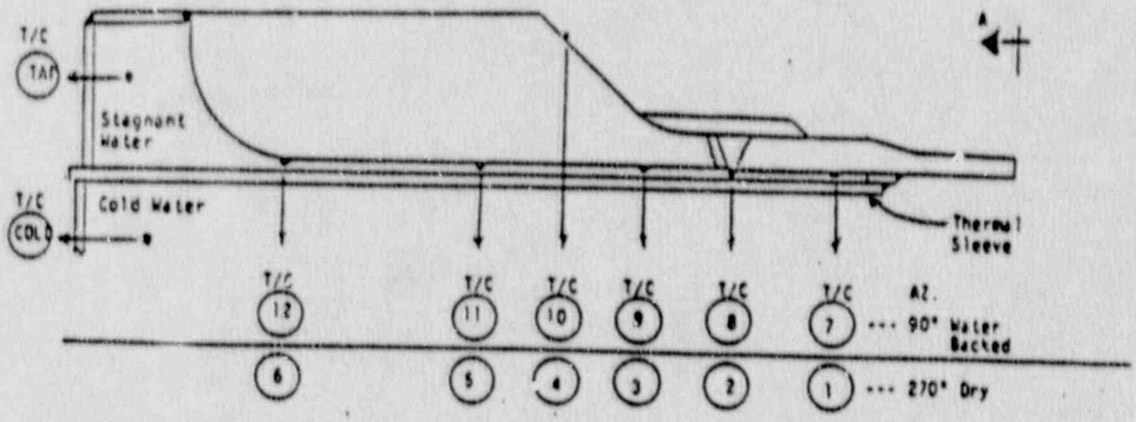
THERMOCOUPLE (T/C) LOCATIONS

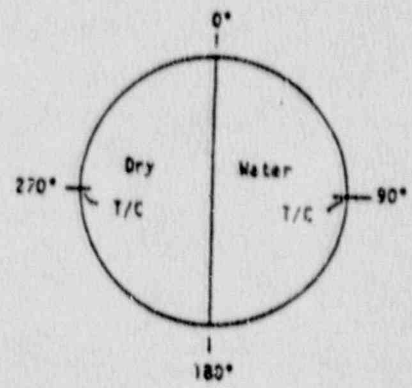




SECTION A

THERMOCOUPLE (T/C) LOCATIONS





SECTION A

- PEAK TEMPERATURE DURING WELDING

	T/C # °F								
LAYER	9	3	Pass	8	2	Pass	7	1	Pass
1	--	--	--	--	--	--	--	--	--
2	231	352	19	246	356	27	--	--	--
3	221	331	53	230	356	45	125	220	37
4	222	322	56	215	335	65	123	281	72
5	213	293	87	181	295	80	106	238	73
6	204	292	93	187	285	100	99	242	106
7	199	280	118 120	181	343	112	94	198	107
8	186	267	126	174	274	136	88	208	140

W/O H5224

___ of ___

RECORD OF T/C TEMP. DURING WELDING

PASS	LAYER	COMMENT	1	2	3	4	5	6	7	8	9	10	11	12	COLD H_2O	TAP H_2O
			DRY						H2O BACKED							
			T/C I.D. (°F)													
1	1	12-10-86 11:30 Before W.	53	53	52	53	53	54	39	43	45	48	48	48	35	
2	1	1:20 Before W	86	72	62	57	57	55	47	50	[illegible]	52	52	53	36	
3	1	Before	125	98	75	62	61	57	61	62	60	[illegible]	58	60	38	68
3	1	3:26 After	248	191	82	63	62	59	73	72	66	62	62	62	41	67
4	1	12-11-86 7:30 AM Before	44	44	44	44	44	45	34	37	39	41	41	41	34	45
4	1	8:17 After	141	135	76	49	51	48	80	77	56	47	46	45	36	48
5	1	8:51 After	203	215	93	57	56	52	62	62	57	52	51	50	36	56
6	1	9:39 "	146	113	83	67	66	59	79	92	67	55	54	52	36	58
7	1	10:05 "	192	152	115	69	68	61	57	60	59	58	57	55	37	59
8	1	10:34 "	198	174	117	78	76	63	71	89	73	59	58	55	37	66
9	1	10:57 "	188	262	187	78	77	63	64	71	67	65	64	62	39	67
10	1	11:30 "	191	183	130	88	85	71	71	113	89	66	65	63	38	66
11	1	11:54 "	173	266	173	89	86	73	64	74	72	70	68	65	41	68
12	1	12:47 Before	107	95	94	79	79	76	54	61	62	64	64	64	42	73
12	1	After	135	187	126	87	85	75	63	125	102	75	66	63	40	75
13	1	1:30 Before	114	107	93	83	82	75	57	63	64	67	65	64	38	68
13	1	1:52 After	108	258	197	95	83	75	62	72	71	70	68	65	40	74
14	1	2:23 "	137	158	133	97	94	76	62	104	99	72	70	65	41	71
15	1	Before / Peak			94 / 281						/ 184					74
15	1	After	113	199	179	102	94	78	55	62	65	69	67	66	37	70
16	1	[illegible] Bef. / Pk	119 / 117	138 / 215	120 / 217	95 / 96	93	79	57 / 55	58 / 113	62 / 210	66 / 67	66	65	41	78
16	1	3:31 After	129	181	134	103	100	81	58	90	93	75	71	65	40	67
17	1	3:38 / 3:48 Bef. / Pk.	117 / 119	180 / 137	105 / 368	95 / 96	[illegible]	85	58 / 59	90 / 108	93 / 220	78 / 75	72	66	46	76
17	1	355 After	116	185	179	109	105	83	60	68	71	74	72	67	40	71
18	1	12-12-86 7:40 AM Before	48	47	47	47	47	48	37	40	43	45	44	45	34	47
18	1	AM 8:32 After	68	91	87	67	64	52	43	72	79	60	56	47	36	53
-	1	AM 4:46 Before Repair	46	46	46	46	46	46	38	38	41	43	42	42	35	41
-	1	AM 7:15 After Repair	277	205	116	71	69	60	53	54	55	56	55	54	36	54

W/O H5224

____ of ____

RECORD OF T/C TEMP. DURING WELDING

DRY ⟷ H_2O BACKED

PASS	LAYER	COMMENT	T/C ID. 1	2	3	4	5	6	7	8	9	10	11	12	COLD H_2O	TAP H_2O
19	2	Am 8:35 After Peak	100	154	167/352	87	82	63	50	58	61/231	62	60	55	36	54
20	2	9:00 After Peak	118	129	115/332	92	89	69	53	73	77/211	70	66	57	38	60
21	2	9:28 After Peak	109	182	175/315	100	95	74	55	64	66/200	68	65	61	38	58
22	2	9:56 After Peak	127	149	132/287	102	99	79	59	90	93/178	74	70	63	37	62
23	2	10:27 "	112	228/285	214/263	100	97	81	60	70/183	72/162	73	70	66	38	64
24	2	10:52 "	141	165	141	106	103	84	62	107	102	75	72	67	38	65
27	2	Before	107	99	90	85	84	81	53	58	61	65	64	64	38	62
27	2	Pm 1:29 After Peak	146	190/356	141	90	88	77	58	69/246	65	67	65	64	39	66
36	2	Pm 8:12	218	171	110	77	76	70	57	61	62	64	62	62	37	60
36	2	Pm [illegible] After Peak	205/375	156	109	82	80	72	65/-	68	65	64	64	63	44	64
37	3	Before	49	48	47	47	47	47	36	39	41	43	41	41	34	48
37	3	After Peak	171/220	132	74	51	50	49	51/125	52	49	47	46	45	36	[illegible]
45	3	Before	175	160	120	88	86	73	71	83	76	68	67	64	42	65
45	3	After Peak	162	297/356	171	87	85	75	69	78/330	75	71	69	66	44	66
49	3	Before	145	148	124	98	96	82	63	83	81	73	71	66	38	63
49	3	After Peak	126	215	194/366	102	99	82	61	72	73/172	74	71	67	39	61
50	3	After Peak	142	169	198/396	109	106	85	59	107	119/195	77	73	67	43	62
51	3	After Peak	120	203	223/316	107	103	86	62	74	76/207	77	74	69	38	67
52	3	After Peak	131	155	141/328	112	109	88	59	92	100/220	81	76	68	36	66
53	3	After Peak	115	173	183/331	115	111	89	59	69	73/221	77	74	69	37	66
54	3	After Peak	125	146	138/330	115	113	91	58	83	92/224	84	79	69	38	65
55	4	After Peak	107	155	176/282	117	114	91	59	69	79/196	78	75	69	39	65
56	4	"	118	154	156/322	121	118	93	58	93	123/222	86	79	69	38	66
57	4	"	104	170	219/318	113	108	92	60	72	76/218	79	75	69	40	67
58	4	"	120	150	148/313	114	111	91	63	100	118/230	80	75	68	38	64
59	4	"	109	193	203/298	110	106	90	61	72	75/199	77	74	69	40	63
60	4	"	128	159	146/277	111	109	90	60	113	126/190	77	73	68	39	66
65	4	Before	159	157	130	105	103	88	65	76	75	74	71	68	38	64
65	4	After Peak	168	240/335	166	101	99	88	64	73/215	73	73	71	68	39	66
72	4	Before	191	162	108	73	72	64	57	60	60	60	59	58	37	62
72	4	After Peak	228/281	179	115	76	75	66	108/123	101	69	61	61	61	39	63

W/O H5224

____ of ____

RECORD OF T/C TEMP. DURING WELDING

DRY "T" H2O BACKED

PASS	LAYER	COMMENT	T/C ID. 1	2	3	4	5	6	7	8	9	10	11	12	COLD H_2O	TAP H_2O
73	5	AFTER PEAK	238/228	218	108	76	75	68	106/71	75	69	65	65	64	38	65
80	5	BEFORE	178	168	132	100	98	82	65	78	75	73	70	67	39	67
80	5	AFTER PEAK	167	213/295	178	101	98	83	64	73/181	73	74	71	67	39	68
83	5	"	118	160	143/262	97	95	82	60	69	71/182	71	69	67	41	82
84	5	"	132	152	135/273	103	101	83	60	99	103/188	76	72	66	39	81
85	5	"	120	178	170/229	105	102	84	60	70	72/206	74	72	68	39	80
86	5	"	105	104	98/290	91	90	85	59	63	66/207	70	69	68	48	76
87	5	"	95	157	184/293	101	97	82	60	72	75/213	75	72	69	40	65
88	5	"	108	113	106/290	97	96	75	59	85	98/193	82	77	67	41	66
89	5	"	97	140	158/290	110	106	84	64	73	76/187	79	76	70	47	66
90	6	AFTER PEAK	108	130	128/273	111	108	88	60	83	95/193	88	82	70	40	69
91	6	"	102	151	172/279	116	112	89	61	71	76/211	81	77	71	40	68
92	6	"	109	131	129/288	109	107	90	58	87	102/203	83	78	68	38	65
93	6	"	103	164	176/292	113	109	89	60	72	75/204	78	75	70	40	66
94	6	"	122	145	136/271	112	110	91	61	90	98/190	82	77	69	40	67
95	6	"	114	189	190/260	112	108	91	62	74	76/170	78	75	70	41	67
100	6	BEFORE	108	160	126	74	73	59	55	62	62	60	58	54	36	58
100	6	AFTER PEAK	137	151/285	118	80	78	63	63	102/197	88	62	60	55	37	61
105	6	BEFORE	188	175	121	85	84	75	53	59	61	64	62	61	37	58
105	6	AFTER PEAK	213/242	185	126	86	84	75	95/99	111	74	63	63	64	37	66
107	7	BEFORE	132	113	94	81	81	75	54	59	61	64	62	63	37	63
107	7	AFTER PEAK	192/118	210	110	79	79	75	69/94	76	70	66	65	64	37	65
112	7	BEFORE	197	207	149	95	93	79	63	72	70	70	68	66	37	65
112	7	AFTER PEAK	210	209/243	155	101	98	80	72	127/181	99	71	69	66	39	66
116	7	"	144	145	126/238	103	101	87	62	77	77/157	75	73	68	39	67
117	7	"	132	175	159/248	107	104	86	60	70	73/168	75	72	69	40	66
118	7	"	137	144	129/280	107	105	89	63	79	81/196	78	75	69	45	67
119	7	"	129	150	137/277	110	108	90	62	69	78/190	76	74	71	41	68
120	7		104	104	98/262	93	92	87	55	62	66/199	77	69	68	40	66
121	7	"	101	133	132/258	104	102	84	57	65	70/189	74	71	68	38	67
122	7	"	109	123	118/253	105	103	87	59	74	80/188	81	76	69	38	67
123	7	"	103	134	140/229	114	111	88	58	68	73/168	78	75	70	38	66

W/O H5224

RECORD OF T/C TEMP. DURING WELDING

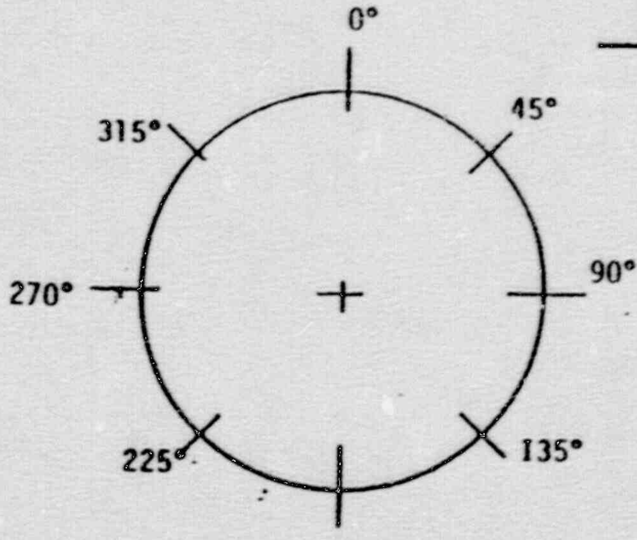
___ of ___

PASS	KAV. 5a	COMMENT	T/C I.D. 1	2	3	4	5	6	7	8	9	10	11	12	COLD H_2O	TAP H_2O
124	8	AFTER / PEAK	108	123	121/214	110	108	92	58	73	90/157	84	79	71	40	67
125	8	"	102	141	154/233	119	116	92	59	69	75/167	81	77	72	39	67
126	8	"	107	113	111/267	104	103	94	59	76	83/186	83	78	70	39	67
127	8	"	103	145	151/256	113	110	91	58	69	73/186	78	75	71	38	67
128	8	BEFORE	45	45	45	46	45	46	34	37	39	41	40	41	36	51
128	8	AFTER / PEAK	62	77	76/225	62	60	51	44	62	67/170	57	53	45	36	48
129	8	"	70	130	137/231	77	73	56	49	60	62/168	60	57	51	37	53
130	8	"	97	135	124/223	86	83	62	49	99	121/155	64	61	54	37	56
131	8	AFTER	94	181	204	84	81	67	57	73	74	69	65	58	38	61
136	8	BEFORE	140	160	130	94	92	80	57	63	65	68	66	69	44	62
136	8	AFTER / PEAK	163	180/274	140	95	93	80	65	[illegible]	[illegible]	[illegible]	[illegible]	66	38	65
140	8	BEFORE	160	149	118	91	89	79	58	65	66	69	67	66	38	64
140	8	AFTER / PEAK	188/208	171	128	92	90	80	92/98	98	80	68	67	65	39	64
2ND TEMPER BEAD		BEFORE	127	135	134	100	97	76	56	65	69	72	69	65	41	63
2ND TEMPER BEAD		AFTER / PEAK	115	126	130/159	102	98	79	56	65	69/100	72	70	66	41	67

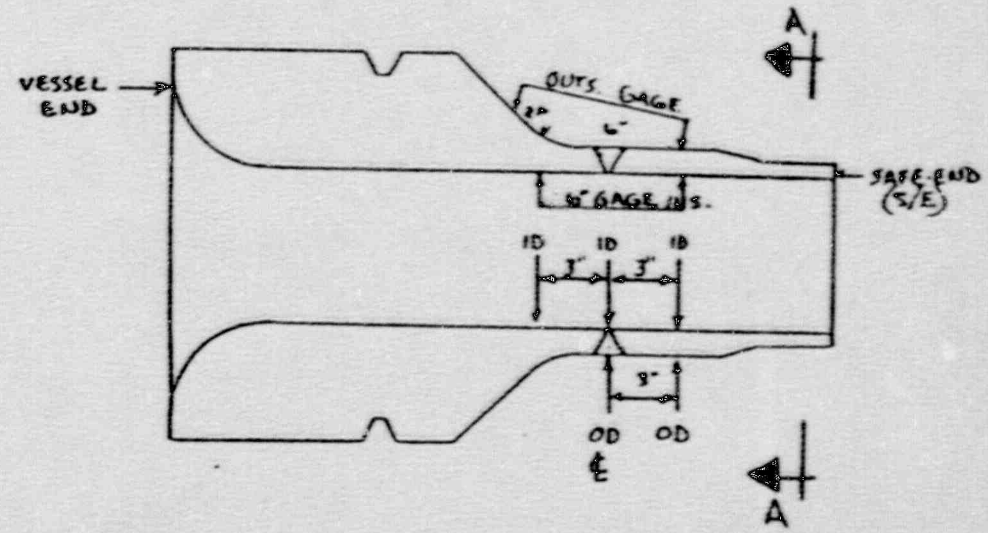
.ENSIONAL CHECKS

BEFORE WELDING OVERLAY

W/O [illegible] 224



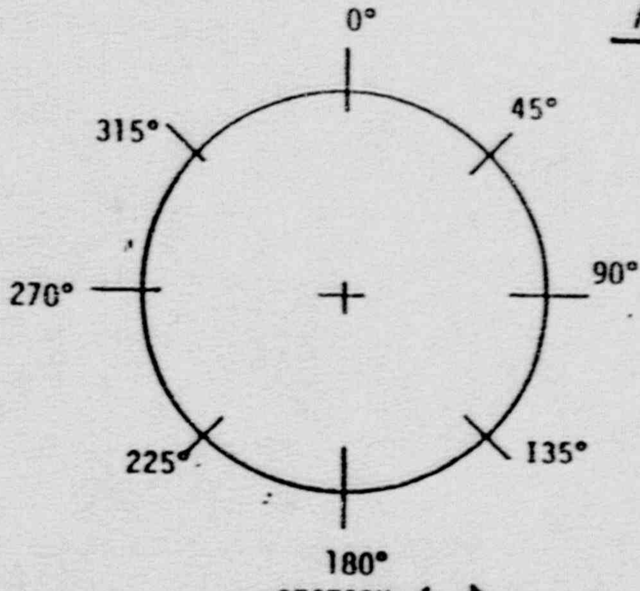
SECTION A-A



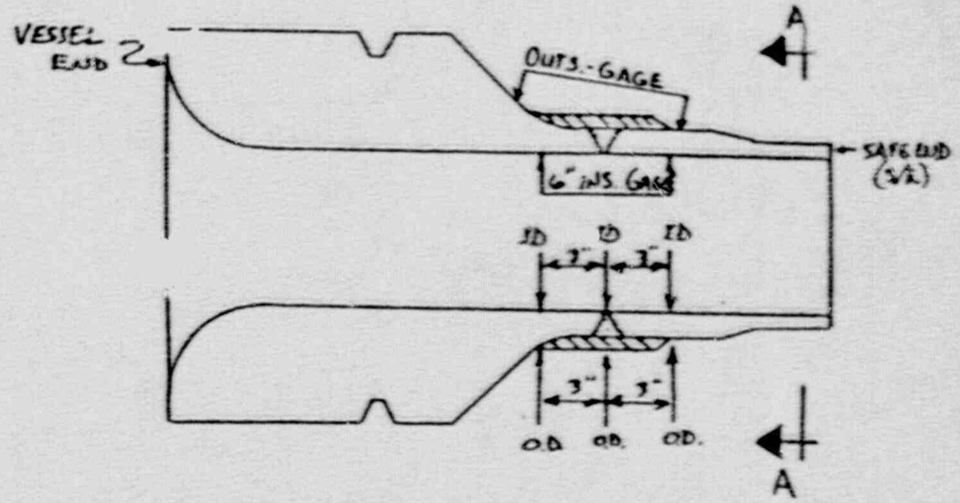
PIPE OR COMPONENT	LOCATION DIMENSION	0°	45°	90°	135°	180°	225°	270°	315°					
	6" INS. GAGE	6.006	6.004	6.005	6.007	6.003	5.998	6.009	6.005					
	OUTS. GAGE	7.740	7.719	7.745	7.748	7.693	7.744	7.745	7.730					
	3" TOWARD S/E I.D.	11.491	11.501	11.487	11.485									
	℄ OF WELD I.D.	11.413	11.432	11.426	11.416									
	3 TOWARD VESSEL END I.D.	11.594	11.590	11.581	11.584									
	3" TOWARD S/E O.D.	13.888	13.894	13.887	13.882									
	℄ OF WELD OD.	13.905	13.937	13.895	13.883									

MENSIONAL CHECKS
AFTER WELDING OVERLAY

W/O 224



SECTION A-A

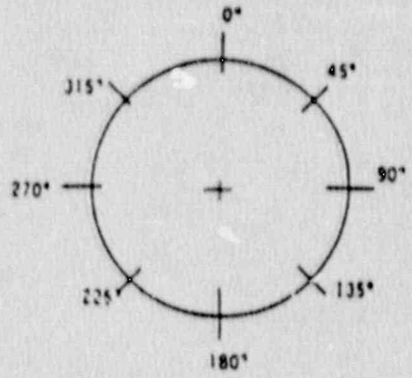


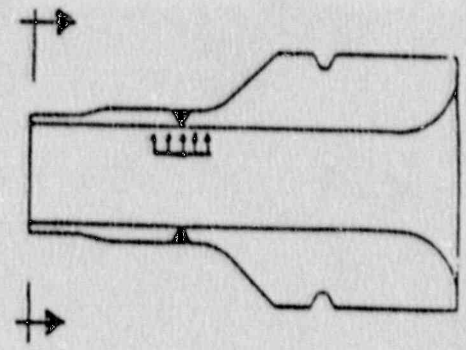
PIPE OR COMPONENT	LOCATION DIMENSION	0°	45°	90°	135°	180°	225°	270°	315°					
	6" INS. GAGE	5.983	5.980	5.988	5.993	5.977	5.976	5.973	5.974					
	OUTS. GAGE	7.668	7.659	7.687	7.688	7.628	7.662	7.669	7.668					
	3" TOWARD S/E I.D.	11.418	11.419	11.413	11.410									
	℄ OF WELD I.D.	11.371	11.383	11.379	11.360									
	3" TOWARD VESSEL END I.D.	11.585	11.572	11.570	11.575									
	3" TOWARD S/E O.D.	13.851	13.833	13.836	13.834									
	℄ OF WELD O.D	14.916	14.903	14.869	14.886									
	3" TOWARD VESSEL END O.D.	14.944	14.911	14.895	14.941									

W/O H5224

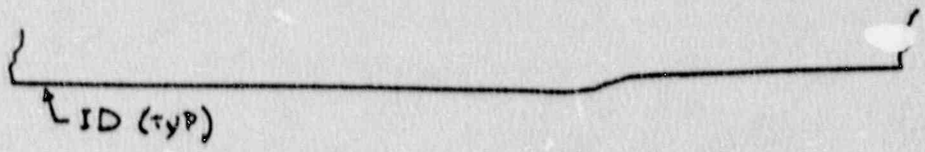
CONTOUR GAGE TRACING

LOCATION ID - BEFORE WELDING OVERLAY





0°

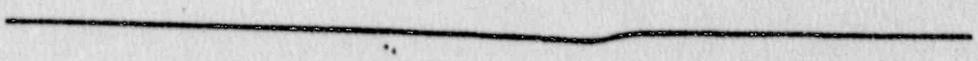


45°

90°

135°

180°



225°

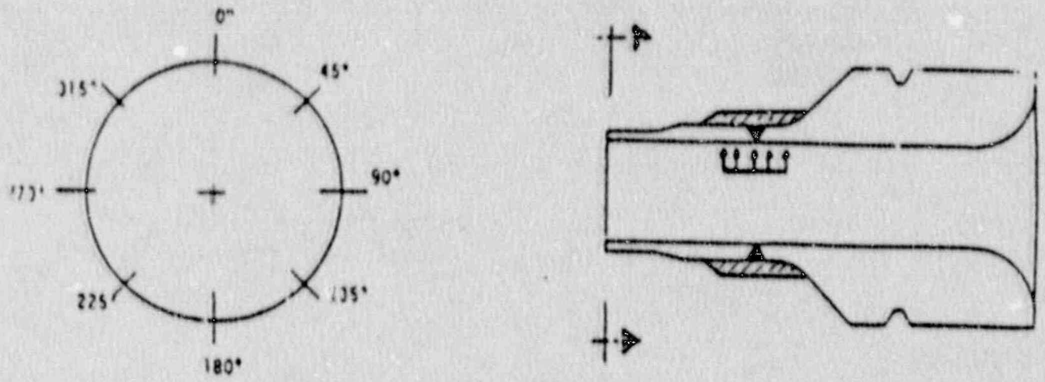
270°

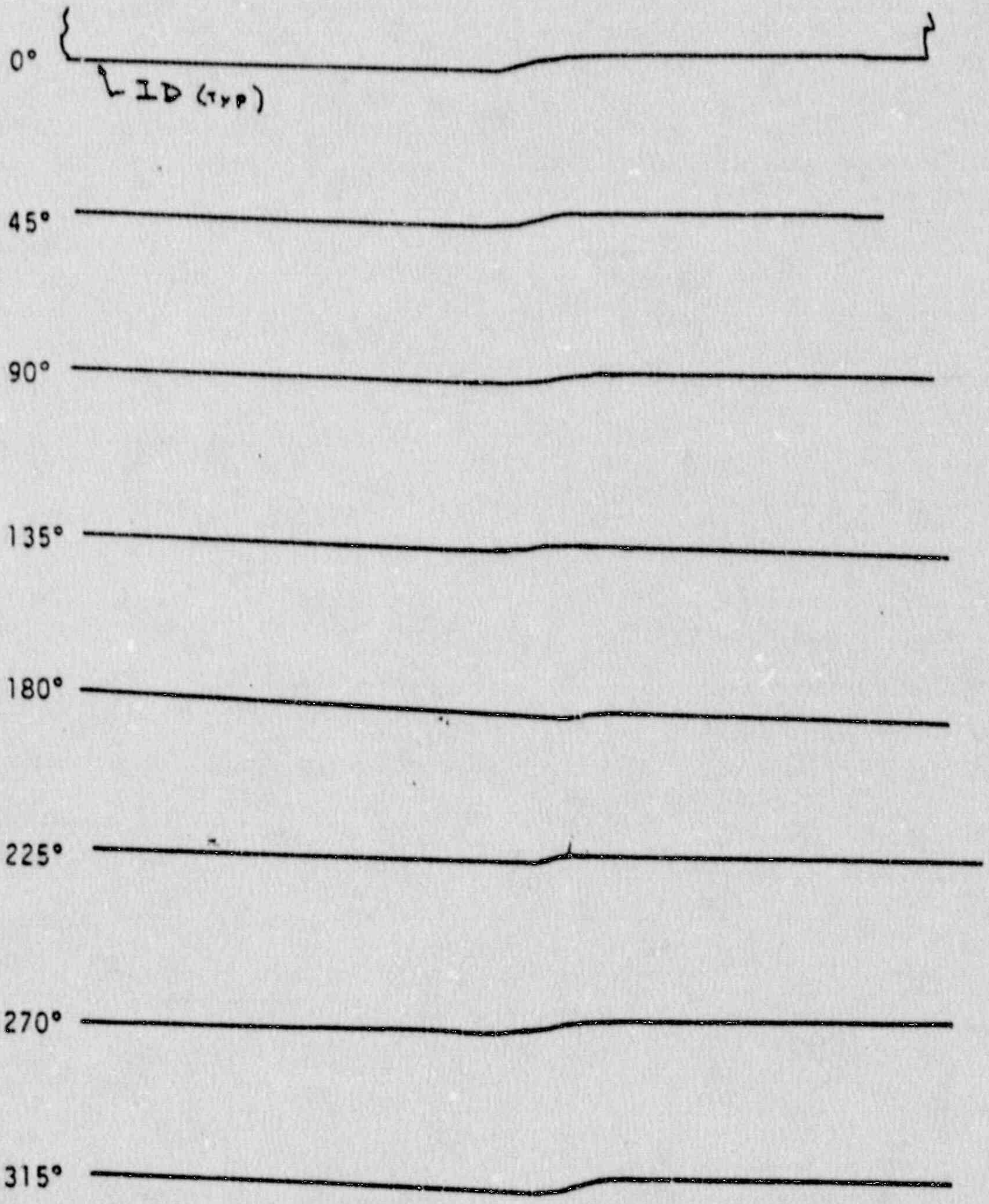
315°

W. H5224

CONTOUR GAGE TRA ING

LOCATION ID - AFTER WELDING OVERLAY

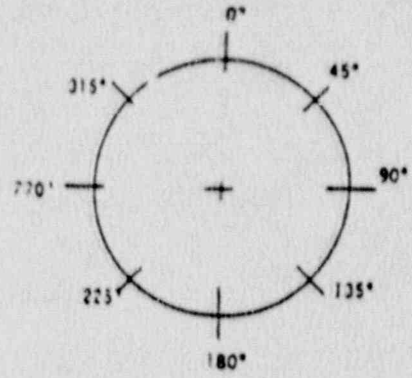


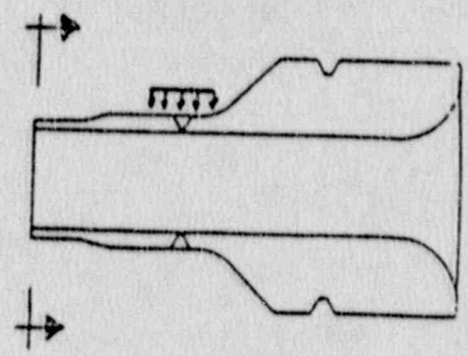


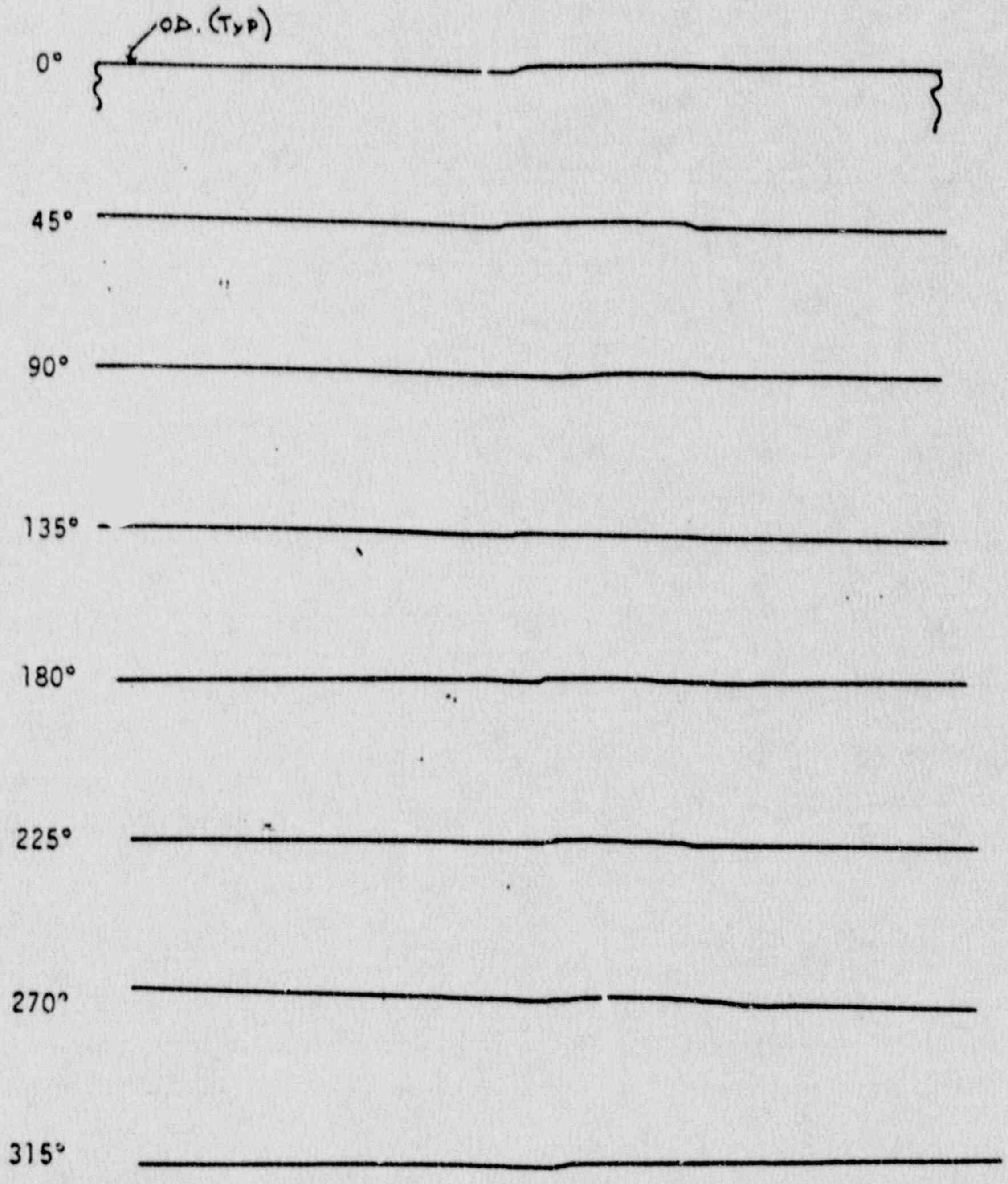
W/O H5224

CONTOUR GAGE TRA ING

LOCATION O.D - SAFE END WELD - BEFORE WELDING OVERLAY.

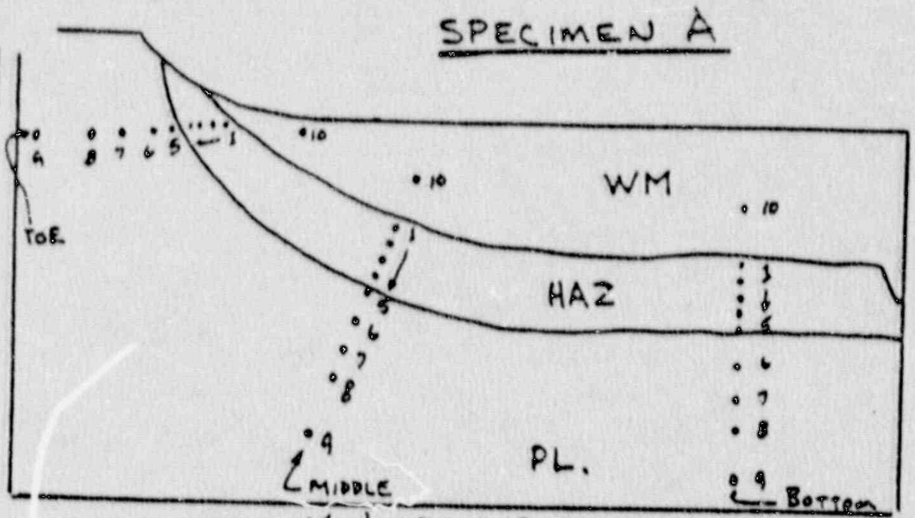






METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN A



VICKERS 10 KG

Work Order No.:	H5224
Material:	SA508 CL 2
Thickness:	1.2" To 1.75"
Electrode:	ERNiCr-3
PWHT:	None
Position:	5G
Test By:	AEH
Date:	3-10-87
Location:	Houston

AREA	TOE	MIDDLE	BOTTOM		
1	257	295	302		
2	254	315	331		
3	236	240	298		
4	240	199	250		
5	233	181	222		
6	191	181	183		
7	177	181	183		
8	164	177	172		
9	167	177	171		
10 (WM)	163	178	203		

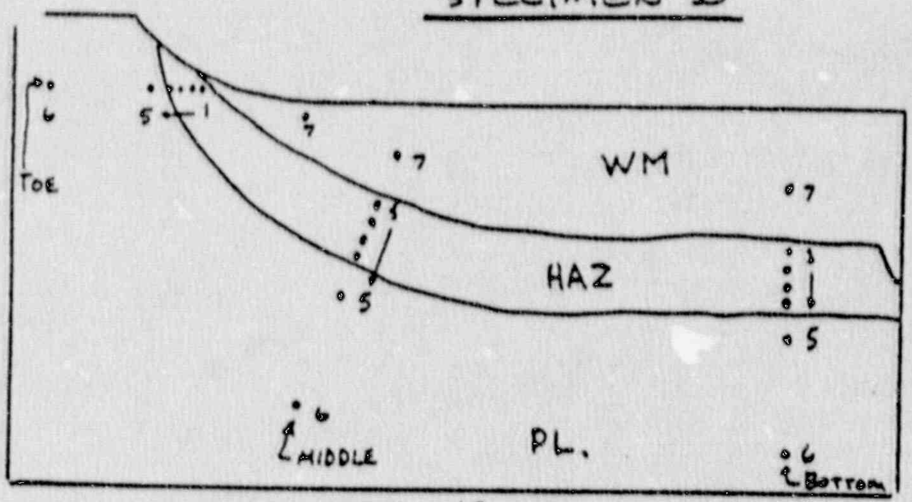
TRAVERSE SPACING
1 TO 5 = 1/2 mm
5 TO 8 = 1 mm
8 TO 9 : 4 TO 8 mm

DEPTH AT TOE = 1/2 To 1 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN B



Work Order No.: H5224
Material: SA508 CL 2
Thickness: 1.2" To 1.75"
Electrode: ER NiCr-3
PWHT: NONE
Position: 5G
Test By: AEH
Date: 3-11-87
Location: HOUSTON

VICKERS 10 KG

AREA	TOE	MIDDLE	BOTTOM		
1	400	310	305		
2	291	322	286		
3	204	249	267		
4	191	192	226		
[illegible]	181	179	182		
[illegible]	171	174	179		
7 (WM)	163	195	200		

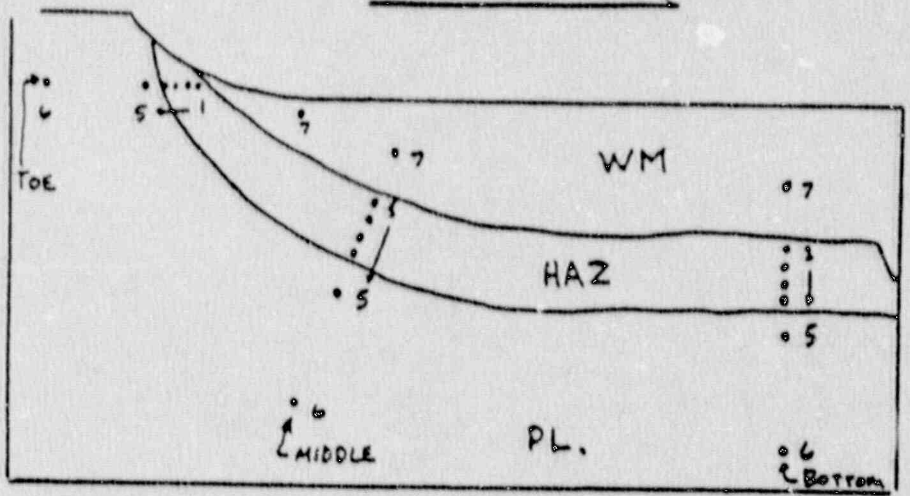
TRAVERSE SPACING
1 To 4 = 1/2 mm
4 To 5 = 1 mm
5 To 6 = 4 To 8 mm

DEPTH AT TOE = 1/2 To 1 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN B2



Work Order No.: H5224
Material: SA508 CL 2
Thickness: 1.2" To 1.75"
Electrode: ER NiCr-3
PWHT: NONE
Position: 5G
Test By: RCW
Date: 3-13-87
Location: HOUSTON

VICKERS 10 KG

AREA	TOE	MIDDLE	BOTTOM		
1	387	316	300		
2	256	273	314		
3	206	227	274		
4	190	203	234		
[illegible]	182	184	180		
[illegible]	172	174	177		
7 (WM)	164	195	203		

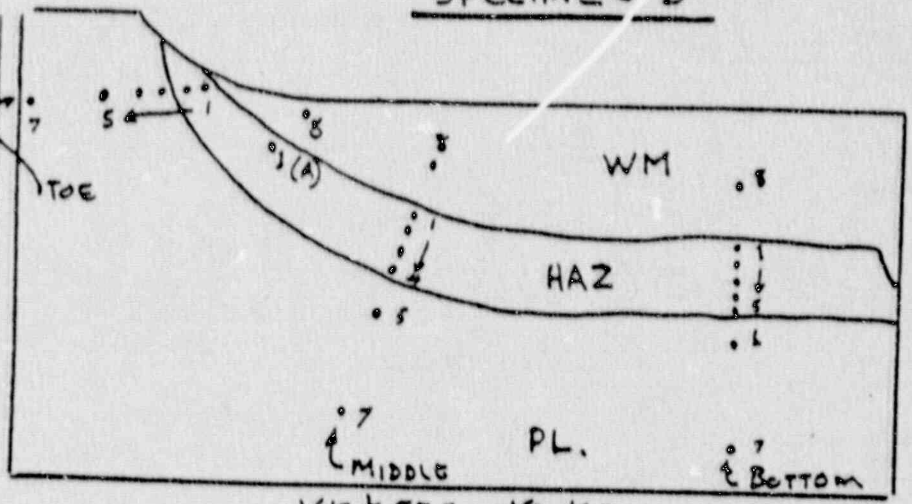
TRAVERSE SPACING
1 To 4 = 1/2 mm
4 To 5 = 1 mm
5 To 6 = 4 To 8 mm

DEPTH AT TOE = 1/2 To 1 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN D



Work Order No.:	H5224
Material:	SA508 CL2
Thickness:	1.2" To 1.75"
Electrode:	ER NiCr-3
PWHT:	NONE
Position:	5G
Test By:	AEH
Date:	3-11-87
Location:	HOUSTON

VICKERS 10 KG

AREA	TOE	MIDDLE	BOTTOM	A	
1	341	282	272	416	
2	235	331	267	–	
3	196	261	249	–	
4	185	187	225	–	
5	171	177	201	–	
6	–	–	179	–	
7	181	166	178	–	
8 (WM)	168	176	202	–	

TRAVERSE SPACING

@ Bottom 1 to 5 = 1/2 mm
5 to 6 = 1 mm
6 to 7 = 4 to 8 mm

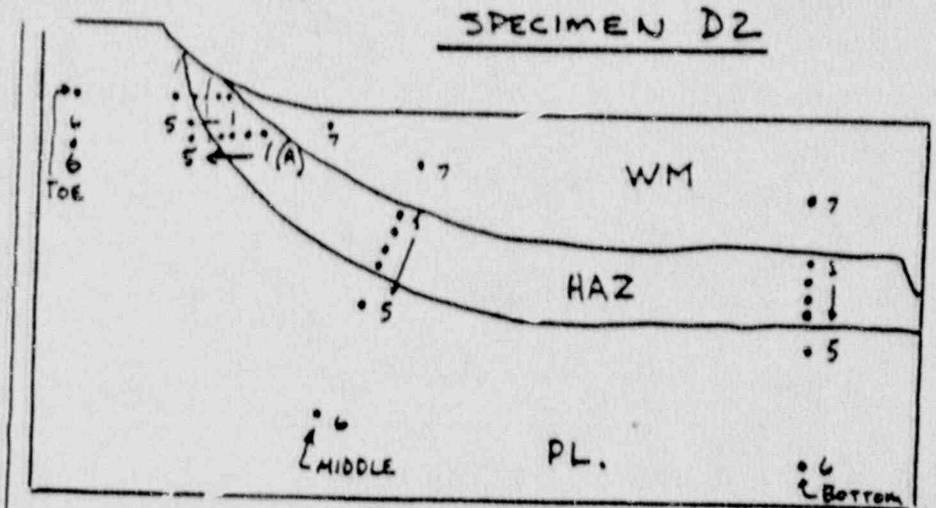
@ Toe & Middle 1 to 4 = 1/2 mm
4 to 5 = 1 mm
5 to 7 = 4 to 8 mm

DEPTH AT TOE = 1/2 To 1 mm.

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN D2



Work Order No.: H5224
Material: SA508 CL 2
Thickness: 1.2" TO 1.75"
Electrode: ERNiCr-3
PWHT: NONE
Position: 5G
Test By: BCW, AEH
Date: 3-13-87
Location: HOUSTON

VICKERS 10 KG

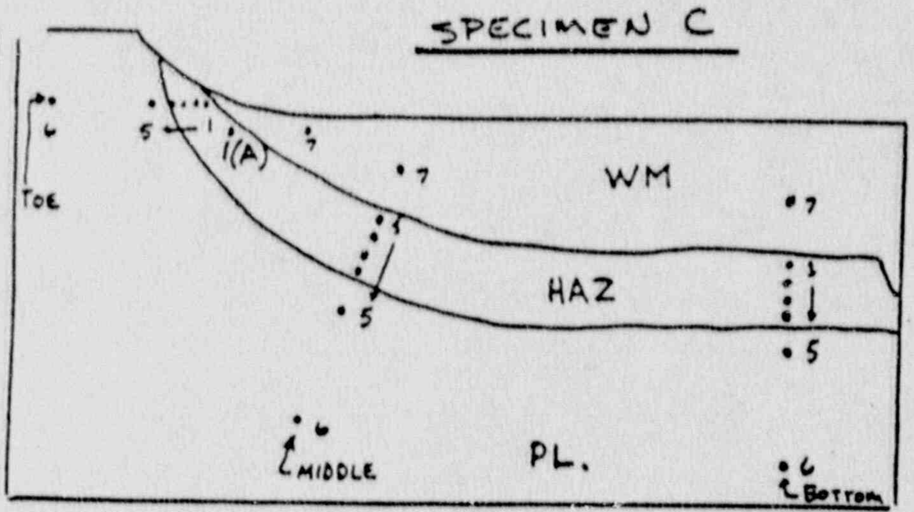
AREA	TOE	MIDDLE	BOTTOM	A	
1	350	308	284	434	
2	252	307	274	417	
3	196	267	248	316	
4	189	224	233	270	
[illegible]	188	183	176	256	
[illegible]	174	181	172	182	
7 (WM)	163	190	197	—	

TRAVERSE SPACING
1 TO 4 = 1/2 mm
4 TO 5 = 1 mm
5 TO 6 = 4 TO 8 mm

CBI

METALLURGICAL LABORATORY
HARDNESS TEST REPORT

SPECIMEN C



Work Order No.: H5224
Material: SA508 CL 2
Thickness: 1.2" To 1.75"
Electrode: ERNiCr-3
PWHT: NONE
Position: 5G
Test By: RCW
Date: 3-13-87
Location: HOUSTON

VICKERS 10 KG

AREA	TOE	MIDDLE	BOTTOM	A	
1	307	310	329	426	
2	348	314	272	—	
3	239	265	279	—	
4	201	214	234	—	
5	179	180	186	—	
6	177	176	177	—	
7 (WM)	168	190	203	—	

TRAVERSE SPACING
1 To 4 = 1/2 mm
4 To 5 = 1 mm
5 To 6 = 4 To 8 mm

DEPTH AT TOE = 1/2 To 1 mm

CBI LIQUID PENETRANT EXAMINATION REPORT

WELD LAB HOUSTON, TEXAS — ☐ Field ☒ Shop — N61122 — PT #1

LOCATION — CONTRACT — REPORT OR SEQUENCE NO.

Customer
CBI

Description and stage of items examined
OVERLAY DEPOSIT AREA PRIOR TO WELDING

Outside ☒ Inside ☐ Edge ☐ of items

Procedure and Rev No.
PT14 REVISION 3

Manufacturer's Brand Name	Type and Batch Number		
	Penetrant	Cleaner/Remover	Developer
SHERWIN	DP-40	DR-60	D-100
INCORPORATED	1E-823	518-D4	528-G6

Location of Defects or Unacceptable Cavities Not Repaired During Examination.

ID	Location From Reference Point	Date

Remarks or Sketch

Check Applicable Box(es):

☐ Weld repairs were made during examination and have been re-examined and found acceptable (includes repair cavity).

☒ No welded repairs made during examination.

☐ Final surfaces requiring blend grinding during examination have been completed per GR ______ Rev. ______ re-examined and found acceptable.

Examinations were performed and all indications evaluated in accordance with the referenced procedure.
Defects not repaired during the examination are listed by location above.
All other examined areas included in this report were found acceptable.

Charles V. Hulock — III — 11/10/86

OPERATOR/EVALUATOR — LEVEL — DATE

Report results reviewed and accepted by: Charles V. Hulock — III — 11/10/86

LEVEL — DATE

Reviewed and accepted by –

CUSTOMER'S INSPECTOR — DATE — ANI OR AI — DATE

Printed in USA

WL 246 REV AUG 81

CBI MAGNETIC PARTICLE EXAMINATION REPORT

WELD LAB HOUSTON, TEXAS	☐ Field ☒ Shop N61122	MT #1
LOCATION	CONTRACT	REPORT OR SEQUENCE NO.

Customer: CBI

Description and stage of items examined: A508 GROOVE PREP PRIOR TO WELDING

☒ Outside ☐ Inside ☐ Edge of items

Procedure and Rev No.: MT11 REVISION 4

☐ Prods ☒ Yoke

Unit Mfg and Model: MAGNAFLUX Y6

Particles: ☐ Wet ☒ Dry

Prod Unit ID: N/A

Prod Unit Rating: N/A Amps

Prod Mode: N/A ☐ AC ☐ HWDC ☐ DC

Yoke Mode: ☒ AC ☐ DC

Mfg & Color: MAGNAFLUX 3A BLACK

Location of Defects or Unacceptable Cavities Not Repaired During Examination.

ID	Location From Reference Point	Date

Remarks or Sketch

Check Applicable Box(es):

☐ Weld repairs were made during examination and have been re-examined and found acceptable (includes repair cavity).

☒ No welded repairs made during examination.

☐ Final surfaces requiring blend grinding during examination have been completed per GR ______ Rev. ______ re-examined and found acceptable.

Examinations were performed and all indications evaluated in accordance with the referenced procedure.
Defects not repaired during the examination are listed by location above.
All other examined areas included in this report were found acceptable.

Charles W Sherlock	III	11/10/86
OPERATOR/EVALUATOR	LEVEL	DATE

Report results reviewed and accepted by: Charles W Sherlock III 11/10/86

LEVEL DATE

Reviewed and accepted by --

CUSTOMER'S INSPECTOR	DATE	ANI OR AI	DATE

CBI ULTRASONIC EXAMINATION REPORT

N61122
CONTRACT

Field ☐
Shop ☒

WELD LAB - HOUSTON, TX
LOCATION

UT #1
Report or Sequence No.

Primary Ref. Level 62 Db

Customer CBI

Description and stage of items examined
1) OVERLAY DEPOSIT AREA PRIOR TO WELDING
2) A508 GROOVE AREA PRIOR TO WELDING

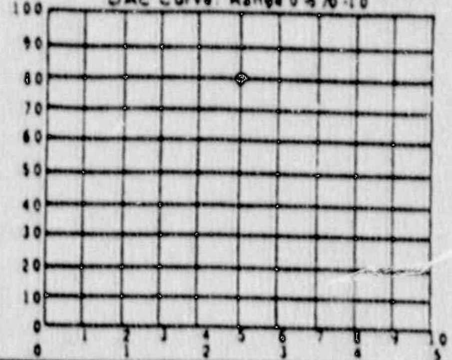
Procedure and Rev No.

Couplant ULTRAGEL II

Transducer DUAL
Mfg KB-AERO
Size 3/8" ⌀
Angle 5T
Frequency 5 MHz
J07313

Instrument Mfg KRAUTKRAMER/BRANSON
Model # USL-38 Serial # 212045

DAC Curve: Range 0-5 / 0-10



Location of Unacceptable Indications or other Indications Required by the Procedure to be Recorded.

ID	Location From Reference Point	Defect Size Length	Defect Size Depth	Depth from Outside ☐ Inside ☐	Date

Remarks or Sketch

Examinations were performed and evaluated per the referenced procedure.
Unacceptable Indications found Yes ☐ No ☒
Unacceptable and other indications required to be recorded are listed with their location above.
All other examined areas included in this report were found acceptable.

Charles N. Kuhlock	III	11/10/86	Charles N. Kuhlock	III	11/10/86
OPERATOR	LEVEL	DATE	EVALUATOR	LEVEL	DATE

Reviewed and accepted by –

CUSTOMER'S INSPECTOR	DATE	ANI OR AI	DATE

CBI ULTRASONIC EXAMINATION REPORT

N61122
CONTRACT

Field ☐
Shop ☒

WELD LAB - HOUSTON, TX
LOCATION

UT #1
Report or Sequence No.

Primary Ref. Level 32 Db

Customer CBI

Description and stage of items examined
1) OVERLAY DEPOSIT AREA PRIOR TO WELDING
2) ASOB GROOVE ~~PREP~~ PRIOR TO WELDING

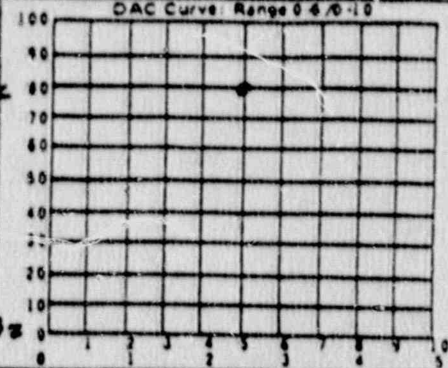
Procedure and Rev. No.

Couplant ULTRAGEL II

DUAL Transducer
Mfg. KB-AERO
Size .5" X 1"
Angle 5T
Frequency 2.25 MHz
J26619

Instrument Mfg KRAUTKRAMER/BRANSON
Model # USL-38 Serial # 212045

DAC Curve: Range 0-5/0-10



Location of Unacceptable Indications or other Indications Required by the Procedure to be Recorded.

ID	Location From Reference Point	Defect Size – Length	Defect Size – Depth	Depth from Outside ☐ Inside ☐	Date

Remarks or Sketch

Examinations were performed and evaluated per the referenced procedure.
Unacceptable Indications found Yes ☐ No ☒
Unacceptable and other indications required to be recorded are listed with their location above.
All other examined areas included in this report were found acceptable.

Charles W. Wheelock	III	11/10/86	Charles W. Wheelock	III	11/10/86
OPERATOR	LEVEL	DATE	EVALUATOR	LEVEL	DATE

Reviewed and accepted by –

CUSTOMER'S INSPECTOR	DATE	ANI OR AI	DATE

Printed in USA

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CBI LIQUID PENETRANT EXAMINATION REPORT

WELD LAB HOUSTON, TEXAS — LOCATION

☐ Field ☒ Shop

N61122 — CONTRACT

PT #2 — REPORT OR SEQUENCE NO.

Customer: CBI

Description and stage of items examined: FINISHED WELDS AFTER GRINDING

☒ Outside ☐ Inside ☐ Edge of items

Procedure and Rev No.: PT14 REVISION 3

Manufacturer's Brand Name	Type and Batch Number		
	Penetrant	Cleaner/Remover	Developer
SHERWIN	DP-40	DR-60	D-100
INCORPORATED	1E823	518-D4	528-G6

Location of Defects or Unacceptable Cavities Not Repaired During Examination.

ID	Location From Reference Point	Date

NO UNACCEPTABLE INDICATIONS FOUND

Remarks or Sketch

Check Applicable Box(es):

☐ Weld repairs were made during examination and have been re-examined and found acceptable (includes repair cavity).

☒ No welded repairs made during examination.

☐ Final surfaces requiring blend grinding during examination have been completed per GR ______ Rev. ______, re-examined and found acceptable.

Examinations were performed and all indications evaluated in accordance with the referenced procedure.
Defects not repaired during the examination are listed by location above.
All other examined areas included in this report were found acceptable.

Ronald W. Kruger — OPERATOR/EVALUATOR — III LEVEL — 12/30/86 DATE

Report results reviewed and accepted by: Ronald W Kruger — III LEVEL — 12/30/86 DATE

Reviewed and accepted by —

CUSTOMER'S INSPECTOR ______ DATE ______ ANI OR AI ______ DATE ______

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WL 246 REV AUG 81

CBI ULTRASONIC EXAMINATION REPORT

N61122
CONTRACT

Field ☐
Shop ☒

WELD LAB - HOUSTON, TX
LOCATION

UT #2
Report or Sequence No.

Primary Ref. Level 62 Db

Customer CBI

Description and stage of items examined
1) OVERLAY DEPOSIT FINISHED WELD
2) GROOVE WELD DEPOSIT FINISHED WELD
(BOTH AFTER GRINDING)

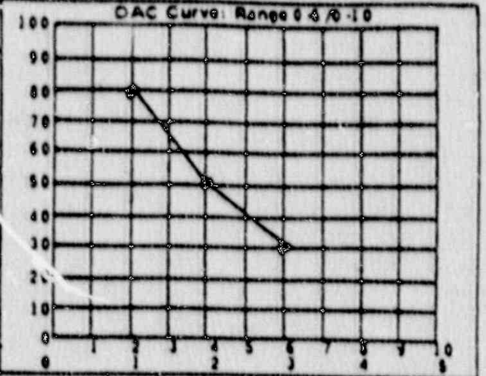
Procedure and Rev No.
UT5 REV. 0
UT6 REV. 0

Couplant
ULTRAGEL II

Transducer
Mfg. KB-AERO
Size .5 X .5"
Angle ST.
Frequency 5 MHZ
H16432

Instrument Mfg KRAUTKRAMER/BRANSON

Model # USL-38 Serial # 212045



Location of Unacceptable Indications or other Indications Required by the Procedure to be Recorded.

ID	Location From Reference Point	Defect Size Length	Defect Size Depth	Depth from Outside ☐ Inside ☐	Date

Remarks or Sketch

INDICATION AREAS MARKED ON GROOVE WELD

Examinations were performed and evaluated per the referenced procedure.
Unacceptable Indications found Yes ☒ No ☐
Unacceptable and other indications required to be recorded are listed with their location above.
All other examined areas included in this report were found acceptable.

RW Kunze	III	12/30/86	R. Kunze	III	12/30/86
OPERATOR	LEVEL	DATE	EVALUATOR	LEVEL	DATE

Reviewed and accepted by—

CUSTOMER'S INSPECTOR	DATE	ANI OR AI	DATE

Printed in USA

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CBI ULTRASONIC EXAMINATION REPORT

N61122
CONTRACT

Field ☐
Shop ☒

ELO LAB - HOUSTON, TX
LOCATION

UT #2
Report or Sequence No.

Primary Ref. Level 64 Db

Customer CBI

Description and stage of items examined
1) OVERLAY DEPOSIT FINISHED WELD
2) GROOVE WELD DEPOSIT FINISHED WELD
(BOTH AFTER GRINDING

Procedure and Rev No.
UT 5 REV. 0
UT6 REV. 0

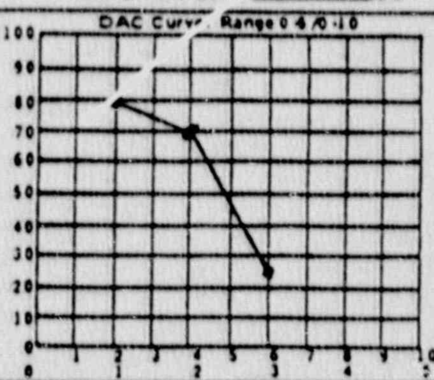
Couplant
ULTRAGEL II

Transducer
Mfg. KB-AERO
Size 3/8" X 3/4"
Angle 60° L
Frequency 3.5 MHZ
F05446

Instrument Mfg KRAUTKRAMER / BRANSON

Model # USL-38 Serial # 2J2045

DAC Curve Range 0 4 /0-10



Location of Unacceptable Indications or other Indications Required by the Procedure to be Recorded.

ID	Location From Reference Point	Defect Size		Depth from Outside ☐ Inside ☐	Date
		Length	Depth		

Remarks or Sketch

INDICATION AREAS MARKED ON GROOVE WELD

Examinations were performed and evaluated per the referenced procedure.
Unacceptable Indications found Yes ☒ No ☐
Unacceptable and other indications required to be recorded are listed with their location above.
All other examined areas included in this report were found acceptable.

RWKunze	III	12/30/86	RWKunze	III	12/30/86
OPERATOR	LEVEL	DATE	EVALUATOR	LEVEL	DATE

Reviewed and accepted by—

CUSTOMER'S INSPECTOR	DATE	ANI OR AI	DATE

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Appendix V

Procedure Qualifications

1. Code Case N-432 Groove - PQR 7673
2. Water Backed Nozzle to Safe-End Overlay PQR-7717
3. Non-Water Backed Nozzle to Safe-End Overlay-PQR 7718

Page

Contract

CBI

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX *

PART II ESSENTIAL VARIABLES

PQR No. 7673

Date 2/18/87

Process GTAW (Pulsed) (360° Orbital)

Manual [ ] Machine [X] Automatic [ ] Semiautomatic [ ]

Material specification SA508 Class 2

ASME p. no. 3, Gp. 3 To ASME p. no. ---

Thickness (if pipe, dia and wall thick) 5 3/16"

Filler metal group no. F. 43

Weld metal analysis no. A. ERNiCr-3

ASME specification no. SFA 5.14

AWS specification no. A 5.14

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition 100% Argon

Flow rate 40 CFH

Is backing strip used? No

Preheat temperature range 300°F -450°F (IPT)

Postweld heat treatment None***

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 5G

Filler Metal ERNiCr-3**

Electrode EWTH-2, Ø 1/8"

Filler wire diameter .045"

Type of backing None

Welding current Direct Current, Electrode Negativ (Straight Polarity)(Pulsed)

Consult PART III WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

(Round Specimen) Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
A (Transverse)	---	0.504	0.200	17.6	88.0	606.7	Ductile in BM
B (Transverse)	---	0.506	0.201	17.5	87.1	600.5	Ductile in BM
C (All Weld Metal)	---	0.250	0.049	5.1	104.1	717.7	—
D (All Weld Metal)	---	0.253	0.050	5.2	104.0	717.0	—

Bends Type	Result	Type	Result
4 Transverse Side	OK	---	---

Welder's name Jerry E. DeHay / John D. Matthews Social Security no. 464-76-3339 / 301-50-1193 Welder's Symbol JED / JDM

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H5173 Rev. 0 Date 11/2/86

We certify that the statements in this record are correct and that the test weld was prepared, welded and tested in accordance with the requirements of Section IX of the ASME code.

Signed CBI

By Alan E. Hudson Alan E. Hudson Date 2/18/87

Remarks: *)Qualified in accordance with Code Case N-432 using a SA508-2 nozzle forging machined to a 22"Ø OD. & 11 5/8" ID. with a 1" deep repair groove machined 360° around the OD. GTAW machine welded using a remote video monitor. The forging was IHT for 24 Hrs. at 1150°F prior to welding. The repair area was satisfactorily examined by PT & UT after the completed weld had been at ambient temperature for 48 Hrs.

**) Arcos type 382, Ht. Y4875N382.

***) Post Heat: 2 Hrs. at 500°F immediately after welding.

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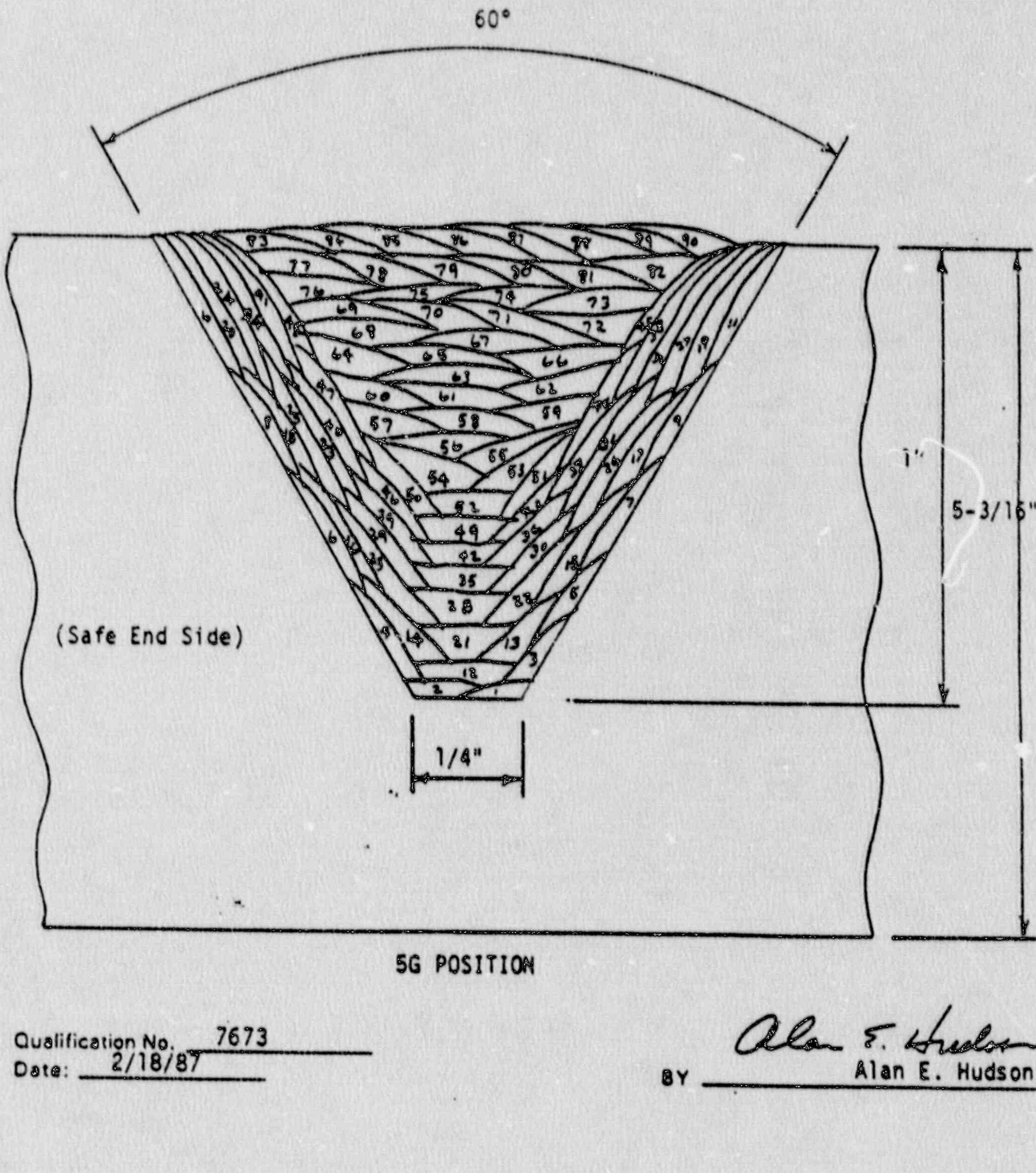
PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



5G POSITION

Qualification No. 7673
Date: 2/18/87

BY Alan E. Hudson
Alan E. Hudson

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WL 154 REV NOV 85

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES

Low Pulse Frequency = 1.5

Low Pulse Width = 60%

Synchronization	Pulse Arc	Voltage control	Continuous.
Upslope time	3 Sec.	Downslope time	10 Sec.
Wire Start Delay	5 Sec.	Travel Start Delay	4 Sec.

.s Number	1-4	5-6	7-9	10-11	12	13-16	17-18	19-20	21-23	24
Primary Weld Current (amps.)	200	200	200	200	200	200	200	200	200	200
Background Current (amps.)	100	100	100	100	100	100	100	100	100	100
Out Dwell (primary)(sec. x 1)	--	--	--	--	--	--	--	--	--	--
Excursion time (sec. x 1)	--	--	--	--	--	--	--	--	--	--
In Dwell (primary) (sec x 1)	--	--	--	--	--	--	--	--	--	--
Oscillation (in.)	--	--	--	--	--	--	--	--	--	--
Primary Wire Feed (IPM)	31	31	31	31	31	31	31	31	31	31
Background Wire Feed (IPM)	21	21	21	21	21	21	21	21	21	21
Travel (IPM) (Torch Speed)	4.23	4.14	4.05	3.97	4.23	4.14	4.05	3.97	4.14	3.97
Primary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Background Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	20.16	20.58	21.02	21.48	20.16	20.58	21.02	21.48	20.58	21.48
Energy Density (MJ/in^3)	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93

Qualification No. 7673
Date: 2/18/87

Alan E. Hudson
BY Alan E. Hudson

Page
Contract

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES

Pass Number	25-27	28	29	30	31-34	35	36	37-38	39	40-41
Primary Weld Current (amps.)	200	210	215	210	200	200	200	200	200	200
Background Current (amps.)	100	110	115	110	100	100	100	100	100	100
Out Dwell (primary)(sec x .1)	-	-	-	-	-	-	-	-	-	-
Excursion time (sec. x .1)	-	-	-	-	-	-	-	-	-	-
In Dwell (primary)(sec. x .1)	-	-	-	-	-	-	-	-	-	-
Oscillation (in.)	-	-	-	-	-	-	-	-	-	-
Primary Wire Feed (IPM)	31	31	31	31	31	31	31	31	31	31
Background Wire Feed (IPM)	21	21	21	21	21	21	21	21	21	21
Travel (IPM) (Torch Speed)	4.05	4.25	4.92	4.92	4.92	4.74	4.92	5.09	4.92	5.09
ary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
ackground Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	21.02	21.31	18.94	18.41	17.33	17.96	17.33	16.74	17.33	16.74
Energy Density (MJ/in^3)	1.93	2.05	2.12	2.05	1.93	1.93	1.93	1.93	1.93	1.93

Pass Number	42	43-48	49-56	57	58	59	60	61-62	63	64
Primary Weld Current (amps.)	210	200	210	200	210	200	220	220	220	220
Background Current (amps.)	110	100	110	100	110	100	110	110	110	110
Out Dwell (primary)(sec. x 1)	-	-	-	-	-	-	-	-	-	-
Excursion time (sec. x 1)	-	-	-	-	-	-	-	-	-	-
In Dwell (primary) (sec x 1)	-	-	-	-	-	-	-	-	-	-
Oscillation (in.)	-	-	-	-	-	-	-	-	-	-
rimary Wire Feed (IPM)	31	31	31	31	35	30	35	35	35	38
ackground Wire Feed (IPM)	21	21	21	21	25	20	25	25	25	28
ravel (IPM) (Torch Speed)	4.74	4.92	4.92	4.48	4.48	4.92	4.64	4.91	4.64	4.64
rimary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
ground Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Input (Kilojoules/in.)	19.08	17.33	18.41	19.00	20.18	17.33	20.18	19.08	20.18	20.18
ergy Density (MJ/in^3)	2.05	1.93	2.05	1.93	1.79	2.00	1.84	1.84	1.84	1.68

Printed in USA

QUALIFICATION NO. 7673
DATE 2-18-87

BY Alan E. Hudson

WL 154 REV NOV 85

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Contract

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES

Pass Number	65-68	69-76	77-82*	83-90						
Primary Weld Current (amps.)	220	225	225	220						
Background Current (amps.)	110	115	115	110						
Out Dwell (primary)(sec x .1)	-	-	-	-						
Excursion time (sec. x .1)	-	-	-	-						
In Dwell (primary)(sec. x .1)	-	-	-	-						
Oscillation (in.)	-	-	-	-						
Primary Wire Feed (IPM)	40	45	45	40						
Background Wire Feed (IPM)	30	35	35	30						
Travel (IPM) (Torch Speed)	4.56	4.47	4.38	4.64						
Primary Arc Volts	9.0	9.0	9.0	9.0						
Background Arc Volts	8.5	8.5	8.5	8.5						
Heat Input (Kilojoules/in.)	20.57	21.58	22.02	20.18						
Energy Density (MJ/in^3)	1.59	1.44	1.44	1.59						

*Passes 78 & 79 - 2/3 of circum. downhill side.

Pass Number										
Primary Weld Current (amps.)										
Background Current (amps.)										
Out Dwell (primary)(sec. x 1)										
Excursion time (sec. x 1)										
In Dwell (primary) (sec x 1)										
Oscillation (in.)										
Primary Wire Feed (IPM)										
Background Wire Feed (IPM)										
Travel (IPM) (Torch Speed)										
Primary Arc Volts										
Background Arc Volts										
Heat Input (Kilojoules/in.)										
Energy Density (MJ/in^3)										

QUALIFICATION NO. 7673
DATE 2-18-87

BY [signature]

CBI

IMPACT TEST [illegible]

TYPE OF NOTCH VEE

PQR 7673

W.O. #H5173

2/18/87

SPEC. NO.	SPEC. ORIENT	SPEC. SIZE	NOTCH LOCATION	TEST TEMP DEG F.	ENERGY		LATERAL EXPANSION MILS	PER CENT SHEAR
					FT-LB	J		
A-1**	LONG.	FULL	HAZ	+20	70	95	37	45
A-2**	LONG.	FULL	HAZ	+20	62	84	44	40
A-3**	LONG.	FULL	HAZ	+20	84	114	63	50
A-4**	LONG.	FULL	HAZ	+20	98	133	59	70
A-5**	LONG.	FULL	HAZ	+20	91	123	55	65
A-6**	LONG.	FULL	HAZ	+20	93	126	56	70
5224 B-1	LONG.	FULL	PLT	+20	43	58	36	40
5224 B-2	LONG.	FULL	PLT	+20	48	65	45	50
5224 B-3	LONG.	FULL	PLT	+20	60	81	40	50
5224 C-1	LONG.	FULL	PLT	+20	43	58	33	40
5224 C-2	LONG.	FULL	PLT	+20	51	69	42	35
5224 C-3	LONG.	FULL	PLT	+20	45	61	37	35
AA-1*	LONG.	FULL	HAZ	+20	73	99	53	60
AA-2*	LONG.	FULL	HAZ	+20	79	107	56	60
AA-3*	LONG	FULL	HAZ	+20	72	97	46	60
*	HAZ Specimen taken 1/16" from surface.							

REMARKS: ** HAZ specimen taken at maximum practical depth of groove weld (approximately 3/4" from surface to centerline of specimen) at Azimuth 270° (Uphill side). PLT specimen taken at 1/4T from OD surface in the necked down portion of the nozzle assembly adjacent to the safe-end at Azimuth 90° for "B" specimen and 270° for "C" specimen.

BY: Alan E. Hudson

Alan E. Hudson

Laboratory Technician Jerry DeHay

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PROCEDURE QUALIFICATION RECORD

DROPWEIGHT TEST DATA

SPECIMEN TYPE P 2

SPECIMEN	LOCATION	TEST TEMP °F	RESULTS
PLATE H5173-1	Longitudinal	-30	No Break
H5173-2	Longitudinal	-30	No Break
H5173-3	Longitudinal	-40	Break
PLATE T_{NDT} = -40°F			
HEAT AFFECTED ZONE			
HEAT AFFECTED ZONE T_{NDT}			
WELD METAL			
WELD METAL T_{NDT}			

Qualification No. 7373
Date 2/18/87

CHICAGO BRIDGE & IRON COMPANY

BY Alan E. Hudson

WL 20 G REV NOV 76

PQR NO. 7673

W.O. NO. H5173

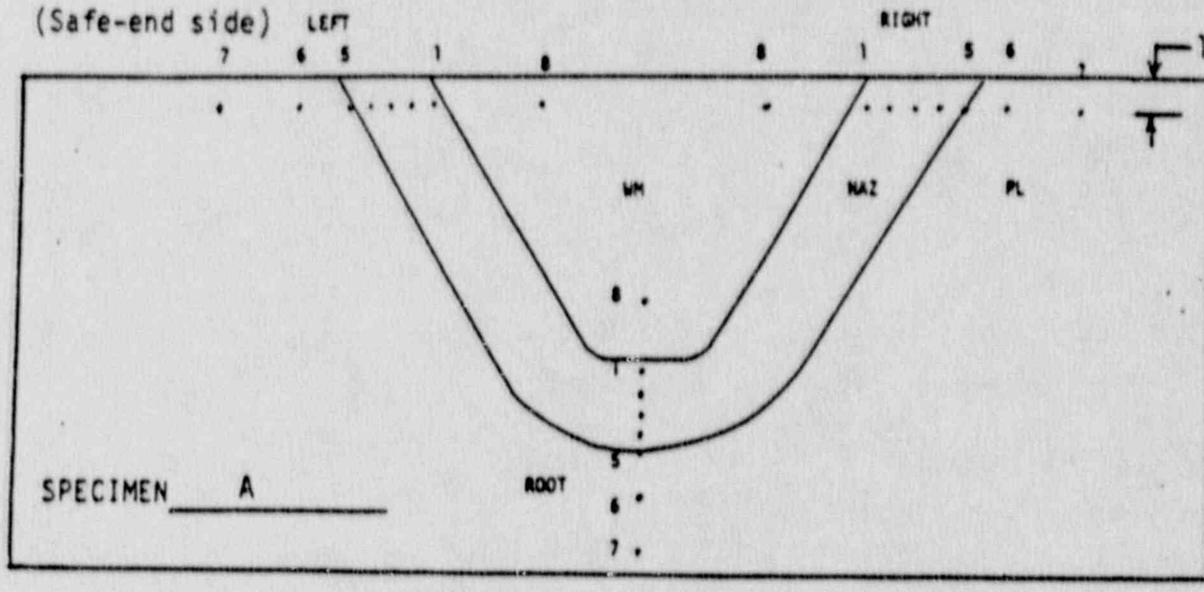
CBI

PROCEDURE QUALIFICATION RECORD

Traverse Spacing
1-5 = 1/2mm
5-6 = 1mm
6-7 = 6 to 10mm

VICKERS HARDNESS TEST

10 KG LOAD



LOCATION	(Safe-End Side) LEFT SIDE	RIGHT SIDE	ROOT
1	386	408	315
2	362	417	300
3	255	312	227
4	224	261	198
5	183	188	180
6	184	184	181
7	179	185	184
8	177	183	222

Alan E. Hudson
Alan E. Hudson

DATE 2/18/87

PQR NO. 7673

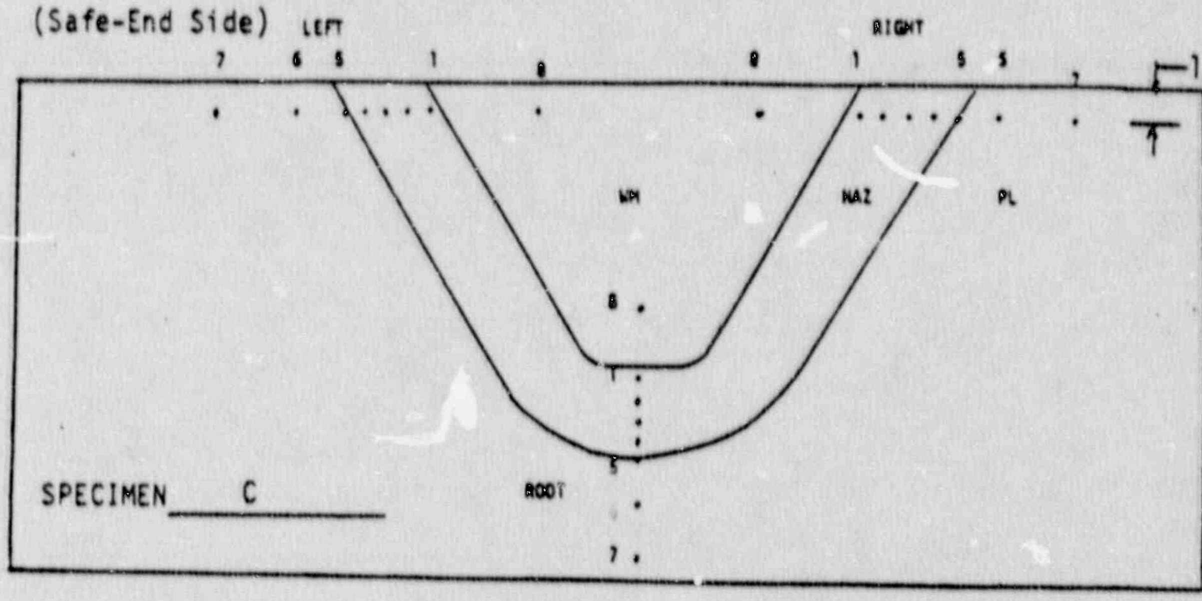
W.O. NO. H5173

PROCEDURE QUALIFICATION RECORD

Traverse Spacing
1-5 = 1/2mm
5-6 = 1mm
6-7 = 6 to 10mm

VICKERS HARDNESS TEST

10 KG LOAD



LOCATION	(Safe-End Side) LEFT SIDE	RIGHT SIDE	ROOT
1	379	306	297
2	396	292	288
3	281	239	248
4	241	208	208
5	194	177	179
6	179	177	178
7	178	174	177
8	174	172	213

Alan E. Hudson

BY Alan E. Hudson

DATE 2/18/87

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PQR NO. 7673

W.O. NO. H5173

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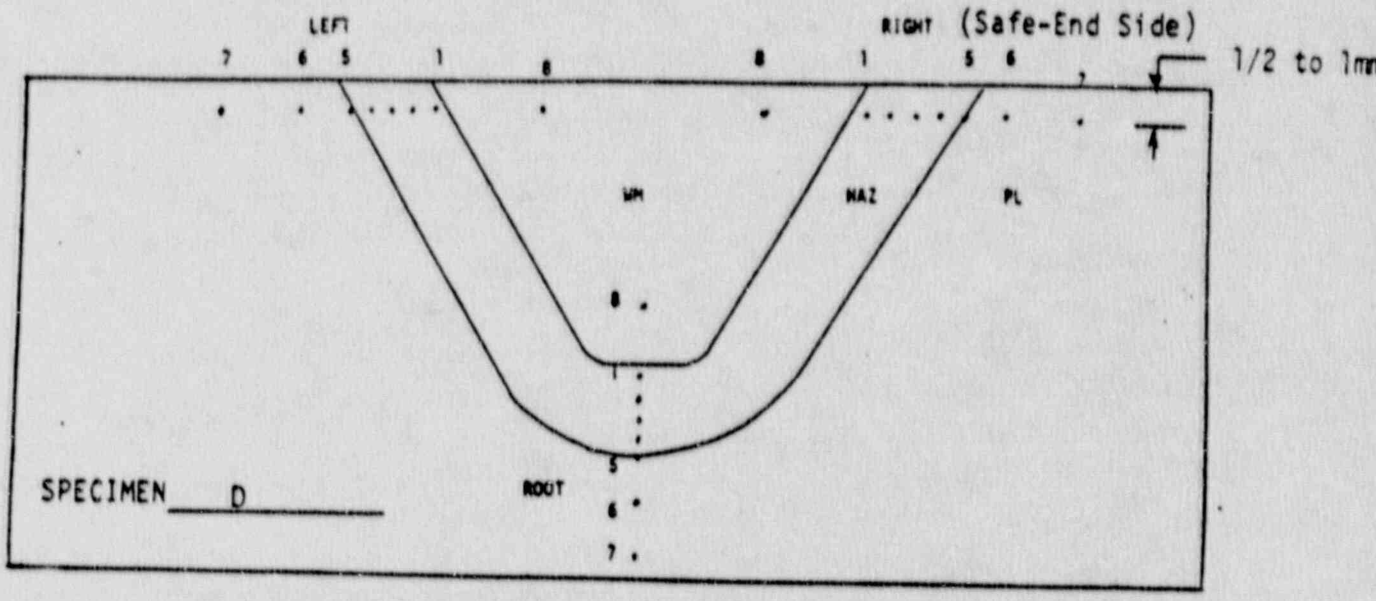
PROCEDURE QUALIFICATION RECORD

Traverse Spacing
1-5 = 1/2mm
5-6 = 1mm
6-7 = 6-10mm

VICKERS HARDNESS TEST

10 KG LOAD



LOCATION	LEFT SIDE	(Safe-End Side) RIGHT SIDE	ROOT
1	384	390	308
2	400	395	336
3	327	300	264
4	230	243	211
5	211	200	183
6	185	183	187
7	187	180	189
8	175	175	208

Alan E. Hudson

Alan E. Hudson

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PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX

PART II ESSENTIAL VARIABLES

PQR No. 7717 Date 5-15-87

Process GTAW (Pulsed - 360° Orbital) Manual [ ] Machine [X] Automatic [ ] Semiautomatic [ ]

Material specification SA508 Cl. 2 & A312 Tp 304L*

ASME p. no. 3, Gp. 3 To ASME p. no. 8, Gp. 1

Thickness (if pipe, dia and wall thick) 13.9"Ø x 1.20"

Filler metal group no. F. 43

Weld metal analysis no. A. ERNiCr-3

ASME specification no. SFA 5.14

AWS specification no. A 5.14

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition 100% Argon

Flow rate 40 CFH

Is backing strip used? No

Preheat temperature range See page 2

Postweld heat treatment None **

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 5G

Filler Metal ERNiCr-3***

Electrode EWTh-2, 1/8"Ø Filler wire diameter .045"

Type of backing None Welding current Direct Current, Electrode Negative (Straight Polarity - pulsed)

Consult PART III WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

(Turned Specimen) Reduced Section Tensile Results - Transverse All Weld Metal

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
H5224-A	--	0.253	0.0502	4.77	95.0	655.0	----
H5224-B	--	0.250	0.0490	4.86	99.2	684.0	----

Guided Bend Test

Type	Result	Type	Result
4 Transverse Side	OK	-------	---

Jerry E. DeHay, Alan E. Hudson 464-70-3339, 455-66-6391 JED, AE

Welder's name John D. Matthews Social Security no. 301-50-1193 Welder's Symbol JDM

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H5224 Rev. 0 Date 12-9-86

We certify that the statements in this record are correct and that the test weld was prepared, welded and tested in accordance with the requirements of Section IX of the ASME code.

Signed CBI

By Alan E. Hudson Alan E. Hudson Date 5-15-87

Remarks: Water backed - see page 2 for details.

GTAW machine welded using a remote video monitor.

*) SA508-CL 2 nozzle neck welded to A312 Tp 304L safe end with a ENiCrFe-3 butter and GTAW ERNiCr-3 butt weld. (SA508 Cl. 2 Heat No. C124 FN2-1-5)

**) The nozzle safe end assembly was PWHT at 1150°F for 24 hrs. prior to welding.

***) Arcos Type 382 Ht. Y4875N382.

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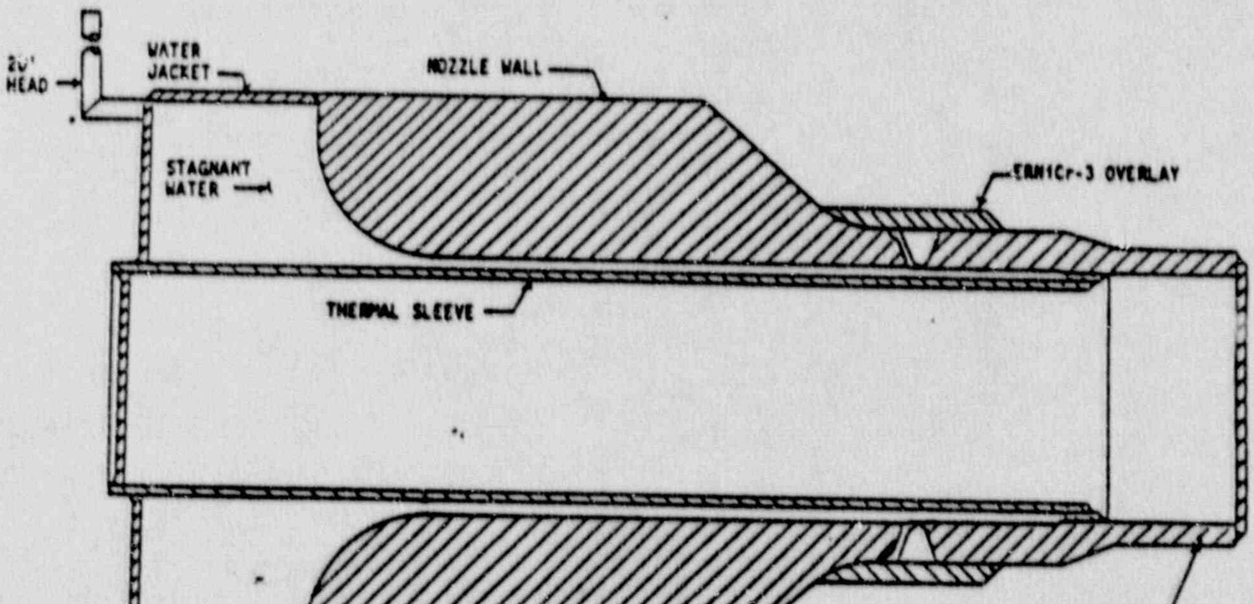
Water Backed:

Water contained in annulus space of the thermal sleeve and nozzle wall. Water was considered to be stagnant with 20 feet of head pressure yet allowed to circulate (2 GPM maximum) as the welding heat input was absorbed by the water. Circulation did not start until the water temperature had risen to approximately +60°F. The water temperature ranged from +41°F to 82°F peak with the majority of the welding being performed with the water temperature in the range of +45°F to 65°F.



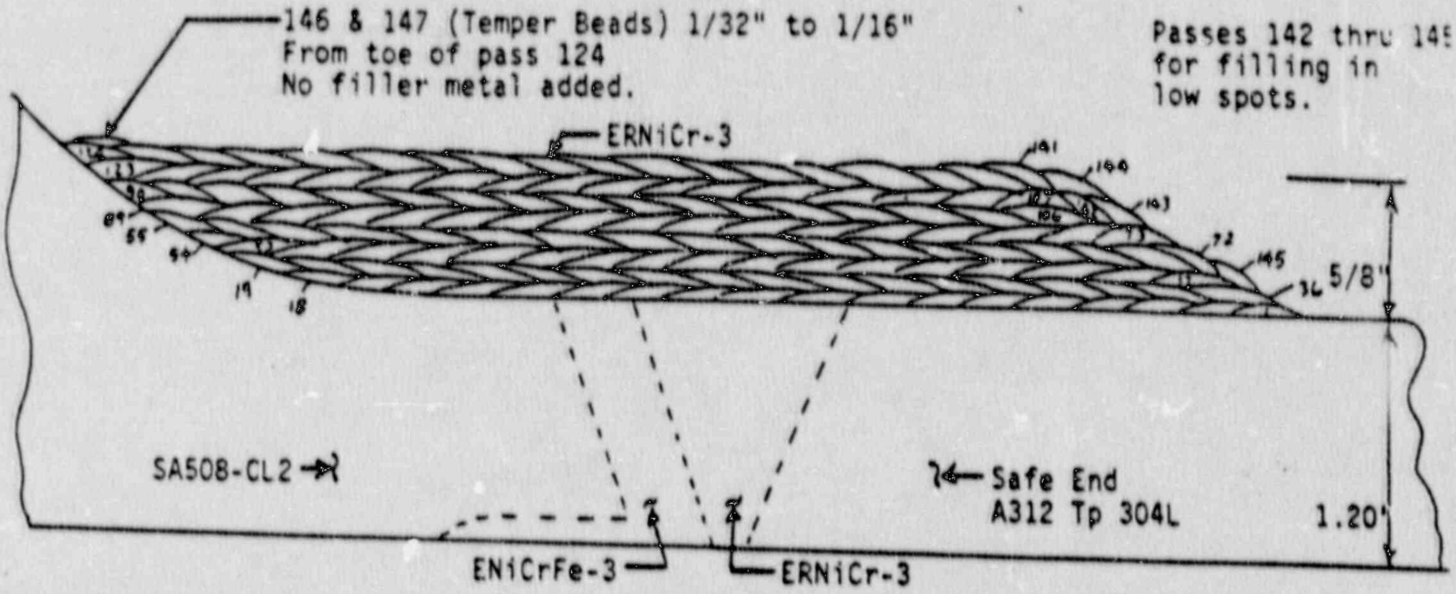
WATER BACKED NOZZLE TEST ASSEMBLY CROSS SECTION

Qualification No. 7717

By Alan E. Hudson

Date 5-15-87

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
PART III WELDING VARIABLES



Synchronization	Syn Pulse	Voltage control	Continuous
Upslope time	5 Secs.	Downslope time	10 Secs.
Wire Start Delay	7 Secs.	Travel Start Delay	6 Secs.

..s Number	1	2-4	5	6-18	19-36	37-54	55-72	73-89	90	91-1[illegible]
Primary Weld Current (amps.)	220	220	220	220	220	220	220	220	220	220
Background Current (amps.)	110	110	110	110	110	110	110	110	110	110
Out Dwell (primary)(sec. x 1)	.4	.4	.4	.4	.4	.4	.4	.4	.4	.3
Excursion time (sec. x 1)	.3	.2	.2	.2	.2	.2	.2	.2	.2	.2
In Dwell (primary) (sec x 1)	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4
Oscillation (in.)	.20	.24	.24	.24	.24	.24	.24	.24	.24	.24
Primary Wire Feed (IPM)	40	40	35	35	33	35	35	35	35	35
Background Wire Feed (IPM)	30	30	25	25	25	25	25	25	25	25
Travel (IPM) (Torch Speed)	2.55	2.55	2.55	2.55	2.38	2.62	2.64	2.66	2.68	2.68
Primary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Background Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heat Input (Kilojoules/in.)	36.04	38.39	38.39	37.64	40.33	36.72	36.38	36.08	35.76	35.76
Energy Density (MJ/in^3)	1.57	1.64	1.89	1.87	2.00	1.87	1.87	1.87	1.87	1.87

QUALIFICATION NO. 7717

DATE 5-15-87

Alan E. Hudson

BY Alan E. Hudson

CBI

PROCEDURE QUALIFICATION RECORD
To ASME Section IX
PART III Welding Variables

Synchronization	Syn Pulse	Voltage control	Continuous
Upslope time	5 Secs.	Downslope time	10 Secs.
Wire Start Delay	7 Secs.	Travel Start Delay	6 Secs.

Pass Number	107-123	124-145	146	147						
Primary Weld Current (amps.)	220	220	180	120						
Background Current (amps.)	110	110	90	60						
Out Dwell (primary)(sec. x 1)	.3	.3	.3	.3						
Excursion time (sec. x 1)	.2	.2	.2	.2						
In Dwell (primary) (sec x 1)	.4	.4	.4	.4						
Oscillation (in.)	.24	.24	.24	.24						
Primary Wire Feed (IPM)	35	35	--	--						
Background Wire Feed (IPM)	25	25	--	--						
Travel (IPM) (Torch Speed)	2.71	2.72	2.72	2.72						
Primary Arc Volts	9.0	9.0	9.0	9.0						
Background Arc Volts	8.5	8.5	8.5	8.5						
Heat Input (Kilojoules/in.)	35.47	35.19	28.79	19.19						
Energy Density (MJ/in^3)	1.87	1.87	--	--						

Qualification No. 7717

Date May 15, 1987

Alan E. Hudson

By Alan E. Hudson

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IMPACT TEST DATA

TYPE OF NOTCH VEE

PQR 7717

W.O. #H5224

5/15/87

SPEC. NO.	SPEC. ORIENT	SPEC. SIZE	NOTCH LOCATION	TEST TEMP DEG F.	ENERGY		LATERAL EXPANSION MILS	PER CENT SHEAR
					FT-LB	J		
A-1	LONG.	FULL	HAZ	+20	95	129	60	50
A-2	LONG.	FULL	HAZ	+20	76	103	57	40
A-3	LONG.	FULL	HAZ	+20	95	129	65	55
B-1	LONG.	FULL	PLT	+20	43	58	36	40
B-2	LONG.	FULL	PLT	+20	48	65	45	50
B-3	LONG	FULL	PLT	+20	60	81	40	50

REMARKS: HAZ specimen taken at maximum practical depth of overlay weld on the end of the overlay opposite the safe end at AZ 90°. PLT specimen taken at 1/4T depth from O.D. of SA508-2 adjacent to the HAZ specimen.

BY: Alan E. Hudson

Alan E. Hudson

Laboratory Technician Jerry DeHay

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PROCEDURE QUALIFICATION RECORD

DROPWEIGHT TEST DATA

SPECIMEN TYPE P

SPECIMEN	LOCATION	TEST TEMP °F	RESULTS
PLATE H5224-1	Longitudinal	-30	No Break
H5224-2	Longitudinal	-30	No Break
H5224-3	Longitudinal	-40	Break
PLATE T_{NDT} = -40°F			
HEAT AFFECTED ZONE			
HEAT AFFECTED ZONE T_{NDT}			
WELD METAL			
WELD METAL T_{NDT}			

Qualification No. 7717
Date 5/15/87

CHICAGO BRIDGE & IRON COMPANY

Alan E. Hudson

BY Alan E. Hudson

WL 28 G REV NOV 76

PQR NO. 7717

W.O. NO. H5224

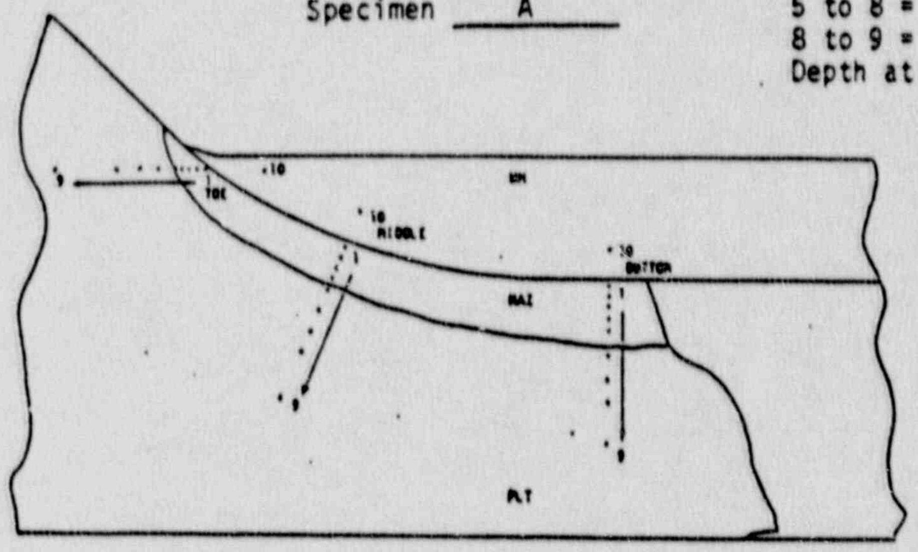
PROCEDURE QUALIFICATION RECORD

VICKERS HARDNESS TEST

10 KG LOAD

Specimen A

Transverse
Spacing
1 to 5 = 1/2mm
5 to 8 = 1mm
8 to 9 = 4 to 8mm
Depth at toe = 1/2 to 1m



LOCATION	TOE	MIDDLE	BOTTOM
1	257	295	302
2	254	315	331
3	236	240	298
4	240	197	250
5	233	181	222
6	191	181	183
7	177	181	183
8	164	177	172
9	167	177	171
10	163	178	203

Alan E. Hudson

BY Alan E. Hudson

DATE 5/15/87

PQR NO. 7717

W.O. NO. H5224

CBI

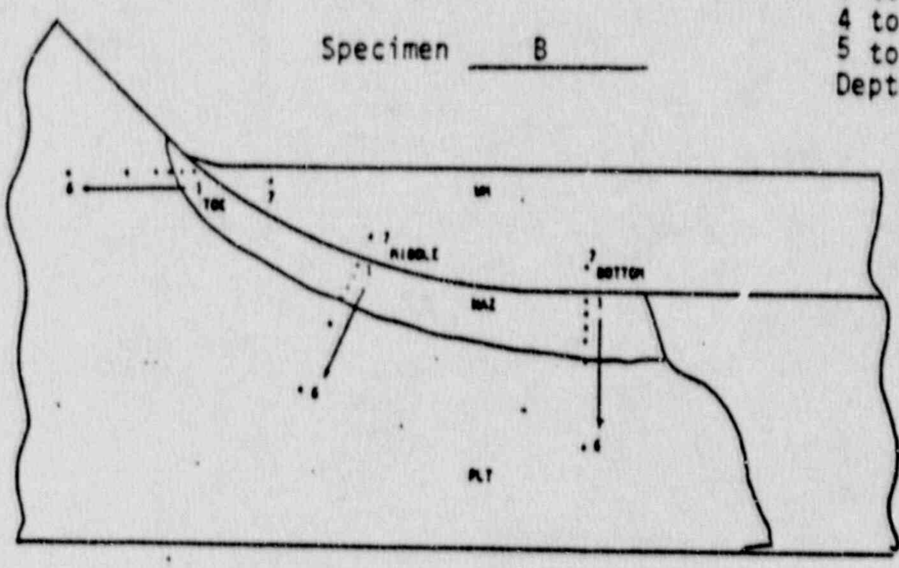
PROCEDURE QUALIFICATION RECORD

VICKERS HARDNESS TEST

10 KG LOAD

Transverse
Spacing
1 to 4 = 1/2mm
4 to 5 = 1mm
5 to 6 = 4 to 8mm
Depth at toe = 1/2 to 1mm

Specimen B



LOCATION	TOE	MIDDLE	BOTTOM
1	400	310	305
2	291	322	286
3	204	249	267
4	191	192	226
5	181	179	182
6	171	174	179
7	163	195	200
8			
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--			

Alan E. Hudson
Alan E. Hudson

DATE May 15, 1987

PQR NO. 7717

W.O. NO. H5224

CBI

PROCEDURE QUALIFICATION RECORD

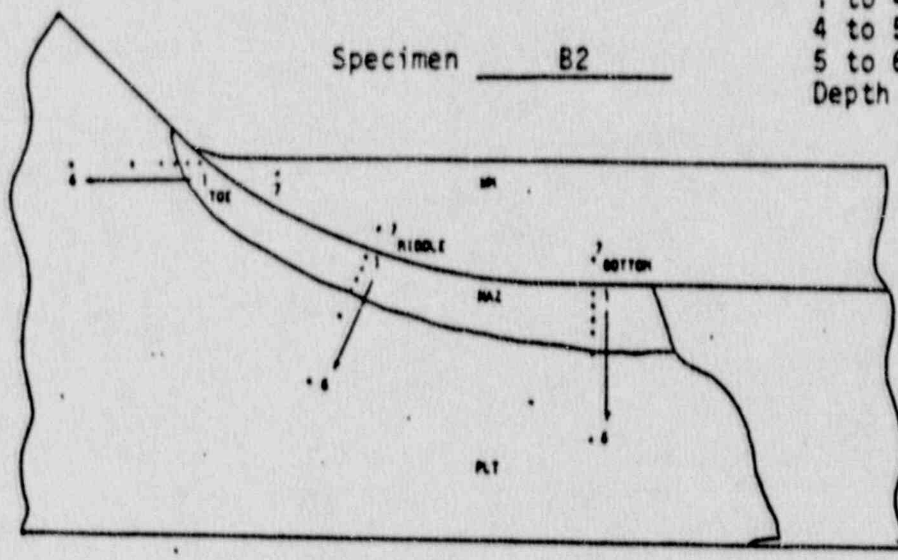
VICKERS HARDNESS TEST

10 KG LOAD

Transverse Spacing

1 to 4 = 1/2mm
4 to 5 = 1mm
5 to 6 = 4 to 8mm
Depth at Toe = 1/2 to 1m

Specimen B2



LOCATION	TOE	MIDDLE	BOTTOM
1	387	316	300
2	256	273	314
3	206	227	274
4	190	203	234
5	182	184	180
6	172	174	177
7	164	195	203
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BY *Alan E. Hudson*
Alan E. Hudson

DATE 5/15/87

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PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX

PART II ESSENTIAL VARIABLES

PQR No. 7718 Date 5-15-87

Process GTAW (Pulsed - 360° Orbital) Manual [ ] Machine [X] Automatic [ ] Semiautomatic [ ]

Material specification SA508 Cl. 2 & A312 Tp 304L*

ASME p. no. 3, Gp. 3 To ASME p. no. 8, Gp. 1

Thickness (if pipe, dia and wall thick) 13.9"Ø x 1.20"

Filler metal group no. F. 43

Weld metal analysis no. A. ERNiCr-3

ASME specification no. SFA 5.14

AWS specification no. A 5.14

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition 100% Argon

Flow rate 40 CFH

Is backing strip used? No

Preheat temperature range 44°F - 350°F (IPT)

Postweld heat treatment None **

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 5G

Filler Metal ERNiCr-3***

Electrode EWTh-2, 1/8"Ø Filler wire diameter .045"

Type of backing None Welding current Direct Current, Electrode Negative (Straight Polarity - pulsed)

Consult PART III WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

(Turned Specimen) Reduced Section Tensile Results - Transverse All Weld Metal

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
H5224-C	--	0.252	0.0498	4.85	97.4	672.0	----
H5224-D	--	0.247	0.0481	4.70	97.7	674.0	----

Guided Bend Test

Type	Result	Type	Result
4 Transverse Side	OK	---------	---

Welder's name Jerry E. DeHay, Alan E. Hudson John D. Matthews Social Security no. 464-76-3339, 455-66-6391 301-50-1193 Welder's Symbol JED, AEH JDM

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H5224 Rev. 0 Date 12-9-86

We certify that the statements in this record are correct and that the test weld was prepared, welded and tested in accordance with the requirements of Section IX of the ASME code.

Signed CBI

By Alan E. Hudson Alan E. Hudson Date 5-15-87

Remarks: *) Non water backed structural overlay test assembly consisting of SA508 CL. 2 nozzle welded to A312 Tp 304L safe end with a ENiCrFe-3 butter and GTAW ERNiCr-3 butt weld & a thermal sleeve inside the nozzle. (SA508 Cl. 2 Heat No. C124 FN2-1-5).

**) Nozzle/safe end assembly was PWHT @ 1150°F for 24 hrs. prior to welding.

***) Arcos Type 382 Ht. Y4875N382. GTAW machine welded using a video monitor.

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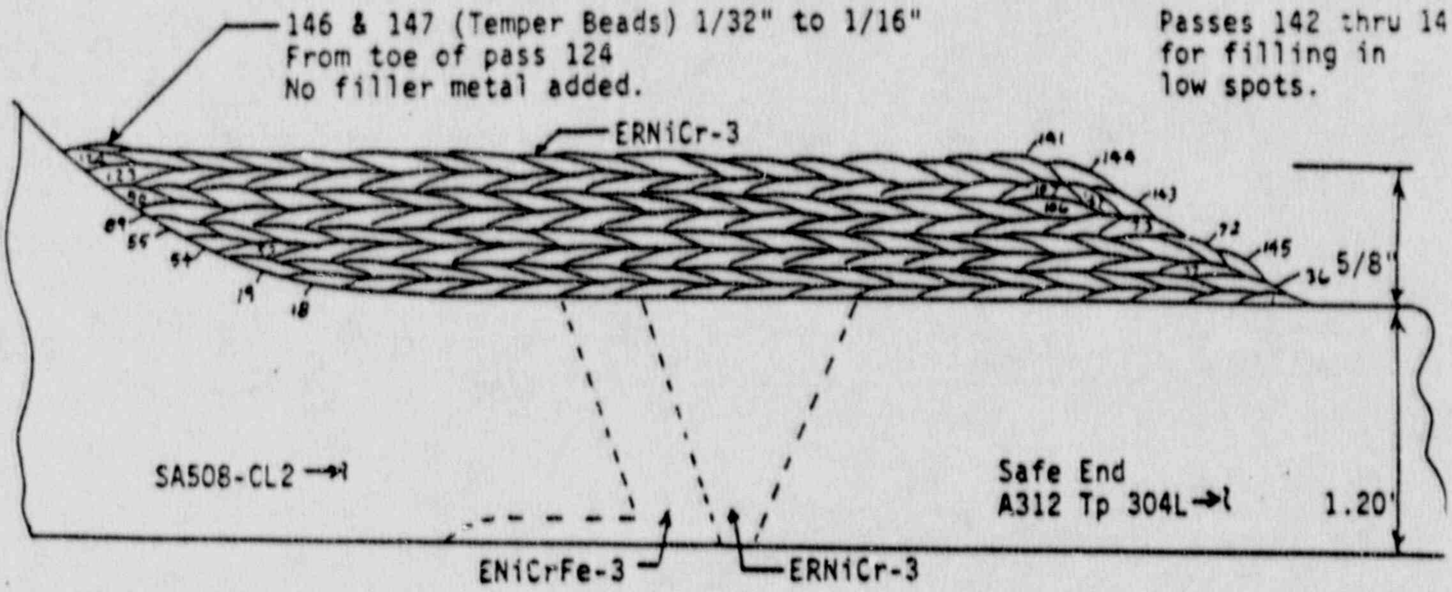
PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
PART III WELDING VARIABLES



Synchronization	Syn Pulse	Voltage control	Continuous
Upslope time	5 Secs.	Downslope time	10 Secs.
Wire Start Delay	7 Secs.	Travel Start Delay	6 Secs.

.s Number	1	2-4	5	6-18	19-36	37-54	55-72	73-89	90	91-1
Primary Weld Current (amps.)	220	220	220	220	220	220	220	220	220	22
Background Current (amps.)	110	110	110	110	110	110	110	110	110	11
Out Dwell (primary)(sec. x 1)	.4	.4	.4	.4	.4	.4	.4	.4	.4	.
Excursion time (sec. x 1)	.3	.2	.2	.2	.2	.2	.2	.2	.2	.
In Dwell (primary) (sec x 1)	.4	.4	.4	.3	.3	.3	.3	.3	.3	.4
Oscillation (in.)	.20	.24	.24	.24	.24	.24	.24	.24	.24	.24
Primary Wire Feed (IPM)	40	40	35	35	33	35	35	35	35	35
Background Wire Feed (IPM)	30	30	25	25	25	25	25	25	25	25
Travel (IPM) (Torch Speed)	2.55	2.55	2.55	2.55	2.38	2.62	2.64	2.66	2.68	2.68
Primary Arc Volts	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.
Background Arc Volts	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.
Heat Input (Kilojoules/in.)	36.04	38.39	38.39	37.64	40.33	36.72	36.38	36.08	35.76	35.7
Energy Density (MJ/in^3)	1.57	1.64	1.89	1.87	2.00	1.87	1.87	1.87	1.87	1.8

QUALIFICATION NO. 7718

DATE 5-15-87

Alan E. Hudson

BY Alan E. Hudson

CBI

PROCEDURE QUALIFICATION RECORD
To ASME Section IX
PART III Welding Variables

Synchronization	Syn Pulse	Voltage control	Continuous
Upslope time	5 Secs.	Downslope time	10 Secs.
Wire Start Delay	7 Secs.	Travel Start Delay	6 Secs.

Pass Number	107-123	124-145	146	147						
Primary Weld Current (amps.)	220	220	180	120						
Background Current (amps.)	110	110	90	60						
Out Dwell (primary)(sec. x 1)	.3	.3	.3	.3						
Excursion time (sec. x 1)	.2	.2	.2	.2						
In Dwell (primary) (sec x 1)	.4	.4	.4	.4						
Oscillation (in.)	.24	.24	.24	.24						
Primary Wire Feed (IPM)	35	35	--	--						
Background Wire Feed (IPM)	25	25	--	--						
Travel (IPM) (Torch Speed)	2.71	2.72	2.72	2.72						
Primary Arc Volts	9.0	9.0	9.0	9.0						
Background Arc Volts	8.5	8.5	8.5	8.5						
Heat Input (Kilojoules/in.)	35.47	35.19	28.79	19.19						
Energy Density (MJ/in^3)	1.87	1.87	--	--						

Qualification No. 7718

Date May 15, 1987

Alan E. Hudson

By Alan E. Hudson

CBI

IMPACT TEST DATA

TYPE OF NOTCH Vee

PQR 7718

W.O. #5224

5/15/87

SPEC. NO.	SPEC. ORIENT	SPEC. SIZE	NOTCH LOCATION	TEST TEMP DEG F.	ENERGY FT-LB	ENERGY J	LATERAL EXPANSION MILS	PER CENT SHEAR
D-1	Long	Full	HAZ	+20	111	151	75	50
D-2	Long	Full	HAZ	+20	89	121	63	40
D-3	Long	Full	HAZ	+20	99	134	72	70
C-1	Long	Full	PLT	+20	43	58	33	40
C-2	Long	Full	PLT	+20	51	69	42	35
C-3	Long	Full	PLT	+20	45	61	37	35

REMARKS: HAZ specimen taken at maximum practical depth of overlay weld on the end of the overlay opposite the safe end at AZ 90°. PLT specimen taken at 1/4T depth from O.D. of SA508-2 adjacent to the HAZ specimen.

BY: Alan E. Hudson

Alan E. Hudson

Laboratory Technician Jerry DeHay

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WL 253 REV NOV 85

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Page
Contract
Rev
W.O. #H5224

PROCEDURE QUALIFICATION RECORD

DROPWEIGHT TEST DATA

SPECIMEN TYPE P

SPECIMEN	LOCATION	TEST TEMP °F	RESULTS
PLATE H5224-1	Longitudinal	-30	No Break
H5224-2	Longitudinal	-30	No Break
H5224-3	Longitudinal	-40	Break
PLATE T_{NDT} = -40°F			
HEAT AFFECTED ZONE			
HEAT AFFECTED ZONE T_{NDT}			
WELD METAL			
WELD METAL T_{NDT}			

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CHICAGO BRIDGE & IRON COMPANY

Alan E. Hudson

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PQR NO. [illegible]

W.O. NO. H5224

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PROCEDURE QUALIFICATION RECORD

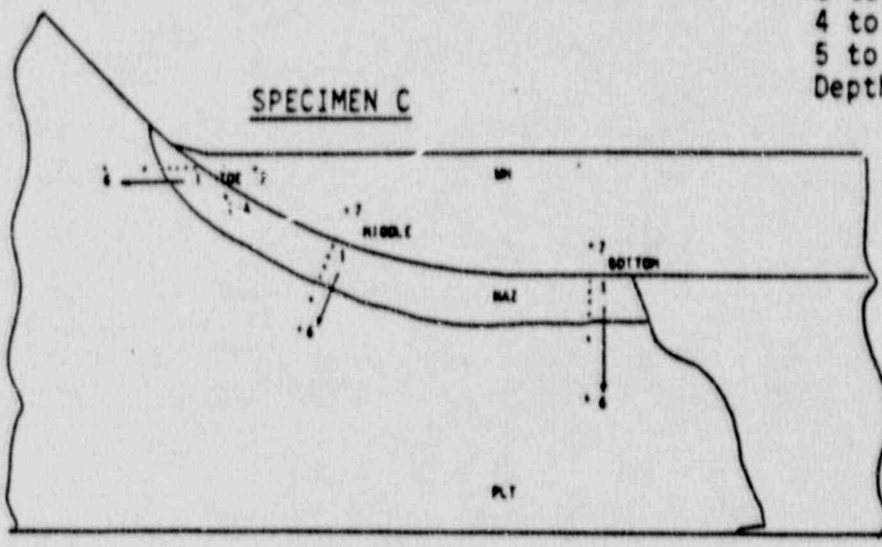
VICKERS HARDNESS TEST

10 KG LOAD

TRAVERSE SPACING

1 to 4 = 1/2 mm
4 to 5 = 1 mm
5 to 6 = 4 to 8 mm
Depth at Toe = 1/2 to 1 mm

SPECIMEN C



LOCATION	TOE	A	MIDDLE	BOTTOM
1	307	426	310	329
2	348	-	314	272
3	239	-	265	279
4	201	-	214	234
5	179	-	180	186
6	177	-	176	177
7	168	-	190	203

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PROCEDURE QUALIFICATION RECORD

VICKERS HARDNESS TEST

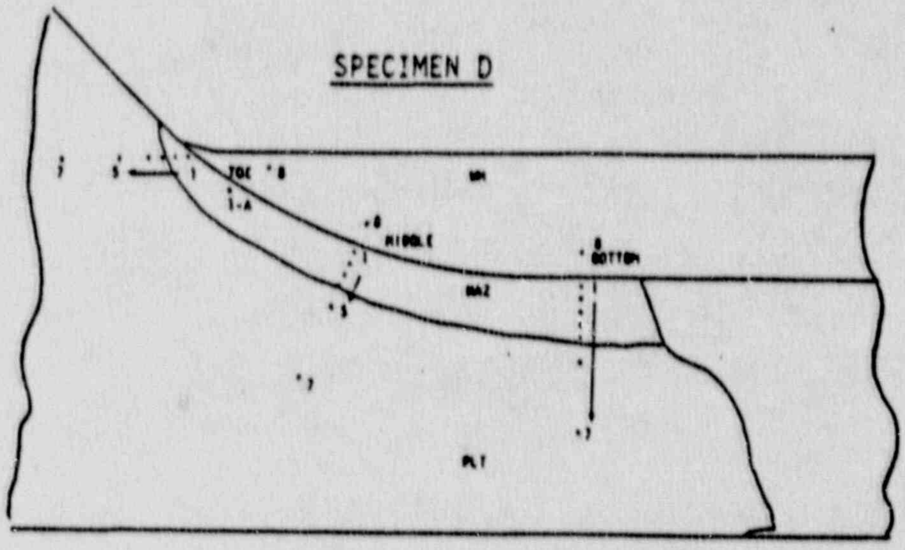
10 KG LOAD

TRAVERSE SPACING

@ Bottom
1 to 5 = 1/2 mm
5 to 6 = 1 mm
6 to 7 = 4 to 8 mm

@ Toe & Middle
1 to 4 = 1/2 mm
4 to 5 = 1 mm
5 to 7 = 4 to 8 mm
Depth at toe = 1/2 t
1 mm

SPECIMEN D



LOCATION	TOE	A	MIDDLE	BOTTOM
1	341	416	282	272
2	235	--	331	267
3	196	--	261	249
4	185	--	187	225
5	171	--	177	201
6	-	--	-	179
7	181	--	166	178
8	168	--	176	202

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PROCEDURE QUALIFICATION RECORD

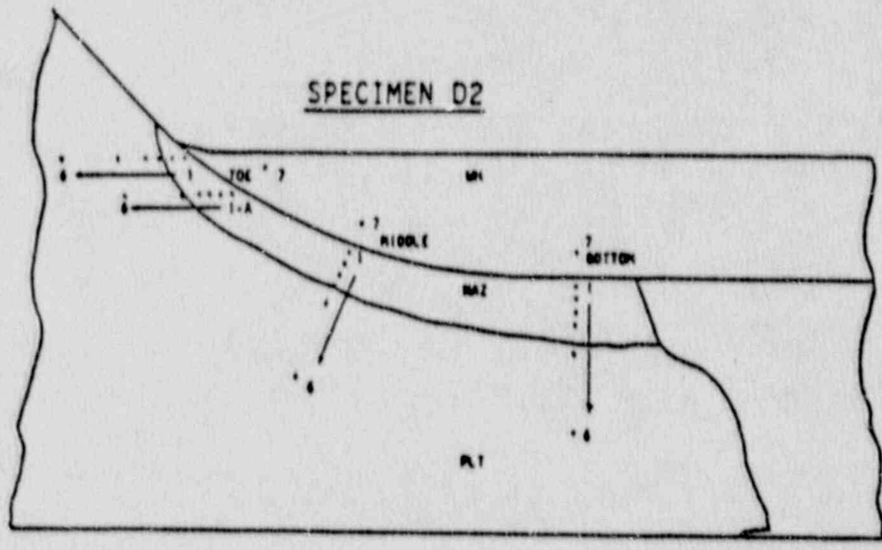
VICKERS HARDNESS TEST

10 KG LOAD

TRAVERSE SPACING

1 to 4 = 1/2 mm
4 to 5 = 1 mm
5 to 6 = 4 to 8 mm
Depth at Toe = 1/2 to 1 mm

SPECIMEN D2



LOCATION	TOE	A	MIDDLE	BOTTOM
1	350	434	308	284
2	252	417	307	274
3	196	316	267	248
4	189	270	224	233
5	188	256	183	176
6	174	182	181	172
7 -	163	-	190	197

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